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Evaluating and comparing the healthy food and physical activity environment in schools in Sri Lanka and New Zealand: A study among 5- to 13-year-old children

A thesis presented in partial fulfilment of the requirements for the degree of

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Nutritional Science

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Thalagalage Shalika Harshani Perera

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Abstract

Background

Schools are critical environments for shaping children's physical activity (PA) and dietary behaviours, yet comparative evidence across diverse national contexts remains scarce. This thesis addresses this gap by evaluating and comparing school PA behaviours, food environments, and dietary adequacy among children aged 5–13 years in Sri Lanka (SL) and New Zealand (NZ), two countries with contrasting socio-economic contexts, cultural norms, and school health policies. This comparison provides insights into how diverse environments influence children's health behaviours and identifies opportunities for context-specific interventions. The research also advances methodological approaches for PA measurement and dietary assessment in paediatric populations. While the study provides valuable cross-country insights, it is based on a convenience sample of schools and should be considered exploratory rather than nationally representative.

Objectives

The research aimed to: (1) synthesise evidence on accelerometer-based PA measurement in Asian children and identify methodological gaps; (2) compare objectively measured PA and children's subjective experiences of physical education in SL and NZ; (3) examine school food environments, including food policy and physical food availability, across both countries; (4) develop and validate a modified 24-hour multiple-pass dietary recall (24-MPR) protocol tailored for NZ children; and assess and compare energy and key nutrient intake adequacy among schoolchildren aged 9–13 years in both contexts.

Methods

This thesis comprises a narrative review, two cross-country pilot studies, a validation study, and an exploratory dietary adequacy analysis. Data collection included accelerometer-based PA measurement, child-reported experiences, and school food environment assessment using structured questionnaires completed by school staff and food suppliers. Dietary intake was assessed using a modified 24-MPR protocol validated against weighed food records. Nutrient adequacy was evaluated using national nutritional reference values, including Estimated Average Requirements (EAR), Adequate Intake (AI), and Acceptable Macronutrient Distribution Ranges (AMDR) applied separately to both country-specific recommendations. Statistical analyses included descriptive statistics and comparative tests (e.g., t-tests and chi-square tests) to examine differences across countries, genders, and other relevant variables. Significance was set at $p < 0.05$. Analyses were performed using R software for descriptive and inferential statistics, while validity and reliability metrics were calculated using Hopkins' spreadsheets.

Results

The accelerometry review revealed limited validation studies and context-specific cut points for Asian children, highlighting the need for culturally tailored calibration protocols. The PA comparison demonstrated significant differences in objectively measured activity levels and subjective experiences, with gender and cultural factors influencing engagement and motivation. Valid accelerometer data were obtained from 464 children in NZ and 124 in SL. New Zealand children recorded more steps overall (992 vs 873 steps per hour; $p < 0.01$) and on weekdays (1034 vs 867; $p < 0.01$), while SL children achieved higher moderate-to-vigorous physical activity (MVPA) (11 vs 7 min per hour; $p < 0.001$). Sedentary time was greater in NZ (34 vs 31 min per hour; $p < 0.001$), and light activity was marginally higher in NZ (19 vs 18

min per hour; $p < 0.001$). Younger children (5–8 years) accumulated more steps than older peers ($p < 0.001$), and boys were consistently more active than girls in both countries ($p < 0.001$). School food environment assessments revealed that 87% of the SL schools in the sample of 30 had a canteen, while 64% of the NZ schools in the policy and practices survey sample of 75 reported having a written food policy. Comparative analyses of Chi-square revealed a significant difference in access to food and drinks for school activities between NZ and SL schools ($\chi^2 = 16.39$, $p < 0.001$), while other factors such as water fountain availability and promotion of healthy eating did not differ significantly. However, only 28% of these NZ schools had updated their policy within the past two years, and compliance with the national School Canteen Policy in SL was weak, with only one school reporting regular committee meetings. Canteens in the SL schools frequently sold deep-fried foods, confectionery, and sweetened beverages, whereas packaged snacks and sweet baked goods dominated the menus of these NZ schools. Validation of the modified 24-MPR in NZ showed minimal mean bias for energy (−0.2%) and moderate validity for macronutrients ($r = 0.43–0.63$), while micronutrients were more variable ($r = 0.10–0.42$). Reliability was small for macronutrients (ICC = 0.30) and moderate for calcium (ICC = 0.56), supporting its use for group-level dietary assessment. Nutrient adequacy analysis indicated widespread inadequacies in SL, where more than 90% of children had insufficient fibre and calcium, and energy inadequacy exceeded 87% in younger and 97% in older age groups. In NZ, energy and protein intakes were adequate, but inadequacies were common for fibre (42–45%), calcium (42–50%), and vitamin A (80–92%) among children.

Conclusions
This research demonstrates the feasibility and value of integrated, school-based strategies that combine objective PA monitoring, child-centred perspectives, enforceable food policies, and validated dietary assessment tools. In spite of differences in policy framework, both countries have similar gaps between policy intention and implementation. They consequently cause such wide-ranging exposure to unhealthy food environments for school-aged children. Findings inform policy and practice by emphasising culturally appropriate PA promotion, mandatory healthy canteen standards, and investment in school meal programmes to address nutritional gaps. Methodological contributions include considerations of accelerometry in SL contexts and a validated child-friendly dietary recall protocol. Future research should focus on larger, nationally representative samples to validate these findings and strengthen generalisability.

Keywords
physical activity; school food environment; dietary assessment; nutrient adequacy; accelerometry; policy implementation.

SDG Keywords
SDG 3 – Good Health and Well-being; SDG 4 – Quality Education; SDG 10 – Reduced Inequalities; SDG 11 – Sustainable Cities and Communities; SDG 12 – Responsible Consumption and Production.

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List of Abbreviations

24-MPR	24-hour multiple-pass dietary recall
AI	Adequate Intake
AMDR	Acceptable Macronutrient Distribution Range
BMI	Body mass index
CI	Confidence interval
CPM	Counts per minutes
CV	Coefficient of Variation
DDS	Dietary Diversity Score
DLW	Doubly labelled water
DRIs	Dietary Reference Intakes
EAR	Estimated Average Requirement
FFQ	Food frequency questionnaire
HAL	Healthy Active Learning
HICs	High income countries
ICC	Intraclass Correlation Coefficient
ICMR	Indian council of medical research
IOM	Institute of Medicine
LMICs	Low to middle income countries
LSAC	Longitudinal study of Australian children
LTPA	Leisure time physical activities
MeSH	Medical Subject Headings
MET	Metabolic Equivalent of Task
MPA	Mean Probability of Adequacy
MVPA	Moderate to vigorous physical activities
NA	Not applicable
NZ	New Zealand
OPHD	Oxford poverty and human development index
PA	Physical Activity
PAQ-C	Physical Activity Questionnaire for Older Children
PE	Physical Education
RDA	Recommended Dietary Allowance
SDG	Sustainable development goals
SFP	School food programme
SL	Sri Lanka
TEE	Total Energy Expenditure
UK	United Kingdom
UNDP	United Nation Development Project
USA	United State of America
WFR	Weighted Food Record
WHO	World Health Organisation

Chapter 1

Introduction

The thesis evaluates and compares school food environments and physical activity behaviours among children aged 5–13 years in Sri Lanka (SL) and New Zealand (NZ). Schools are critical settings for health promotion, influencing both PA and dietary behaviours. Despite global recognition of their importance, research comparing these environments across different national contexts remains limited.

The chapter outlines the significance of addressing childhood obesity and the concept of obesogenic environments, highlights gaps in physical activity and dietary assessment methods, and explains why SL and NZ offer unique opportunities for comparison. It presents the aims and objectives of the thesis, which include synthesising evidence on accelerometer-based physical activity measurement, comparing physical activity behaviours and experiences, examining school food environments, validating a modified dietary recall method, and assessing nutrient adequacy. Finally, it describes the thesis structure and expected contributions, followed by a summary of researcher roles in each component of the work.

1.1 Background and rationale for the thesis

The childhood years, particularly ages 5 to 13, represent a critical development period where health behaviours are established and consolidated, setting the foundation for lifelong patterns of physical activity (PA) and dietary habits (LeitÃO, 2018). During this formative stage, children spend a significant portion of their waking hours in school environments, making educational institutions pivotal settings for health promotion and disease prevention (Pulimeno et al., 2020). The World Health Organisation (WHO) recognises schools as key environments for addressing the global childhood obesity epidemic and promoting healthy lifestyles among young populations (Langford et al., 2015).

The obesogenic environment concept, characterised by conditions that promote weight gain through excessive caloric intake and insufficient PA, has gained increasing recognition in public health research (Swinburn et al., 2011). Childhood obesity has become one of the most urgent global public health challenges of the 21st century, affecting over 390 million children and adolescents worldwide and ranking as one of the most common paediatric chronic diseases (Hampl et al., 2023; WHO, 2025). Contemporary public health challenges require comprehensive approaches that address both PA and nutritional components of children's health environments. Schools contribute significantly to these environments through their policies, practices and the broader community context in which they operate. School environments play an important role in shaping children's health behaviours and intervention strategies (Story et al., 2009). Comparing these environments across different national settings can further inform policy development.

Physical activity during childhood represents one of the most critical modifiable determinants of both immediate and long-term health outcomes (Bull et al., 2020). The WHO's 2020 updated guidelines recommend that children and adolescents aged 5 to 17 years should accumulate an average of at least 60 min per day of moderate-to-vigorous PA, with additional emphasis on muscle and bone-strengthening activities at least three times per week (Chaput et al., 2020). Despite these clear recommendations, evidence indicates that many children and adolescents worldwide do not meet current PA guidelines. For example, global studies show that most children fail to achieve recommended activity levels, with low overall adherence observed across countries, highlighting the urgent need for effective policies and programmes to increase PA levels (Guthold et al., 2020; Srivastav et al., 2023; Tapia-Serrano et al., 2022).

Schools provide both structured and unstructured opportunities for PA, including physical education (PE) curricula, active transportation to and from school, playground activities during breaks, and after-school programmes (Singh et al., 2019). However, the availability and quality of these opportunities may vary across contexts, particularly between high- and low-resource settings, where differences in school infrastructure, funding, and broader socioeconomic conditions can influence access to facilities and participation in school-based PA (Hu et al., 2021a).

Understanding the effectiveness of these opportunities requires examination of not only objective activity levels but also children's engagement, motivation and quality of experiences within PA and PE settings. Beyond quantitative measurement of movement patterns, children's subjective experiences significantly influence their long-term engagement with PA. Factors such as enjoyment, perceived competence, autonomy support and social interactions within PE

classes and playground activities contribute to the development of positive attitudes toward PA that extend beyond the school setting (Wallhead & Buckworth, 2004).

Evidence from Asian countries, including SL, highlights the growing concern around declining PA among children due to rapid urbanisation and lifestyle changes. Sedentary behaviours are increasingly replacing traditional movement patterns, yet interventions aimed at promoting PA have shown mixed results (Metcalf et al., 2012; Müller et al., 2013). These inconsistencies are largely attributed to methodological limitations, small sample sizes and a lack of culturally tailored approaches. While some school-based programmes have demonstrated that PA interventions can work, especially when they respect cultural needs, overall reviews find only modest success because many studies don't use objective measurements or controlled evaluation (Ahmed et al., 2021).

In NZ, similar concerns exist about declining PA among children, particularly among obese children and indigenous populations. Lower PA levels among Māori children from the Taranaki region, compared to their non-indigenous peers, emphasise the need for culturally responsive strategies (Anderson et al., 2017). Objective tools like accelerometers offer more accurate insights into children's activity patterns, but their application in diverse cultural contexts remains limited. Gender disparities also persist globally, with girls consistently engaging in less PA than boys, often due to cultural norms, safety concerns and unequal encouragement (Ricardo et al., 2022).

Complementing PA promotion, the school food environment encompasses a complex ecosystem of policies, practices and physical structures that collectively influence children's food choices and dietary behaviours. Children consume approximately 35-50% of their daily caloric intake during school hours, making the school food environment a primary determinant of nutritional adequacy and dietary quality that directly interacts with their PA patterns (Story et al., 2009). This environment extends beyond traditional cafeteria services to include the broader food landscape surrounding educational institutions, creating a comprehensive nutritional context that operates alongside PA environments.

A comparison between SL and NZ provides a unique opportunity to examine how different national contexts influence childhood health. As a lower-middle-income South Asian country, SL faces the double burden of malnutrition in children aged 5 to 10 years, with 19.3% experiencing thinness and 13.4% overweight (including obesity) (Kiridana, 2024; Shinsugi et al., 2019). This represents a complex nutritional transition occurring alongside rapid urbanisation and lifestyle changes, where traditional activity patterns are being replaced by more sedentary behaviours associated with modernisation (Popkin, 2009). In contrast, NZ reports that 61.2% of children aged 2–14 years have a healthy weight, while the remaining proportion includes children who are overweight, obese, or underweight, with obesity alone affecting 13.5% (Ministry of Health NZ, 2023). New Zealand, as a high-income Pacific nation, addresses established childhood obesity challenges through comprehensive policy frameworks. The government has introduced several initiatives to promote healthy eating and PA across all educational settings, with recent data showing encouraging reductions in obesity prevalence among 4-year-old children from 2017 to 2019 (Ministry of Health, 2022). However, as these data relate to early childhood populations, their relevance to school-aged children is uncertain. Evidence among older children remains mixed, with some studies reporting no significant change in obesity prevalence, particularly among Māori and Pacific Islander populations (Rush et al., 2017).

Health system capacity and implementation frameworks differ between SL and NZ. New Zealand's well-resourced health system, led by Health NZ, delivers school health programmes through national strategies and monitoring systems (Health NZ, 2024). Although NZ also faces challenges such as workforce shortages and service inequities, it has substantially greater health system capacity, reflected in higher health expenditure and workforce availability (Ministry of Health NZ, 2022, 2025). For example, total health expenditure in NZ was approximately USD 5,022 per capita in 2024, whereas in SL it was approximately USD 134 per capita in 2023 (World Bank, 2025b). Similarly, health expenditure accounts for a larger share of national resources in NZ (around 10% of GDP in 2024) compared with approximately 4% of GDP in SL (2023) (World Bank, 2025a). In addition, differences in health workforce capacity are evident, with physician density in NZ estimated at approximately 3.6 doctors per 1000 population in 2022, whereas substantially lower workforce availability is observed in countries such as SL, where physician density is approximately 1.1 doctors per 1000 population in 2023(World Bank, 2025a). Together, these indicators demonstrate that, while both countries experience resource constraints, the magnitude and impact of these constraints are considerably greater in SL, which may limit the implementation and sustainability of school health initiatives (Rajapaksa et al., 2021; Wickramasinghe et al., 2019).

These contrasting epidemiological profiles provide valuable insights into how different national environments shape childhood health behaviours. Both SL and NZ share commitments to improving school environments for the betterment of children's health, yet differ substantially in their economic development, health system capacity and implementation frameworks. Understanding how these contextual differences translate into variations in health behaviours and outcomes among children is essential for developing evidence-based policies that not only address disparities but also leverage context-specific strengths to improve school-based health promotion.

1.2. Justification of the research

Despite global recognition of schools' importance for child health promotion, significant knowledge gaps persist in understanding how school food and PA environments function across different national contexts. Current research is predominantly conducted in high-income Western countries, creating uncertainty about the transferability of findings to other settings, particularly South Asian contexts, which differ in socio-cultural norms, health system capacity, and environmental determinants influencing PA and dietary behaviour. According to a systematic review of PA interventions in Asian children and adolescents, findings remain inconsistent despite some promising outcomes, mainly due to small sample sizes and methodological limitations (Ahmed et al., 2021).

The measurement of PA in paediatric populations has been dramatically improved with the use of objective monitoring technologies, particularly accelerometery. These devices provide continuous, objective data on movement patterns, intensity levels and sedentary time, overcoming many limitations associated with subjective reporting methods (Rowlands, 2018). However, the application and validation of accelerometery in diverse cultural contexts, particularly Asian populations, remains limited compared to Western countries. Evenson et al. (2022) found that among 155 observational studies using accelerometery in adults, the highest number originated from the United States, the United Kingdom, and Japan, with notably fewer studies from Africa (Evenson et al., 2022). This disparity is attributed to multiple barriers in

low- and middle-income countries (LMICs), including financial constraints, a shortage of trained personnel, and import restrictions that limit access to motion sensors (Hallal et al., 2012). Consequently, population-based PA studies in LMICs rely almost exclusively on self-report measures rather than objective accelerometery (Hallal et al., 2012). In Asian populations specifically, PA research has utilised both subjective and objective methods, but studies have been hampered by the lack of standardised, reliable, and cost-effective measurement tools (Muller et al., 2013).

More critically, limited attention has been given to children's subjective experiences of PA within school settings, that is, their engagement, motivation and quality of experiences in PE and playground activities. Research specific to South Asian populations reveals additional complexity; however, most studies, such as, Pallan et al. (2019) have focused primarily on intervention outcomes using objective measures, with limited exploration of children's subjective experiences of PA. This intervention, which was culturally adapted through the provision of bilingual family resources, sensitivity to religious and dietary practices and integration of teacher-led initiatives within the school day, demonstrated effectiveness in promoting positive behavioural change, including reductions in sedentary screen-based behaviours and modest but measurable increases in PA engagement. However, evidence from systematic reviews shows only modest promise, with outcomes difficult to interpret due to the lack of controlled evaluations and limited use of objective measures, underscoring the need for more rigorous and culturally responsive research in this area (Goode et al., 2017).

Gender disparities in PA participation represent another important public health concern. A study conducted by Guthold et al. (2020) demonstrated that girls engage in less PA than boys, with these differences becoming more pronounced during adolescence. These gender differences in PA participation vary across countries and cultural contexts, highlighting the need to understand the underlying social, environmental, and policy factors.

Similar to challenges observed in PA research, dietary assessment in paediatric populations faces significant methodological challenges, particularly due to factors affecting memory, portion-size estimation, and communication skills (Adamson & Baranowski, 2014). The 24-hour Multiple-Pass dietary Recall method (24-MPR) has emerged as the gold standard for population-level dietary assessment, offering advantages of being quick, culturally sensitive and not requiring high cognitive demands on participants (Gibson et al., 2017). However, its application in children requires careful consideration of age-appropriate protocols and validation procedures.

Another critical consideration of the dietary assessment of younger children is proxy reporting bias, which arises when parents report a child's dietary intake. This issue is particularly important for children under approximately 9 years of age, as children at this developmental stage have limited ability to accurately recall and report their own food intake, necessitating reliance on parental reporting. However, parental dietary recall often introduces inaccuracies, especially as parents may not fully capture food consumed at school or outside the home (Pérez-Rodrigo et al., 2015). To address these limitations, objective biomarkers, such as skin carotenoid measurements using the Veggie Meter®, have been explored as complementary tools for estimating fruit and vegetable intake (Rush et al., 2020). As part of a collaborative dietary assessment study in NZ, I contributed extensively to research applying this technology to school-aged children, which was published in *Nutrients* (see Appendix 1.3.2). This work

informed the methodological considerations of the present thesis and highlights the value of integrating objective and subjective measures in paediatric nutrition research.

While dietary assessment focuses on individual-level intake, understanding children's nutrition more broadly also requires examining the school food environment in which these behaviours occur. The school food environment encompasses the availability, accessibility, affordability, and promotion of foods and beverages within the school setting, including school meals, canteen operations, pricing structures, and nutrition-related policies. These factors collectively influence children's dietary behaviours and food choices during school hours (Story et al., 2009). These components of the school food environment are shaped by national policies and programmes, which vary across countries such as SL and NZ.

In both SL and NZ, various interventions have been implemented among schoolchildren to combat malnutrition. For childhood obesity prevention, the Ministry of Education in SL has provided nutrition education materials for schools and has actively contributed to implementing initiatives, such as Circular No. 35/2015, the Maintenance of Healthy Canteens in Schools, to ensure healthy food consumption among schoolchildren in SL. This Circular No 35/2015 prohibits canteen owners from selling foods with high amounts of sugar, salt and oils to schoolchildren (Ministry of Health SL, 2018). Additionally, the incorporation of physical activities (e.g., a mandatory 30-min period allocated for exercise per day) is part of the school curriculum in SL (de Silva & Barraclough, 2009). In NZ, the Childhood Obesity Plan was launched in 2015, aiming to improve a model for reducing childhood obesity. This model has 15 indicators that measure factors related to childhood obesity (Ministry of Health, 2017). Moreover, a more recent initiative called Healthy Active Learning (HAL) aims to deliver education and health outcomes for children across NZ is a joint government initiative between Sport NZ and the Ministries of Health and Education to improve the well-being of children/tamariki through healthy eating, drinking and quality PA. This is driven by a $47m Government commitment to the Child and Youth Wellbeing Strategy. As part of the HAL initiative, the Ministry of Health has updated its food and nutrition guidance for education settings. The guidance aligns with the National Healthy Food and Drink Policy for District Health Boards, but is adapted to meet the needs of children with the aim of creating a consistent message across a range of education settings (Sport New Zealand, 2025). Currently, there are limited established methodologies to measure the effectiveness of the above programmes of both countries.

The lack of comprehensive comparative studies examining both PA and nutritional environments across national contexts limits our understanding of how environmental factors shape children's health behaviours in different settings. Without such evidence, policies and interventions risk being modelled on Western contexts and may not address the unique cultural, economic, and infrastructural realities of countries such as SL. A systematic comparison between SL and NZ provides an opportunity to identify not only contrasts in school food and PA environments but also transferable lessons and context-specific challenges. This outcome-driven approach can inform the design of policies that are both evidence-based and sensitive to differing developmental and economic contexts, thereby enhancing their effectiveness and sustainability.

This study is designed to address this gap by examining PA behaviours and school food environments among schoolchildren in SL and NZ. It aims to generate insights into how environmental factors interact to influence children's health behaviours across contrasting

contexts, with a focus on methodological innovation and cross-country relevance. As a foundational step, a literature review was conducted to examine the use of accelerometers in Asian children, revealing significant methodological gaps. Most existing accelerometer cut points have been developed in Western contexts and may not accurately reflect the PA patterns of Asian children due to differences in body composition, age, sex, body mass index, geographical context, seasonality, and cultural behaviours. Building on this, our study compares objectively measured PA levels using accelerometers and children's engagement in PE settings across both countries to explore how environmental and cultural contexts are associated with movement behaviours. It also investigates school food policy environments by examining food availability, institutional policies, and practices to understand how these factors shape children's dietary behaviours in different country settings. Dietary assessment in children aged 9 to 13 years is particularly critical due to their unique nutritional needs during this developmental stage, including increasing energy requirements to support rapid growth, higher demands for key micronutrients such as calcium, iron and the need to support bone development and cognitive function. Recognising the 24-hour dietary recall as one of the most effective methods for capturing dietary intake in both SL and NZ settings, this study employed the 24-MPR approach to enhance data accuracy. To further strengthen the validity and reliability of this method, a modified recall protocol was developed and validated specifically for NZ children. Following its validation, the same modified method was applied to collect dietary data from SL schoolchildren, ensuring consistency in assessment while accounting for contextual differences. Assessing and comparing nutrient intake adequacy using 24-MPR methods highlights population-specific nutritional risks, guiding targeted interventions. This approach supports the generation of robust, comparable dietary intake data across diverse populations and contributes to improved paediatric nutrition research and supporting evidence-based policy and program development. However, no previous study has systematically compared both PA and school food environments between a lower-middle-income South Asian country (SL) and a high-income Pacific nation (NZ), highlighting a unique gap this thesis addresses.

1.3. Aims and objectives

This thesis aims to provide an evaluation and comparison of the healthy food environment and PA behaviours in a convenience sample of schools serving children aged 9-13 years in SL and NZ. The research addresses critical knowledge gaps through comparative analyses that collectively contribute to our understanding of how school food and PA environments influence child health across different national contexts.

The specific objectives include:

1.3.1 To synthesise current evidence on the use of accelerometers for measuring PA in Asian children, highlighting significant methodological gaps and informing best practices for objective activity assessment.

1.3.2 To compare objectively measured PA levels and children's subjective experiences of PE, including engagement, motivation, and perceived quality, between a sample of SL and NZ schoolchildren aged 5–13 years.

1.3.3 To examine school food environments in SL and NZ by analysing food availability, institutional policies, and practices, in order to understand how these factors shape children's dietary behaviours across both countries.

1.3.4 To develop and validate a modified 24-MPR protocol specifically tailored for NZ children aged 9–13 years, thereby enhancing the validity and reliability of dietary assessment methods in paediatric nutrition research.

1.3.5 To assess and compare the adequacy of energy and key nutrient intakes among schoolchildren aged 9–13 years in SL and NZ using the 24-MPR method, to identify population-specific nutritional inadequacies.

1.4 Thesis structure and approach

This thesis follows the thesis-by-publication format as outlined in Massey University guidelines. This thesis comprises nine chapters. One chapter is based on a published article, while the remaining research chapters, apart from the introductory, general discussion and critical reflection chapters, are structured as manuscripts prepared for submission to peer - reviewed journals. As each chapter is a standalone piece of work, some repetition of information across chapters is unavoidable. This thesis comprises chapters that together provide a thorough examination of school food and PA environments across two distinct national contexts. Following this introductory chapter, Chapter 2 presents a general literature review that establishes the theoretical and empirical foundations for understanding school food environments, PA measurement, and dietary assessment in paediatric populations.

Chapter 3 provides a narrative review of accelerometer-based assessment of PA in Asian children, addressing current challenges, identifying trends, and proposing future directions for objective PA measurement in this population. This chapter establishes the methodological foundation for PA assessment in Asian contexts, with particular relevance to the SL component of this research.

Chapter 4 evaluates PA observations in NZ and SL schoolchildren, examining both objectively measured PA levels using standardised accelerometery protocols and children's quantitative PA data, including experiences of engagement, motivation, and quality of experiences within PA and PE settings in a convenience sample of schools. This comparative analysis provides insights into how different national contexts influence both quantitative activity patterns and qualitative experiences of movement behaviours.

Chapter 5 explores food environments in a sample of NZ and SL schools, emphasising school food policies, practices, and food availability on school premises. This environmental analysis examines how institutional policies and community food landscapes interact to create distinct nutritional environments for children across countries.

Chapter 6 validates the modified 24-MPR method specifically developed for NZ children, incorporating methodological enhancements to ensure precise nutrition monitoring. This methodological study advances paediatric dietary assessment techniques and provides validated tools for future research in the NZ context.

Chapter 7 analyses nutrient intake among schoolchildren aged 9-13 years in NZ and SL, using the 24-MPR method to assess dietary patterns and identify population-specific nutritional concerns. This comparative nutritional analysis provides insights into the dietary adequacy and consumption patterns across both national contexts.

Chapter 8 provides a general discussion and conclusion, synthesising findings across all studies, discussing implications for policy and practice, addressing study limitations, and proposing directions for future research.

Chapter 9 provides a critical reflection on the ethical and methodological considerations encountered during this cross-national school-based research. It discusses ethical governance, institutional access, methodological decision-making, cross-country comparison, study limitations and lessons for future research.

1.5. Significance and expected contributions

This research addresses gaps in understanding school food and PA environments across two countries with distinct contexts. The cross-country comparison provides insights into how school-level practices and policies influence children's health environments, supporting the development of contextually appropriate interventions. The methodological contributions include validated approaches for PA measurement in Asian populations, enhanced understanding of children's subjective PA experiences, detailed evaluation of school food availability, policy and practices in both countries, and the development of a modified dietary assessment method validated for NZ children.

While this research provides valuable insights, it is based on a convenience sample of schools and should be considered a pilot study. Therefore, findings cannot be generalised to all schools in NZ and SL. Instead, they offer preliminary evidence and methodological contributions that can inform larger-scale studies and policy development.

The findings will provide insights that can support evidence-based policy discussions in both countries by identifying gaps and opportunities within school food and PA environments. By highlighting effective practices and areas for improvement, this research offers practical recommendations that can guide policymakers and educators in strengthening school health strategies addressing both PA and nutrition.

This thesis demonstrates the value of multi-component approaches to understanding child health environments. Rather than isolating individual factors, it considers the interplay of objective PA levels, subjective experiences, nutritional environments, and policy frameworks that collectively influence children's health behaviours and outcomes.

The comparative approach between a lower-middle-income South Asian country and a high-income Pacific nation provides valuable insights for international development efforts and health system strengthening initiatives, particularly for countries experiencing epidemiological transitions similar to those observed in SL. The methodological frameworks developed through this research, particularly the modified dietary assessment method, can be adapted and applied in other similar contexts, extending the impact of this work beyond the immediate study populations.

In conclusion, this thesis makes a significant contribution to understanding school food and PA environments across different developmental contexts, while advancing methodological approaches in paediatric health research. Through its comparative approach, this research provides evidence to support the development of effective, culturally appropriate interventions and policies that promote healthy behaviours among school-aged children.

1.6. Contributions by each researcher

The following table outlines the contributions by each researcher involved in this PhD thesis.

Table 1.1. Researcher Contribution

Researcher	Contribution
Harshani Perera *PhD researcher*	• Overall responsibility for research in SL and NZ. • Conceptualised and design, searched literature, drafted, and edited all chapters • Obtained ethical approvals for all data collection done in SL and dietary data collection in NZ • Recruited participants for NZ for dietary data collection and all data collection in SL • Organised and contributed to data acquisition in the HAL study • Supported data collection as part of the HAL project in NZ • Led all PA, food environment, and dietary data collection in SL • Conducted and reviewed 24-hour dietary recalls; processed data using nutrient analysis software • Processed and analysed all PA and dietary data • Interpreted study results • Co-supervised Masters in Nutrition and Dietetic students in NZ-school nutrition data collection
Professor David Rowlands *Primary Supervisor*	• Overall primary supervision • Conceptualisation and design, acquisition of funding, supervision of data collection and processing • Mentorship, connecting PhD candidate with key collaborators • Reviewing of thesis • Co-authoring manuscript versions of chapters
Professor Ajmol Ali *Co-Supervisor*	• Conceptualisation and design of the evaluation of the HAL initiative, acquisition of funding, supervision of data collection and processing • Mentorship, connecting PhD candidate with key collaborators • Reviewing of thesis and connected manuscripts

Professor Carol Wham *Co-supervisor*	• Involved in methodology, data analysis and reporting of HAL • Trained interviewers for 24-MPR and supervision of the whole process including dietary data processing • Reviewing of thesis
Professor Ananda Chandrasekara *Co-supervisor*	• Supervision of data collection and processing in SL arm • Reviewing of thesis
Owen Mugridge	• Assisted with accelerometer protocol and data handling • Supervised HAL data collection
Varshika Patel	• Interviewed NZ schoolchildren to collect dietary data • Processed 24-MPR data into nutrient data
Alexandra Murphy	• Interviewed NZ schoolchildren to collect dietary data • Processed 24-MPR data into nutrient data
Sarah McArley	• Processed weighted food records into nutrient data
Karen Mumme	• Assisted with statistical data analysis
Krutika Nanavati	• Openly shared knowledge in HAL

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Chapter 2

Literature Review: A review of physical activity, food environments, and nutritional adequacy in schoolchildren

This chapter synthesises existing evidence to establish the theoretical and methodological foundation for the thesis. It explores how school environments influence children's health behaviours, focusing on physical activity (PA), nutrition, and dietary assessment. Schools are recognised globally as critical settings for health promotion, yet research comparing these environments across diverse contexts remains limited, particularly in low- and middle-income countries.

This literature review is organised to provide the conceptual and methodological foundation for four empirical areas addressed in Chapters 4 - 7.

Section 2.2 examines physical activity and school-based environments, including children's perspectives, assessment methods, and global and regional trends, which underpin Chapter 4.

Section 2.3 briefly introduces physical activity measurement approaches; however, an in-depth literature review on this topic is presented in Chapter 3, which is a published narrative review addressing one of the thesis objectives.

Section 2.4 reviews school food environments and policy frameworks, providing context for Chapter 5.

Section 2.5 addresses nutrition and dietary assessment in school-aged children, including dietary inadequacies, methodological challenges, and measurement error, which support Chapters 6 and 7.

Collectively, these sections establish the theoretical and methodological basis for the comparative analyses presented later in this thesis.

Abstract

School environments, guided by policies and practices, are pivotal in shaping children's health behaviours by providing structured routines, equitable access to resources, and policies that promote nutrition and physical activity (PA). Despite this, global disparities persist, particularly between high-income countries (HICs) and low- and middle-income countries (LMICs). This review provides a narrative synthesis evidence on school PA environments, food environments, and dietary adequacy among children aged 5-13 years, focusing on New Zealand (NZ) and Sri Lanka (SL). A literature search was conducted using PubMed, Scopus, Google Scholar, and Massey University Discover databases. MeSH terms included Motor Activity, Schools, Students, Health Behaviour, Nutrition Policy, School Health Services, and Diet Surveys. Studies published in English from 2010–2025 were prioritised. Inclusion criteria encompassed research on PA perceptions, school food environments, and nutrient adequacy among schoolchildren aged 5-13 years. Exposure of children to the school environment can contribute up to 50% of the WHO-recommended 60 min of daily moderate-to-vigorous PA through physical education, recess, and active transport. Children's PA perceptions are shaped by enjoyment, competence, social support, and environmental factors, with older girls reporting greater barriers. Self-efficacy and peer/parental support emerged as strong correlates of PA. School food environments, comprising physical, economic, socio-cultural, and policy dimensions, significantly influence dietary behaviours. In NZ and SL, voluntary guidelines lack enforcement, and menus remain dominated by energy-dense, nutrient-poor items. Barriers include convenience, parental resistance, and profit-driven operations. National programmes such as NZ's Ka Ora, Ka Ako and SL's National School Meal Programme show promise but face challenges in coverage and sustainability. Nutritional adequacy during middle childhood is critical for growth and cognitive development. Evidence indicates persistent inadequacies in calcium, iron, and vitamins A and C, even with improved dietary diversity. School feeding and breakfast programmes enhance nutrient intake but require integration with broader strategies. Dietary assessment methods, particularly 24-hour multiple-pass recalls, offer reliable group-level estimates but face recall bias and measurement error. Significant gaps remain in cross-cultural comparisons, policy enforcement, and integrated PA-nutrition interventions. Future research should prioritise longitudinal designs, culturally tailored tools, and equity-focused strategies to strengthen school health environments and improve child health outcomes globally.

Keywords: physical activity, schoolchildren, school food policy, dietary adequacy, SDG 3 – Good Health and Well-being; SDG 4 – Quality Education; SDG 10 – Reduced Inequalities

2.1. Introduction

School environments play a key role in shaping children's health behaviours, particularly in relation to nutrition and PA. They include physical infrastructure, resources, policies, cultural norms, and social interactions that affect children's daily experiences (Pulimeno et al., 2020). Schools offer structured routines and equal access to health-promoting resources, such as nutritious meals, physical education, and recreational facilities for all children during critical developmental stages, unlike home or community settings (Jourdan et al., 2021). Furthermore, schools can adopt coordinated policies and curricula that strengthen healthy behaviours across various domains, supported by leadership, teacher involvement, peer influence, and institutional policies to foster a culture of health (Kalubi et al., 2023). Consequently, understanding the key factors influencing school food and PA environments is vital for assessing their effect on child health and guiding interventions (Cale, 2000).

While food and PA environments are often studied separately, they are deeply interconnected in shaping children's overall health and development (Economos et al., 2015). These environments can be understood through interactions among individual behaviours, relationships, school policies, and broader societal factors (Langille & Rodgers, 2010).

This chapter aims to synthesise existing evidence to establish the theoretical and methodological foundation for the thesis by examining how school environments influence children's health behaviours, with a particular focus on PA, nutrition, and dietary assessment. Specifically, it reviews evidence on PA and school-based environments, including children's perspectives, assessment methods, and global and regional trends, while also summarising approaches for measuring PA, noting that an in-depth review is presented in Chapter 3. Furthermore, it examines school food environments and policy frameworks that shape dietary behaviours and evaluates nutrition and dietary assessment in school-aged children, addressing dietary inadequacies, methodological challenges, and measurement error.

2.2. Physical activity and its role in school-based health promotion

The World Health Organisation (WHO) defines PA as any bodily movement produced by skeletal muscles that requires energy expenditure, encompassing activities such as walking, cycling, sports, active play, and recreation (World Health Organization, 2024). This foundational definition distinguishes PA from exercise, which is a planned, structured subset of PA aimed at improving or maintaining physical fitness (Thompson et al., 2003). Building on this distinction, physical education (PE) is a structured school subject that teaches children the skills, knowledge, and attitudes needed to be active for life. While PA is the behaviour, PE is the educational foundation that supports and promotes it (Coulter & Ní Chróinín, 2013). Research demonstrates that quality PE programmes can significantly enhance moderate-to-vigorous PA (MVPA) levels through in-class activity and by fostering positive attitudes toward PA (Trudeau & Shephard, 2005). Simple modifications in PE lessons can effectively increase activity during class (Slingerland & Borghouts, 2011), and successful PE-based interventions often target psychological determinants such as perceived competence, enjoyment, and self-determination, which are associated with higher participation in PA and sustained engagement over time (Wallhead & Buckworth, 2004). Given the rising prevalence of obesity and sedentary behaviours, updating PE curricula is essential, as schools provide an ideal setting for promoting lifelong health. PE thus represents the educational framework for developing PA behaviour (Motevalli, 2024).

Schools are uniquely positioned to promote PA because children spend approximately 30 hours per week in this setting, offering opportunities through PE, recess, active transport, and extracurricular activities (Cline et al., 2021). The WHO recommends at least 60 min of MVPA daily for children, and schools can contribute up to half of this target (Centers for Disease Control and Prevention, 2024; Cline et al., 2021; Watson et al., 2017).

The school PA environment refers to the multidimensional setting that shapes students' ability, motivation, and opportunities to be active (Crooks et al., 2021). The Social Ecological Model provides a framework for understanding these influences by categorising them into five levels: intrapersonal, interpersonal, organisational, community, and public policy (Table 2.1). This classification highlights that PA is shaped not only by individual factors such as self-efficacy and motor skills but also by broader determinants, including school policies, cultural norms, and national legislation (Hu et al., 2021b; Sallis et al., 2006). Recognising these interconnected levels is essential for designing interventions that address barriers and facilitators across the entire school environment.

Table 2.1. Influence levels and descriptions in the school physical activity context.

Level	Description
Intrapersonal	Individual knowledge, attitudes, self-efficacy, and motor skills.
Interpersonal	Support from peers, teachers, and parents.
Organisational	School-level policies, curriculum design, health education, teacher training, and facility availability.
Community	Cultural norms and neighbourhood safety.
Public Policy	National and regional legislation, guidelines, and funding for school PA programmes.

A well-designed PA environment plays a critical role in health promotion. Physiologically, regular PA reduces the risk of non-communicable diseases, supports healthy growth, musculoskeletal fitness, and weight management (Tambalis, 2022). It also contributes to reduced stress and anxiety, enhanced mood, and improved social interactions (Goran et al., 1999). Participation in school sports has also been associated with greater self-esteem and confidence than non-participation (Harrison & Narayan, 2003). Moreover, PA supports cognitive outcomes by improving thinking, judgment, and learning skills, which are critical to academic achievement (Watson et al., 2017). Habits formed during childhood strongly predict adult activity patterns, reinforcing the importance of early intervention (Green et al., 2005). However, disparities persist globally: High-income countries (HICs) often provide structured PE and facilities, while low- to middle-income countries (LMICs) face challenges such as inadequate infrastructure and limited policy support (Bann et al., 2019; Li et al., 2024). Addressing these gaps requires multi-level strategies that integrate policy enforcement, infrastructure investment, and community engagement.

2.2.1 Literature search and study selection

A focused narrative search was conducted to identify studies that assessed determinants of PA perceptions among schoolchildren, as outlined in Table 2.2.

Table 2.2. Search framework for determinants of physical activity perceptions.

Component	Details
Databases	PubMed, Scopus, Google Scholar; Massey University Discover (aggregated academic search platform)
MeSH Terms	Motor activity, exercise, physical fitness, health behaviour, child, adolescent, students,
Free-text Keywords	Physical activity perceptions, attitudes toward physical activity, beliefs, barriers, facilitators, determinants, school-age children, school environment
Boolean Operators	AND, OR (e.g., (“physical activity” AND (“perceptions” OR “attitudes” OR “beliefs” OR “barriers” OR “facilitators”) AND (“children” OR “adolescents”) AND (“school” OR “school environment”)))
Time Frame	2010–2025 (prioritise recent studies relevant to determinants of PA perceptions)
Language	English
Inclusion Criteria	Peer-reviewed studies examining determinants of PA perceptions among schoolchildren (5–17 years), including individual, interpersonal, environmental, and policy-level factors
Exclusion Criteria	Studies focusing on adults or preschool children, intervention-only studies without perception data, non-peer-reviewed sources, review articles

2.2.2 Frameworks and approaches to children's physical activity perceptions

While schools provide structured opportunities for PA, these efforts can only succeed if they resonate with children's own experiences and motivations. Understanding these perceptions is critical for designing interventions that are both relevant and effective. Children's views on PA are shaped by multiple interconnected factors across individual, social, and environmental levels.

At the individual level, enjoyment, perceived health benefits, and rewards act as motivators, while time constraints and lack of interest serve as barriers (Tay et al., 2021). Social influences, such as peer support, parental permission, and group belonging, significantly affect participation (Eskola et al., 2018; Stanley et al., 2013; Tay et al., 2021). Environmental factors include access to facilities, weather conditions, playground availability, and neighbourhood safety (Eskola et al., 2018; Stanley et al., 2013; Tay et al., 2021). Children also identify unique barriers such as bullying, teasing by peers, and fear of dangerous animals or objects (Stanley et al., 2013). Primary-age children generally maintain active lifestyles through play with friends and organised activities, though older girls show decreased enthusiasm, suggesting a need for targeted interventions (Mulvihill et al., 2000).

Children aged 5–13 years are in a key developmental period where their attitudes and behaviours towards PA are influenced by their surroundings, experiences, and social factors (Tay et al., 2021). Traditional methods of assessing PA often depend on parental reports; however, research has demonstrated notable differences between parent and child reports of PA activities (Thorn et al., 2013). These differences emphasise the need to gather data directly from children to ensure accuracy and contextual relevance. Involving children as active participants in research not only improves data quality but also makes the findings more applicable to real-world contexts (Jacquez et al., 2013).

The Youth PA Promotion Model provides a useful framework for understanding these perceptions (Figure 2.1). It highlights three key components: Predisposing factors, which include individual-level influences such as motivation, attitudes, beliefs, self-efficacy, enjoyment, and perceived competence; Enabling factors, which refer to environmental supports like access to facilities, equipment, and safe spaces, as well as the individual's fitness and skills; and Reinforcing factors, which involve social influences such as encouragement and support from parents, peers, and teachers/coaches (Belton et al., 2014; Welk, 1999). These factors are further shaped by demographics such as age, gender, ethnicity, and socioeconomic status, which impact how children perceive and engage with PA opportunities (Welk, 1999).

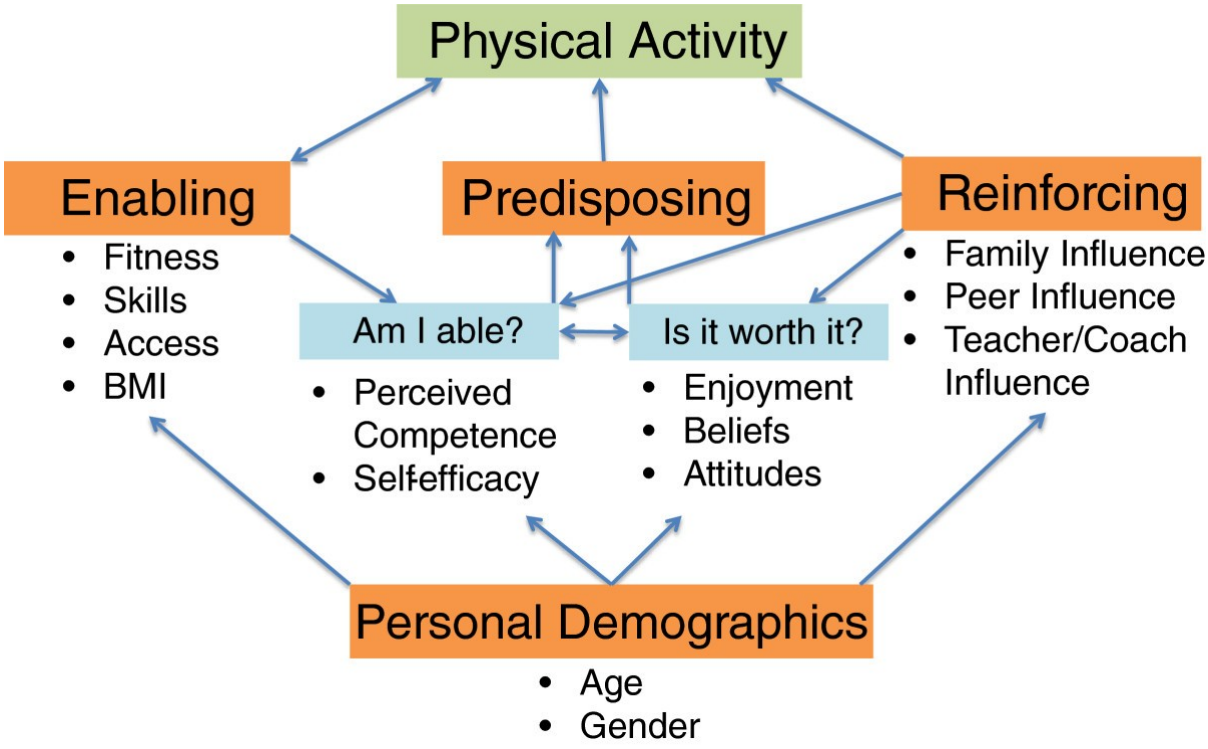


Figure 2.1. Interrelationships within the youth PA promotion model.

Note: Figure adapted from Belton et al. (2014).

Several methods have been developed and validated to assess children's perceptions of PA. Focus group discussions are commonly used to explore shared experiences, motivations, and barriers in a peer-supported setting, particularly effective for children aged 9 to 13 (Tay et al., 2021). Semi-structured interviews offer a more individualised approach, allowing researchers to delve deeper into personal experiences and preferences, especially among younger children who may feel more comfortable in one-on-one settings (James & Christensen, 2017). Creative assessment techniques, such as children's drawings, offer engaging alternatives to traditional surveys and have revealed positive conceptualisations of PA among children in weight-management programmes (Sharpe et al., 2004; Walker et al., 2009). Self-report questionnaires, such as the PA Questionnaire for Children (PAQ-C), are suitable for children aged eight and above, offering structured insights into activity types and contexts (Kowalski et al., 1997). Additionally, combining device-based measures (e.g., accelerometers) with child feedback through diaries or interviews can enrich understanding by linking objective data with subjective experiences (Migueles & Solis-Urra, 2024).

Building on these conceptual and methodological insights, the next section synthesises empirical evidence on determinants of PA perceptions among schoolchildren.

2.2.3 Studies examining determinants of physical activity perceptions among school-age children

Evidence from multiple contexts demonstrates that children's perceptions of PA are shaped by interacting individual, social, and environmental factors. The studies in Table 2.3 operationalise the child-centred perspective outlined in 2.2.1 by combining qualitative, survey, longitudinal, quasi-experimental, and case-study approaches to capture how children perceive

and experience PA across socio-ecological levels. Qualitative designs (focus groups, drawings, interviews) elicit context-specific barriers/facilitators (e.g., bullying, uniform, rules, and "hang-out" space needs) that are difficult to surface with standard questionnaires, thereby improving intervention relevance (Martinez-Andres et al., 2020; Pawlowski et al., 2014; Stanley et al., 2012).

Qualitative studies provide depth but limited generalisability; their rigour is strengthened where triangulation and structured content analysis are applied (Martinez-Andres et al., 2020; Pawlowski et al., 2014). Cross-sectional surveys quantify patterns but are constrained by self-report bias; multilevel modelling Wilk et al. (2018) enhances internal validity by partitioning school- and neighbourhood-level variance and privileging child-perceived support over parent report (Taylor et al., 2018; Wilk et al., 2018). Quasi-experimental evidence links structured PE content to improved fitness perceptions, a key motivational mediator for sustained PA (Sepúlveda-Figueroa, 2023). The case study of five Japanese public elementary schools demonstrated how multiple PA opportunities were embedded within daily school routines through policy and organisational support, highlighting how system-level policy alignment normalises daily PA opportunities, an organisational condition rarely measured in quantitative work (Webster & Suzuki, 2014).

Gender and age consistently shape perceived barriers and engagement; girls and older children report more safety and opportunity constraints (Martinez-Andres et al., 2020; Taylor et al., 2018). Barrier self-efficacy emerges as the strongest individual correlate of PA, underscoring the role of perceived capability (Zhang et al., 2012). Child-perceived parental and peer support are robust correlates of activity; simple behaviours (e.g., taking a child to a sporting event) predict participation and lower dropout (Vella et al., 2014; Wilk et al., 2018). Social friction at recess (conflicts, teasing) directly suppresses play and reshapes perceptions of safety and acceptance (Pawlowski et al., 2014; Stanley et al., 2012).

Perceived barriers are place-dependent: urban children emphasise traffic/strangers, whereas rural children cite distance and infrastructure deficits (Taylor et al., 2018). School context explains more variance than neighbourhood proximity, suggesting that how spaces and routines are organised (rules, equipment rotation, supervised conflict management) matters more than mere access (Pawlowski et al., 2014; Wilk et al., 2018). System-level policies that embed PA across the school day can recalibrate children's expectations (Webster & Suzuki, 2014).

Notably, all studies identified through the search were conducted in high-income countries, highlighting a lack of evidence on children's perceptions of PA in low- and middle-income settings. Consequently, the transferability of these findings to developing countries should be considered with caution. Collectively, these studies confirm that effective interventions should target multiple levels of influence. This includes enhancing children's perceived competence, strengthening social support networks, and adapting strategies to contextual factors such as urbanicity and school culture.

Table 2.3. Summary of research on determinants of physical activity in schoolchildren.

Author (Year)	Country	Sample size, sex & age	Investigated factors	Methods	Key findings
Martinez-Andres et al. (2020)	Spain	n=98 8–11 y urban & rural	Individual: sex, age. Microsystem: parental scheduling/ academics priority, fathers as PA models, friends. Mesosystem: overloaded schedules, work–family balance. Exosystem: safety and weather.	22 focus groups and drawings;	Main barriers: family-organised schedules restricting spontaneous outdoor play; girls have fewer unscheduled PA opportunities; recommend parental awareness and gender-sensitive options.
Taylor et al. (2018)	Canada	n=892; 8–14 y; urbanicity spectrum	Intrapersonal: girls and visible minorities report more barriers; older children—safety concerns. Interpersonal: maternal employment and low-income barriers. Physical: urban vs rural differences—urban safety, rural distance and infrastructure.	Cross-sectional surveys (child and parent)	Context-specific barriers: rural: lack sidewalks/bike lanes, distance; Urban: traffic/strangers; suburban: crowding & crime perceptions. Emphasizes place-tailored interventions.
Wilk et al. (2018)	Canada	n=1,517; 9–11 y; 99 schools	Individual: gender; father's higher education Interpersonal: child-perceived parental and peer support; Environmental: school-level neighbourhood; proximity	PAQ-C; child/parent surveys;	Interpersonal perceptions explain most PA variance; school context matters more than neighbourhood; geographic distance to facilities not associated with PA.
Pawlowski et al. (2014)	Denmark	n=111 53 boys 58 girls ~10.4 y	Physical: lack of space, facilities, maintenance, occupied areas, weather. Social: conflicts, peer influence, limited teacher support. Organisational: recess rules, indoor allowances, electronic devices.	Qualitative; 17 focus groups;	Top 5 barriers: weather, conflicts, lack of space, lack of play facilities, and screen use. Gendered needs: Boys - activity facilities; Girls - secluded hang-out spaces
Vella et al. (2014)	Australia	n=4,042 8–10 y (LSAC)	Individual: sex Interpersonal: parental support (sport event), household size, parental education, language. Community/School: specialist PE teacher access. Socio-economic status: household income.	Longitudinal; Waves 3 - 4; parent/teacher questionnaires;	Participation predictors: male, fewer household members, higher income, English at home, higher parental education, taken to sporting event, specialist PE teacher.

					Dropout predictors: lower income, lower parental education, non-English, not taken to sporting event.
Webster and Suzuki (2014)	Japan	5 public schools Grade 2 classes	Policy: national course emphasises PA/health/moral education. Organisational: principals schedule recess, equipment, long lunch. Interpersonal: PE leaders coordinate events and support teachers. Individual: multiple PA opportunities daily.	Qualitative case study;	Ample PA opportunities across day (recess, cleaning, assemblies). Strong top-down policy alignment; professional collaboration enabling school-wide PA.
Bengoechea et al. (2013)	Spain	n=3,249 12–17 y; 1,548 girls	Demographic/biological: age, BMI. Psychological: physical self-perceptions; health-related participation motives. Behavioural: smoking. Social: parental & friends' attitudes; parental LTPA. School: perceptions of PE; grade in PE; type of school	Population-based school survey; self-reported LTPA and PA Index	Higher odds of nonparticipation with lower physical self-perceptions, smoking, friends' apathy, father never active, less-positive PE perceptions and lower PE grades; among LTPA participants,
Stanley et al. (2012)	Australia	n=54 23 boys 31 girls 10–13 y	Physical: space/access/ condition, equipment, weather, uniform, safety. Social: peers (bullying/acceptance), teachers. Individual: enjoyment, competence, motivation. Organisational: school rules, time constraints.	Same-gender focus groups;	Barriers: bullying, rules, uniform, equipment condition; facilitators: enjoyment, peer support, access to equipment, rule-modification for games.
Zhang et al. (2012)	USA	n = 285 142 boys 143 girls 12–15 y	Individual: Barrier self-efficacy (strongest predictor) Interpersonal: Support from friends, parents, PE teachers Physical environment: Equipment accessibility, neighbourhood safety	Cross-sectional survey; PA measured via PAQ-C;	Self-efficacy was the strongest predictor of PA; friends' and parents' support were significant; equipment accessibility had a small effect; neighbourhood safety was not significant.

y – years, PA – Physical activity, PE – Physical education, LTPA – leisure time physical activity, LSAC - longitudinal study of Australian children, PAQ-C- Physical activity questionnaire - children

2.2.4 Insights and cultural relevance in PA research in school-aged children

Researchers characterising PA among school-aged children have identified a concerning global trend of low engagement. Guthold et al. (2010), analysing data from 72,845 children across 34 countries, found that only 23.8% of boys and 15.4% of girls reached the WHO recommended activity levels, with significant differences ranging from 8.8% in the Philippines and Zambia to 37.5% in India (Guthold et al., 2010). Similarly, Tremblay et al. (2014), in a 15-country comparison using standardised indicators, reported generally low levels of children's PA worldwide, highlighting the inconsistency that countries with poorer infrastructure often had higher activity levels (Tremblay et al., 2014). Research examining PA among culturally and linguistically diverse populations reveals significant disparities and intervention challenges. Objective measurements demonstrate that PA varies among ethnic groups; for example, South Asian children accumulate significantly less MVPA and spend more time sedentary compared to White European peers, while Black children tend to achieve higher MVPA levels but show similar sedentary patterns. However, findings for Hispanic/Mexican American children remain inconsistent (Eyre & Duncan, 2013). Among culturally and linguistically diverse communities in Australia, migration is associated with decreased PA, particularly leisure-time activity, influenced by perceptions of PA, language barriers, financial constraints, and cultural/religious considerations (Wang et al., 2023). Such insights are essential for designing culturally appropriate and effective interventions.

In recent years, investigators have increasingly explored children's perspectives on PA behaviours and influencing factors. These studies, primarily conducted in Western contexts such as NZ (Deng et al., 2025), England (Stanley et al., 2012) and the USA (Harrison & Narayan, 2003), have provided valuable insights into children's motivations, barriers, and environmental influences, including the importance of enjoyment, peer relationships, parental support, access to facilities, and safety perceptions in shaping PA participation (Tay et al., 2021). Although the specific barriers and facilitators varied across settings, common themes included the influence of social support, opportunities for play, and access to supportive environments for PA. Some research has emerged from Asian contexts, notably in China and Japan; however, these studies often lack stratification by age and gender, which limits their applicability across diverse populations (Aoyagi et al., 2020; Wang et al., 2020). In culturally diverse countries like Singapore, understanding PA behaviours among younger adolescents (aged 9-12 years) is particularly important, as they have less autonomy over their activity choices compared to older adolescents (Doggui et al., 2021; Kneeshaw-Price et al., 2013). Therefore, stratifying data by gender and age enables researchers to identify unique patterns and preferences.

2.2.5 Trends in physical activity among schoolchildren in Sri Lanka and New Zealand

Research on PA practices among South Asian schoolchildren reveals concerning patterns of insufficient activity levels such as low compliance with the recommended 60 min of MVPA per day, high sedentary time, and limited participation in organised sports compared to other ethnic groups. Environmental and cultural factors create barriers to PA, including parental constraints, safety concerns, perceptions of weather, and religious practices (Eyre et al., 2015; Smith et al., 2018a). However, schools provide important foundations for promoting PA attitudes and behaviours among South Asian children (Eyre et al., 2015).

Physical activity data for SL children are limited, but existing studies suggest low levels of structured PA in schools and limited opportunities for active play, particularly in urban settings (Senarath, 2021). Physical activity among schoolchildren in SL has been a growing concern due to increasing sedentary behaviours and associated health risks. A study conducted in urban Colombo schools found that while over half of children aged 8–12 engaged in more than one hour of daily PA. The study also reported substantial television viewing and high attendance at tuition classes, indicating that sedentary behaviours occupied a considerable portion of children's time(Wickramasinghe et al., 2009). Similarly, Godakanda et al. (2018) reported that only 33.1% of adolescents aged 14–15 years were sufficiently active, with males being more active than females (Godakanda et al., 2018). A national survey by the Medical Research Institute revealed regional disparities in PA levels and highlighted the link between low activity and rising obesity rates among children aged 6–12 years (Jayatissa et al., 2017). Furthermore, the Ministry of Health's National Action Plan (2021–2025) emphasises school-based interventions, including mandatory PA sessions and participation in non-competitive sports; yet, only 15.5% of adolescents aged 13–17 meet the WHO guidelines for daily PA (Ministry of Health, 2021).

In NZ, while many children participate in organised sports, overall, PA levels remain below recommended thresholds, with significant disparities across ethnic and socioeconomic groups. Pacific children, in particular, face barriers such as limited access to safe recreational spaces, cultural norms around body image, and competing academic pressures (Ministry of Health New Zealand, 2025). The Active Healthy Kids Global Alliance Report Card grading framework assigns grades according to the proportion of children meeting a defined benchmark: A (81-100%), B (61-80%), C (41-60%), D (21-40%), and F (0-20%), with plus (+) and minus (-) modifiers indicating values at the upper or lower end of each grade range(Active Healthy Kids Global Alliance, 2022). The 2014 Report Card showed that overall PA received a B grade, but sedentary behaviour was concerning with a C grade, particularly due to age-related decline in participation among adolescent females (Maddison et al., 2014). By 2018, approximately one-third of NZ children failed to meet the recommended ≥60 min of daily moderate-to-vigorous PA (Smith et al., 2018b). The 2022 Report Card revealed persistent issues, with overall PA declining to C+ and active transportation scoring poorly at D, alongside substantial inequities across gender, ethnicity, disability status, and socioeconomic factors (Wilson et al., 2022).

2.3. Physical activity level assessment in children

Detailed discussion of PA level assessment methods, particularly the use of accelerometers in children, is provided in **Chapter 3: Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions**, a published narrative review that highlights context-specific considerations and emerging best practices.

2.4. School food environment and its role in children's health

The school food environment comprises physical, economic, socio-cultural, and policy factors influencing students' dietary behaviours, as shown in Table 2.4 (O'Halloran et al., 2020; Swinburn et al., 2013). It includes all spaces within and around school premises where food is available, purchased, or consumed, such as canteens, tuck shops, vending machines, and food vendors (Downs et al., 2020). Given that children consume up to 37% of their daily energy intake during school hours, schools represent a critical setting for promoting healthy eating habits and preventing diet-related non-communicable diseases (Bell & Swinburn, 2004).

Table 2.4. Four food environment dimensions and measurement methods.
(adapted from (O'Halloran et al., 2020))

Dimensions	***Description***
The physical environment (What was available?)	Refers to the availability and condition of food service infrastructure within schools, including purpose-built canteens, inadequate facilities, or the absence of facilities altogether. It also includes the types of food items offered and the frequency with which they are sold.
The economic environment (What were the financial factors?)	Encompasses financial aspects such as whether the food service operates for profit, is outsourced to private vendors, or runs on a not-for-profit basis. It includes the pricing of healthy versus unhealthy food items, children's spending limitations, and the influence of product placement and pricing strategies within the canteen.
The socio-cultural environment (What were the attitudes and perceptions?)	Involves the attitudes, beliefs, and practices of individuals responsible for food provision. This includes their nutrition knowledge and training, the prioritization of healthy eating within school management, and the extent to which the food service offers nutritionally valuable options.
The policy environment (What were the rules?)	Relates to the presence and effectiveness of school food policies that regulate the types of food and beverages sold, promotional practices, and pricing strategies. It also considers who is responsible for enforcing these policies and how well they are implemented.

The quality and accessibility of school food environments vary significantly across countries, depending on income levels, which in turn shape children's dietary behaviours and nutritional outcomes. In HICs, schools often offer a diverse range of food options, including fruits, dairy products, and whole grains, but also face challenges related to the availability of ultra-processed foods and sugary snacks (Global Child Nutrition Foundation, 2024). In contrast, LMICs typically rely on staple-based school meal programs that prioritise food security and basic nutrition, often constrained by limited resources and infrastructure (Aliyar et al., 2015; World Food Programme, 2021). These disparities reflect broader socioeconomic inequalities: HICs invest in food quality and regulation, while LMICs prioritise consistent access, often sourcing locally to support health and community livelihoods (Rockefeller Foundation, 2025).

Despite these differences, increasing attention to the role of school food environments in promoting child health, significant gaps remain in the design and evaluation of food environment interventions. A systematic review by O'Halloran et al. (2020) identified 38 studies assessing the school food environment globally. The majority (87%) were conducted in HICs, with only two studies from Asia, highlighting a significant geographic gap in the literature. Furthermore, the review revealed a lack of standardised methodologies, with studies

using diverse tools such as menu audits, surveys, interviews, and observations. This methodological heterogeneity limits the ability to compare school food environments across countries and undermines efforts to develop globally applicable interventions. O'Halloran et al. (2020) also found that most studies focused on the physical environment (47%) and policy environment (37%), while the economic and socio-cultural dimensions were underexplored.

Schools worldwide, often supported by government initiatives, have implemented a range of food-related interventions aimed at improving students' eating behaviours, food choices, and nutritional knowledge (Chaudhary et al., 2020). School-based interventions are typically classified into two categories: environmental and behavioural (Bonell et al., 2013). Environmental strategies modify the physical food environment by restricting energy-dense, nutrient-poor items and promoting healthier options in canteens, while behavioural approaches target individual attitudes, knowledge, and preferences through nutrition education, awareness campaigns, and counselling (Bonell et al., 2013). Evidence suggests that environmental interventions alone improve food choices, whereas educational approaches, particularly curriculum-based programmes, enhance diet quality and nutrient intake (Bahnfleth et al., 2022; French & Stables, 2003). Multi-component approaches therefore appear most effective for promoting healthy eating among schoolchildren (Chaudhary et al., 2020).

At the same time, the quality of food provided in educational institutions plays a crucial role in evaluating children's nutritional status and long-term health prospects. Nutritional quality involves two main aspects: adequacy, which ensures access to nutrient-rich, health-promoting foods such as fruits, vegetables, whole grains, lean proteins, and essential nutrients, and moderation, which restricts the intake of foods high in added sugars, saturated fats, and sodium, as these are linked to negative health outcomes (Clark & Fox, 2009).

Research on school meal programmes reveals mixed outcomes regarding children's dietary quality. Most public schools in the USA provide lunch meals that meet federal standards for protein, vitamins, and minerals. Still, fewer than one-third met standards for total fat or saturated fat in lunches (Crepinsek et al., 2009). They also found the school breakfast programme in the USA performed better on fat standards, although both meal types contained excessive sodium and insufficient fibre compared to dietary guidelines (Crepinsek et al., 2009). While school meal programmes in the USA were linked to reduced nutrient inadequacy among children, they also correlated with increased intake of excess sodium (Clark & Fox, 2009). Notably, 80% of public school children had excessive saturated fat intake and 92% had excessive sodium intake, regardless of programme participation (Clark & Fox, 2009). These findings emphasise the need for updated nutrition standards that better align with current dietary recommendations, particularly focusing on reducing fat and sodium while increasing fibre content (Institute of Medicine Committee on Nutrition Standards for National School & Breakfast, 2010).

2.4.1. Literature search and study selection

A focused narrative search was conducted to identify studies that assessed school food policy and compliance measurement, as outlined in Table 2.5.

Table 2.5. Search framework for school food policy and compliance measurement.

Component	Details
Databases	PubMed, Scopus, Google Scholar; Massey University Discover (aggregated academic search platform)
MeSH Terms	Nutrition policy, food services, school health services, health promotion, child, students,
Free-text Keywords	School food policy, school food availability, school meals, school canteen, food environment, schoolchildren, compliance, monitoring,
Boolean Operators	AND, OR (e.g., ("schoolchildren" AND ("school food policy" OR "school food availability") AND ("compliance" OR "monitoring")))
Time Frame	No strict upper bound; prioritise recent studies relevant to school food policy implementation and compliance
Language	English
Inclusion Criteria	Peer-reviewed studies assessing school food policy**,** food availability, and compliance measurement
Exclusion Criteria	Studies where food policy is not relevant to school settings**,** intervention studies**,** policies for non-school environments (e.g., workplaces, hospitals), not included review articles, website articles.

2.4.2. Physical and policy food environment in schools

In this review, we focus exclusively on two components of school food environments: (1) the physical environment, which refers to the availability and accessibility of foods within the school setting, and (2) the policy environment, which encompasses the rules, standards, and guidelines that govern the provision and sale of foods in schools (O'Halloran et al., 2020). Physically, school canteens and tuck shops often offer energy-dense, nutrient-poor items such as sugary drinks, fried snacks, and processed foods, which contradict dietary guidelines and promote unhealthy eating patterns (Sanigorski et al., 2005; Vandevijvere et al., 2019). Food choices are further shaped by taste preferences, convenience, cost, peer influence, and cultural norms, with barriers to healthy eating often outweighing enabling factors (Ghaffar et al., 2019; Neumark-Sztainer et al., 1999). Socioeconomic disparities also limit access to nutritious options, particularly in low-income urban neighbourhoods where healthy foods may be less available, less affordable, or more difficult to access than energy-dense processed foods (Pinheiro et al., 2022).

School food policies aim to improve this environment by setting standards for food availability, pricing, marketing, and nutritional quality within and around schools (Food and Agriculture Organization of the United Nations, 2022). Effective policies can increase healthy food options and reduce unhealthy ones, but implementation is often hindered by financial constraints, inadequate facilities, and stakeholder resistance (Reilly et al., 2018; World Health

Organisation, 2021). Effective implementation requires adequate funding, strong leadership, stakeholder engagement, and integration with broader health and education policies (Mâsse et al., 2013).

Globally, there is growing momentum toward institutionalising school food policies. Over 466 million children benefit from school meal programmes, with governments investing approximately USD 84 billion annually (World Food Programme, 2024). Many countries have adopted nutrition standards, marketing restrictions and home-grown feeding models linking local agriculture to schools (Gabriel, 2009; Woods et al., 2014). However, enforcement and success vary, and resource limitations in LMICs, LMICs remain a major challenge (World Health Organisation, 2021).

As shown in Table 2.6, studies across diverse countries consistently highlight gaps between school food policy intentions and actual compliance within school food environments. In Saudi Arabia, audits of primary and high schools revealed moderate adherence to national guidelines, with widespread availability of energy-dense foods and an absence of fruits and vegetables (Alsiwat et al., 2025; Aldubayan & Murimi, 2019). Similarly, in Iran, over half of the foods sold in school canteens failed to meet national standards, and compliance with WHO – Eastern Mediterranean Region Nutrient Profile Model (WHO-EMR) nutrient criteria was even lower, underscoring the need for policy revision and stronger monitoring mechanisms (Babashahi et al., 2021).

Evidence from NZ and Australia indicates that while many schools have policies in place, menus remain dominated by unhealthy items, and voluntary guidelines often lack enforcement power (Hills et al., 2015; Pillay et al., 2025; Woods et al., 2014). Barriers such as convenience, parental resistance, and profit-driven canteen operations were common across contexts (Girona et al., 2019). In Canada, facility adequacy and staff capacity were positively associated with policy adherence, suggesting that infrastructure investment is critical for success (McIsaac et al., 2019).

Global trends, including initiatives in South Korea, Uruguay, and India, show that even where policies exist, such as traffic-light systems or bans on sugary drinks, compliance remains modest without robust enforcement, financial support, and stakeholder engagement (Choi et al., 2017; Bassi et al., 2021). Collectively, the studies in Table 2.6 emphasise that effective implementation requires multi-component strategies: mandatory standards, regular audits, training, incentives, and integration with broader health and education frameworks. Without these measures, school food environments continue to promote unhealthy dietary patterns, contributing to childhood obesity and poor nutrition outcomes.

Table 2.6. Food policies and food environment compliance across countries.

Author	Study Country	Objective of the Study	Setting	Respondent	Description of Method	Main Findings	Existing policy	Recommendations
Alsiwat et al. (2025)	Saudi Arabia	Explore compliance of public primary schools with Saudi school canteen policy guidelines.	80 public primary schools in Riyadh	School store audits	Unscheduled visits; checklist scoring; structured questionnaire.	70% average compliance; 98.8% lacked healthy options; none offered fruits or vegetables; many still sold chocolate and fried snacks.	Saudi School Canteen Policy guidelines for healthy food provision in primary schools.	Enforce the mandate and monitor compliance regularly
Pillay et al. (2025)	New Zealand	To examine how school food policies and perceived barriers influence food provision in primary school canteens using the Healthy Food and Drink Guidance for Schools.	Primary schools across New Zealand (n=239 for survey; n=80 for menu analysis).	School leaders; menus coded	Cross-sectional study: school food policy and practices survey; menu audits using traffic-light classification system.	Most schools had policies, but menus dominated by unhealthy items; barriers include convenience and parental resistance.	Voluntary Healthy Food & Drink Guidance; traffic-light system suggested.	Mandate guidelines; set clear targets; monitor compliance; multi-component support (training, feedback, incentives).
Babashahi et al. (2021)	Iran	To analyse the Healthy School Canteen policy and identify challenges in its implementation to improve school food environments.	Primary schools in Tehran province.	Key informants and audits	Mixed-method study: policy analysis using interviews and document review; quantitative assessment of 64 school canteens against national and WHO-EMR standards.	Over 54% of foods did not comply with national guidelines and 85% with WHO standards;.	Policy needs revision with evidence-based criteria, improved monitoring, stakeholder engagement, and financial support for healthy food provision.	Clarify nutrient criteria; adopt WHO standards; improve monitoring
Bassi et al. (2021)	India	To examine the food environment in and around schools and	Schools and colleges in urban and	Schools, students, parents	Cross-sectional observational study; audits of food outlets	High availability of energy-dense,	Food Safety and Standards Authority	ban sale of unhealthy foods within school

		colleges and its influence on students' dietary choices.	semi-urban India.		and canteens; interviews with stakeholders.	nutrient-poor foods both inside and outside schools; limited healthy options;.	of India guidelines for school canteens	premises, regulate vendors near schools, and implement nutrition education programs.
Aldubayan and Murimi (2019)	Saudi Arabia	Assess compliance of boys' public high schools with Saudi school nutrition policy and evaluate nutritional value of foods offered using IOM standards.	76 boys' public high schools in Riyadh	Principals and canteen managers	Interviews with principals and canteen managers; observation checklist.	Moderate compliance with Saudi policy; low alignment with IOM standards; energy-dense foods common; no fruits or vegetables.	Saudi School Nutrition Policy aimed to restrict unhealthy foods list (2004/2013) and promote healthy options.	Provide training and resources; align with international standards
Girona et al. (2019)	Uruguay	To evaluate implementation of the healthy snacking initiative and explore factors underlying compliance from school principals' perspective.	Primary and secondary schools in Montevideo.	Principals and audits	Mixed-method approach: semi-structured interviews and survey of foods/beverages sold and advertised.	Low compliance; barriers included advertising, lack of knowledge, and profit-driven canteen operations.	Policy recommends clearer communication, monitoring, sanctions, and incentives for healthy options.	Introduce sanctions for violations; prioritise minimally processed foods
McIsaac et al. (2019)	Canada	Examine how adequacy of facilities and staff capacity relate to food availability and policy adherence.	Public schools in Nova Scotia	School principals	Cross-sectional online survey;	Adequate facilities linked to higher adherence;	Nova Scotia School Food and Nutrition Policy requiring healthy food standards in schools.	Increase funding for facilities; integrate adherence checks
Choi et al. (2017)	South Korea	To assess changes in food availability in school stores after implementation of food-based and nutrient-based policies.	Middle and high schools in Seoul.	School store audits	Observational study comparing foods sold before (2006) and after (2013) policy implementation.	Soft drink availability decreased; energy dense nutrient poor foods remained widely	Special Act on Safety Management of Children's Dietary Life (enacted in 2007, revised in 2009).	Strengthen competitive food standards and implement monitoring

						available; compliance modest.		
Hills et al. (2015)	Australia	To assess changes in adherence to the NSW Healthy School Canteen Strategy and identify school characteristics influencing compliance.	Primary schools in Hunter New England region, NSW.	Primary schools	Prospective cohort study; menu audits in 2007 and 2010 using traffic-light classification system.	Proportion of schools with no 'red' items increased; median proportion of 'red' items decreased; rural schools lag.	Mandatory policy using traffic-light system	Include stronger enforcement, targeted support for small and rural schools, and monitoring mechanisms
(Woods et al., 2014)	Australia	To assess compliance of school canteen menus with state or territory guidelines using the traffic-light system and identify factors influencing adherence.	Government-funded primary and secondary schools across all Australian states and territories (263 menus assessed).	Government schools	Cross-sectional audit of online school canteen menus; classification of items into 'green', 'amber' and 'red'; cost comparison between healthy and unhealthy items.	Western Australia had highest compliance other states compliance low. Menus dominated by amber items;, Discretionary and banned items common. Healthy options cost more than unhealthy ones.	Traffic-light system; bans on sugary drinks & confectionery; Western Australia mandates annual menu checks, others voluntary.	Enforce monitoring; subsidize healthy foods; train schools; incentivize manufacturers for 'green' items.
Hood et al. (2013)	USA	Examine association between federally required wellness policy components and availability of foods/beverages in competitive venues.	Middle & high schools	School administrators	Questionnaire data; nationally representative sample.	Higher wellness policy scores linked to more healthy options and fewer sugary drinks	Child Nutrition and WIC Reauthorization Act (2004) mandated local wellness policies in schools.	Mandate numeric targets; implement audit-feedback systems
de Silva-Sanigorski et al. (2011)	Australia	To assess compliance of Victorian schools with the School Canteens and Other	Primary and secondary schools	School menus	Cross-sectional study; menu audits of 106 school canteens	No school met both policy and traffic-light guidelines.	School canteens and other School food services policy.	stronger enforcement, clearer targets, monitoring systems,

	School Food Services Policy and traffic-light guidelines.	across Victoria.	against policy and traffic-light criteria.	Menus dominated by amber and red items; compliance did not improve healthiness.	and multi-strategy interventions to improve compliance.

IOM- Institute of medicine
WHO-EMR - World Health Organization – Eastern Mediterranean Region Nutrient Profile Model
WIC- Special supplemental nutrition program for women, infants, and children

2.4.3. New Zealand's food policy and physical food environments

New Zealand schools have progressively adopted food policies, with recent data showing 82.9% of schools reporting healthy food and drink policies (Pillay. et al., 2022) and 58.8% in Hawke's Bay having food policies (Chote et al., 2022). Earlier studies indicated only 16.5% of primary schools had food policies, suggesting an improvement over time (Carter & Swinburn, 2004). However, implementation remains inconsistent. Only 57.4% of teachers felt they upheld their school food policy (Pillay. et al., 2022), and many policies use generic templates lacking comprehensive guidance (Chote et al., 2022). Key barriers include the convenience of processed foods, parental resistance, profit concerns, food insecurity, and nearby food outlets (Chote et al., 2022; Pillay. et al., 2022). Secondary schools face particular challenges, being more likely to sell unhealthy food and use food as rewards (Chote et al., 2022).

Despite policy efforts, the school food environment remains obesogenic. Under the traffic light food classification system, schools are encouraged to provide predominantly "green" foods (healthy choices for everyday consumption), while limiting "red" foods (energy-dense, nutrient-poor choices high in fat, sugar, and/or salt) (Healthy Eating Advisory Service, n.d.). Menu audits reveal that energy-dense, nutrient-poor items dominate offerings, with "red" category foods comprising 40–53.6% of items in primary and secondary schools, and only 3.3% of intermediate/secondary schools meeting the recommended 75% "green" threshold (Green et al., 2025; Pillay et al., 2024). These findings reiterate earlier data from Carter and Swinburn (2004), who reported that unhealthy food options exceeded healthy choices by more than two to one in school sales (Carter & Swinburn, 2004). Socioeconomic disparities further compound the issue. Low-decile schools (deciles 1-3, serving communities with the highest levels of socioeconomic disadvantage) tend to offer fewer healthy options and a higher proportion of unhealthy foods compared to high-decile schools (deciles 8-10, serving communities with lower levels of socioeconomic disadvantage), indicating inequities in food access and quality across the education system (Green et al., 2025; Pillay et al., 2024). Infrastructure limitations also play a role; only 15% of schools were found to have purpose-built canteen facilities, which restricts their capacity to prepare fresh meals and increases their reliance on pre-packaged foods (Carter & Swinburn, 2004).

Several national programmes aim to address these challenges. The Ka Ora, Ka Ako Healthy School Lunches Programme, launched in 2019, provides free nutritious lunches to low-decile schools and now reaches over 921 schools (de Seymour et al., 2022; Ministry of Education, 2022). Complementary initiatives include Fruit in Schools, which increased fruit intake during intervention periods (Ashfield-Watt et al., 2009), and the Fonterra Milk for Schools programme, which improved dairy intake without adverse BMI effects (Marsh et al., 2018). A school breakfast programme was also developed using a stepped wedge design across 16 primary schools, offering cereal, milk, and toast (Ni Mhurchu et al., 2010). National survey data further confirmed that skipping breakfast is associated with higher BMI and poorer dietary behaviours, particularly among older children from socioeconomically deprived backgrounds (Utter et al., 2007). While these interventions show promise, they are not universal and primarily target low-decile schools. Furthermore, economic and procurement priorities can affect the quality and acceptability of school meals, as highlighted by concerns about food quality, appropriateness, and service delivery that prompted an Auditor-General inquiry into the Ka Ora, Ka Ako Alternative Provision Model in 2025 (Auditor-General, 2025). Broader, sustained efforts integrating policy enforcement, infrastructure investment, and equity-focused strategies are needed to create healthier school food environments nationwide (de Seymour et al., 2022).

2.4.4. Sri Lanka's food policy and physical food environments

Sri Lanka has implemented several initiatives to improve school food environments. The National School Meal Programme (NSMP) serves over one million children aged 5 to 10 years in Grades 1–5 across 7,902 schools, aiming to reduce hunger, boost attendance, and enhance learning. However, limited budgets and rising food costs hinder consistent delivery. Partnerships with NGOs like Save the Children support food supply in some schools (NewsWire, 2024).

To regulate food sold within school, the Ministry of Education introduced the School Canteen Circular 2015/35 and the School Canteen Policy Guide, which prohibit the sale of foods high in sugar, oil, and salt (Ministry of Education, 2015). School principals are responsible for enforcing these guidelines, including limiting the availability of deep-fried foods and eliminating junk food from school canteens (Ministry of Education, 2015).

Despite these efforts, implementation challenges persist. Studies report that only 30.7% of schools in Rathnapura had functioning canteens, and overall compliance was unsatisfactory due to poor coordination between health and education sectors (Malwenna et al., 2020). Service quality assessments in the Western Province revealed substantial gaps, including inadequate food preparation areas, a lack of proper food covering, and minimal use of protective equipment by staff (Weerasinghe et al., 2017). Teachers also face barriers to nutrition education, including time constraints, lack of resources, and insufficient parental support (Rumaisa et al., 2021).

The physical food environment further undermines policy goals. Research shows that over 90% of food outlets near schools sold unhealthy foods, with 72.3% of students consuming confectionery, and healthy food choices accounted for only 5-12% (Senevirathne et al., 2023). Proximity to energy-dense food outlets doubles the risk of consuming low-nutrient foods (Senevirathne et al., 2024). A UNICEF-supported review found that only 30% of children met minimum dietary diversity standards, while over 60% regularly consumed fried snacks and sugary drinks, often purchased from school canteens or nearby vendors (Gardner, 2025). These patterns contribute to both undernutrition and rising overweight and non-communicable disease prevalence. (Gardner, 2025).

Despite the presence of 10,155 government schools in SL, most schools do not offer any meals for students (Department of Census and Statistics, 2016). While some rural schools benefit from localised meal programmes initiated by non-profit organisations, national-level efforts remain fragmented (Townsend et al., 2015). Students typically rely on homemade meals or purchase food from external vendors. Although fast food sales are prohibited on school premises, the influence of these policies is limited because student can easily obtain processed foods from vendors remain widely accessible just outside school boundaries (Townsend et al., 2015). Schoolchildren in urban areas are migrating away from traditional, locally produced foods due to the availability of highly processed and advertised foods across the country (Townsend et al., 2015). Urban children are increasingly shifting away from traditional diets due to the aggressive marketing and availability of ultra-processed foods, while rural children face persistent malnutrition and food insecurity (Wickramasinghe, 2022). These dual burdens highlight the need for comprehensive, nationwide strategies that strengthen enforcement of policies, improve infrastructure, and ensure equitable access to nutritious foods across all schools. (Wickramasinghe et al., 2004).

2.5. Role of nutrition in school-age children

Middle childhood and early adolescence (ages 5–15) constitute a vital period of growth and development, characterised by puberty, bone maturation, brain development, and increasing independence in behaviour and decision-making. Nutrition plays a crucial role in supporting these changes, facilitating catch-up growth from earlier undernutrition and reducing the risks associated with overnutrition (Abdullah, 2015; Pulimeno et al., 2020). Adequate intake of energy and protein is crucial for physical development and cognitive functioning, with brain glucose metabolism reaching its peak during this stage (Langille & Rodgers, 2010). Micronutrient requirements also increase during this period, with iron, calcium, vitamin D, zinc, iodine, and folate being particularly important. For example, iron deficiency is linked to impaired learning and concentration, while calcium and vitamin D are crucial for bone health (Story et al., 2002). Zinc and protein are especially vital where animal-source foods are limited, and their deficiency can hinder growth and immune function(Neumann et al., 2002). Notably, evidence shows that catch-up growth and cognitive recovery are possible during the school-age years, even after early childhood deficits, emphasising this stage as a key window for nutritional intervention (Economos et al., 2015).

Worldwide, children of school age face a dual challenge of malnutrition—undernutrition alongside increasing rates of overweight and obesity. Although data for children aged 5–15 are limited, existing evidence indicates that nutritional deficiencies continue into middle childhood, especially in LMICs (Best et al., 2010). According to UNICEF/WHO/World Bank Group (Joint Child Malnutrition Estimates) (2023), 22.3% of children under five had low height-for-age (stunting), 6.8% had low weight-for-height (wasting), and 5.6% had high weight-for-height (overweight or obese). These trends are likely to persist into school-age groups, with a rising prevalence of obesity seen in regions such as Latin America, Asia, and Africa, while low height-for-age, low BMI-for-age, anaemia, and other micronutrient deficiencies continue to affect many children and adolescents, reflecting the double burden of malnutrition (Wrottesley et al., 2022). Micronutrient deficiencies remain widespread, with approximately 25% of school-age children suffering from anaemia, primarily due to iron deficiency. Deficiencies in vitamin A, vitamin D, calcium, and zinc are also common, especially in LMICs (Best et al., 2010). Dietary patterns among school-age children often feature poor diversity, high intake of ultra-processed foods, and low consumption of fruits and vegetables, contributing to both undernutrition and obesity (Manyanga et al., 2017).

Despite the recognised importance of this developmental stage, middle childhood and early adolescence have historically received less focus in nutrition research compared to infancy and late adolescence. A review of PubMed literature from 2005–2016 found that over 95% of studies concentrated on children under five, with just 4% addressing the 5–15 age group (Bundy et al., 2017). This research gap is notable given increasing recognition of middle childhood and adolescence as critical periods for growth, development, and the establishment of lifelong health behaviours (Sawyer et al., 2018). More recently, Saavedra and Prentice (2023) highlighted the continued neglect of school-aged children and adolescents in nutrition research and policy despite their substantial nutritional needs. This oversight partly arises from inconsistent terminology; terms like “school age,” “middle childhood,” and “early adolescence” are used interchangeably across disciplines, often defined by biological, social, legal, or educational criteria (Saavedra & Prentice, 2023). Figure 2.2 summarises the terminology most commonly used for childhood growth and developmental stages.

Public health databases such as Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) usually track nutrition indicators for children under five and resume in adolescence or adulthood, leaving a significant gap in data for the 5–14 age group (Gray et al., 2013). This lack of age-specific data hinders the development and implementation of targeted interventions during a crucial phase of growth and cognitive development (Saavedra & Prentice, 2023)

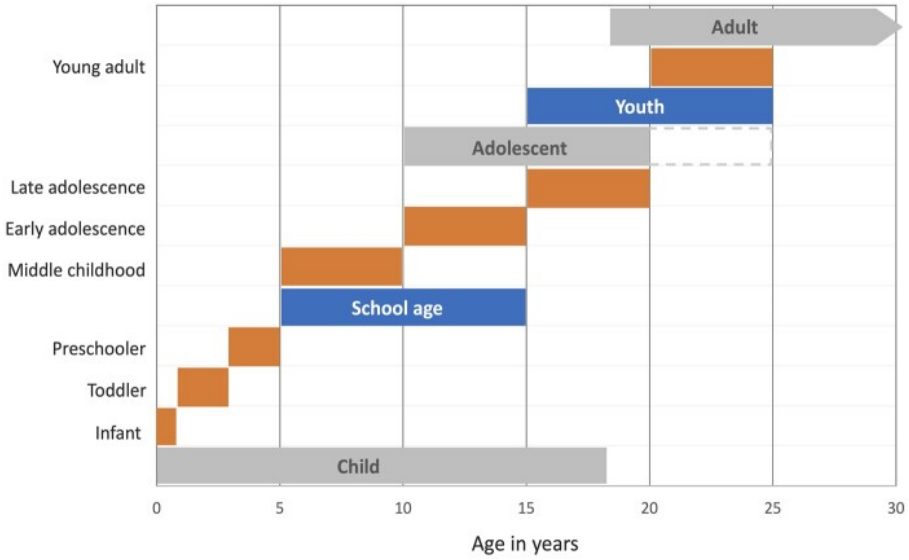


Figure 2.2. Major development life stage and commonly used terminology.
Note: Literature search and study selection for specific developmental stages as related to age (Saavedra & Prentice, 2023).

A focused narrative search was conducted to identify studies that assessed nutrient adequacy among school-age children and examined the dietary assessment methods employed, as outlined in Table 2.7.

Table 2.7. Search framework for identifying studies on nutrient adequacy.

Component	Details
Databases	PubMed, Scopus, Google Scholar; Massey University Discover (aggregated academic search platform)
MeSH Terms	Nutritional Status, Diet Surveys, Energy Intake, Feeding Behaviour, Micronutrients, Child, Students, Dietary Recall, Nutrition Assessment
Free-text Keywords	nutrient adequacy, dietary adequacy, school-age children, micronutrient intake, dietary diversity, 24-hour recall, EAR, AR, AI, RDA, Sri Lanka, New Zealand
Boolean Operators	AND, OR (e.g., (“school-age children” AND (“nutrient adequacy” OR “dietary adequacy”) AND (“dietary assessment” OR “24-hour recall”))
Time Frame	No strict upper bound; emphasis on studies relevant to current dietary adequacy frameworks
Language	English

Inclusion Criteria	Peer-reviewed studies assessing nutrient intake adequacy in school-age children (5–19 years) using dietary assessment methods and adequacy cut-offs
Exclusion Criteria	Clinical samples not representative of general schoolchildren (e.g., specific medical conditions), Studies on preschool (<5 years), tertiary education, or those not addressing school settings, not included review articles, case studies, website articles.

2.5.1. Evaluating nutrient adequacy in schoolchildren

The Dietary Reference Intakes (DRIs) framework, developed by the Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (National Academies), provides age- and sex-specific benchmarks for nutrient requirements (Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference, 2000). According to them, DRIs include several components: Estimated Average Requirement (EAR) for assessing population adequacy, Recommended Dietary Allowance (RDA) for individual goals, Adequate Intake (AI) when EAR is unavailable, and Tolerable Upper Intake Level (UL) to avoid excess. In research, nutrient intakes are compared to these reference values to determine the proportion of individuals meeting adequacy or to calculate metrics such as the Mean Probability of Adequacy (MPA). Nutrient adequacy was assessed by comparing observed intakes to these reference values: if the group mean intake was ≥ EAR, the prevalence of inadequacy was considered low; if < EAR, inadequacy was likely high (Barr et al., 2002). For nutrients with AI, adequacy was inferred when mean intake met or exceeded AI, though this does not quantify the prevalence of inadequacy. For macronutrients, adequacy was assessed against Acceptable Macronutrient Distribution Ranges (AMDR), and fibre against RDI benchmarks (Gibson, 2024). Table 2.8 provides key definitions of DRIs.

Table 2.8. Definitions of Dietary Reference Intakes (DRIs).

Component	**Definition**
Recommended Dietary Allowance (RDA)	Average daily intake level sufficient to meet the nutrient requirements of nearly all (97–98%) healthy individuals in a specific life stage and gender group.
Estimated Average Requirement (EAR)	Median daily intake value estimated to meet the requirement of half the healthy individuals in a particular life stage and gender group.
Adequate Intake (AI)	Recommended average daily nutrient intake level based on observed or experimentally determined approximations of intake by a group of apparently healthy people; used when evidence is insufficient to set an EAR and RDA.
Acceptable Macronutrient Distribution Range (AMDR)	Range of intake for a macronutrient (as % of total energy) associated with reduced risk of chronic disease while providing adequate intake of essential nutrients.

Source - Definitions follow the DRI framework (National Academies) (Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference, 2000).

Several studies have examined nutrient adequacy among school-age children using different approaches. Evidence across studies in Table 2.9 shows that diet quality, school meal exposure, meal timing, and socio-economic context consistently shape nutrient adequacy among school-

age children.

In Israel, Peng et al. (2019) found that higher adherence to the Mediterranean diet, assessed using the KIDMED-index, was associated with improved micronutrient profiles and lower energy density; however, calcium, potassium, fibre, vitamin E and often vitamin A and folate remained common inadequacies even when overall diet quality improved. Similarly, in Kenya, lower-income settings, dietary diversity scores (DDS) calibrated to nutrient contributions or using portion thresholds most closely track the mean probability of adequacy (MPA), reflecting cereal-heavy diets with very low intake of animal-source foods and particularly poor calcium adequacy (Gewa et al., 2014).

Building on these findings, evidence from Ghana shows that school feeding and breakfast programmes that include micronutrient-dense or fortified items (e.g., corn and soy blend, fruit) markedly raise MPA and close specific gaps such as vitamin A and C, though iron status changes may lag (Abizari et al., 2014). Likewise, research from India indicates that regular breakfast consumption is associated with higher daily energy and micronutrient intakes and fewer nutrient deficits, while skipping breakfast is common and associated with lower nutrient adequacy (Durgannavar & Vijayalakshmi, 2021).

Further, in the Philippines, dietary diversity alone is insufficient; even at a DDS of 9, the MPA reached a steady state of around 60%, with calcium, folate, and vitamins A and C remaining inadequate. This underscores the need for food fortification and improved access to nutrient-rich foods, particularly among rural and low-socioeconomic status groups. (Mak et al., 2019). In Ethiopia, beyond food choices, behavioural factors such as nutrition knowledge, consumption of at least three meals per day, and higher DDS independently predict energy and protein adequacy among adolescent girls (Ayal et al., 2025).

These themes guide the exploratory comparison between SL and NZ. Applying harmonised criteria (EAR/AI) and considering diet-quality indices, school food environments, breakfast/meal frequency, and rural/urbanicity will be critical for interpreting differences in nutrient intake and adequacy and for identifying policy levers, e.g., school breakfasts/lunches with calcium-rich and fortified items, fruit/vegetable provision, and diet-quality promotion, to address persistent gaps (fibre, Ca, folate, vitamins A, E, K) across contexts.

Table 2.9. Summary of studies assessing schoolchildren nutrient intake adequacy.

Author (Year)	Country	Sample size (n, age)	Objective	Data collection procedure	Nutrients analysed	Adequacy reference	Key findings (nutrient adequacy)
Ayal et al. (2025)	Ethiopia (Meshenti)	n=401; 10–19 y (girls)	Macronutrient intake inadequacy and associated factors	Single 24-h multiple-pass recall; DDS from 10 food groups	Energy, protein, carbohydrate, fat	WHO/FAO/IOM RDAs	57.6% inadequate energy; 18.5% inadequate protein; carbs high, fat low; low DDS strongly associated with inadequacy
Badaik (2025)	India (Jharkhand)	n=200; 7–9 y	Nutrient adequacy, food group consumption, diet quality (nutrient adequacy ratio, mean adequacy ratio, average overall ratio)	3 non-consecutive 24-h recalls and FFQ	Energy, protein, fat, Ca, Fe, vitamins B_1, B_2, C, beta-carotene	ICMR 2020 RDAs; Nutrient adequacy ratio ≥0.66 adequate	Mean Nutrient adequacy ratio boys 0.66, girls 0.59; Mean adequacy ratio boys 0.72, girls 0.67; severe deficits in milk, fruits, green leafy vegetables; energy/protein/fat below RDA
Durgannavar and Vijayalakshmi (2021)	India (North Bengaluru)	n=200; 10–12 y; government & private schools	Breakfast consumption pattern and impact on nutritional adequacy	Questionnaire on breakfast habits; 24-h recall for 7 consecutive days	Energy, protein, fat, calcium, iron, β-carotene, vitamin C	ICMR RDAs (2010); adequacy expressed as % of RDA	Breakfast skippers had lower intake of all nutrients; consumers had higher energy, protein, calcium, iron, β-carotene, vitamin C; even consumers below RDA except calcium; socioeconomic disparities influenced adequacy
Horikawa et al. (2020)	Japan	n=836; 10–11 y; 19 schools	Role of school lunches in nutrient adequacy and income disparities	4-day weighed dietary records with photos (2 weekdays with school lunch, 2 weekend days without school lunch)	Energy, macros, vitamins A, B_1, B_2, B_6, C, D, E, K; minerals Ca, Fe, Zn, Mg, P, K, Mn, Cu	Japanese DRIs (EAR, AI, Dietary goal)	School lunch improved adequacy; non-lunch days had higher inadequacy; low-income children most affected
Mak et al. (2019)	Philippines	n=6460; 6–12 y	Relationship between dietary diversity and probability of adequacy of 11	Single 24-h recall; DDS based on 9 food groups; Probability of adequacy and MPA	Calcium, iron, zinc, folate, vitamins A, C, B_1, B_2, B_6, B_{12}, niacin	EAR-based probability of adequacy; MPA as overall adequacy indicator	Mean DDS=4; MPA at DDS=4 ≈35%; even at DDS=9, MPA only ≈60%; Ca, folate, vitamin A, vitamin C remained inadequate even at high DDS;

			micronutrients by socio-economic status and dwelling location	calculated using EAR cut-offs			higher socio-economic status and urban children achieved better adequacy
Ndungu and Chege (2019)	Kenya (Nairobi)	n=312; 8–11 y	Dietary diversity and micronutrient adequacy	Three-day 24-h recall; DDS from 7 food groups	Ca, Fe, Zn, vitamins A, C, B vitamins, folate	FAO/WHO Recommended nutrient intakes; nutrient adequacy ratio and mean adequacy ratio	Mean DDS=3.8; Mean adequacy ratio=0.59; widespread inadequacy (Ca, Fe, Zn, Vit A, B12); DDS positively correlated with adequacy
Peng et al. (2019)	Israel	n=5005; 11–18 y	Mediterranean diet adherence and micronutrient adequacy	Validated FFQ (95 items), calibrated with 24-h recall	17 nutrients: Ca, Fe, Mg, P, K, Zn, Cu, vitamins A, E, C, B_1, B_2, B_3, B_6, B_{12}, folate, fibre	Israeli guidelines (based on US IOM RDAs/AIs)	Higher KIDMED* score - better adequacy; poor adherence group had severe inadequacy for Ca, K, fibre, vitamin E, folate
Rubio-Lopez et al. (2017)	Spain (Valencia)	n=1176; 6–9 y	Calcium adequacy and association with overall nutrient adequacy	3-day food records by parents	Calcium, energy, macros, fibre, vitamins A, C, D, E, B-complex; minerals Fe, Zn, Mg, I	Spanish DRIs (EAR, AI, AMDR)	25.8% inadequate Ca; adequate Ca linked to better overall adequacy; excess protein/fat; low carbs/fibre
Abizari et al. (2014)	Ghana (Northern Region)	n=383; 5–13 y; 196 in SFP, 187 non-SFP	Compare nutrient intake adequacy and iron status between SFP and non-SFP participants	Quantitative 24-h recalls and weighed food records for school lunch; blood samples for Haemoglobin, serum ferritin	Energy, protein, fat, carbohydrate, Fe, Zn, Ca, vitamins A, C, B_{12}, folate	EAR-based probability of adequacy; MPA calculated; WHO cut-offs for anaemia and Fe status	Energy and nutrient intakes significantly higher in SFP group; MPA = 0.61 vs 0.18 in non-SFP; school lunch contributed >90% of daily vitamin A and C intake; Hb higher in SFP group (+6 g/L); anaemia prevalence slightly lower;
Gewa et al. (2014)	Kenya (Embu)	n=529; 4–14 y	DDS and micronutrient adequacy	Up to 3 non-consecutive 24-h recalls; mothers interviewed	14 micronutrients: Fe, Zn, Ca, Mg, K, vitamins A, B_6, B_{12}, C, E, thiamine, riboflavin, niacin, folate	EAR (IOM); AI for K; Fe/Zn adjusted for bioavailability	MPA ≈57%; Ca adequacy lowest; DDS strongly correlated with adequacy; widespread micronutrient inadequacy
Chitra and Reddy (2007)	India (Secunderabad)	n=802; 10–15 y	Breakfast habits and impact on nutrient adequacy	24-h recall and 1-week breakfast record	Energy, protein; some micronutrients discussed	Indian RDAs (ICMR); Nutrient adequacy ratio ≥0.66 adequate	57% skipped breakfast; breakfast eaters had higher energy/protein; overall intakes below RDA; underweight prevalent

Lopez-Frias et al. (2005)	Spain (Granada)	n=521; 6–11 y	Compare adequacy vs Spanish recommended intake; effect of school canteen use	4-day food record and FFQ; weighed portions in canteen	Energy, macros, fiber, vitamins A, B_1, B_2, B_6, C, D, E; minerals Ca, Fe, Zn, Mg, I	Spanish recommended intake	Protein and fat high; carbs low; vitamins mostly adequate except D/E; Zn and Mg slightly low; canteen users had better intake

AI- adequate intake; AMDR - acceptable macronutrient distribution range; EAR - estimated average requirement; MPA – mean probability of adequacy; RDA – recommended dietary allowance;
DDS - Dietary Diversity Score; FFQ – food frequency questionnaire;
FAO – Food and Agriculture Organisation; ICMR – Indian Council of Medical Research; IOM – Institute of medicine;
WHO – World Health Organization;
SFP -school feeding programme
KIDMED* - Mediterranean diet quality index for children and adolescents

2.5.2. Dietary assessment in children

Dietary assessment involves the systematic collection and interpretation of food consumption data to evaluate nutritional intake and its connection to health outcomes (Lennernäs, 1998). Accurate assessment helps to identify undernutrition, overnutrition, and micronutrient deficiencies, which impact physical health, cognitive performance, and long-term disease risk (Sherwood, 2008). Furthermore, dietary data are essential for informing school-based nutrition programmes, guiding public health initiatives, and shaping evidence-based policies that promote healthy eating habits within diverse cultural and socioeconomic contexts (Saavedra & Prentice, 2023).

Selecting appropriate dietary assessment methods for school-aged children requires careful consideration of validity, reliability, and context-specific factors. Dietary assessment approaches can be prospective or retrospective, each presenting unique challenges (McPherson et al., 2000). Table 2.10 summarises commonly used dietary assessment methods for school-aged children, outlining their respective strengths and limitations. Therefore, method selection should account for participant age, lifestyle, and study objectives, as all methods have inherent limitations, including under-reporting and errors in portion size estimation (Rupasinghe et al., 2020).

Prospective methods, such as estimated food records and weighed records, reduce reliance on memory and can capture detailed intake; however, they are demanding for both children and parents, and may alter usual eating behaviours due to self-monitoring (Thompson & Subar, 2017). Retrospective methods, including 24-hour dietary recalls and FFQ, are more practical in large populations and less burdensome; however, children's limited cognitive ability to recall foods, estimate portion sizes, and report independently introduces significant recall bias (Livingstone & Robson, 2000; Shim et al., 2014). Consequently, dietary assessment in this age group requires a careful balance between accuracy and feasibility, often involving parental assistance or support from the interviewer to improve data quality.

Research on dietary assessment methods for school-aged children highlights significant methodological challenges and variations in accuracy across different approaches. A systematic review comparing dietary methods to doubly labelled water (DLW) found that 24-MPR conducted over at least three days with parental help provided the most accurate energy intake estimates for children aged 4-11 years, while weighed food records were best suited for younger children (0.5-4 years) (Burrows et al., 2010). Food records consistently underestimated energy intake by 19-41%, whereas 24-hour recalls tended to over-report by 7-11% (Burrows et al., 2010). In school settings, specifically, meal observations consistently demonstrated good interrater reliability, while school meal recalls showed poor accuracy for individual food reporting but provided acceptable group-level energy intake estimates (Tugault-Lafleur et al., 2017). Overall, correlations between validation standards and dietary methods were generally higher for recalls and records compared to food frequency questionnaires. However, generalising results remains challenging due to inconsistent study designs and validation standards across research (McPherson et al., 2000).

Table 2.10. Comparison of methods to measure dietary intake.
(Table adapted from (Tugault-Lafleur et al., 2017) and (Staudacher et al., 2022))

	Description	Strengths	Limitations
Prospective			
Weighed food record (WFR)	Participants or their support persons document the weight and details of all foods and beverages consumed, using kitchen scales, over a specified period of one to seven days. Researchers often utilise two-dimensional representations of shapes, like a matchbox, along with participant-taken photographs of foods and beverages to convert volume or area descriptions into mass estimates.	• Provides detailed information on timing of meals, portion size (objective actual amount consumed) • Description of the food, without reliance on memory. • Higher reproducibility compared to estimated food records.	• High participant burden including sound literacy and numeracy skills requirements. • Demands a high degree of cooperation from the participant. • Labour-intensive task of inputting data into analysis software. • Ideally requires skilled researchers with having knowledge of use coding rule
Unweighted food records	Similar to the weighed food record, this method estimates consumption subjectively rather than using kitchen scales. Household measures (jugs, cups, bowls, spoons), often calibrated by researchers, are commonly employed. Researchers also use two-dimensional shapes (e.g.,matchboxes) and photographs of foods/beverages taken by participants to convert volume or area into mass estimates.	• Provides detailed information on timing of meals, portion size (subjective estimate of amount consumed) • Description of the food, with reduced reliance on memory due to real-time or near-time recording. • Greater feasibility and lower participant burden compared to weighed food records. • Suitable for free-living populations and larger-scale studies.	• Moderate participant burden including sound literacy and numeracy skills requirements. • Moderate researcher burden due to the labour-intensive task of inputting and coding data. • Ideally requires skilled researchers and the use of standardised coding rules. • Relies on participants' ability to estimate and describe portion sizes accurately.
Direct observation	Trained observers systematically record all foods and beverages consumed by participants in real time, typically within controlled settings such as schools or research facilities. Observers note portion sizes, preparation methods, and consumption behaviours using standardised recording sheets or digital tools. To estimate quantities, they may use visual aids (e.g., reference portions, food models) and calibrated utensils. This method minimises reliance on participant memory.	• Provides detailed information on timing of meals, portion size (visually estimated by trained observers) • Description of the food, without reliance on participant memory • Minimises reporting bias and social desirability effects • Useful for populations with limited literacy or cognitive ability •	• High researcher burden due to the need for trained observers and extensive time commitment • Logistically challenging in free-living or home settings • May influence participant behaviour (reactivity) • Limited scalability for large population studies • Requires standardised protocols to ensure consistency across observers • Ethical and privacy considerations may restrict use in certain environments

	Description	Strengths	Limitations
Retrospective			
24-hour recall	Structured interview, intended to capture detailed information about all foods and beverages (types and portions) consumed by the participant in the past 24 hours. Often used for estimating large populations' dietary intake (e.g. national nutrition surveys). Often, two-dimensional representations of different shapes (such as a matchbox) and photographs participants have taken of foods/beverages are used to help the researcher convert volume or area descriptions to estimates of mass.	• Provides detailed information on meal timing, food and beverage types and quantities, preparation methods, and brand names. • Does not require literacy or numeracy skills • Suitable for diverse populations, including children and those with limited literacy • Can be repeated on non-consecutive days to estimate usual intake	• Relies on participant memory and recall ability • Requires trained interviewers and standardised protocols • Potential for underreporting or overreporting, especially of socially desirable or undesirable foods • Labour-intensive data collection and analysis • Requires multiple recalls on non-consecutive days to estimate usual intake
Food frequency questionnaire (FFQ)	Assess typical food and drink consumption over a set timeframe, such as weekly, monthly, or yearly, by asking participants how often they consume specific items from a predetermined list. Response options typically range from 'never' or 'less than once per week/month/year' to 'two or more times per day.' The food list can vary in length, from 20 to 200 items, depending on the FFQ design. Only the foods included in this list are recorded, meaning results are limited to those items.	• Low participant burden. • Estimates usual dietary intake over an extended period. • Can capture habitual consumption patterns and meal frequency. • Can account for seasonal variation in diet. • Does not influence dietary behaviour. • Useful for classifying participants into dietary intake categories.	• Relies on memory, which can lead to recall bias. • Requires literacy and numeracy skills, limiting use in some populations. • Not suitable for children due to its complexity. • Limited accuracy in estimating portion sizes and nutrient intake. • Requires skilled researchers to design and validate culturally appropriate tools.
Diet history	A trained interviewer asks individuals about their typical food intake and eating habits over a specified period, most commonly the past month, to assess and estimate their usual dietary patterns.	• Requires little effort from participants • Provides insight into typical dietary intake and patterns across an extended timeframe • Considers seasonal changes in eating habits • Does not alter or interfere with usual eating behaviour • Enables grouping of individuals based on their food consumption habits	• Depends on the participant's ability to recall past food intake • Needs an experienced interviewer with specialised training • Places a significant workload on the researcher • Portion sizes are often estimated after the fact, leading to frequent inaccuracies • People are likely to overstate how much they eat compared to more precise dietary records

2.5.3. Improving children's 24-hour recall accuracy using the multiple-pass technique

The 24-hour dietary recall method is considered preferable for assessing group-level dietary intake in children, as it provides consistent results upon repeated administration, unlike the dietary history method, which shows significant variation in mean intakes when repeated (Räsänen, 1979). The 24-hour recall is also highlighted as a valid tool for estimating average group intake when standardised and repeated, with lower respondent burden compared to food diaries and fewer limitations than FFQ (Rupasinghe et al., 2020). However, all methods are subject to some degree of misreporting and inherent error (Burrows et al., 2010; Walker et al., 2018).

The accuracy and completeness of the 24-hour dietary recall can be significantly improved by using the 24-MPR method, a structured approach designed to reduce underreporting and enhance memory retrieval. Unlike the single-pass recall, the MPR follows a five-step process: (1) a quick list of all foods and beverages consumed, (2) probing for forgotten items, (3) assigning time and eating occasion, (4) collecting detailed descriptions including portion sizes, preparation methods, and brand names, and (5) a final review to capture any missed items (MRC Epidemiology Unit, 2025). Validation studies have demonstrated the effectiveness of this method in paediatric populations. A systematic review by Burrows et al. (2010) found that 24-MPR conducted over at least 3 days provided the most accurate energy intake estimates for children aged 4-11 years when validated against DLW (Burrows et al., 2010). Similarly, Johnson et al. (1996) showed that three days of 24-MPR provided valid group estimates of energy intake in children aged 4-7 years, showing no significant difference from total energy expenditure measured by DLW (Johnson et al., 1996). Nightingale et al. (2016) validated a triple-pass 24-hour recall in Ugandan children, demonstrating only marginal underestimation of energy (2.8%) with 79% correct quartile cross-classification (Nightingale et al., 2016). The method's effectiveness is further enhanced when adapted for children using child-friendly language, visual aids, and caregiver involvement (Grewal et al., 2014). Although some studies, such as Montgomery et al. (2005), report slight overestimation of energy intake, the 24-MPR still provides acceptable group-level estimates in children aged 5–7 years (Montgomery et al., 2005). The use of visual aids, such as food photographs and household measures, improves portion size estimation. At the same time, interviewer training ensures consistency, reduces bias, and facilitates the effective management of caregiver-child dynamics (MRC Epidemiology Unit, 2025). Overall, incorporating the 24-MPR protocols marks a methodological advancement that increases the reliability and validity of dietary assessments in children (Burrows et al., 2010; Johnson et al., 1996).

2.5.3.1. Implications of measurement error for validity and reliability in dietary assessment

Measurement error is a vital issue in dietary assessment research, referring to the difference between an individual's actual dietary intake and the intake reported through assessment tools (Freedman et al., 2010). These errors can be random, resulting from daily variations in food consumption, or systematic, stemming from consistent biases in reporting or data collection methods. Unlike random error, systematic error introduces bias into the data and cannot be reduced or removed by repeated measurements (Bingham, 2008). Both types of error can significantly impact the validity and reliability of dietary data, leading to misclassification of nutrient intake and inaccurate associations in diet-health research (Freedman et al., 2010).

Measurement error in dietary assessment arises from multiple sources. One of the most common is recall bias, which occurs when respondents fail to accurately remember the foods

and beverages they have consumed, leading to omissions or incorrect reporting. This is particularly problematic in children, whose cognitive limitations often require caregiver assistance, which can introduce further bias (Livingstone & Robson, 2000). Closely related is the social desirability bias, which causes individuals to report foods they see as healthy while underreporting those viewed as unhealthy. This bias is prevalent across all age groups but is particularly pronounced in children, who may be motivated to provide responses that please adults or avoid disapproval. As a result, socially valued behaviours like healthy eating are often overreported, while less desirable behaviours are underreported (Hebert et al., 1997; Livingstone & Robson, 2000).

Reactivity bias refers to behavioural changes that occur when individuals alter their actions because they are aware of being observed or measured (Harnack & Pereira, 2017). For example, children may modify their food intake when completing dietary recalls in order to appear healthier. Such changes compromise the validity of measurements, as they capture modified rather than habitual behaviours (Thompson & Subar, 2017). Another important source is interviewer bias, which arises when interviewers unintentionally influence responses through inconsistent probing, leading questions, or variations in technique, thereby introducing both random and systematic errors into the data. This type of bias is particularly relevant in interviewer-administered methods, where variations in how questions are asked or recorded can impact the accuracy and reliability of dietary intake estimates. It is particularly significant in studies involving children, where the interaction between the interviewer, child, and caregiver can further complicate data collection and impact report accuracy (Rosalind, 2025).

Finally, coding errors represent a technical but significant source of measurement error. These errors occur during data entry or when converting reported foods into their corresponding nutrient values, especially in automated systems or limited food composition databases. These errors may result from misclassification, incorrect portion size conversions, or limitations in food composition databases (Rosalind, 2025). Together, these sources of error highlight the complex challenges in obtaining accurate dietary data, particularly in paediatric populations.

2.5.3.2. Measurement error in dietary intake assessment - Impacts and strategies for minimisation

Measurement error in dietary assessment can significantly distort estimates of nutrient intake, leading to a misinterpretation of dietary patterns and weakened associations with health outcomes (Hu et al., 2022). One of the most well-documented issues is the misestimation of energy intake (Livingstone & Black, 2003). Among these, systematic underreporting of energy intake is common, particularly among individuals with a higher body mass index (BMI), which can obscure true dietary behaviours and mislead conclusions in nutritional epidemiology (Lichtman et al., 1992). Another major source of error is portion size misestimation, especially for mixed dishes or foods consumed outside the home, where visual estimation is difficult. Inaccurate portion size reporting contributes substantially to errors in nutrient intake calculations (Whitton et al., 2022).

Additionally, omitting nutrient supplement usage is a common limitation in 24-hour recalls, as respondents often forget or are not prompted to report supplement intake. This results in an underestimation of micronutrient intake, particularly in populations with high supplement use (Subar et al., 2015). Together, these issues emphasise the critical need for careful methodological design and interpretation in dietary assessment research (Rosalind, 2025).

To address these concerns, rigorous quality-control procedures must be integrated throughout the data collection process. Structured approaches such as the 24-MPR help improve

completeness and reduce recall bias by guiding respondents through a systematic process of memory retrieval (Moshfegh et al., 2008). Conducting thorough interviewer training is essential to ensure consistency, neutrality, and effective probing. Additionally, visual aids such as food models and portion-size photographs enhance the accuracy of portion size estimation. Repeated recalls on non-consecutive days help account for within-person variability, while pretesting instruments and standardised coding protocols minimise technical errors (Thompson & Subar, 2017). Advances in technology, including web-based recalls and automated FFQs, offer promising solutions, though their effectiveness depends on validation within the target population (Amoutzopoulos et al., 2018). Addressing random error, which affects all respondents and intake days, typically involves increasing the number of observations to enhance reliability (Block & Hartman, 1989).

In contrast, systematic error, often associated with specific respondent characteristics, interviewer practices, or particular food types, requires more targeted strategies (Kipnis et al., 1999). These include tailoring assessment methods to the target population and calibrating data against more accurate reference tools. Repeated assessments or reference data should be collected from a random subsample of the study population. (Kohlmeier & Bellach, 1995). Where this is not feasible, external datasets with similar demographic and behavioural characteristics may be used to adjust for bias and improve the accuracy of dietary intake estimates (Kohlmeier & Bellach, 1995).

2.5.4. Dietary inadequacies among schoolchildren in New Zealand and Sri Lanka

New Zealand

Nutrition trends in NZ show a concerning prevalence of household food insecurity, particularly among Māori and Pacific children. Dietary habits often include high consumption of sugary drinks and processed foods, with insufficient intake of fruits and vegetables (Ministry of Health New Zealand, 2025). Television food advertising is a prominent feature of the food environment. In NZ, 70% of food advertisements shown during children's viewing times promoted foods considered "counter to improved nutrition", highlighting children's substantial exposure to unhealthy food marketing (Wilson et al., 2006). Nationally representative survey data from the NZ health survey indicate that overweight and obesity remain common among NZ children, with substantial ethnic inequities persisting and higher prevalence observed among Pacific and Māori children compared with other ethnic groups (Ministry of Health, 2025). Key dietary risk factors among schoolchildren include skipping breakfast and purchasing food from outside sources (Utter et al., 2007). Since children obtain approximately one-third of their daily nutrient intake during school hours, improving the nutritional quality of available foods, especially morning snacks, is essential. Targeted interventions are particularly needed for Pacific children, who may be at greater risk due to dietary patterns and limited access to healthy options (Regan et al., 2008).

Despite these challenges, NZ has implemented several school-based initiatives aimed at improving nutrition and PA, including the Healthy Active Learning programme and updated national guidelines. These efforts show a strong commitment to reducing health inequalities and supporting the overall development and well-being of children (Pillay. et al., 2022).

South Asia with a focus on Sri Lanka

Information on malnutrition for school-age children and adolescents (5–19 years) in South Asia is uneven and inconsistent, which limits the prioritisation of nutrition policies, programmes

and research for this age group (Choedon et al., 2024). According to a comprehensive nutrient gap assessment by Beal et al. (2021), South Asia faces significant nutritional challenges characterised by widespread micronutrient deficiencies and poor dietary practices. Critical gaps exist in iron, zinc, vitamin A, folate, and vitamin B_{12} during complementary feeding periods, with nutrient-dense foods like liver, small fish, and eggs being essential sources (Beal et al., 2021).

Sri Lanka faces a complex nutritional setting marked by both undernutrition and emerging concerns about overweight and obesity. According to the Global Nutrition Report, 17.3% of children under five are stunted, and 15.1% are wasted, figures that are lower than the regional averages for South Asia, at 30.7% for stunting and 14.1% for wasting, yet still indicate persistent challenges in early childhood nutrition. Although the country is on track to meet targets for preventing childhood overweight, progress in reducing anaemia and wasting has been limited (Global Nutrition Report, n.d.). Urban preschool children in North-western SL demonstrated limited dietary diversity, with a mean dietary diversity score of 4.56 out of 9, and inadequate fruit and vegetable consumption, meeting approximately half of the national recommendations (Sirasa et al., 2020). However, one study of preschool children in southern SL found satisfactory intakes of protein and iron, although 44-55% had energy intakes below recommended levels, with females being more affected (Hettiarachchi & Liyanage, 2010). The economic impact of the COVID-19 pandemic further exacerbated these issues, as families reported reducing food consumption, particularly of nutrient-dense items like meat and dairy, due to financial constraints (Gardner, 2025). These patterns are consistent with broader findings across South Asia, where poor dietary practices and limited access to healthy foods contribute to undernutrition and micronutrient deficiencies. Despite efforts to improve school-based nutrition programmes, gaps remain in the availability of balanced meals and nutrition education, especially in underserved regions of the country (Choedon et al., 2024).

2.6. Overall summary, conclusions and future research

Despite growing recognition of the importance of school environments in shaping children's health behaviours, significant gaps remain in the literature concerning PA behaviours, physical and policy food environments, and dietary intake among children aged 5 to 13 years. Research frequently considers PA and nutrition independently, neglecting their combined effect on child health. Research on PA often lacks an age-specific focus, with limited attention paid to younger children and developmental differences in activity patterns. Comparative studies between high-income countries and LMICs, such as NZ and SL, are scarce, leaving a gap in understanding how socio-cultural and policy contexts influence PA engagement. Furthermore, while policies promoting PA exist, few studies assess their implementation, reliability, or sustainability at the school level, particularly in resource-constrained settings. Children's perspectives on PA are underrepresented, especially in LMICs like SL, and culturally tailored assessment tools remain limited. In terms of food environments, there is a lack of robust evaluations of school food policies and their impact on children's dietary behaviours. Cultural influences, informal food sources such as tuck shops and street vendors, and the incorporation of nutrition education into curricula are underexplored areas, especially in South Asian contexts. Dietary intake research also presents gaps, including the limited use of validated tools adapted for younger children, insufficient analysis of micronutrient deficiencies, and a lack of longitudinal studies that track dietary patterns over time. Moreover, few studies have linked dietary intake to health outcomes, such as growth, cognitive development, or academic performance. Addressing these gaps is essential for developing contextually relevant, evidence-based interventions that promote healthy behaviours and improve nutritional outcomes among children aged 5 to 13 in diverse settings.

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Chapter 3

Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions: A Narrative Review

This chapter contains a reformatted version of the narrative review article "Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions", authored by Perera T. S. H., David S. Rowlands, Ananda Chandrasekara, Scott Duncan, and Ajmol Ali; published in the *Physical Activity* journal of the Asian Society of Kinesiology on 20th May 2024. The published version is available in Appendix 1.2.2.

This chapter addresses Research Objective 1 (Section 1.3.1). It provides a narrative review of the literature on the main challenges, trends, and future directions in accelerometer-based physical activity assessment among Asian children, highlighting significant methodological gaps to guide best practices for objective activity assessment. By narrowing the scope from the broader school-based physical activity and nutrition environments discussed in Chapter 2, this chapter highlights the unique considerations and gaps in objectively measuring physical activity in Asian contexts. Special attention is given to methodological issues relevant to the Sri Lankan component of this research, providing a foundation for best practices in accelerometer-based activity assessment in similar settings.

HP was responsible for drafting the manuscript, including synthesising relevant literature, structuring the content, and articulating the key challenges, trends, and future directions in accelerometer-based physical activity assessment among Asian children. The manuscript was subsequently reviewed and approved by all co-authors, ensuring collaborative input and academic rigour**.**

Abstract

The rise of sedentary lifestyles and increasing rates of obesity among Asian children have raised concerns regarding public health. Accelerometer-based evaluation provides an objective and reliable method to measure children's physical activity, and its use is increasingly common in Asian studies. This review aims to examine the factors that need to be considered before conducting accelerometer-derived studies in Asian children while exploring the utility of accelerometers in assessing PA and sedentary behaviours. This narrative review was undertaken using publications retrieved from PubMed, Google Scholar, and MEDLINE databases. The publications contained a combination of words related to accelerometry-based assessment of PA, sedentary behaviour, and PA in Asian children. Despite the recognised benefits of PA, accurate measurement remains challenging. Accelerometer-based devices offer objective and quantitative data, yet their use in Asian countries is underexplored compared to Western nations because of wearing reluctance, fear of damage, stigma, and overemphasis on academic achievement. Challenges such as cultural preferences, socioeconomic factors, and technical limitations hinder the widespread adoption of accelerometers in PA research. Moreover, existing cut-points for defining PA levels are primarily based on Western populations, raising questions about their applicability to Asian children. This review highlights the need for culturally specific and age-appropriate PA guidelines and emphasises the importance of validating accelerometer-based measurements for accurate PA assessment in Asian children. When assessing PA, consideration needs to be given to specific challenges within the Asian context, including ethnicity, body composition, diet, and seasonal variation. Future research should focus on assessing the validity and reliability of accelerometer-derived cut-points tailored to the Asian population to advance our understanding of PA behaviours and inform targeted interventions to promote active lifestyles in this demographic.

Keywords: Calibration, Cut points, Movement, Reliability, Validity

3.1. Introduction

Since the dawn of time, humans have created new technologies that make daily tasks less physically demanding, more effective, and consequently more sedentary (Woessner *et al*., 2021). Low levels of physical activity (PA) and rising obesity rates are significant public health concerns in Asia, affecting both developed and developing nations as a result of an increase in sedentary lifestyles and growing academic pressure on children (Zhu *et al*., 2019). However, this socioeconomic change is linked to dietary and lifestyle changes that lead to reduced PA and, when combined with the increased consumption of energy-dense foods, results in an average increase in body weight and the onset of obesity (Pechey and Monsivais, 2016; Amugsi *et al.,* 2017). However, to intervene, first, it is necessary to generate accurate and reliable metrics of PA by use of practical and economically accessible tools. PA domains include all types of activities performed during free time or leisure time, transportation activities, all tasks performed in the home environment, physical education sessions, and break-time at school (Physical Activity-World Health Organisation, 2020). Further, PA behaviour can be characterised according to the dimensions of type, intensity, frequency, and duration (Thivel *et al*., 2018). It is vital to have legitimate and trustworthy methods that are capable of encompassing all significant dimensions and domains to measure PA behaviour effectively.

Accelerometer-based devices are often used to collect reliable data on free-living PA behaviours in diverse studies (Troiano *et al*., 2014). Typically, the accelerometer is an unobtrusive small machine that is placed on the hip, hand, or ankle using an elastic belt or strap (Pate *et al*., 2004; Pulido and Iglesias 2021). Accelerometers provide precise, reliable, and accurate communicable data for measuring PA in children and adolescents relative to other conventional methods (Corder *et al*., 2008; Oliver *et al*., 2007; Hustyi *et al*., 2011). Accelerometers are used in various studies to assess PA in different population sizes. The use of accelerometers in a nationally representative sample of Americans aged 6 and older as part of the National Health and Nutrition Examination Survey serves as an example of the viability of using accelerometers in large-scale research (NHANES) (Corder *et al*., 2008).

As a result of the rapid economic growth and changing living conditions over the past 20 years, there are significantly more Asian children and adolescents in developed and developing countries who are mostly physically inactive or often too inactive to fulfil PA recommendations (de Moraes *et al*., 2013; Müller *et al.,* 2013). However, numerous studies have been conducted to collect reliable and accurate data for the evaluation of PA in children and adolescents around the world (USA, German, Belgium, Greece, Hungary, the Netherlands, and Switzerland and UK) based on the time of wearing, intensity (Burchartz *et al*., 2020), age (Cooper *et al*., 2015), position (Khawaja *et al*., 2019), seasonal variations (Rich *et al*., 2012), and body weight (Vorwerg *et al*., 2013; Park *et al*., 2018). However, there is a notable lack of PA assessment data from Asia, the Eastern Mediterranean, and Arab countries relative to Western countries (Tremblay *et al*., 2014; Collings *et al*., 2017). Several studies have revealed that South Asian children living in the United Kingdom exhibited greater levels of sedentary behaviour and lower levels of PA when compared to native white British children (Barber *et al*.,2017; Collings *et al*., 2017; Sherry *et al.,* 2019; Williams *et al*., 2011). These discrepancies are frequently attributed to cultural preferences, socioeconomic considerations, a lack of intrinsic drive, ignorance about the advantages of PA, and an inability to incorporate PA into regular activities (Jepson *et al*., 2012). According to Nagy *et al*., (2019), ethnicity, sex, BMI, and local socioeconomic position are key children-specific characteristics linked to PA behaviours and cut-points, while weekends, school breaks, and seasonality of nations are significant temporal factors.

However, population studies based on self-reports reveal that Asian people tend to exercise infrequently, and self-reported surveys account for most of the data on the low prevalence of PA in Asian individuals (Williams *et al*., 2011). These measurements have known drawbacks, including imperfect recall, bias in social desirability, and difficulty in accurately estimating the frequency, duration, and intensity of activities. Also, since some parents reported that their children were reluctant to wear accelerometers at school and during sports owing to the potential of stigma and bullying, measuring PA with an accelerometer has a plethora of challenges (de Moraes *et al*., 2013). Additionally, among school children (7-11 years old), the major problem was a perception that the accelerometer was perceived to be *seeing them* and that it featured a webcam or microphone (Rowlands and Eston, 2007). Furthermore, children may not use the device during specific activities, like swimming and contact sports (Robertson *et al*., 2011). The impact of a humid subtropical environment in some Asian countries on daily activity behaviour measurements is another hurdle and remains unknown (Zheng *et al*., 2019). Thus, sedentary time and actual PA energy expenditure are frequently overestimated or underestimated in Asian countries (Althubaiti, 2016). To measure current and fluctuating sedentary time and PA levels and to assess the efficacy of interventions intended to increase activity levels, an accurate assessment is essential. When determining the measurement method based on the purpose of the research, factors such as the measurement tool's reliability and validity, acceptability by individuals, group size, age, gender, education, time, cost, and comorbidity must be considered. Accelerometers offer accurate estimations of sedentary time, PA, and sleep, and their use has significantly increased in developed nations (Can, 2019). However, accelerometer methods are almost always designed for Western populations, making their applicability to non-Western populations questionable.

Asian children, in particular, are under-researched in the literature despite comprising a substantial proportion of the world's population. Additionally, the data we have may be misleading if the methods are not appropriate. Therefore, the purpose of this review is to examine the factors that need to be considered before conducting accelerometer-derived studies in Asian children. In this review, selected publications were discovered by searching PubMed, Google Scholar and MEDLINE databases, which contain the following combinations of words: PA assessment of Asian children, drawbacks of PA measurement, accelerometer measurements, cut-points, and accelerometry-based assessment of PA.

3.2. Methods of physical activity assessment

There are numerous methods for measuring PA, both subjective and objective. Pedometers and accelerometers are categorised as objective methods among frequently used techniques, while survey questions and logs belong to the category of subjective techniques (Sylvia *et al*., 2014). Generally, PA assessment can be categorised into five groups: behavioural observation, self-reported methods, physiological markers, calorimetry, and motion sensors (Westerterp, 2009). Each of these methods has its own strengths and limitations (Table 3.1). The lack of a suitable standard to which procedures can be compared has been the biggest barrier to the validation of laboratory and field methods of quantifying PA in individuals. Although there may be some benefits in how different methods interact, it is hard to identify which method is truly the gold standard because all methods have flaws (Montoye *et al*., 1996; Table 3.1).

The most promising technology for measuring PA in recent years is accelerometers. Free-living subjects can be exposed to sensors for extended periods (Jung *et al*., 2020). They can also be used to study patterns of PA over time when empowered with a memory space to store information on body movement. Different sensors, including mechanical devices and

electronic accelerometers, have been developed. The total amount, frequency, intensity, and duration of PA can be determined using accelerometers (McCarthy and Grey, 2015).

Table 3.1. Advantages and limitations of physical activity measuring approaches.

Approaches	Advantages	Limitations	References
Direct observation	• Provides relevant information • low cost	• Time-consuming • Limited monitoring time • The observer's appearance may affect the subject's behaviour during the activity.	Pate *et al*., (2010), Plasqui and Westerterp, (2009)
Self-reporting (Questionnaires and daily activity log)	• Affordable • Applicable in epidemiological studies • Suitable for use with large populations • Valid for overweight cataloguing of PA level	• Poor reliability and validity for regular PA assessment • No comprehensive data on PA	Cain *et al*., (2013); Sylvia *et al.,* (2014)
Heart rate monitoring	• Energy expenditure pattern is obtained • Used in validation studies at observation intervals of 7 to 14 days for 2-4 days.	• Only valid for a specific range of heart rate • Poor validity in long-term free-living behaviours of PA • Some factors (hydration, temperature, emotion) could limit the use	Yang *et al*., (2020), and Sylvia *et al.,* (2014)
Calorimetry	• Measuring short-term energy expenditure reliably and accurately.	• Expensive • Usually restricted to laboratory conditions unless using portable devices • Device calibration takes significant time	Chen and Bassett, (2005)
Motion sensors (pedometer, and accelerometer)	• A lightweight, portable, simple, and inexpensive device • Non-reactive • Monitor free-living subjects for extended periods. • Track patterns of movement over time	• Inadequate validity for energy expenditure assessment • No information on precise behaviours	Plasqui and Westerterp, (2009); Ke, (2019)

3.3. Evolution of the accelerometer and utilisation in physical activity measurement

The body part where the sensor is attached experiences accelerations that are measured by wearable accelerometers. Accelerometers are in the category of motion sensors, widely used to detect movements in terms of acceleration and estimate PA. The monitor typically filters and pre-processes the signal to produce activity counts, or accelerations brought on by body movement (Yang and Hsu, 2010). By classifying activity counts that have been accumulated over a given amount of time (epoch length) with a set of *cut-points*, or intensity thresholds for PA intensity classification, it is possible to determine the quantity and intensity of regular sedentary activities and PA (Altenburg *et al*., 2021). Applying algorithms to objectively determine activity counts can also be used to estimate PA energy expenditure or sleep-related behaviour (Crouter *et al*., 2006). Instead of using activity counts, new techniques have been developed to evaluate these factors from raw acceleration signals (Yang and Hsu, 2010).

In the 1980s, the first accelerometry-based PA evaluation was conducted (Troiano *et al*., 2014). Because of the conventional device's high production cost, as well as issues with consistency, authentication, and calibration, a novel accelerometry-based research device was created in the 1990s (Montoye *et al*., 1996; Chen *et al*., 2005). Generally, the number of peer-reviewed papers reporting PA or exercise monitoring using an accelerometer grew from <10 per year from 1981-1996 to ~90 per year in 2003-2004 with the development of calibration of the accelerometer (Troiano, 2005). As a result of the reliability and validity of accelerometry-derived data, the practice of accelerometry to collect PA data in children over multiple regular days has improved exponentially in the early 2000s with ~30 publications per year. Over 300 research articles were published in 2010 based on the accelerometer-derived PA research, while more than 1100 papers were published in 2017 (Rowlands, 2018).

Initially, accelerometer-based PA devices had many drawbacks, including short battery life, limited storage capacity, low sensitivity, and less connectivity with other equipment (Sasaki *et al.,* 2016). Owing to remarkable technical advances in accelerometers in PA monitoring since 2004, researchers have access to raw acceleration PA data using wearable accelerometry devices (Chen *et al*., 2012). However, advances in activity monitor technologies are connected to the sampling frequency (acceleration rate detected every second) and modern activity monitors can reach 100 Hz, as opposed to the 10 Hz of earlier monitors. Updated models offer several gigabytes of storage space, allowing them to save data for many days or weeks whereas older models were only able to store data for a few hours. Furthermore, battery life enables activity sensors to gather data for more than 29 days without recharging. In addition to collecting raw acceleration data in three axes rather than counts, modern activity monitors may also have wireless connections to computers, tablets, and heart rate belts through WiFi and Bluetooth (Bonomi *et al*., 2009; Sasaki *et al.,* 2016). Recent activity trackers also feature screens where the devices may provide consumers with immediate feedback. Other sensors have been integrated with accelerometry to offer data on ambient light, global location, body posture, and a variety of physiological indicators to researchers. Wearable triaxial accelerometers and multi-sensor devices that measure several physiological activities have grown from basic pedometers to these sensors (Plasqui, 2017). The current ActiGraph accelerometer is the only type that can be utilised to identify sleep patterns as well as measure the PA of children (Hjorth *et al*., 2012). Such varied sensor deployment is not only helpful in enhancing PA and sedentary behaviour predictions but also enables simultaneous data gathering of several health-related parameters (Crouter *et al*., 2006; Sasaki *et al.,* 2016).

3.4. Types of accelerometers for assessing physical activity

Accelerometers can be categorised into three types based on the number of axes (Table 3.2). Triaxial accelerometers, found in devices like the RT3, Actigraph, GENEA, and, GENEActive, detect acceleration along three orthogonal axes, as opposed to omnidirectional accelerometers, found in devices like the MiniMitter and Actical, which measure acceleration in all directions but are particularly sensitive to movement in the vertical plane. Microelectromechanical systems (MEMS) accelerometer chips are often used in modern accelerometers (Strong *et al*., 2005).

Table 3.2. Different types of axes in accelerometers

Axis type	Description
A. Single axis	• The most common type is a single-axis accelerometer. These are often used to calculate the magnitude of simple vibration points. A single-axis device is a piezoresistive accelerometer, for instance.
B. Two-axis	• Accelerometers are intended to measure acceleration/vibration along both the x and y axes.
C. Three-axis	• The vertical z-axis augments the device's two-axis accelerometer. Triaxial devices can monitor complex three-dimensional positioning and measurements.

(Resource: Strong *et al*., 2005)

To measure acceleration along a certain axis, accelerometers can use a variety of technologies, such as piezoelectricity, piezoresistance, micromechanical springs, and capacitance changes (Welk, 2002). Primarily, accelerometers can be categorised into three types; piezoelectric, piezoresistive, and capacitive accelerometers. There are many accelerometers accessible that assess PA, and the majority of them also record step counts. The study objectives, the target demographic, the activity aspect of interest, the limitations of the device as well as the budget and logistics, all influence the choice of the monitoring device (Table 3.3).

Table 3.3. Overview of accelerometer sensor technologies and their performance characteristics.

Type	Operation Principle and aspects	Technical advantages	Limitations
1. Piezoelectric Accelerometers	• Rely on a piezoelectric substance to perceive changes in acceleration, such as quartz crystal or polycrystalline ceramic. • The change in the material's electric charge is comparable to the force applied to accelerate mass.	• Conscience • Electronic output • Basic interface circuit • Outstanding base deflection and temperature isolation • High resonance frequency • High linearity	• Unable to monitor impulses with zero frequency • The poor responsiveness of piezoelectric materials to direct current (DC) • The size of the gadget is considerable.
2. Piezoresistive Accelerometer	• Resistance changes are used to gauge reading output.	• Appropriate design architecture	• Minimal sensitivity • Extremely sensitive to temperature

	• It consists of semiconductors with several unique resistive circuits for all measurement axes.	• Easy manufacturing procedure • Simple readout circuit. • Possess silicon micro-accelerometers. • Low electricity usage	• Huge and hefty appearance • high shock wave measurements to low-frequency readings with sensitivity DC
3. Capacitive accelerometer	• A silicon mass linked to four chains serves as a spring system in this semiconductor sensing device. • Polar-distance-variable capacitive sensors are provided using the capacitance theory.	• Hypersensitivity • Effective DC efficiency • Low frequency • Small drift • Sensitivity to low temperatures • Simple circuit design • linearity of under 1%; • Reliable results • Minimal measurement erroneous	• Sensitive to electromagnetic interference (EMI) • Range is restricted • A high-impedance signal source is a capacitive sensor. • Low-frequency measurement adaptation • Expensive equipment

A variety of practical considerations impacting monitor selection, such as the size, weight, stability, and strength of the accelerometer and how tamper-proof the device is, may be particularly pertinent for monitoring PA in young children, especially preschool-aged children (Cliff *et al*., 2009). Although triaxial and omnidirectional accelerometers theoretically offer advantages over uniaxial monitors in assessing the distinct PA behaviours of young children, few studies have examined this issue among children aged 3-11 years (Duncan *et al*., 2011; Kelly *et al*., 2004). Uniaxial monitors may also fail to recognise issues such as walking slowly up a 5% elevation may consume more energy than walking quicker on level ground (Mindell *et al*., 2014). None of these technical parameters discussed above is likely to be different in Asian children.

3.5. Cut-points for accelerometry

Cut-points can change depending on the findings of studies that calibrated accelerometers by defining counts per minute about the intensity of PA. Calibration studies have been conducted in laboratories and the field using a range of methodologies (Welk., 2005). The use of published threshold values or cut-points to convert accelerometer counts into minutes of PA has resulted in an ongoing debate about which cut-points to use in research (Corder *et al*., 2008). Often, calibration studies are undertaken to provide techniques for converting accelerometer data into physically significant measurements like metabolic equivalents (METs) in health-related assessment of children (Boddy *et al*., 2018), energy expenditure ($kcal \cdot min^{-1}$) in PA and sedentary behaviour assessment (Forseth *et al*., 2022) or oxygen uptake (VO_2) in the validation of accelerometers related to PA assessment (Jurado-Castro *et al*., 2022). Over the past 20 years researchers have undertaken multiple calibration experiments to find optimal cut-points for preschoolers and school-aged children (Lynch *et al*., 2019; Bassett *et al*., 2012; Evenson *et al*., 2008; Migueles *et al*., 2017). The classification of children's PA levels according to existing cut-points may be improved, which could benefit subsequent intervention and observational studies, with the development of a low-cost, scalable field-based protocol to produce population-specific accelerometer cut-points that are behaviourally valid (Mackintosh *et al*., 2012).

Table 3.3. Evaluation of cut-points, specification, and sensitivity of different accelerometers in PA studies

Reference	Country	Age (# participants)	BMI (kg/m^2)	Accelerometer type	Place	PA Type	Specificity (%)	Sensitivity (%)	Cut-point **SD**	**MPA**	**VPA**
Mackintosh *et al*., (2012)	UK	10-11 y (n=28) Healthy	20 ±4.7	GT1M ActiGraph (Uniaxial)	Hip	Drawing, DVD Watching, Brisk Walking, Jogging, Playground Games, Free-choice Games	96-97	89-99	≤372 counts/m	>2160 counts/m	>4806 counts/m
Cauwenbergh e *et al*., (2011)	Belgium	5.8 ± 0.4 y (n=18) Healthy	16.4 ±1.1.	GT1M ActiGraph	Hip, wrist	Free playing, standing, sitting, drawing, walking, and jogging on the treadmill	82-91	86-88	373 counts/15 s	585 counts/15 s	881 counts/15 s
Duncan *et al*, (2020)	UK	8-12 y (n=20) Healthy boys	17.3 ±1.9	GENEActiv monitor	Nondominant, Wrist,	Football	66.2-84.8	84.4-84.7	4.5	16.5	-
					Dominant, Wrist,		53.3-84.6	67.5-84.7	4.4	12.5	-
					waist		88.1-97.2	86.8-87.8	4.0	8.9	-
					Dominant Ankle		66.8-95.9	73.1-74.2	3.5	39.3	-
					Nondominant Ankle		81.2-96.4	76.3-82.5	4.0	81.7	-
Chandler *et al*., (2016)	USA	8-12 y (n=45) Healthy	-	ActiGraph GT3X+,	Wrist	Resting, Coloring, Walking, Playground, Splash Pad, Swimming, and Progressive Aerobic Cardiovascular Endurance Run	61.7-86.6	60.3-61.7	<113	114-372	777+

Keawutan *et al*., (2016)	Australia	4-5 y (n=84) With cerebral palsy	-	GT3X ActiGraph and GT3X+ ActiGraph	lower back close to the center of mass of the body	Sedentary behaviour	27-37	65-81	40 counts/5 S	-	-
Bianchim *et al*., (2022)	UK	7-17 y (n=63) with 35 cystic fibrosis girls	18.0 ± 4.2	ActiGraph GT9X Link	Wrist	Video, Writing, playing with the device, walking, Stairs	63.3-85.4	76.5-92.9	74.2	82.5	262.7
				GENEActiv			66.8-84.4	91.7-98.0	74.6	85.3	222.5
Romanzini *et al*., (2014)	Brazil	10-15 y (n=79) Healthy	-	ActiGraph GT3X	waist	Rest, DVD watching, Writing, playing video games, walking, running, playing volleyball and basketball, and soccer	84.9-93.9	97.9-98.3	46 counts/15 s	607 counts/15 s	818 counts/15 s
				RT3			84.9-94.2	91.2-98.3	5.6 counts/s	20.4 counts/s	32.2 counts/s
				Actical			85.1-94.2	98-98.3	17 counts/15 s	441 counts/15 s	873 counts/15 s

*SD- sedentary behaviour; MPA- moderate-intensity physical activity; VPA- vigorous-intensity physical activity
*Sensitivity refers to the ratio of change in acceleration (input) to change in the output signal.
*Specificity refers to the proportion of actual non-wear events correctly identified by the model.

of triaxial and omnidirectional accelerometers in 570 participants (aged 3 to 18). The mean specificity varied from 71% to 96% and the mean sensitivity varied from 46% to 96% across all trials and the range of the average area under the curve was 69% to 98%. Additionally, Lynch *et al.,* (2019) were able to determine that accurate measurement was optimal when monitoring inactivity and poorest when monitoring light PA. Montoye *et al*., (2016) explained how the accelerometer performed more accurately when it was worn on the hip as opposed to the wrist. Also, according to the available data, triaxial and omnidirectional accelerometers can measure children's levels of PA and sedentary with accuracy. According to Cauwenberghe *et al*., (2011), accelerometer cut-points with strong discriminating power were created to differentiate between PA levels in pre-schoolers, although the choice of the cut-points might result in considerable variances. Furthermore, the calibration and cut-points of several accelerometers were evaluated for various PA levels, age-specific investigations, and wearing postures in children all over the world (Table 3.4). These studies included clinical trials of children with cerebral palsy (Keawutan *et al*., 2016) and cystic fibrosis (Bianchim *et al*., 2022), which also focused on cut-points for light PA and sedentary behaviour. Romanzini *et al*., (2014) concluded that cut-points of three different accelerometers in their studies can be used to screen PA in adolescents.

According to Duncan *et al*., (2020), triaxial accelerometry cut-points developed for calibration, placed on wrists, waist, and ankles, have an excellent capacity to discern children's sedentary behaviour and moderate intensity PA-encompassing motor skill exercise. However, others suggest that existing cut-points for evaluating PA in children are only valid for the population rather than for individual children (Chandler *et al*.,2016; Mackintosh *et al*., 2012). In addition to selecting cut-points for different levels of PA and sedentary behaviour, the calibration of the accelerometer takes into account the accelerometer model, epoch length, concept of non-wear time within a day, interpretation of a valid day, and the necessary number of valid wear days (Cain *et al*., 2013).

The Healthy China 2030 concept states that school-aged children should engage in at least 1 hour of PA every day, and more than 25% of them should have an "outstanding" fitness grade (Zhu *et al*., 2019). Zhu *et al.,* (2019) reported MVPA, screen time, and age- and sex-specific BMI using 131,859 children (aged 7 to 19) from 986 public China schools in 2017. The lack of culturally specific and age-appropriate PA and intervention guidelines for school-aged children and adolescents are all significant obstacles to PA measuring (Zhu *et al*.,2019). Table 3.5 shows that most Indian school-age children are just moderately active. According to the worldwide recommendations, MVPA, as measured with an accelerometer in Vietnam is on average 28 min/d, implying a significant occurrence of physical inactivity. Children from South Korea and China had daily step counts that were less than the recognised cut-points. Müller *et al*., (2013) showed that the majority of Asian children did not exceed the PA standards, and the minimal PA guidelines of 30 minutes, 3 days per week, were only reached by less than 50% of the samples examined.

Table 3.4. Accelerometry-derived measurements of physical activity in Asian children

Reference	country	No of applicants	Male	Female	Device	Output
Corder *et al*., (2010)	India	30	15	15	Accelerometer [7 days, obtain average movement in counts per minute (CPM)]	• Ø337.7 CPM (light active) • MVPA=37.5 min/d (average of the whole group) • MVPA for at least more than 30 mins per day- 31% of boys, 0% of girls
Lachat *et al*., (2008)	Vietnam	227	Not mentioned		Accelerometer (8 days, total counts and time of MVPA measured)	• ØMVPA=28 min/day • MPA for at least 30 min/day=46% • MPA for at least 60 min/day=16%
Yamauchi *et al*., (2007)	South Korea and China	159	80	79	Accelerometer (7 days, provide TEE, STP, and PAL)	• STP=10,946 (male: 11,388; female: 10,504) (below cut-points) • TEE=1.54 kcal/d (male: 1.5; female: 1.57)
Tudor-Locke *et al*., (2003)	Philippines	1629	756	873	Accelerometer (1 day, energy expenditure on PA of 1 day recorded)	• EEPA(24h)=378 ± 164.5 kcal (male); • EEPA(24h)=271 ± 105.4 kcal (female)
Nguyen *et al*., (2010)	Vietnam	617	333	284	Accelerometer (7 days, average time spent with MVPA calculated)	• Ø MVPA=60.3 min/day
Rowlands *et al*., (2002)	Hong Kong	50	24	26	Accelerometer [5 weekdays and 1 weekend day, obtain average movement in counts per day (cpd)]	• Ø 299,407 ± 147,075 cpd (moderately active) (averaged over 5 weekdays)

EE= Energy Expenditure; MVPA=moderate to vigorous PA; PAL=Physical Activity Level; STP=Daily step frequency; TEE=Total Energy Expenditure; Ø=Arithmetic means.

Wang *et al*., (2013) outlined the findings of a national survey of Chinese city children and adolescents, which used accelerometers to objectively measure the PA and sedentary time of Chinese city children and youth aged 9 to 17 and to investigate for differences by sex, age, grade, and body weight. Based on cut-points specially designed for Chinese children and adolescents, Wang et al (2013) concluded that only 9.4% of boys and 1.9% of girls achieved recommended level (60 min/day) of MAPA, boys were more active than girls, children were more active on weekdays than weekends, and based on the BMI of children, variations in PA and sedentary behaviour were not found. However, Wang *et al*., (2013) concluded the inadequacy of PA, the excess of sedentary behaviour in Asian children and, one of the challenges of measuring PA in Asian children is limited evidence on accelerometer-based PA assessment in Asian children.

There is a dearth of information with regard to calibration and cut-points of accelerometers for Asian children based on body composition, geographical, nutritional, seasonality, cultural and socioeconomic gaps. For Chinese children and teenagers, Zhu *et al.,* (2013) conducted research to create new ActiGraph cut-points for moderate-to-vigorous PA (MVPA) and vigorous PA (VPA) and to assess the classification accuracy against a set of pre-existing cut-points. Zhu *et al.,* (2013) suggested using CPM ≥2,800 as the cut-point value for MVPA and CPM ≥4,000 as the cut-point for VPA for Chinese kids and teenagers. Moreover, Yates *et al*., (2015) observed variations in self-reported and objectively recorded PA levels between white and South Asian groups. However, there have been few studies in the previous decade evaluating existing cut-points, validations, and reliability of accelerometers paired with PA in Asian children with varying gaps such as BMI, body composition, sex, and age.

3.6. Validity and reliability of accelerometer-based physical activity measurements

Validity is measured by taking into account how accurately the procedure can be simulated. Reliability is the capacity of technology to produce the same outcome from day to day when no intervention is utilised (Currell and Jeukendrup, 2008). Numerous examples of the usage of various accelerometer types to analyse PA in various disciplines can be found. The many types of accelerometers and their technical specifications that were evaluated against doubly labelled water (DLW) methods are listed in Table 3.6 (Plasqui *et al*., 2013). The DLW method, which is normally evaluated over a 7- to 14-day period, is still the gold standard for calculating total energy expenditure (Wong *et al*., 2014). It is noteworthy because the approach is acceptable for usage in a free-living setting, is non-intrusive, and requires minimal participant burden (Ainslie *et al*., 2003). There are certain drawbacks to the approach, such as the inability to quantify the mode, intensity, or duration of activities when calculating total energy expenditure over a selected number of days (Hills *et al*., 2014). Based on those limitations, several studies have made major contributions to manufacturing improved versions of the accelerometer as a self-monitoring tool for PA assessment.

Table 3.5. Technical specifications of the different accelerometers used in PA assessment

Name of accelerometer	Country	No. of axes	Accelerometer Type	Wearing place	Frequency response (Hz)	Sampling frequency (Hz)	Size (mm)	Weight (g)
RT3 (Jacob *et al.*, 2007; Maddison *et al.et al.*, 2009)	USA	3	Piezo-resistive	Waist	-	-	68 × 48 × 18	63
Tritrac (Jacob *et al.*, 2007)	USA	3		Waist	-		120 × 65 × 22	168
Actigraph (model 7164) (Pomeroy *et al.*, 2011; Corder *et al.*, 2009)	No longer available	1	Piezoelectric	Waist	0.25-2.5	10	51 × 41 × 15	43
Tracmor (Bonomi *et al.*, 2009)	Netherlands	3	Piezo-capacitive	Lower back	-	20	80 × 35 × 10	35
Tracmor (Bonomi *et al.*, 2010)	Netherlands	3	Piezo-capacitive	Lower back	-	-	32 × 32 × 5	13
Actigraph (GT1M) (Farooq *et al.*, 2018)	USA (no longer available)	1	Capacitive	Waist	0.25-2.5	30	38 × 37 × 18	27
Actiheart (Bonomi *et al.*, 2010)	UK	1	Piezoelectric	Chest	1-7	32	7 ×33; 100-mm length wire	8
Lifecorder (Ohkawara et al., 2011; Lim *et al.*, 2018)	Japan	1	Piezoelectric	Waist	-	32	62 × 46 × 26	42
3dNX (Carter *et al.*, 2008; Konstabel *et al.*, 2019)	UK	3	Piezoelectric	Hip/lower back	0.2-10	100	125 × 58 × 8	93
ActivPAL (Skipworth *et al.*,2011)	UK	1	Capacitive	Thigh	-	10	35 × 53 × 7	15
Actigraph GT3X+ (Skipworth *et al.*,2011)	USA	3	Piezoelectric	Wrist	0.25-2.5	30–100 Hz	46 × 33×15	19

It is crucial for researchers studying sedentary behaviour and PA to assess both the validity of the observed behaviour and the instrument's reliability (Barreira *et al*., 2015). According to Van *et al*., (2011), the validity evaluation demonstrated a substantial and positive correlation between mean ActiGraph accelerometer activity counts and average Observational System for Recording PA in Children-Preschool (OSRAC-P) activity intensity (r = 0.66; p 0.001; n = 31). Furthermore, the sedentary cut-points revealed low to good classification accuracy, whereas the light PA and MVPA cut-points showed poor classification accuracy in identifying sedentary behaviour, light PA, and MVPA, respectively. Valkenet and Veenhof, (2019) demonstrated the validity of three different accelerometers in PA (Figure 3.1).

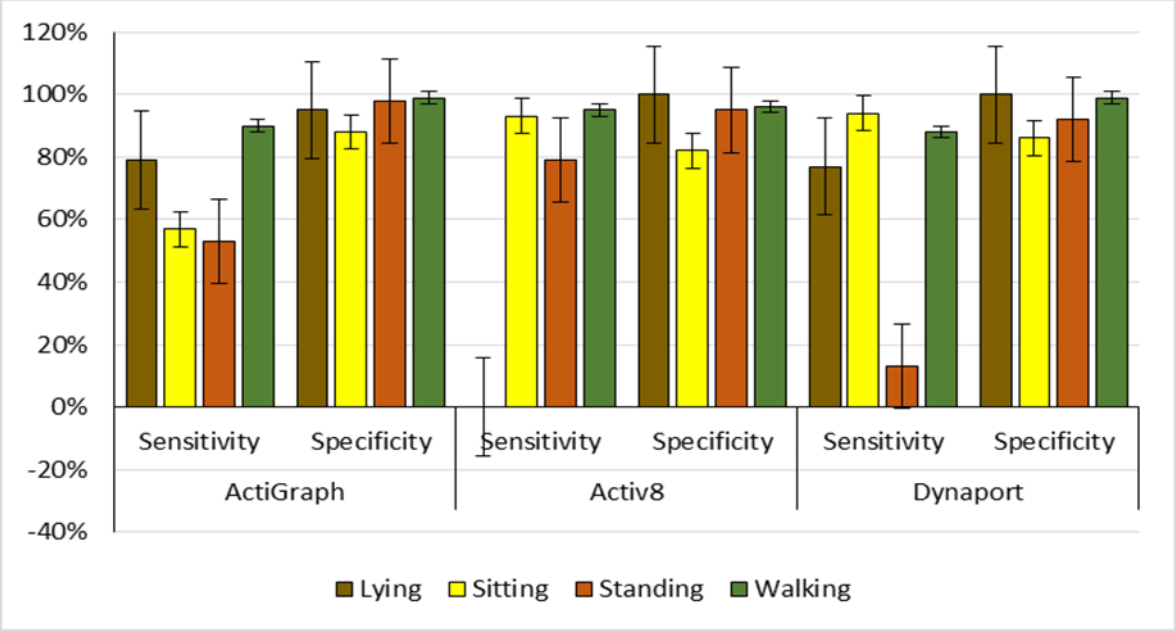


Figure 3.1. Validity of different accelerometers were established for each activity
Error bars are denoted standard deviation (Valkenet and Veenhof, 2019)

According to Pedišić and Bauman (2015), there are four potential factors of concern that could weaken the validity of accelerometer-based estimation methods of PA and sedentary behaviour in children: (1) technical issues, such as some accelerometers cannot be utilised to evaluate aquatic activities (Hallal et al., 2012) and overestimate the amount of energy required for a variety of other regular tasks and leisure activities like climbing stairs and playing tennis (Lee, 2013); (2) periods of non-wearing time i.e., most children do not have accurate accelerometer data for complete days (Roth and Mindell, 2013), and children avoid wearing accelerometers due to aesthetic concerns and physical pain (Pedišić, 2014); (3) participant interference with the results like accelerometer data interfere by purposefully choosing not to wear the device, changing their usual behaviour, moving the device, or shaking it (Audrey et al., 2013), and also 12-16-year-olds were worried about losing or destroying the gadget (Pedišić. and Bauman, 2015); and (4) use of intensity cut-points such as MVPA estimation may derive from alternative methods like pattern recognition rather than employing cut-points (Guinhouya et al., 2013). Variable sets of cut-points have been devised for various accelerometer models and are recommended to be used since they can produce significantly different prevalence estimates and intensity-specific PA levels (Bailey et al., 2013).

According to Pedišić. and Bauman, (2015), metrics employed for PA monitoring should be sufficiently reliable to generate valid estimates at the group level. Also, errors from

technological human-related factors might influence the reliability of an accelerometer. Baumgarter (1989) distinguished two categories of reliability: relative and absolute. The degree to which participants maintain their place in a sample after repeated assessments is known as relative reliability, whereas the level of individual variation in repeated measurements is known as absolute reliability. Accelerometers revealed strong intra-instrument and inter-instrument constancy in lab conditions, with coefficients of variation (CV) typically below 5% and 10%, respectively (Reneman and Helmus, 2010). In free-living situations, the inter-instrument reliability of accelerometers varied from moderate for RT3 accelerometers (CV 9.8-39.8%) to a sufficient level for Actigraph 7164 and GT1M models (CV 0.9-15.5%) (Pedišić. and Bauman, 2015; Vanhelst *et al*., 2012). The high reliability of the accelerometer acquired over two 7-day periods in free-living situations was demonstrated by a test-retest reliability study (ICCs 0.77–0.90; Pedišić. and Bauman, 2015). According to Helmerhorst *et al*., (2012), the reliability of accelerometer-based estimations of PA and sedentary behaviour could be appropriate for public health surveillance. Conversely, there are positive developments in reliability that wrist-worn accelerometer compliance is higher than that of hip-mounted accelerometers (Freedson and John, 2013).

Mindell et al., (2014) emphasised several practical issues of accelerometers in PA assessment such as no devices recognise load-carrying, which also underestimates energy expenditure when carrying a big school bag, for instance, and because most accelerometers are not waterproof, they must be taken off before swimming. Although accelerometers are excellent at capturing time spent doing nothing and time spent engaging in dynamic activity, such as running or walking up to a particular speed, they are less effective at monitoring static activity and non-wear period, which is frequently crucial for total energy expenditure assessment (Roth and Mindell, 2013; Scholes and Mindell, 2016). Additionally, some ethical committees could set limitations, such as advising athletes to take their devices off before engaging in contact sports (Mindell et al., 2014).

3.7. Future directions

This review explored PA monitoring using an accelerometer for Asian children, but several concerns still require further investigation. Due to the absence of detailed investigation, methodologies for the use of accelerometers in different age groups could not be established. We suggest that further extended studies to assess the specific validity and reliability of cut-points in accelerometer measurements in Asian children are needed for the accurate evaluation of PA when choosing an accelerometer. Thus, based on the seasonality, BMI, age, sex, and type of PA, extended research on assessing suitable parameters such as validity, reliability, sensitivity, and specificity of the accelerometer is further required to measure the sedentary and physically active behaviours of Asian children, due to the majority of existing cut-points only being valid for children in Western countries.

3.8. Conclusion

Extended and accurate measurement of PA in Asian children is crucial to evaluate and intervene in the changing lifestyles leading to reduced inactivity and increased risk of non-communicable diseases stemming from increasing rates of obesity in children living in Asian countries. The accelerometer is a feasible, accurate, and self-monitoring device that can be used to measure children's PA. The validity of accelerometer outputs depends on the validity and reliability of cut-points for the targeted population, and it changes with body composition, age, sex, BMI, geographical area, seasonality, and cultural behaviour of children. However, the majority of existing cut-points for monitoring PA in children have been developed using data from Western countries, and more data is required for Asian countries. The current validity and reliability values of accelerometer measures of PA in Asian children are less precise due to variance body composition, BMI, sex, and age-specific cut-point gaps. Although few studies were undertaken relating to Asian children, further validity and reliability assessment studies of cut-points in accelerometer measurements in Asian children are requisite for the accurate evaluation of PA.

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Chapter 4

Physical Activity Measurement and Perception in Schoolchildren in New Zealand and Sri Lanka: a Pilot Study of a Developed vs a Developing Nation

This chapter presents a manuscript titled *"Physical Activity Measurement and Perception in Schoolchildren in New Zealand and Sri Lanka: A Pilot Study of a Developed vs a Developing Nation"* authored by Harshani Perera, Ajmol Ali, Carol Wham, Ananda Chandrasekara, David S Rowlands. The manuscript is prepared in journal format and will be submitted to a peer-reviewed journal for publication in the future.

This chapter addresses **Research Objective 2 (Section 1.3.2)**. It compares objectively measured physical activity levels and children's subjective experiences of physical education, including engagement, motivation, and perceived quality, between Sri Lankan and New Zealand schoolchildren aged 5–13 years. By focusing on both objective and subjective measures, this chapter provides insights into cross-national differences in PA behaviours and perceptions, contributing to the understanding of contextual influences on children's physical activity in developed and developing country settings.

HP, AA, CW, AC, and DR designed the research and obtained ethical approval. AA coordinated with the Healthy Active Learning (HAL) initiation and sought guidance from the special HAL committee regarding the use of HAL data. Data collection for the Sri Lankan arm was led by HP with assistance from AC. HP was responsible for participant recruitment and data entry for the Sri Lankan arm, while Karen supported HAL data extraction and cleaning of accelerometer data for both countries. HP and DR conducted data analysis and interpreted the results. HP drafted the chapter and manuscript draft, and all authors reviewed and approved the final version.

Abstract

This cross-sectional pilot study compared perceptions of physical activity (PA) and objectively measured PA among schoolchildren in New Zealand (NZ) and Sri Lanka (SL) using questionnaires and accelerometers, respectively. Questionnaire data were collected from 1,476 NZ and 165 SL students aged 5–13 years. Following data cleaning, the final questionnaire samples comprised 1,311 NZ and 165 SL students, with accelerometer samples of 464 and 124 students, respectively. Sri Lankan children accumulated more moderate-to-vigorous PA (MVPA) (11 vs. 7 min/hour; mean difference = 3.6 (95% CI: 3.0, 4.1), $p<0.001$), while NZ children recorded higher step counts (+119 steps/hour (95% CI: 86, 153), $p<0.001$) and greater sedentary time (+2.8 min/hour (95% CI: 2.3, 3.4), $p<0.001$). Weekday–weekend variability was greater among schoolchildren sampled from NZ schools, whereas those from SL schools showed more stability. New Zealand students reported more active travel (44%) and diverse school activities, whereas public transport was the most common mode of travel among SL students (53%), followed by private motorised transport (31%), and SL children engaged more frequently in informal weekend activities. New Zealand children were more likely than SL peers to like doing PE (aOR = 1.58, 95% CI: 1.11–2.25), feel good at PE (aOR = 2.28, 95% CI: 1.62–3.19), and report varied opportunities (aOR = 2.67, 95% CI: 1.86–3.83), while SL children reported greater cultural diversity (aOR = 0.46, 95% CI: 0.31–0.70) and encouragement to be active (aOR = 0.42, 95% CI: 0.27–0.65). Analysis from this pilot study revealed differences in MVPA, sedentary time, and perceptions between NZ and SL, demonstrating the feasibility of using mixed-method approaches to capture both behavioural and perceptual dimensions across diverse contexts. Findings underscore the need for culturally-adapted tools and larger samples to confirm trends and guide context-specific strategies.

Keywords: child, accelerometry, gender, schools, Healthy Active Learning, humans, SDG 3 – Good Health and Well-being, SDG 4 – Quality Education, SDG 10 – Reduced Inequalities

4.1. Introduction

Physical activity (PA) plays a fundamental role in children's physical, mental, and social development, supporting fitness, cognitive performance, and emotional well-being (Tambalis, 2022). Despite these benefits, research shows that most school-aged children fail to achieve the WHO recommendation of at least 60 min of moderate-to-vigorous PA (MVPA) daily (Neil-Sztramko et al., 2021). This gap is concerning given the rising prevalence of childhood obesity and non-communicable diseases across both high-income and low- and middle-income countries (Hallal et al., 2012). Schools are widely recognised as critical environments for promoting PA because they provide structured opportunities during the day (Guthold et al., 2020). However, evidence indicates that the effectiveness of school-based PA initiatives varies substantially across contexts, influenced by infrastructure, policy implementation, cultural norms, and socioeconomic conditions (García Bengoechea et al., 2024).

Understanding children's own perceptions of PA is increasingly recognised as critical to improving PA engagement. Children are not passive recipients of health interventions; they actively interpret and respond to their environments (Kesten et al., 2015). Many children perceive PA as something linked to sports performance or competitive success rather than benefiting general health, which can discourage those who feel less skilled (Alberga et al., 2019). Some children perceive PA as secondary to academic achievement, especially in cultures where educational success is prioritised over play (Rajaraman et al., 2015). Their views on what motivates or discourages PA, such as enjoyment, health benefits, peer support, safety concerns, or fear of bullying, can significantly influence their participation (Laukkanen et al., 2020). Children's perceptions are shaped by age, gender, ethnicity, and cultural background, which should be considered when designing interventions to promote PA (Martin, 2024).

While perceptions provide valuable insights, they do not always reflect actual behaviour (Marasso et al., 2021). Traditional assessments of children's PA often rely on proxy reports from parents or teachers, yet these reports frequently misrepresent actual behaviours and perceptions (Sumonja & Jevtic, 2019). To address this, recent research supports direct engagement with children through interviews, focus groups, and creative methods to obtain genuine insights into their perceptions and experiences of PA, thereby reducing the bias inherent in proxy reports (Laukkanen et al., 2020). However, self-reported PA data remain vulnerable to recall bias and social desirability, particularly among children (Sallis & Saelens, 2000). In contrast, objective measures, such as accelerometers, provide reliable data on the intensity, frequency, and duration of PA, thereby overcoming the limitations associated with self-report tools (Reilly et al., 2008).

Sri Lanka (SL) faces unique challenges in promoting PA among school-aged children. National surveys indicate that only 15.5% of adolescents aged 13-17 years meet WHO guidelines for daily MVPA (Ministry of Health SL, 2021), with significant gender disparities; boys are consistently more active than girls (Godakanda et al., 2018). School environments often prioritise academic achievement over active play, limiting time for physical education and recreational activities (Peiris et al., 2024). Infrastructure constraints, such as inadequate playgrounds and sports facilities, further restrict opportunities, particularly in rural districts (Chinthani et al., 2023). Cultural norms and parental expectations also influence participation, with concerns about safety, weather conditions, and the perceived value of PA contributing to low engagement (Perera et al., 2022; Ranasinghe & Fonseka, 2021). Despite policy commitments, including the National Action Plan for NCD Prevention (2021–2025),

implementation of school-based PA programmes remains inconsistent, leaving many children without structured opportunities for movement (Ministry of Health SL, 2021).

In contrast, New Zealand (NZ) has a well-established framework for promoting PA through national guidelines and school-based programs such as Healthy Active Learning (HAL) and MoveWell, alongside funding schemes like Tū Manawa Active Aotearoa (Sport New Zealand, 2024). While many children participate in organised PA, with 68% of young people taking part weekly (Soprt New Zealand Active NZ, 2024), overall, PA levels remain below recommendations, with only 7% of children meeting daily guidelines (Sport New Zealand - children and young people, 2024). Disparities persist across ethnic and socioeconomic groups; Pacific and Māori children face barriers, including cost, limited access to safe spaces and competing academic demands (Ministry of Health NZ, 2025). The 2022 Report Card graded overall PA at C+, indicating that approximately 47–53% of children and young people met the benchmark for the indicator, while active transportation received a D grade, indicating that only 27–33% met the benchmark. The report also highlighted inequities by gender, ethnicity, disability, and socioeconomic status (Wilson et al., 2023).

Few studies have combined subjective and objective PA measures across contrasting socioeconomic environments (Bann et al., 2019; Kesten et al., 2015). Despite extensive research on PA, little is known about how children's perceptions align with objectively measured PA across contrasting socioeconomic and cultural contexts. Most studies focus on single-country samples or rely solely on self-reports, limiting validity and cross-context insights. This pilot study addresses this gap by comparing perceptions and accelerometer-measured PA among schoolchildren in NZ and SL using data drawn from the wider HAL evaluation and a Sri Lankan sample. Understanding these relationships is important for developing culturally relevant assessment tools and informing equitable school-based PA strategies.

This pilot study aimed to assess the feasibility and cultural relevance of PA evaluation tools developed in high-income settings when applied in a low- and middle-income context. Using questionnaire and accelerometer data, we described patterns of objectively measured PA and perceptions of PA among children in NZ and SL. We compared these patterns at the group level to evaluate the applicability of existing PA assessment tools across contrasting socioeconomic and cultural environments. Findings will inform culturally adapted assessment methods and guide strategies to promote equitable PA opportunities in schools.

4.2. Methods

4.2.1. Study design

A cross-sectional pilot study was conducted to examine children's perceptions of PA and objectively measured PA levels in two socioeconomically diverse contexts: Rathnapura District, SL, and the Auckland region, NZ. Rathnapura was selected for its high multidimensional vulnerability in education, health resilience, and living standards (United Nations Development Programme (UNDP) & Oxford Poverty and Human Development Initiative (OPHI), 2023), making it a socioeconomically disadvantaged setting. This design enabled comparison of PA patterns across contrasting cultural and socioeconomic environments.

4.2.2. Ethical considerations

Participants were informed of their right to withdraw at any time without penalty. Students were recruited in approximately equal numbers of boys and girls (self-identified). All procedures were reviewed and approved by the Massey University Human Ethics Committee, under protocols Application NOR 20/07 for the HAL study and Application NOR22/16 for the SL study. All necessary administrative approvals and permissions were obtained from the Ministry of Education, Provincial Education Offices, and school principals prior to data collection in SL, and the study was conducted in accordance with the protocols and guidelines provided by these authorities. Additionally, guidance was sought from the special HAL committee regarding the use of the HAL data for this study.

4.2.3. Study setting and participant recruitment

New Zealand

Data for this study were drawn from the baseline data collection of the HAL project, only from the Auckland region. Data were collected between August 2020 and March 2021 as part of the Phase One baseline evaluation. For further details, visit the Sport New Zealand website (Sport New Zealand HAL, 2023).

During data collection for the HAL project, advisors from Sport NZ managed school engagement through Regional Sports Trusts, which served as the primary point of contact with schools. For evaluation, Sport NZ provided school contact details and secured participation agreements. Researchers from Massey University then liaised with school leaders to schedule data collection. Within these schools, classes were selected based on school schedules and teacher availability. Parents and caregivers were informed about the evaluation through newsletters, school notice boards, and information sheets before data collection. Consent forms were distributed through schools and returned before participation. Verbal assent was obtained from all children immediately before data collection. At the start of each session, the research team briefed the study to students in their classrooms. Students who did not have parental consent to participate, or who chose not to provide assent, engaged in alternative classroom activities arranged by the teacher. Data were collected from 14 schools in the Auckland region, including both primary and intermediate schools, with a total of 1,311 students. Questionnaire data were obtained from 216 students aged 5-8 years and 1,095 students aged 9-13 years, while accelerometer data were collected from a purposive subsample of 470 students. Figure 4.1 shows a flow diagram of school selection, participant recruitment and questionnaire development in NZ and SL.

Sri Lanka

The sampling frame consisted of government schools in Rathnapura District that offered classes from Grade 1 to at least Grade 8 and had an enrolment of more than 500 students. These criteria were applied to ensure access to sufficient numbers of eligible students across the target age range while maintaining the feasibility of data collection within available resources. Based on these criteria, 92 schools were eligible, representing 13.7% of all schools in the district and 32.2% of the student population (n = 71,860). A convenience sample of 10 schools was selected from four educational divisions to ensure coverage of all geographic and socioeconomic zones. The 10 schools represented approximately 11% of the eligible schools and were considered sufficient to provide reasonable representation of the target population while ensuring feasibility of data collection. Data for the SL component was collected in 2022.

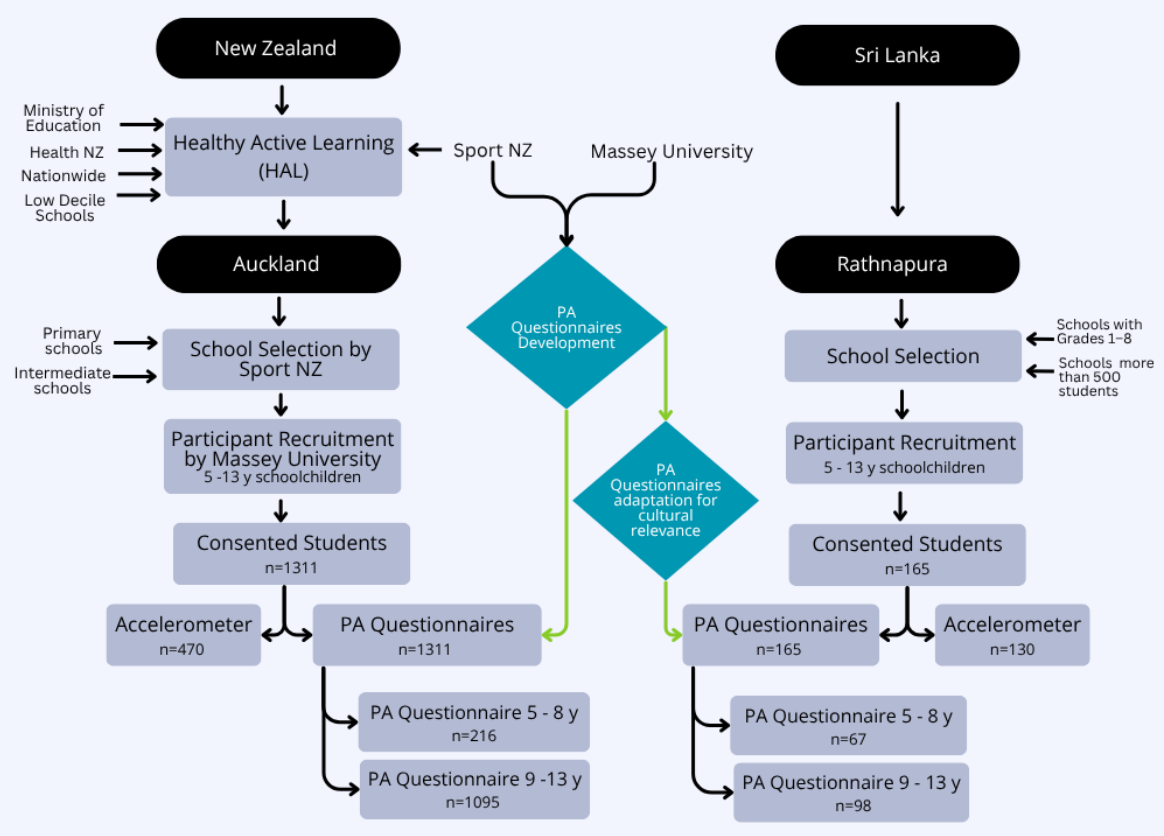


Figure 4.1. Flow chart of school selection, recruitment, and questionnaire development.

NZ-New Zealand, PA-physical activity

In SL, an information meeting was arranged at each school to explain the study objectives and procedures, and written parental consent was obtained either during the meeting or via consent forms returned to the school office. Verbal assent was obtained from all children immediately before data collection. At the start of each session, the research team briefed the students in their classrooms about the study. Students who did not have parental consent to participate, or who chose not to provide assent, engaged in alternative classroom activities arranged by the teacher.

From the 10 Rathnapura government schools, data from 165 students were collected. Questionnaire data were obtained from 67 students aged 5-8 years and 98 students aged 9-13 years, while accelerometer data were collected from a purposive subsample of 130 students. The subsample was selected in consultation with students, parents, and teachers to identify children who were willing and able to wear the accelerometer continuously for 7 consecutive days.

4.2.4. Data collection procedures

Accelerometer measurement

Objective PA was measured using accelerometers (ActiGraph GT3X+, ActiGraph LLC, Pensacola, FL, USA) that were fitted to the non-dominant wrist of participating students. Devices were worn continuously for 7 consecutive days, including weekends, to capture both in- and out-of-school activity. In SL, accelerometer data were collected from a purposive subsample of 130 students, while in NZ, data were collected from a purposive subsample of 470 students. Devices were fitted and removed by trained research assistants. Parents were

instructed to remove the device if the child experienced discomfort and to store it safely until return. Extra wristbands were provided to replace any that broke. The participant's name, class number, ActiGraph ID, and the time and date of device fitting and removal were recorded. Data were processed using ActiLife software (version 6.13.3; ActiGraph LLC, Pensacola, FL, USA) with an epoch length of 15 s. Non-wear time was defined as ≥60 consecutive minutes of zero counts, allowing for up to 2 min of counts between 0 and 100 (Troiano et al., 2008). PA was categorised into sedentary, light, moderate, and vigorous intensity using validated cut-points for children. PA intensity was classified using Evenson et al. (2008) cut-points: sedentary (0–100 counts/min), light (101–2295 counts/min), moderate (2296–4011 counts/min), and vigorous (≥4012 counts/min). Moderate to vigorous PA was defined as ≥2296 counts/min. These thresholds are widely validated for children aged 5–13 years and were applied consistently across all data. Participants with at least 10 h of valid wear time across at least 4 days (including one weekend day) were included in the analysis during data cleaning (Cain et al., 2013).

While wrist placement is more practical for children, it has been shown to record higher activity counts than hip placement (Gall et al., 2022). To account for this discrepancy, conversion factors derived from an unpublished validation study based on age-specific calibration results from researchers at Massey University were applied. From this study, a factor of 2.00 was used for children aged 11 years and older, and 2.09 for children under 11 years (Massey University, Unpublished).

Questionnaire survey

Based on information from Sport NZ, Massey University researchers collaborated with Sport NZ to develop the PA questionnaires used for the HAL evaluation. These questionnaires assess the PA patterns and perception of doing PA among schoolchildren in NZ aged 5 to 13 for the HAL initiative.

The PA questionnaires developed for HAL were adapted to reflect school PA for the SL context. The adaptation process involved reviewing each questionnaire item for cultural relevance and appropriateness to the SL school setting in consultation with the research team and local experts. Minor modifications were made to ensure cultural relevance, particularly in activity examples. Activities uncommon in Rathnapura District, SL, such as playing on the beach and fishing, were removed, while locally relevant activities were retained. Content validity was assessed through expert panel review. The adapted questionnaire was reviewed by PE lecturers, public health academics, school teachers, sports scientists, nutritionists, and Ministry personnel. Experts evaluated each item for relevance, clarity, and cultural appropriateness for the SL school context and provided recommendations for additions, modifications, and deletions where necessary. The final version was revised following consensus from the expert panel to ensure that key constructs were retained while culturally irrelevant items were removed. Following translation into Sinhala and Tamil, language specialists undertook forward translation and back-translation procedures to verify linguistic accuracy and consistency across versions.

Two versions of questionnaires were administered in both contexts: a shorter version (18 items) for younger children (5–8 years) and a more extended version (21 items) for older children (9–13 years) (see Appendices 3.10 and 3.11, respectively). The shorter version excluded questions requiring estimation of time spent in different activities, as younger children may have difficulty accurately recalling and reporting durations. The extended version included additional questions on the estimated duration of participation in various PA and related

behaviours. In NZ, surveys were completed on iPads using Qualtrics XM (Qualtrics, Provo, Utah, USA), a secure web-based platform designed for academic research. In SL, printed questionnaires were administered in the local language by trained assistants. Students aged 5-8 years received individual support; students aged 9-13 years completed surveys in whole-class sessions with assistance when needed.

4.2.5. Statistical analysis

Descriptive statistics were used to present questionnaire responses and accelerometer-derived PA measures. Independent t-tests were used to compare the means of objectively measured PA variables, including sedentary activities, light physical activities, MVPA, and step counts, between countries (SL vs. NZ), days (weekday vs weekend), contexts (in and out of school), gender (male vs female) and bins of two age groups (5-8 vs 9-13 years). To compare changes in PA patterns between countries while accounting for baseline differences, a difference-in-differences (DiD) approach was applied (Ye et al., 2025). This method estimates between-day differences and school context relative changes across countries by calculating the difference in the mean differences. This approach reduces bias from inherent group differences and isolates the effect of the time or context factor (Ye et al., 2025).

Adjusted odds ratios (aOR) and 95% confidence intervals (CI) were estimated using multivariable logistic regression models to examine associations between students' perceptions, opportunities and practices and the independent variables (country, gender, and age category). Odds ratios were interpreted as follows: OR = 1 indicates no difference between groups; OR > 1 suggests the outcome is more likely in the comparison group; OR < 1 indicates the result is less likely. Statistical significance was determined by whether the 95% CI excluded one and by p-values. A significance level of $p < 0.05$ was used for all statistical tests. Analyses were conducted using R software, version 4.4.1 (R Core Team, 2024).

4.3. Results

Table 4.1 summarises the distribution of participants by gender and age category for accelerometer measurements and questionnaire responses in NZ and SL. In NZ, 470 children initially wore accelerometers, but six were excluded during data cleaning because they did not meet data quality requirements, including valid wear time criteria, leaving 464 valid cases. In SL, 130 children participated, and six were excluded during data cleaning for similar reasons, resulting in 124 valid datasets. Across both countries, the sample included more females than males, and the mean age was 9.32 ± 1.91 years in NZ and 9.42 ± 2.22 years in SL.

4.3.1. Objectively measured data

Figure 4.2 illustrates cross-country differences in PA patterns among children aged 5–13 years in NZ and SL (Supplementary Table A). Accelerometer data revealed significant cross-country differences in PA metrics (all $p < 0.01$ except weekend steps). New Zealand children accumulated more steps overall (992 vs. 873 steps/hour; mean difference = 119 (95% CI: 86, 153), $p < 0.01$) and during weekdays (1034 vs. 867 steps/hour; difference = 167 (95% CI: 134, 201), $p < 0.01$), while SL children achieved higher MVPA (11 vs. 7 min/hour; difference = -4.7 (95% CI: -55, 45), $p = 0.85$). Sedentary time was greater in NZ (34 vs. 31 min/hour; difference = 2.8 (95% CI: 2.3, 3.4), $p < 0.01$), whereas light activity was slightly higher in NZ (19 vs. 18 min/hour; difference = 1.2 (95% CI: 0.9, 1.5), $p < 0.01$). Age and sex differences were evident: younger children (5–8 years) recorded more steps than older peers (difference = 215 steps/hour (95% CI: 152, 278), $p < 0.01$), and boys were more active than girls in both

countries (difference = 137 steps/hour (95% CI: 84, 190), $p < 0.01$). Weekday–weekend variation was larger in NZ (weekday steps = 1034; weekend steps = 885), whereas SL patterns were more stable.

Table 4.1. Number of participants by country, data collection method, gender, and age group.

Variables		Accelerometer		Questionnaires	
		NZ	SL	NZ	SL
Gender	Female	248	67	629	91
	Male	202	57	662	74
	Prefer not to answer/NA	14	0	20	0
	Total	464	124	1311	165
Age category	5-8 years	120	24	216	67
	9-13 years	344	100	1095	98
	Total	464	124	1311	165

Table 4.2 summarises mean step counts, sedentary time, light activity, and MVPA across weekdays, weekends, in-school, and out-of-school periods for children in NZ and SL (Appendix 2.1 Table A). New Zealand children had significantly higher step counts and sedentary time than SL peers, while SL children accumulated more MVPA across all segments. Light activity was slightly greater in NZ, especially outside school. Differences were most pronounced on weekdays and during school hours. Younger children showed larger step count advantages, whereas older children exhibited greater sedentary differences.

Table 4.3 presents descriptive statistics on differences in activity levels by day type (weekdays vs. weekends), setting (in-school vs. out-of-school), gender (male vs. female), and age group (5-8 vs. 9-13 years) within each country (Appendix 2.1 Table B). Children in NZ were notably more active on weekdays than on weekends, with higher step counts and MVPA and slightly less sedentary time. In contrast, SL children showed no significant weekday-weekend difference in step counts, though sedentary time was lower and light activity higher on weekdays, while MVPA peaked on weekends. During school hours, both countries recorded higher step counts and lower sedentary time, though NZ children engaged in more MVPA outside school. Gender differences were evident only in NZ, where boys had higher step counts than girls. Age-related differences were also observed in NZ, with younger children being more active and less sedentary, whereas SL children showed no significant age-related differences.

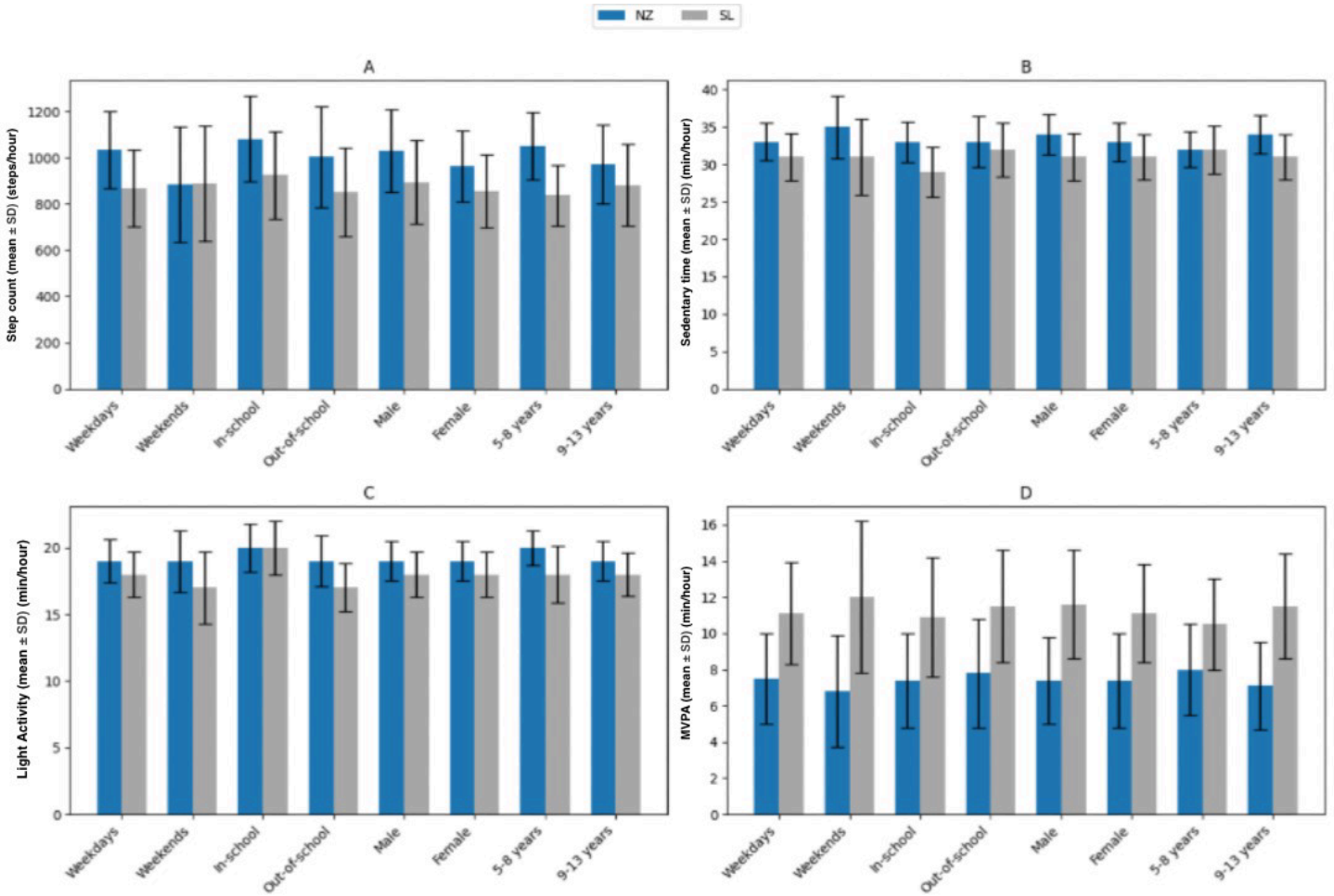


Figure 4.2. Comparison of physical activity patterns between NZ and SL.

Data represent physical activity patterns among children aged 5–13 years in New Zealand (NZ, n = 464) and Sri Lanka (SL, n = 124). Comparisons are shown across weekdays and weekends, by sex and age groups. Panels illustrate: (A) step count, (B) sedentary time, (C) light-intensity activity, and (D) moderate-to-vigorous physical activity. Error bars represent standard deviations. Statistical comparisons between NZ and SL were conducted using independent-samples t-tests.

Table 4.2. Comparison of PA metrics per hour between NZ and SL Schoolchildren.

Variable	Step Count (steps/hour)		Sedentary Time (min/hour)		Light Activity (min/hour)		MVPA (min/hour)	
Segments	**Mean difference NZ-SL 95%CI (Lower, Upper)**	**p-value**	**Mean difference NZ-SL 95%CI (Lower, Upper)**	**p-value**	**Mean difference NZ-SL 95%CI (Lower, Upper)**	**p-value**	**Mean difference NZ-SL 95%CI (Lower, Upper)**	**p-value**
Overall	119 (86, 153)	<0.01	2.8 (2.3, 3.4)	<0.01	1.2 (0.9, 1.5)	<0.01	-4.0 (-4.6, -3.5)	<0.01
Weekdays	167 (134, 201)	<0.01	2.3 (1.7, 2.9)	<0.01	1.2 (0.9, 1.6)	<0.01	-3.6 (-4.1, -3.0)	<0.01
Weekends	-4.7 (-55, 45)	0.85	4.1 (3.2, 5.0)	<0.01	1.3 (0.7, 1.7)	<0.01	-5.3 (-6.1, -4.5)	<0.01
In-school	157 (120, 194)	<0.01	3.9 (3.3, 4.4)	<0.01	-0.3 (-0.7, 0.0)	0.10	-3.5 (-4.2, -2.9)	<0.01
Out-of-school	153 (111, 196)	<0.01	1.3 (0.7, 2.0)	<0.01	2.3 (1.9, 2.7)	<0.01	-3.7 (-4.3, -3.1)	<0.01
Male	137 (84, 190)	<0.01	3.0 (2.2, 3.8)	<0.01	1.3 (0.8, 1.7)	<0.01	-4.2 (-5.1, -3.4)	<0.01
Female	110 (68, 152)	<0.01	2.6 (1.8, 3.3)	<0.01	1.1 (0.8, 1.6)	<0.01	-3.7 (-4.5, -3.0)	<0.01
5-8 years	215 (152, 278)	<0.01	0.8 (-0.3, 2.0)	0.10	1.7 (1.0, 2.3)	<0.01	-2.5 (-3.6, -1.4)	<0.01
9-13 years	90 (51, 128)	<0.01	3.4 (2.8, 4.0)	<0.01	1.1 (0.7, 1.4)	<0.01	-4.4 (-5.1, -3.8)	<0.01

PA-physical activity, SL- Sri Lanka (n=124), NZ-New Zealand (n=464), MVPA-moderate to vigorous physical activity, CI- confidence interval.
Note: Mean difference = NZ mean – SL mean. p-values indicate the statistical significance of the mean difference between NZ and SL schoolchildren for each segment and PA metric, as determined using independent sample t-tests.

Table 4.3. Differences in PA levels per hour by day type, setting, gender, and age in NZ and SL.

Country	Variable	Weekday vs Weekend		In school vs Out of school		Male vs Female		5-8 years vs 9-13 years	
		Mean difference 95%CI (Lower, Upper)	**p-value**	**Mean difference 95%CI (Lower, Upper)**	**p-value**	**Mean difference 95%CI (Lower, Upper)**	**p-value**	**Mean difference 95%CI (Lower, Upper)**	**p-value**
NZ	Step Count	149 (127, 167)	<0.01	78 (56, 99)	<0.01	67 (-98, -35)	<0.01	81 (49, 113)	<0.01
	Sedentary	-1.6 (-1.9, -1.3)	<0.01	-0.7 (-1.0, -0.3)	<0.01	0.4 (-0.9, 0.1)	0.15	-1.6 (-2.1, -1.1)	<0.01
	Light Activity	0.9 (0.7, 1.1)	<0.01	1.1 (0.9, 1.3)	<0.01	-0.4 (0.1, 0.6)	0.02	0.7 (0.4, 0.95)	<0.01
	MVPA	0.7 (0.5, 1.0)	<0.01	-0.4 (-0.6, -0.2)	<0.01	-0.0 (-0.4, 0.5)	0.94	1.0 (0.5, 1.5)	<0.01
SL	Step Count	-23 (-60, 14)	0.22	74 (45, 103)	<0.01	39 (-100, 21)	0.20	-44 (-108, 21)	0.18
	Sedentary	0.1 (-0.7, 1.0)	0.73	-3.2 (-3.8, -2.6)	<0.01	-0.1 (-1.0, 1.2)	0.92	0.9 (-0.5, 2.4)	0.20
	Light Activity	0.8 (0.4, 1.2)	<0.01	3.7 (3.4, 4.0)	<0.01	-0.4 (-0.2, 1.1)	0.16	0.1 (-0.9, 1.0)	0.91
	MVPA	-0.9 (-1.6, -0.3)	<0.01	-0.6 (-1.1, -0.0)	0.04	0.5 (-1.5, 0.5)	0.34	-1.0 (2.2, 0.2)	0.10

PA-physical activity, SL- Sri Lanka (n=124), NZ-New Zealand (n=464), MVPA-moderate to vigorous physical activity, CI- confidence interval

Note: Mean difference represents the difference between the two categories being compared within each country (Weekday vs Weekend, In-school vs Out-of-school, Male vs Female, and 5–8 years vs 9–13 years). p-values indicate the significance of these mean differences between groups, as determined using independent-samples t-tests.

The DiD analysis indicated that the weekday–weekend changes in step counts, sedentary time, and MVPA differed significantly between NZ and SL children. Compared with SL children, NZ children exhibited a larger weekday–weekend difference in step counts (DiD = +170; 95% CI: 128, 212; $p < 0.001$), sedentary time (DiD = −1.8; 95% CI: −2.7, −0.9; $p < 0.001$), and MVPA (DiD = +1.6; 95% CI: 1.1, 2.3; $p < 0.001$), with no difference for light activity ($p = 0.78$). For in-school vs. out-of-school comparisons, no significant between-country difference was observed for step counts ($p = 0.84$) or MVPA ($p = 0.65$). However, the change in SL children showed a larger reduction in sedentary time (DiD = 2.5; 95% CI: 1.9, 3.2; $p < 0.001$) and a greater increase in light activity (DiD = −2.7; 95% CI: −3.0, −2.3; $p < 0.001$). (Appendix 2.1 Table C)

4.3.2. Self-reported data

The mode of travel to school differed markedly between NZ and SL. In NZ, active transport was common, with 44% of children walking, biking, skateboarding, or using a scooter, compared to only 16% in SL. Conversely, public transport was the predominant mode in SL (53%), whereas it was used by only 5% of NZ children. Private motorised transport accounted for nearly half of the trips in NZ (48%) and about one-third in SL (31%). These findings indicate that NZ children are more likely to engage in active travel, while SL children rely heavily on public transport. Detailed frequencies and percentages for each mode are presented in Appendix 2.1, Table D**.** Multiple responses were permitted.

Before classes began on school days, NZ children were more likely to engage in active behaviours compared to SL children (Appendix 2.1 Table E). Among NZ children aged 5–8 years, 49% participated in active activities such as games, dance, or sport, and 45% walked around, while only 13% and 78% of SL children in the same age group did so, respectively. For NZ children aged 9–13 years, 55% engaged in active activities and 61% walked around, compared to 15% and 84% in SL. Conversely, sedentary behaviours were more prevalent in SL, with 81–86% of children sitting or standing around before school, compared to 32–46% in NZ. These patterns indicate a substantially higher proportion of active engagement in NZ and greater sedentary behaviour in SL across both age groups.

Figure 4.3 presents the percentage of students engaging in different activities during lunch/tea time, stratified by age group and country (Appendix 2.1 Table F). During lunch/tea time, NZ students were more likely to engage in active behaviours such as games, dance, and sport (66–69%). In contrast, SL students are predominantly involved in sedentary activities, such as sitting or standing around (>67%).

During PE or sports time, students aged over 8 years had activity patterns that differed markedly between NZ and SL (Appendix 2.1 Table G). In NZ, the most common activity was playing with a ball (83%), followed by walking/jogging/running (55%) and tag or playground games (35%). Other activities included swimming (22%), aerobics/dancing/ skipping (20%), and riding a bike (14%). In contrast, SL students most frequently engaged in tag or playground games (83%) and walking/jogging/running (64%), while playing with a ball was less common (31%). Activities such as aerobics/dancing/skipping (4%), and other games (4%) were relatively rare in SL. These findings highlight greater diversity and structured sports participation in NZ, whereas SL students favoured playground games.

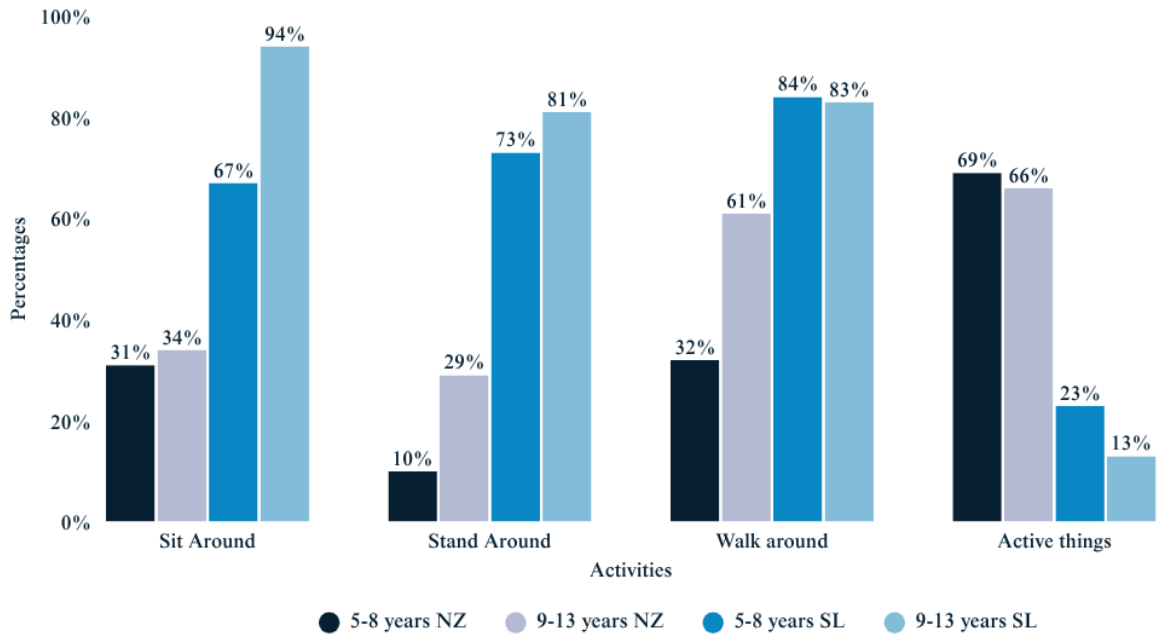


Figure 4.3. Percentage of students engaging in different activities during school lunch/tea time
(New Zealand (NZ): n=1311; Sri Lanka (SL): n=165).

Weekend activity patterns displayed differences across age groups and countries (Appendix 2.1 Table H and I). Among children under 8 years, SL students reported higher levels of active engagement: 91% participated in active activities with friends or individually, and 81% engaged in active activities with family, compared to 63% and 57% of NZ children, respectively. Screen-based activities were common in both samples; 70% of SL children watched TV or movies compared to 66% of NZ children, while NZ children reported higher use of computers or cell phones (58% vs. 50% in SL). Among older students (aged 8+), NZ children reported substantially greater participation in organised sports (55%) than their SL counterparts (10%). Engagement in playing at the beach or park was similar between countries (45% in NZ vs. 47% in SL). Conversely, SL children reported higher involvement in informal outdoor activities, including walking with friends, family, or pets (64% in SL vs. 31% in NZ), riding a bike (48% in SL vs. 20% in NZ), and fun runs (52% in SL vs. 20% in NZ). Activities such as swimming or diving (NZ: 23%; SL: 18%) and climbing trees (NZ: 19%; SL: 25%) were reported at comparable frequencies.

Table 4.4 summarises the adjusted odds ratios (95% confidence intervals) for students' perceptions of PE, PA practices and opportunities adjusted for country, gender, and age category. Compared to SL children, those in NZ were significantly more likely to report positive PE experiences, including enjoyment, progress, competence, learning, inclusion, and sports-based PE (aOR = 1.58–2.78, $p < 0.05$), and to feel included in physical activities (aOR = 2.65, $p < 0.001$). For PA practices, they were more likely to receive teacher feedback, understand cultural diversity, and learn team skills (aOR = 1.63–1.72, $p < 0.05$), but less likely to learn cultural movement patterns or be encouraged to be active (aOR = 0.42–0.46, $p < 0.001$). Regarding opportunities, NZ children reported greater access to varied sports and active options (aOR = 2.67, $p < 0.001$). At the same time, age differences showed that older children were more likely to have game equipment at lunchtime (aOR = 1.62, $p < 0.001$). Gender differences indicated females were less likely to enjoy PE or feel competent (aOR = 0.57–0.62, $p < 0.001$) but more likely to report cultural learning (aOR = 1.37–1.38, $p < 0.05$).

Table 4.4. Adjusted Odds Ratios for perception of PA by Country, Gender, and Age Category.

Dependent Variable	Country (NZ vs SL) aOR (95% CI)	p-value	Gender (Female vs Male) aOR (95% CI)	p-value	Age (9-13 vs 5-8 years) aOR (95% CI)	p-value
Perceptions of PE						
I like doing PE at school	1.58 (1.11-2.25)	0.01	0.57 (0.45-0.73)	<0.001	0.81 (0.60-1.08)	0.16
I feel I am making progress in PE	1.71 (1.22-2.39)	<0.001	0.62 (0.50-0.77)	<0.001	0.90 (0.69-1.19)	0.45
I am good at PE	2.28 (1.62-3.19)	<0.001	0.62 (0.50-0.77)	<0.001	1.28 (0.96-1.70)	0.09
I feel I learn lots during PE	2.68 (1.92-3.76)	<0.001	0.87 (0.69-1.10)	0.24	1.04 (0.77-1.39)	0.79
I feel included and don't get left out in PE	2.78 (1.98-3.90)	<0.001	0.79 (0.63-0.99)	0.04	1.21 (0.90-1.63)	0.21
Most of my PE involves playing sports	2.74 (1.95-3.85)	<0.001	0.79 (0.63-1.00)	0.05	0.52 (0.39-0.68)	<0.001
I feel included and don’t get left out in physical activities	2.65 (1.88-3.72)	<0.001	1.02 (0.80-1.29)	0.87	0.87 (0.65-1.17)	0.35
PA practices						
At school we get to make up our own active games, rules or movement patterns	0.76 (0.54, 1.08)	0.12	0.94 (0.76, 1.16)	0.57	1.19 (0.91, 1.56)	0.21
My teachers give me good feedback about how I could get better at PE or sports	1.63 (1.11, 2.41)	0.01	1.22 (0.91, 1.64)	0.19	0.45 (0.33, 0.63)	<0.001
I learn how to solve problems that happen when we are playing active games or moving	0.97 (0.68, 1.39)	0.87	1.01 (0.81, 1.27)	0.93	1.00 (0.75, 1.34)	1.00
At school I learn games, dance or movement from different cultures	0.46 (0.31, 0.70)	<0.001	1.38 (1.10, 1.73)	0.01	0.67 (0.50, 0.89)	0.01
I understand that families and cultures have lots of different ways of being active	1.68 (1.14, 2.46)	0.01	1.37 (1.04, 1.80)	0.02	0.42 (0.31, 0.57)	<0.001
I learn that people in a team have different skills that we can use	1.72 (1.15, 2.57)	0.01	0.99 (0.74, 1.33)	0.95	0.46 (0.33, 0.64)	<0.001
At school people encourage me to be active	0.42 (0.27, 0.65)	<0.001	1.04 (0.82, 1.32)	0.75	0.87 (0.65, 1.17)	0.35
Opportunities for being physically active						
At school there are lots of different sports and active things I can try out	2.67 (1.86 - 3.83)	<0.001	1.18 (0.90 - 1.54)	0.23	1.06 (0.76 - 1.48)	0.73
At lunchtime we are encouraged to play in lots of different ways	1.13 (0.79 - 1.62)	0.50	1.21 (0.96 - 1.53)	0.11	1.16 (0.88 - 1.54)	0.30
There are lots of things we can play with to make up games at lunchtime	1.01 (0.69 - 1.48)	0.96	1.05 (0.82 - 1.33)	0.69	1.62 (1.21 - 2.16)	<0.001
At school there's lots of active events we can do	1.21 (0.85 - 1.71)	0.29	1.15 (0.92 - 1.43)	0.21	0.98 (0.74 - 1.30)	0.89

SL- Sri Lanka (n=165), NZ- New Zealand (n=1311), PA- physical activity, PE- physical education, CI- confidence interval, aOR- adjusted odd ratio

4.4. Discussion

This pilot study aimed to assess the feasibility and cultural relevance of PA evaluation tools developed in high-income settings when applied in a low- and middle-income context. Using questionnaires and accelerometers, we compared PA patterns and perceptions among schoolchildren in NZ and SL. The findings revealed marked cross-country differences: SL children accumulated more MVPA, whereas NZ children recorded higher step counts and greater sedentary time. NZ children also reported more active travel and a wider range of school activities, while SL children relied heavily on public transport and informal weekend activities. Perceptual differences were evident: NZ children were significantly more likely to enjoy physical education, feel competent, and report varied opportunities than SL peers. These results highlight the influence of cultural and environmental factors on both objectively measured PA and perceptions, underscoring the need for context-specific strategies and culturally adapted assessment tools.

4.4.1. Objectively measured PA

Objectively measured PA levels in this study indicate that, on average, children in both SL and NZ accumulated MVPA levels above the WHO and national recommendations of at least 60 min per day (Sport New Zealand, 2023; Sri Lanka Ministry of Sports and Youth Affairs, 2020). Based on the accelerometer-derived data, SL children demonstrated higher MVPA intensity, averaging 11 min per hour, compared to 7.5 min per hour among NZ children. Considering that only participants with at least 10 hours of valid wear time per day for a minimum of 4 days were included in the analysis during data cleaning, these hourly averages suggest that children in both contexts achieved well above the recommended daily MVPA threshold. Continuous wear of water-resistant accelerometers, with removal only for damaging activities, ensured reliable data. This strengthens confidence that MVPA estimates reflect daily activity and highlights that PA patterns may vary across populations and contexts, underscoring the importance of objective measurement (Guthold et al., 2020). In addition, step count differences were notable; NZ children recorded higher steps per hour than SL children, despite lower MVPA, indicating that much of their movement may have been light-intensity activity rather than vigorous play. This interpretation aligns with evidence showing that step-count monitoring interventions primarily increase total steps without consistently improving MVPA (Wang et al., 2025).

According to accelerometer results, NZ children were more sedentary and engaged in light PA for extended periods, often exceeding three hours per day, compared to their SL counterparts. This is concerning because evidence shows that prolonged light activity of more than three hours per day, combined with high sedentary time, can contribute to vascular deterioration and other adverse health outcomes (Agbaje et al., 2024). Despite these risks, uncertainty remains regarding the most effective strategies for reducing sedentary behaviour and promoting higher-intensity movement among children, underscoring the need for continued research and evidence-based interventions (Chaput et al., 2020).

SL children had lower sedentary time and higher light activity in school. However, they were more sedentary after school, which may reflect differences in after-school activities and daily routines reported in previous SL studies (Peiris et al., 2023, 2024; Sri Lanka Ministry of Sports and Youth Affairs, 2020). Similarly, NZ children showed more light activity in school than out of school. This finding is consistent with previous research highlighting the contribution of school-time activity to children's overall PA levels (Oliver et al., 2023).

Weekday–weekend differences were greater in NZ, aligning with evidence that structured school days boost PA (Brazendale et al., 2021). SL showed slight variation, likely due to limited structured PA and cultural emphasis on academics (Ranasinghe & Fonseka, 2021). In NZ, younger children engaged in more MVPA, consistent with global trends (Guthold et al., 2020). In addition, our study found that NZ children's overall PA decreased with age, which aligns with research showing that sedentary time tends to increase and light activity and MVPA tend to decline as children grow older (Atkin et al., 2025). Sri Lankan children showed a different age-related pattern to NZ, with older children demonstrating higher MVPA and step counts and lower sedentary time. This finding contrasts with the age-related decline in PA observed globally (Guthold et al., 2020b).

Difference-in-Differences analysis further showed that NZ children experienced greater weekday–weekend variability in step counts, sedentary time, and MVPA (Mizdrak et al., 2021). In contrast, SL children showed more stability across the week. Sri Lankan children also demonstrated larger in-school reductions in sedentary time and increases in light activity, suggesting greater movement opportunities during school time (Peiris et al., 2023, 2024). These findings highlight how school environments shape activity differently across contexts, emphasising the need for tailored strategies to reduce sedentary time and promote higher-intensity activity.

4.4.2. Self-reported PA

This study identified apparent differences between NZ and SL in school travel modes, PA behaviours, and perceptions of PA, based on self-reported questionnaire data. These findings highlight how school environments, cultural norms, and infrastructure influence children's activity patterns.

Travel Modes

Mode of travel to school is widely recognised as an essential contributor to children's PA and is recommended for inclusion in monitoring and intervention strategies. In this study, NZ students predominantly used private vehicles or active travel. In comparison, SL students relied mainly on public transport and private vehicles, highlighting how infrastructure and cultural norms shape opportunities for active travel. This disparity likely reflects multiple factors, including differences in transport availability, travel distance, road safety, urban design, public transport accessibility, and cultural norms. In NZ, active transport, particularly walking and cycling, may be influenced by proximity to schools and neighbourhood characteristics, although concerns about traffic safety can also contribute to children being driven to school (Mandic et al., 2016; Smith et al., 2012), whereas SL's reliance on public transport may stem from longer commutes and traffic safety concerns (Damsara et al., 2021).

School-Based Activity Patterns

NZ children were more active before school and during breaks, while SL children mostly sat, stood, or walked lightly, which likely explains the higher light activity detected by accelerometers. These differences may reflect variations in school policies, playground resources, and cultural norms around structured versus unstructured play. Our finding that NZ children were more active before school aligns with national initiatives such as HAL and Ministry of Education guidelines, which promote structured and unstructured PA opportunities before and during the school day (Ministry of Education NZ, 2007; Sport NZ, 2022). Similarly, our results support Zhu et al. (2025) those who identified recess as a key opportunity for MVPA, reinforcing the need for strategies to reduce sedentary behaviour in SL schools.

During PE, NZ students engage in a broad range of activities, including structured sports and swimming, supported by initiatives like HAL, which promotes diverse, culturally relevant, and integrated PA opportunities (Sport NZ, 2022). However, evidence from the DC3.0 report indicates that these opportunities are not consistently available across all schools, with variability reported by both teachers and students (Sport NZ HAL DC3.0, 2023). Aligning with the NZ context, Flory and McCaughtry (2011) emphasise that culturally relevant and well-supported PE programs allow teachers to offer diverse activities, while SHAPE America (2020) highlight that national standards and adequate resources are critical for delivering high-quality, varied PE experiences. These factors likely contribute to the greater activity diversity observed in NZ schools compared to SL schoolchildren, who favoured informal games, reflecting limited resources and teacher training.

Weekend Activity and Cultural Context

Interestingly, SL children reported higher informal outdoor activity on weekends, such as walking and cycling with family, while NZ children participated more in organised sports. This reflects cultural and infrastructural differences: in NZ, organised sport is deeply embedded in school and community systems, supported by national strategies like *Active Schools* and strong school–club partnerships, which promote structured participation from an early age (Sport NZ, 2020). Conversely, in SL, limited access to facilities, financial constraints, and socio-cultural norms often restrict opportunities for structured sports, leading families to prioritise low-cost, informal activities such as walking, cycling, and traditional games (Jayawardhana et al., 2023). These patterns align with research evidence that children are generally less active on weekends than on weekdays, as shown by accelerometer-based studies (Brooke et al., 2014). Furthermore, some researchers highlight that weekend days are associated with increased sedentary time and screen use, underscoring the need for interventions targeting weekends (Esposito et al., 2022; Sigmundová & Sigmund, 2021). However, this pattern was not observed among SL children in the present study, suggesting that weekend-focused interventions may require consideration of local activity patterns and contexts.

Enjoyment, Teacher Influence, and Cultural Diversity in PA

Studies from Australia and NZ show that children generally enjoy PA and recognise its benefits (Deng et al.; Georgakis, 2018b). In contrast, in many developing countries, PE is often undervalued compared to academic subjects and perceived as non-essential (Hardman, 2005). Negative attitudes shaped by parental and cultural beliefs further reduce its priority (Choudhary, 2021). Positive attitudes foster lifelong engagement (Bibik et al., 2007; Linda Rikard & Banville, 2006), while negative attitudes limit participation (Robinson, 1990).

Teacher influence is critical. SL students in this study appeared less motivated by teachers, similar to trends in other developing nations where academics overshadow PE (Awosika, 2004). Teacher encouragement strongly predicts positive attitudes (Georgakis, 2018a), highlighting the need for proactive engagement.

The less positive PE experiences and fewer perceived opportunities reported by SL children may be interpreted alongside previous research highlighting challenges in PE teacher training and curriculum implementation in SL (Abeykoon, 2022). In contrast, NZ promotes multicultural and inclusive activities (Vita, 2025). Barriers in SL include inadequate facilities (Nanayakkara, 2022), resource constraints (Hardman et al., 2013) and dominance of certain sports like cricket (Giulianotti & Robertson, 2004). Incorporating culturally relevant activities can reduce barriers and broaden participation.

Finally, SL children reported fewer opportunities for varied activities compared to NZ peers, consistent with evidence from low-income settings (Finkelstein et al., 2017; Kottyan et al., 2014). Limited diversity restricts options for children with different abilities, including disabilities, and may lead to perceived incompetence, reducing engagement (Kubayi et al., 2013).

Strengths and Limitations

This study has several strengths. Accelerometers are widely considered an objective and reliable method for assessing PA patterns in free-living conditions, although the doubly labelled water technique remains the gold standard for measuring energy expenditure (Welk, 2002). To our knowledge, this is the first study to examine PA patterns among SL schoolchildren using tri-axial accelerometers, contributing novel evidence from a resource-limited setting. High compliance was achieved, with most children wearing devices continuously for seven days as instructed. Additionally, the inclusion of two culturally and socioeconomically distinct contexts enhances the relevance of findings for cross-country comparisons and supports the development of culturally adapted assessment tools.

However, some limitations should be acknowledged. Wrist-worn accelerometers may overestimate activity compared to hip placement, despite applying age-specific correction factors to reduce bias (Gall et al., 2022). The smaller, conveniently sampled SL cohort limits generalisability, and the cross-sectional design prevents underlying implication. In addition, the substantially smaller sample size in SL may have reduced statistical power to detect small differences, and therefore some non-significant findings should be interpreted with caution. Furthermore, questionnaire data are self-reported and therefore subject to recall and social desirability bias, which can be particularly pronounced among younger children due to limited comprehension and recall ability (Klesges et al., 2004). To minimise this effect, we used age-specific questionnaires tailored for two groups (5–8 years and 9–13 years) to improve accuracy of responses.

Implications for Research, Practice, and Policy

Researchers should refine PA tools for cultural relevance and test them in varied contexts. Practitioners can use these insights to design inclusive school programs that balance structured and informal activity. Policymakers may focus on improving active travel and diverse PE opportunities in SL, while also considering school infrastructure and resource availability that support participation in PA. In NZ, efforts should continue to support equitable participation in PA, particularly given the higher activity levels observed among boys than girls in this study.

This study demonstrated the feasibility of applying PA assessment tools from high-income contexts within a low- and middle-income setting. The accelerometer and questionnaire measures were successfully implemented in both NZ and SL, enabling cross country comparisons of objectively measured and self-reported PA. However, contextual and logistical factors observed during data collection suggest that cultural adaptation and implementation considerations may be required when these tools are used in diverse settings. Combining subjective and objective measures gave a fuller picture of PA patterns, reinforcing the value of mixed-method approaches. These insights can guide policy in SL, support initiatives like HAL in NZ, and inform global strategies to reduce health disparities among children.

4.5. Conclusions and future directions

This pilot study demonstrated the feasibility of using mixed-method approaches to assess PA patterns and perceptions among schoolchildren in two contrasting contexts: NZ and SL. Findings revealed marked differences in objectively measured PA and self-reported behaviours, with SL children accumulating more MVPA and NZ children recording higher step counts and greater sedentary time. Differences in perceptions were also evident, with NZ children reporting more positive attitudes toward PE and greater access to diverse opportunities. These results underscore the influence of cultural, infrastructural, and policy factors on PA behaviours and perceptions.

Future research should validate these findings in larger, representative samples and explore longitudinal trends to understand causal relationships. Refinement of culturally adapted PA assessment tools is essential to ensure accuracy and relevance across diverse settings. Interventions should target reducing sedentary time and promoting higher-intensity activity, particularly in NZ, while improving structured PA opportunities and teacher engagement in SL. Policy efforts should focus on enhancing active travel, expanding school-based activities, and addressing gender and socioeconomic disparities. Ultimately, these strategies can inform global initiatives to promote equitable PA opportunities and reduce health disparities among children.

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Chapter 5

School Food Environment in Focus: Availability and Policy Practices in New Zealand and Sri Lanka – An Exploratory Study

This chapter presents a manuscript titled *"School Food Environment in Focus: Availability and Policy Practices in New Zealand and Sri Lanka – An Exploratory Study"* authored by Harshani Perera, Ajmol Ali, Carol Wham, Ananda Chandrasekara, David S Rowlands. The manuscript is prepared in journal format and intended for submission to *Nutrition Research*.

This chapter addresses **Research Objective 3 (Section 1.3.3)**. It examines school food environments in Sri Lanka and New Zealand by analysing food availability, institutional policies, and practices to understand how these factors shape children's dietary behaviours across both countries. By exploring the interplay between policy and practice, this chapter provides insights into how school environments influence children's nutrition and identifies opportunities to improve healthy food access across diverse contexts.

HP, AA, CW, AC, and DR designed the research and obtained ethical approval. AA coordinated with the Healthy Active Learning (HAL) initiative and sought guidance from the special HAL committee regarding the use of HAL data. Data collection for the Sri Lankan arm was led by HP with assistance from AC. HP was responsible for participant recruitment and data entry for the Sri Lankan arm. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.

Abstract

Schools play a critical role in shaping children's dietary habits, yet the availability and regulation of foods vary widely between high-income and low-income countries. Worldwide, unhealthy diets contribute to rising childhood obesity and undernutrition. Policies and programmes aim to create supportive school food environments, but implementation challenges persist. This study examined food availability and policy practices in schools in Auckland, New Zealand (NZ), and Rathnapura, Sri Lanka (SL), to identify contextual differences and inform strategies for healthier school food environments. A cross-sectional study was conducted using structured questionnaires administered to school administrators and food providers. The sample comprised government primary and intermediate schools in Auckland that participated in the Healthy Active Learning baseline survey, and schools in the Rathnapura district enrolling more than 500 students and offering Grades 1–8. Data were collected on policy coverage, communication, stakeholder roles, and food availability. Descriptive statistics and chi-square tests were used to analyse differences between settings where appropriate. Policy implementation was inconsistent in both settings. In the NZ sample, 64% of schools reported having a written food policy, but updates were infrequent, and adherence was voluntary. SL schools followed a national canteen policy, yet compliance with mandated practices was minimal. Food availability differed markedly: SL schools offered deep-fried foods (73%), confectionery (77%), and sweetened dairy beverages (80%), while NZ schools provided packaged snacks (86%) and limited fruit, with no fried or confectionery items. Across both countries, key barriers to healthier provision included the higher cost of healthy options and the convenience and popularity of processed foods. While NZ and SL have different school food policy regimes, children in both settings remain widely exposed to unhealthy foods and beverages at school. Improving these environments will need stronger policy implementation and accountability mechanisms while also helping to reduce financial dependence on the sale of unhealthy food and engage parents, school governance bodies and food providers in lasting, health-promoting.

Keywords: policy implementation, food availability, child nutrition, canteen policy, school food policy, food environment. SDG 2 – Zero Hunger, SDG 3 – Good Health and Well-being, SDG 4 – Quality Education, SDG 10 – Reduced Inequalities

5.1. Introduction

There is a growing global concern about rising childhood obesity and persistent undernutrition, along with non-communicable diseases linked to unhealthy diets (World Health Organisation, 2022). Schools are strategic settings for promoting healthy eating, as they provide a significant proportion of children's daily food intake and influence dietary habits through structured routines (Bryant et al., 2023; Merlo et al., 2023; Pulimeno et al., 2020). The school food environment, comprising physical, economic, socio-cultural, and policy factors, plays a critical role in shaping food choices, growth, health, and academic performance (O'Halloran et al., 2020; Swinburn et al., 2013). Dietary habits formed during school years have lasting effects on health and disease risk into adulthood (Albardan & Platat, 2025). Consequently, schools offer an opportunity to ensure equitable access to nutritious food and implement effective health promotion strategies (Bell & Swinburn, 2004). A supportive school food environment can reduce diet-related health risks and address inequalities among children (World Health Organisation, 2021). Interventions such as nutrition standards and healthy food policies improve diet quality and reduce obesity risk; however, their success depends on adaptation to local socio-cultural and economic contexts (Durão et al., 2023; O'Halloran et al., 2020).

In countries such as New Zealand (NZ), recent data from the NZ Health Survey 2024/25 indicate that approximately 12% of children aged 2–14 years are classified as obese, equivalent to around one in eight children (Ministry of Health, 2025). This marks an increase from 9.5% in 2019/20, following several years of relative stability (Ministry of Health NZ, 2021). Schools are key settings for influencing dietary behaviours, yet the school food environment is complex. It includes home-prepared meals and foods purchased from external vendors or school canteens, which are often managed by third parties (Carter & Swinburn, 2004). Despite the availability of Healthy Food and Drink Guidance for Schools, implementation is inconsistent. Schools have autonomy in applying these guidelines, and enforcement is voluntary rather than mandatory (Ministry of Health NZ, 2020)**.** This flexibility, combined with limited governance resources and a food culture that normalises energy-dense foods and sugary drinks, creates barriers to progress (D'Souza et al., 2022; Pillay et al., 2023). Socioeconomic disparities further intensify these challenges, with schools from low socioeconomic areas less likely to offer healthy options (Londoño-Cañola et al., 2022). Research highlights persistent issues in school food environments, where foods available in canteens are often high in fat sugar and salt and not aligned with the dietary guidelines (Bomboma et al., 2026; WHO, 2026). Third-party canteens often prioritise profit over nutrition, resulting in the provision of low-cost, unhealthy foods (UNICEF, 2025a). A recent review found that most secondary schools fail to meet healthy menu standards, with "red" (least healthy) items commonly available (Pillay et al., 2023). Benchmarking reports emphasise that NZ falls short of international best practice in monitoring and enforcing healthy food policies, calling for mandatory approaches and stronger restrictions on marketing unhealthy foods to children (Mackay et al., 2023).

To address these challenges, NZ introduced initiatives such as Ka Ora, Ka Ako, which provides free, healthy lunches to students in schools from low socioeconomic areas, and Healthy Active Learning (HAL)**,** launched in 2019 to support schools in implementing healthy food and drink guidelines (Ministry of Education NZ, 2024; Sport NZ, 2025). These programmes have reached over 230,000 learners; however, recent evaluations highlight concerns about funding cuts and menu downgrades that may compromise nutritional quality (Toro et al., 2025).

In SL, schoolchildren obtain food from a combination of home-packed meals, school canteens, school meal programmes, and food vendors located near school premises. Although school canteen guidelines promote the provision of healthier foods, studies have reported the continued availability of fried snacks, confectionery, sugar-sweetened beverages, and other energy-dense foods in and around schools (Lokubalasuriya, 2015; Weerasinghe et al., 2018). Food purchasing decisions are also influenced by affordability, convenience, and student preferences, creating challenges for schools attempting to implement nutrition policies. Consequently, the school food environment represents an important setting for influencing dietary behaviours among SL children.

Sri Lanka faces a triple burden of malnutrition: undernutrition, overnutrition, and micronutrient deficiencies among school-aged children (Unicef, 2025b). To address these issues, the government launched a national school meal programme, providing free meals to 1.4 million students across 8,943 schools, with a 2025 budget of 105 million US dollars (Ministry of Education, 2025). The National Nutrition Policy (2021–2030) and Food-Based Dietary Guidelines (2021) highlight the importance of improving school food environments and encouraging healthy eating habits among schoolchildren to combat malnutrition (Ministry of Health - Nutrition Division, 2023). Additionally, school canteen guidelines aim to limit high-sugar, high-fat foods, while promoting nutritious options to support a healthy food environment (Ministry of Health – Nutrition Division, 2020).

However, challenges remain in implementation, including a lack of legal enforcement, resource limitations, and children's preference for unhealthy foods (Lokubalasuriya, 2015). Recent assessments emphasise the need for nationwide nutrition standards and enhanced monitoring systems to ensure the effectiveness of policies (Ministry of Health - Nutrition Division, 2023). These efforts include tools such as traffic light labelling, which aim to simplify nutrition information and promote healthier choices in school canteens.

The traffic light nutrition labelling system categorises foods as green (healthy), amber (moderate), and red (high in sugar, fat, or salt) to promote more nutritious choices in school canteens. This internationally recognised approach has been adopted and adapted across a range of countries to support healthier food choices in school and community food environments. Research demonstrates high stakeholder acceptance of this system, with participants supporting its extension to nutrition education programmes (Pettigrew et al., 2012b). In NZ, voluntary guidelines such as the Healthy Food and Drink Guidance recommend traffic light labelling, but application remains inconsistent due to school autonomy (Pillay et al., 2023). In contrast, SL mandates school canteen guidelines that incorporate similar principles to restrict high-fat and high-sugar foods, yet compliance is poor due to limited awareness and enforcement (Madhusanka et al., 2021).

Despite these initiatives, comparative research on school food environments remains limited, particularly in low- and middle-income contexts, despite recommendations that global policies be adapted to local socio-cultural conditions (Anderson et al., 2014; O'Halloran et al., 2020). The existing literature predominantly focuses on high-income Western countries, leaving gaps in the understanding of low- and middle-income countries (Morales-Juárez et al., 2025). Furthermore, inconsistencies in how food environments are assessed hinder cross-country comparisons (O'Halloran et al., 2020). Addressing these gaps is essential for developing context-specific strategies informed by global best practices.

Therefore, to address the lack of comparative evidence between high-income and lower-middle-income settings, this study examines two key components of the school food

environment—food availability and policy-related practices - by comparing government primary and intermediate schools in Auckland, NZ, and Rathnapura District, SL, using Healthy Active Learning (HAL) baseline data and a parallel survey conducted in SL. These contexts provide an opportunity to examine how structural, cultural, and socioeconomic factors shape food availability and policy practices. This study aims to examine the two components of school food environment (i.e., food availability and policy practices) in a sample of schools in NZ and SL. Findings will inform policy development, supporting initiatives such as HAL in NZ and strengthening school food policies in SL. Globally, this research contributes to understanding how contextual factors influence food environments, advancing strategies to reduce health disparities among children.

5.2. Methods

5.2.1. Study design

This comparative cross-sectional study examined school food policies and availability in Rathnapura District (SL) and Auckland (NZ). Data were gathered between 2020 and 2022 using two structured questionnaires: one for school administrators or food committee members on food policies, communication, content, and practices promoting healthy eating, assessed against the Ministry of Health guidelines in NZ and the Ministries of Health and Education guidelines in SL (refer to Appendix 2.13 – School food policy and practices questionnaire); and another for food suppliers on available food and beverages on the school premises (refer to Appendix 2.12 – Food availability questionnaire).

5.2.2. Ethical considerations

All procedures were reviewed and approved by the Massey University Human Ethics Committee, under protocols Application NOR 20/07 for the HAL study and Application NOR 22/16 for the SL study. Necessary approvals were obtained from the Ministry of Education, Provincial Education Offices, and school principals before data collection in SL. The study followed these authorities' protocols and guidelines, and guidance was also sought from the HAL committee on HAL data use.

5.2.3. Study setting and participants Recruitment

New Zealand

Data for this study were drawn from the HAL project's baseline data collection and included only data from the Greater Auckland region. For further details about the HAL project, visit the Sport New Zealand website (Sport New Zealand HAL, 2023).

During the HAL baseline data collection, information on school food policies, practices, and food availability was collected using online questionnaires administered via Qualtrics (Provo, Utah, USA), a secure web-based platform designed for academic research. Schools were identified via the Education Counts website (Ministry of Education NZ, 2020). Links were emailed to all schools nationwide between 2020 and 2021, and participation was voluntary. To increase response rates, emails were sent on four separate occasions, and schools were encouraged to complete the questionnaires during HAL site visits. The final sample included 43 schools for the food availability survey and 75 schools for the policy and practices survey in the Auckland region.

Sri Lanka

The sampling frame comprised government schools in Rathnapura District that offered classes from grade 1 to at least grade 8, corresponding approximately to children aged 5–13 years, and enrolled more than 500 students. Based on these criteria, 92 schools were eligible, representing 13.7% of all schools in the district and 32.2% of the student population (n = 71,860). Thirty schools were selected using convenience sampling, with purposive selection of schools from different geographic locations (urban, semi-urban, rural) and a range of socioeconomic catchment areas, in order to maximise diversity within the feasible sample. Nominated representatives (food committee members and food suppliers) were contacted for participation. Questionnaires were administered in person in the local language (Sinhala/Tamil) by a trained research assistant to ensure clarity and accurate responses.

5.2.4. Questionnaire adaptation and validation

The questionnaires assessing school food environments in NZ were developed by a team of nutritionists and dietitians from Massey University for the HAL initiative, with feedback from Ministry of Health staff. For SL, the same food availability questionnaire was adapted to reflect local food culture and practices, replacing items such as sushi, Edam cheese, wholemeal or multigrain bread with culturally relevant alternatives. Additional questions assessed compliance with SL school canteen policy guidelines. The policy and practices questionnaire was modified to align with SL's regulatory framework, focusing on food committee structures mandated by Government Circulars 35/2015 and 10/2017, rather than on formal policies set by Boards of Trustees in NZ. Experts in nutrition and health confirmed content validity, ensuring that key constructs were retained while irrelevant items were removed. Content validity was assessed through an expert review process, whereby the adapted questionnaires were circulated to a panel of nutrition and public health experts for evaluation of item relevance, clarity, and cultural appropriateness. Experts provided structured feedback, which was reviewed and incorporated through iterative revisions to refine wording, remove irrelevant items, and ensure that key constructs were adequately represented before finalisation. Food and beverage items were classified as "healthy" or "unhealthy" using the traffic-light style criteria in the NZ Healthy Food and Drink Guidance and the SL National School Canteen Guidelines. For analysis, items classified as green/amber were grouped as "healthier" and red items as "less healthy/unhealthy. Questionnaires were translated into Sinhala and Tamil, and language specialists verified accuracy. Figure 5.1 shows a flow diagram of school selection, participant recruitment and questionnaire development in NZ and SL.

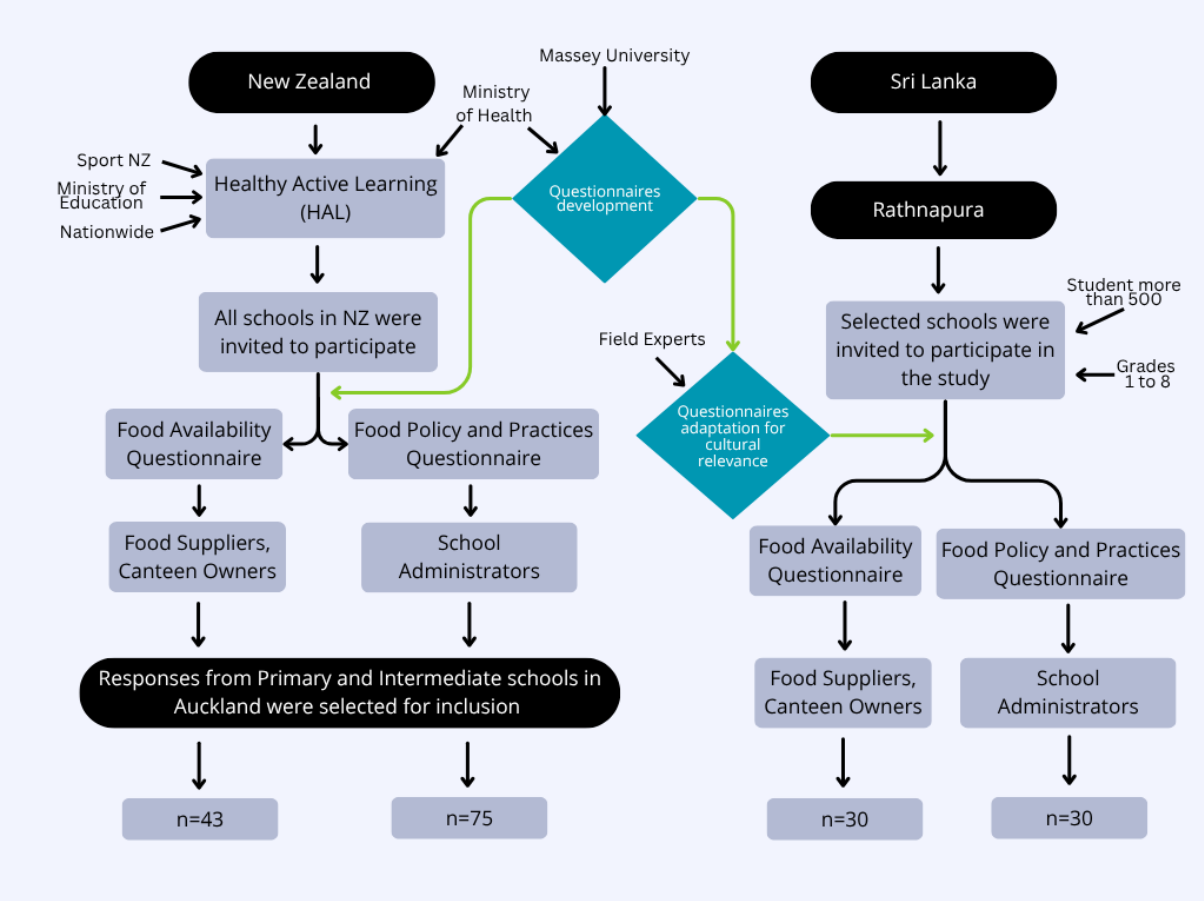


Figure 5.1. Flow diagram of school selection, recruitment and questionnaire development. (NZ=New Zealand)

5.2.5. Statistical analysis

Quantitative data were presented as frequencies of healthy vs. unhealthy food items, adherence to School Food Environment policies and school-level compliance. Data was presented descriptively. Normality testing was not performed because the questionnaire data were categorical and dichotomised for analysis. Chi-square tests were not applied to variables with multiple-choice responses, where respondents could select more than one answer, as this violates the assumption of mutually exclusive categories and independence required by the test. For these variables, descriptive statistics were used instead. Statistical significance was set at $p < 0.05$ for all Chi-square tests.

5.3. Results

5.3.1. School food policy and practices

School food policy coverage

The majority of SL schools (87%) had a school canteen. in contrast, 64% of NZ schools reported having their own food policy. While SL schools operated under the nationally mandated School Canteen Policy, food policies in NZ were developed at the individual school level. Sixteen of the 30 SL schools reported having a functioning food committee; however, compliance with the government's stipulated policy, monthly meetings, reporting to the zonal office, receiving feedback, and implementing corrective actions was extremely low, with only one school holding monthly meetings and sending reports to the zonal office.

Recency of school food policy updates

Among NZ schools, 28% reported updating their food policy within the past two years, and 17% within the past four years. More than half (55%) were either unsure or reported no recent update. In contrast, SL does not have a standalone school food policy; schools follow the national *School Canteen Policy*, which was last updated on August 26, 2024, and revised on December 18, 2024 (Ministry of Education & Ministry of Health SL, 2024).

Comparison of stakeholder roles in utilising healthy food and drink policies

Table 5.1 shows the distribution of stakeholder roles likely to utilise the healthy food and drink policy in schools. Stakeholders most likely to utilise the healthy food and drink policy varied between countries. In NZ, governance bodies and families were frequently identified, whereas in SL, school-level committees and teachers were prominent. Food service providers were more commonly reported in SL than in NZ. Overall, patterns indicate that implementation responsibility is distributed differently across governance, family, and service roles in the two contexts.

Table 5.1. Stakeholder roles likely to utilise healthy food and drink policy.

Stakeholder roles	**NZ (n=75)**	**SL (n=30)**
	N (%)	**N (%)**
Board of trustees (NZ) /School development committee (SL)	50 (67%)	23 (77%)
Parent teacher association (NZ)/ Teachers (SL)	16 (21%)	20 (67%)
Students	37 (49%)	13 (43%)
Whānau (NZ) / parents (SL)	34 (45%)	12 (40%)
Tuck shop providers (NZ) /school canteen owners (SL)	11 (15%)	18 (60%)
Outside food providers	20 (27%)	3 (10%)

Multiple responses permitted.
N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

Modes of communication for healthy food and drink policy in schools

Communication modes for disseminating the healthy food and drink policy differed substantially between countries (Table 5.2). New Zealand schools primarily used printed and digital channels, with newsletters, school websites, and email communication common. In contrast, SL schools relied almost exclusively on physical modes, particularly student assemblies and staff meetings, with occasional workshops. Digital communication was absent in SL, and newsletters were not reported.

Awareness of guidance sources for developing healthy food and drink policies

Awareness of guidance sources for healthy food and drink policy guidelines varied between NZ and SL. In NZ, the Ministry of Education website was the most common source (41%), while in SL it was also a commonly reported source, with a higher proportion of respondents (57%). Awareness of Ministry of Health guidelines was similar across countries (NZ: 28%; SL: 23%). Notably, a greater proportion of SL respondents cited “other sources” (77%) than NZ respondents (8%), while the lack of awareness was slightly higher in NZ (25%) than in SL (20%).

Table 5.2. Modes of communication used to disseminate food and drink policy information.

Communication mode	NZ (n=75)	SL (n=30)
	N (%)	N (%)
School newsletter	52 (69%)	0 (0%)
Staff meetings	35 (47%)	27 (90%)
Student Assemblies	29 (39%)	29 (97%)
Information seminars/Workshops	2 (2.7%)	12 (40%)
Email to staff, students and others	25 (33%)	0 (0%)
School website	35 (47%)	0 (0%)
Other	11 (15%)	0 (0%)
Not applicable	16 (21%)	0 (0%)

Multiple responses permitted.
N - count of responses, % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

Comparison of school environment indicators

Table 5.3 summarises the cross-national comparison of school environment indicators between NZ and SL, including response distributions, chi-square values, and significance levels. A significant difference was observed in access to food or drinks for activities ($p<0.001$), with NZ schools reporting greater access than SL schools. No significant differences were found in water fountain availability or in schools' promotion of healthy eating, indicating similar patterns across countries for these indicators.

Table 5.3. Cross-national comparison of school environment indicators.

Indicator	NZ (n=75)	SL (n=30)	Chi-square value	p value
	N (%)	N (%)		
Water fountains availability (Agree)	34 (56%)	13 (43%)	0.79	0.37
Access to food/drinks for activities (Yes)	54 (72%)	8 (27%)	16.39	<0.001
School promotes healthy eating during school hours (Yes)	58 (77%)	26 (87%)	0.66	0.42

Responses were dichotomized into two categories ('yes/agree' or 'no/disagree') for analysis
N - count of responses, % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

Comparison of barriers to healthy food promotion

Table 5.4 summarises the reported barriers to implementing a healthy food and drink environment in schools in NZ and SL. Multiple responses were permitted, and percentages were calculated based on the total sample size for each country. The most notable differences were observed in the loss of profits from selling less healthy foods and beverages and the lack of choice in catering options, which were reported far more frequently in SL than in NZ. Additionally, "other" barriers were cited by nearly half of SL respondents compared to fewer than 10% in NZ, while the convenience of processed foods and insufficient cooperation from parents were common barriers in both countries.

Table 5.4. Barriers to implementing a healthy food and drink environment in schools.

Barriers	NZ (n=75)	SL (n=30)
	N (%)	N (%)
Resistance from teachers	1 (1.3%)	2 (6.7%)
Resistance from parents	22 (29%)	7 (23%)
Loss of profits from sale of less healthy foods and beverages	3 (4%)	20 (67%)
Convenience and ease of preparation of processed and ready to eat foods and beverages compared to healthier options	27 (36%)	10 (33%)
Lack of choice in options provided by catering company/lunch order system	2 (2.7%)	13 (43%)
Healthy eating is not a priority	5 (6.7%)	2 (6.7%)
Other	7 (9.3%)	14 (47%)
No barriers	18 (24%)	10 (33%)

Multiple responses permitted.
N - count of responses, % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

Participation in school food programmes

NZ schools are actively involved in multiple government- and community-supported food programmes, as shown in Figure 5.2. However, this provides an overall picture of programme uptake and does not account for eligibility criteria or socioeconomic targeting, as several programmes are specifically implemented in schools serving higher-need communities. In SL, participation is highly centralised within the national school meal programme (15 schools) and the non-governmental organisations-supported programme (9 schools).

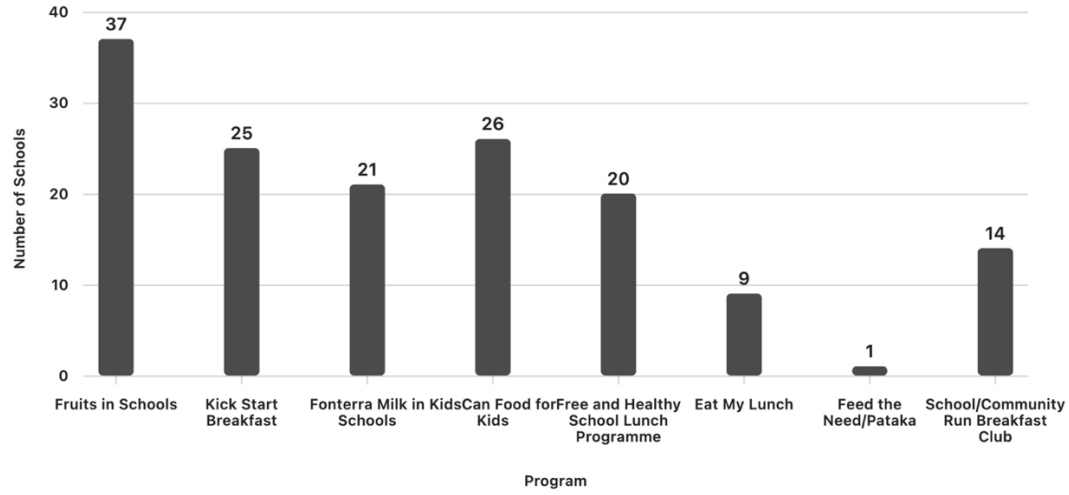


Figure 5.2. Participation of schools (n=75) in various food programmes in New Zealand.

5.3.2. Food availability in school canteens

In SL, foods available in school canteens largely reflected the national canteen policy. The most frequently reported items were wheat-flour-based bakery products (90%) and white bread (87%), followed by wheat-flour-based food items (73%) and rice and curry (70%). Other items included boiled chickpeas and green grams (30%), boiled yams (27%), and rice-flour-based

food items (6.7%). Additionally, 73% of food providers reported following the Ministry of Education's model recipes. When selecting vegetables, 11% considered colour, 73% considered freshness, and 94% considered cost. Only 58% reported using the traffic light system implemented in SL when choosing canteen food items.

In NZ, food providers reported adding vegetables to several commonly offered items: 21% of burgers, 67% of wraps, 21% of hot foods, 84% of sandwiches, and 44% of sushi. Bread-related products were widely available, with 79% of providers indicating they sold white bread or other bread types.

Comparison of key food availability indicators between New Zealand and Sri Lanka

Table 5.5 summarises the comparison of key food availability indicators between NZ and SL. Significant differences were observed for deep-fried foods, confectionery, and sweetened dairy beverages, all of which were more prevalent in SL school canteens. Packaged snack foods showed a smaller but statistically significant difference, with higher availability in NZ.

Deep-fried foods and confectionery were present only in SL schools and absent in NZ schools. In SL schools, deep-fried foods were highly prevalent, with *rice-flour-based* (80%), fried potato or manioc chips (74%), and short eats (56%) most common. Coconut oil was the primary frying medium (63%), followed by vegetable (21%) and palm oil (17%). Confectionery dominated sales, particularly toffees, lollipops, and chewing gum (98%), chocolate (87%), biscuits (86%), ice cream (74%), and cake (34%). Packaged snacks were also frequent, led by salted nuts (63.3%), yoghurt (46.7%), pickles (23.3%), and instant noodles (16.7%). In contrast, NZ schools offered only packaged snacks and fresh fruit. Cookies (72.1%), brownies (62.8%), popcorn (60.5%), and yoghurt (48.8%) were most common, while fruit options such as bananas (34.9%) and apples (32.6%) were less frequent than sweet baked goods. Muffins (18.6%) and pretzels (16.3%) were the least common. In SL schools, canteens commonly sold fried snacks and confectionery, including rice-flour-based fried items, fried potato or manioc chips, and sweets such as toffees and chocolate. In NZ schools, the most frequently available items were packaged baked snacks (e.g. cookies, brownies, popcorn) and yoghurt, while fresh fruit such as bananas and apples was less commonly reported than sweet baked goods.

Table 5.5. Summary of key food availability findings: NZ vs. SL.

Aspects	**NZ (n=43)**	**SL (n=30)**	**Chi-square**	**p-value**
	N (%)	**N (%)**		
Deep-fried food	0	22 (73%)	-	-
Confectionery	0	23 (77%)	-	-
Packaged snack foods	37 (86%)	19 (63%)	3.9	0.048
Sweetened dairy beverages	13 (30%)	24 (80%)	16	<0.001

Responses were collected in a dichotomous format (yes/no) for each item.
N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

5.4. Discussion

This exploratory study aimed to compare food policies and practices, as well as food availability, across a convenience sample of school environments in the Rathnapura district, SL, and Auckland, NZ. The findings highlighted two key differences. First, policy implementation was inconsistent in both settings, and the approaches differed. In SL, most schools reported having school food committees; however, compliance with mandated practices such as monthly meetings and reporting was minimal. In NZ, over half of schools had an official food policy, yet updates were infrequent, and adherence to healthy food guidelines remained voluntary. Second, food availability patterns varied sharply. Sri Lankan schools offered deep-fried foods and confectionery alongside packaged snacks and sweetened dairy beverages, all of which were reported by over half of the schools. In contrast, NZ schools provided only packaged snacks and limited fruit, with no deep-fried or confectionery items, although sweetened dairy beverages were available in nearly one-third of schools.

5.4.1. Contrasting of school food policy and practices

Sri Lanka does not have a standalone school food policy; instead, schools adhere to the government-issued *School Canteen Policy* developed by the Ministry of Health and implemented through the Ministry of Education. This policy specifies permitted foods, highlighting healthy choices and restricting items high in sugar, fat, and salt (Ministry of Health – Nutrition Division, 2020). In contrast, NZ schools report having an official food policy, developed autonomously at the school level. A centralised approach in SL promotes uniformity across canteens, whereas NZ's decentralised model offers flexibility but may lead to variability in policy strength and implementation (Pillay et al., 2023).

Sri Lanka recently revised its *National School Canteen Policy* in 2024, following earlier versions introduced in 2006, updated through guidelines (2007), circulars (2011), and a major review in 2015 (Ministry of Education & Ministry of Health SL, 2024). This demonstrates a significant refresh after nearly a decade. In contrast, NZ does not mandate schools to have or update written food policies (New Zealand Legislation, 2020, 2022). The Ministry of Health issued voluntary *Healthy Food and Drink Guidance for Schools* in 2020 (Ministry of Health NZ, 2020), and the Education (School Boards) Amendment Regulations 2022 introduced a requirement for school boards to promote healthy food and nutrition for all students (New Zealand Legislation, 2022). However, our research confirms that policy updates at the NZ school level are infrequent and vary widely between schools, reflecting the decentralised nature of the system and voluntary compliance.

Despite SL's centralised policy framework, implementation in schools remains weak. Food committees are required but often ineffective, with low attendance at meetings and poor compliance with reporting requirements. Although canteen guidelines ban high-fat and high-sugar foods, enforcement is limited because schools have no direct legal obligation under the SL Food Act beyond basic food safety standards. Monitoring relies on PHIs, and the absence of penalties for non-compliance reduces accountability (Lokubalasuriya, 2015; Weerasinghe et al., 2018). Evidence from Colombo and Gampaha districts shows that having a canteen policy alone does not ensure healthier diets; effective implementation requires clear guidance, stakeholder involvement, and a shift from a profit to a health-focused model (Weerasinghe et al., 2018).

Our findings show that while NZ schools reported having food policies, these were often outdated and reflected the decentralised and voluntary nature of the system. This aligns with

Pillay et al. (2024), who found that even schools with policies frequently included unhealthy items, with "red" foods present in over one-third of menus. Our findings indicate that the widespread presence of packaged snacks in NZ schools reflects persistent structural and behavioural barriers. Factors such as convenience, parental preferences, and financial constraints, previously highlighted by Pillay et al. (2025), continue to shape food choices and limit the effectiveness of voluntary guidelines. These findings indicate that voluntary guidelines and school autonomy are insufficient to fully restrict unhealthy options, highlighting the need for stronger regulatory frameworks and monitoring mechanisms.

A systematic review of European and Western Pacific countries found that strict compliance with school food policies, regular monitoring and evaluation are needed to achieve actual school food policy goals (Matela et al., 2024). Successful implementation also depends on adapting policies to local contexts and addressing enabling and limiting factors. However, most evidence originates from high-income countries, so caution is needed when applying these strategies in lower-income settings, where resource constraints and cultural differences may affect feasibility (Durão et al., 2023).

International guidelines emphasise the use of multiple communication channels to promote nutrition policies and engage stakeholders in school health initiatives. The Centers for Disease Control and Prevention recommends strategies like newsletters, emails, websites, parent nights, and printed materials for accessibility and inclusivity (Centers for Disease Control and Prevention, 2024). While NZ schools typically use digital platforms, SL relies mainly on in-person methods such as assemblies and staff meetings, with limited digital communication due to an infrastructure gap. UNICEF and the International Telecommunication Union report that two-thirds of school-age children worldwide lack home internet, especially in South Asia. (UNICEF & ITU, 2020). These differences highlight the need for context-specific communication strategies; digital approaches may be practical in NZ, but in SL, strengthening in-person engagement and low-tech solutions is critical to ensure equitable access and policy awareness.

Effective school food programmes require appropriate policy framing, robust monitoring and evaluation, and adequate stakeholder engagement (Nelson & Breda, 2013). Stakeholder involvement differs between countries: in SL, school-level committees and teachers are primary actors, whereas in NZ, governance bodies and families play a larger role. Pettigrew et al. (2012a) note that parental involvement is more influential in school policy expansions than that of school-based stakeholders, such as principals and teachers, highlighting the need for family engagement strategies in both contexts. In SL, where digital infrastructure is limited, active engagement from parents and other stakeholders becomes even more important to compensate for resource and communication system gaps.

There was no significant difference in water fountain availability between SL and NZ schools, with moderate levels of availability observed in both settings. This aligns with global recommendations highlighting that hydration infrastructure is frequently neglected, even though it plays a critical role in supporting cognitive function and discouraging sugary drink intake (Centers for Disease Control and Prevention - School Nutrition, 2024). Both countries promote healthy eating during reported school hours, but structural and economic barriers undermine these efforts. Financial dependence on revenue from unhealthy food sales creates tension between health promotion and economic sustainability, particularly in resource-limited settings. This also reflects broader commercial determinants of the food system, where profit-

driven incentives, increasing consumer demand, and the widespread availability of ultra-processed foods shape school food environments in ways that may undermine nutrition policies (UNICEF, 2025a). The cross-national comparison between NZ and SL provides a unique context to examine how these dynamics operate across different economic settings, highlighting the importance of adopting systems-based approaches to improving school food environments. Similar patterns have been documented in low- and middle-income countries, where profit-driven models often undermine nutrition policies (Mozaffarian et al., 2018; Ronto et al., 2020). Convenience and ease of preparation of processed foods remain a universal barrier, reflecting global trends in which time and cost considerations favour ready-to-eat options over healthier alternatives (Pillay et al., 2023). Additionally, parental attitudes strongly influence school food policies, underscoring the need for family engagement and education strategies to align home and school environments (Maclellan et al., 2010; Onorati et al., 2024).

New Zealand's multi-programme approach, including Ka Ora, Ka Ako, Fruits in Schools, and KickStart Breakfast, reflects a strong commitment to improving child nutrition and reducing food insecurity (McKelvie-Sebileau et al., 2023). Healthy Active Learning complements these efforts by promoting nutrition education and physical activity (Sport NZ, 2025). Similarly, SL's National School Nutrition Program provides free meals to millions of primary school children to combat malnutrition and improve attendance, with support from the government and partners such as the World Food Programme (Ministry of Education, 2025). Despite these initiatives, challenges such as sustainability, cultural relevance, and persistent undernutrition highlight the need for coordinated, long-term strategies that integrate food provision with education and community engagement to create supportive school food environments.

5.4.2. Contrasting food availability in school canteens

The comparison between SL and NZ schools highlights distinct food environments shaped by cultural norms and policy frameworks. Sri Lankan schools predominantly offer traditional staples alongside fried snacks and sugary items. In contrast, NZ schools show partial compliance with the Healthy School Food Programme, discouraging high-fat and high-sugar items, yet the available foods lean toward packaged snacks and bread-based products. Prior research (Gerritsen et al., 2017) similarly found low availability of confectionery and fried foods in NZ schools, though packaged snacks remain common, raising concerns about exposure to ultra-processed foods. These patterns reflect socio-cultural preferences and economic considerations but also highlight gaps in policy enforcement and monitoring in both contexts.

Sri Lanka introduced school canteen guidelines in 2007 and strengthened them with recent bans on foods high in fat, salt, and preservatives (Ministry of Education & Ministry of Health SL, 2024). However, studies consistently report poor compliance, with unhealthy items remaining widely available due to economic pressures and limited monitoring capacity (Weerasinghe et al., 2018). Similarly, the traffic light labelling system, intended to guide healthier choices, suffers from low awareness and inconsistent application (Madhusanka et al., 2021). In NZ, voluntary guidelines rather than mandatory regulations result in widespread availability of less healthy "amber" and "red" foods despite policy intentions (Pillay et al., 2023). These findings are similar to international evidence that policy design alone is insufficient without robust enforcement (Matela et al., 2024).

Insights from various countries reveal similar challenges to those observed in SL, where fried snacks and sugary items remain common in schools despite policy bans. Australia's Healthy

School Canteen Policy prohibits ‘red’ foods such as deep-fried items and confectionery, requiring menus to prioritise ‘green’ healthy options (Yoong et al., 2016). Yet compliance remains poor (Woods et al., 2014). Similarly, in Brazil, both public and private school canteens failed to fully comply with government recommendations, with private schools offering a wider range of foods but still including unhealthy options (Gaetani & Ribeiro, 2015). Our findings in SL reflect those in neighbouring India, where similar enforcement challenges allow fried and sugary foods to remain available in schools despite policy restrictions (Rathi & Worsley, 2021). In NZ, although fried foods and confectionery were absent, packaged snack foods were highly prevalent, reflecting patterns observed internationally. Bell and Swinburn (2004) found that 37% of children's total energy intake occurred at school, with energy-dense foods such as packaged snacks, biscuits, and fruit drinks contributing disproportionately to school-based consumption, a concern mirrored in our NZ findings.

These international comparisons reinforce that policy design alone does not guarantee healthier food environments; effective enforcement and contextual adaptation remain critical. International evidence suggests that successful school food environments are characterised by a combination of mandatory nutrition standards, regular monitoring and evaluation, restrictions on the sale and marketing of foods high in fat, sugar, and salt, access to free drinking water, and integration of nutrition education with broader school health initiatives. Effective approaches also engage families and communities, ensure the affordability and availability of healthy foods, and align school food provision with national dietary guidelines. (UNICEF, 2025a; WHO, 2026). These principles provide a useful benchmark against which the findings from both SL and NZ can be interpreted and highlight areas for improvement in each setting. Both contexts face enforcement gaps, driven by economic constraints in SL and voluntary compliance in NZ, resulting in persistent exposure to energy-dense, ultra-processed foods. Addressing these gaps requires stronger monitoring systems, mandatory nutrition standards, and culturally tailored strategies to improve affordability and acceptability of healthy options. These challenges are also underpinned by broader macro-level drivers within the food system, including commercial determinants such as profit-driven supply chains (Gilmore et al., 2023), food industry influence on policy and food environment (Swinburn. et al., 2019), and increasing consumer demand and availability of ultra-processed foods among children (UNICEF, 2025a). Consistent with the Social Ecological Model, these macro-level influences operate at policy, organisational, and community levels, shaping school food environments beyond the control of individual schools. Consequently, voluntary approaches may have limited effectiveness unless these broader structural drivers are also addressed. Given that school food environments are shaped by interacting commercial, organisational and policy-level drivers, future research should evaluate the impact of enforcement mechanisms, explore school-level barriers to compliance, and test interventions that align school food environments with WHO and UNICEF recommendations for nutrient-dense, minimally processed foods to reduce long-term risks of obesity and diet-related noncommunicable diseases (United Nations Children’s Fund (UNICEF), 2019; WHO school food and nutrition policies, 2021).

This study has several limitations. First, data collection in SL took place in 2021–2022, immediately after COVID-19 lockdowns and during a severe economic crisis, both of which disrupted school food environments and temporarily suspended some food programmes. Consequently, the observed food availability may not reflect typical conditions in SL. The assessment focused only on foods sold inside school premises, excluding external vendors and home-packed meals, which are commonly used by students in SL, limiting the depth of the food availability analysis. As an exploratory study, findings cannot be generalised nationally. Reliance on self-reported questionnaires introduces potential reporting bias. Cross-country

comparisons should be interpreted cautiously, given socio-economic and cultural differences that influence policy feasibility. In NZ, the decentralised policy structure results in wide variability across schools, and the sample may not capture all socio-economic contexts.

5.5. Conclusions and future directions

This study compared school food environments in Rathnapura, SL, and Auckland, NZ, focusing on food availability and policy practices. Findings show that contextual factors, policy structure, cultural norms, and economic conditions significantly influence school food environments. SL's centralised framework promotes uniformity but suffers from weak enforcement and resource constraints. At the same time, NZ's decentralised, voluntary approach allows flexibility but results in inconsistent implementation and continued access to less healthy options. In SL, schools operated under a centrally issued National School Canteen Policy with mandated food committees, yet implementation and monitoring were weak, and canteens commonly sold deep-fried items, confectionery and sweetened beverages alongside some staple and traditional foods. In NZ, many schools reported having their own written food policies and access to national Healthy Food and Drink Guidance, but policy updates were infrequent, implementation remained largely voluntary, and canteens predominantly offered ultra-processed snack foods and sweetened dairy drinks, with relatively limited fresh fruit. These patterns indicate that policy-related structures alone are insufficient to ensure health-promoting food availability in schools. The findings show that, although policy frameworks differ substantially, schools in both settings expose children to a range of unhealthy foods. These insights highlight the need for stronger monitoring, stakeholder engagement, and context-sensitive strategies to create equitable, health-promoting school settings.

Future research should include external food sources such as vendors and home-packed meals and adopt longitudinal designs to assess the impact of socio-economic shocks on policy implementation. Expanding to diverse regions and incorporating qualitative perspectives from parents and school staff will improve generalisability and deepen understanding of cultural and economic drivers.

To strengthen school food environments, SL should prioritise enforcement through legal backing and monitoring, while NZ could introduce minimum standards to reduce variability. Both countries need sustainable funding models to minimise reliance on unhealthy food sales, alongside strategies to engage parents and communities in promoting healthy choices. Communication strategies should be tailored to context, combining digital and in-person methods, with greater reliance on in-person approaches in settings with limited digital access, such as SL. Nutrition policies should align with broader health initiatives to support whole-child well-being.

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Chapter 6

Reliability and Validity of a Modified 24-hour Dietary Recall in New Zealand Schoolchildren

This chapter presents a manuscript titled *"Reliability and Validity of a Modified 24-hour Dietary Recall in New Zealand Schoolchildren"* authored by Harshani Perera, Ajmol Ali, Carol Wham, Ananda Chandrasekara, David S Rowlands. The manuscript is prepared in journal format and is intended for submission to *Maternal and Child Nutrition*.

This chapter addresses **Research Objective 4 (Section 1.3.4)**. It aims to develop and validate a modified 24-hour multiple-pass dietary recall protocol specifically tailored for New Zealand children aged 9–13 years, thereby enhancing the validity and reliability of dietary assessment methods in paediatric nutrition research. By improving dietary recall methodology, this chapter contributes to more accurate measurement of children's food intake and supports evidence-based nutrition interventions.

HP, CW, and DR designed the research and obtained ethical approval. HP and CW developed all the data collection sheets, and CW assisted with training the research assistants. HP, AA, and DR contacted schools and negotiated permission for participation. HP, VP, and AM were responsible for participant recruitment and data collection, while VP and SM assisted with data entry. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.

Abstract

Valid dietary assessment tools are essential for monitoring food consumption and evaluating public nutrition interventions in children. New Zealand (NZ) children's dietary intake was last assessed using a 24-hour multiple-pass recall (24-MPR) in 2002. This study aimed to evaluate the validity and reliability of a modified 24-MPR against a weighed food record (WFR) in the context of current eating patterns. Modifications included intensive interviewer training, use of photographic food portion sizes, structured parental clarification during recall, and participant familiarisation sessions. Thirty-two children aged 9–13 years (mean 11.0 ±1.2 y) were recruited from Auckland schools and communities. Dietary data were collected for both a weekday and a weekend day through two 40 min recall interviews, conducted by trained interviewers under the supervision of a senior dietitian. Nutrient intake was analysed using the NZ Food Composition Database. Validity was assessed via regression; Reliability was assessed by the coefficient of variation (CV) and the intraclass correlation coefficient (ICC). Macronutrient intake estimates showed minimal mean bias (e.g., −0.2% for energy, +3% for protein) and moderate correlations (r=0.43–0.63), consistent with previous validation studies. Micronutrient estimates were more variable, with underreporting observed for folate and vitamin C, and poor correlations (r=0.10–0.42). Reliability, assessed via ICC, was small for macronutrients (ICC=0.30) and moderate for select micronutrients (e.g., calcium, ICC = 0.56). The modified 24-MPR method demonstrated feasibility and moderate reliability, suggesting it is suitable for group-level dietary estimation in school children, especially for micronutrients.

Keywords: Dietary assessment, children, 24-hour recall, nutrient intake, method validation, SDG 2 – Zero Hunger, SDG 3 – Good Health and Well-being, SDG 4 – Quality Education

KEY MESSAGES

- The modified 24-hour multiple-pass recall (24-MPR) method is a feasible and moderately reliable tool for assessing dietary intake in New Zealand children aged 9–13 years.
- Macronutrient intake estimates showed minimal bias and moderate validity relative to WFR, supporting the method's use for group-level dietary assessment.
- Micronutrient estimates were more variable, with lower validity and reproducibility, limiting their use for individual-level dietary monitoring.
- Methodological enhancements, including interviewer training, a photographic atlas for food portion sizes, and structured parental input, improved data quality and recall accuracy.
- Further refinement and validation are needed, particularly for micronutrient intake and applications in diverse child populations.

6.1. Introduction

The most recent national dietary data for New Zealand (NZ) schoolchildren were collected over 20 years ago in the 2002 Children's Nutrition Survey (Parnell, 2003). Since then, dietary habits have shifted markedly, influenced by the growing dominance of ultra-processed foods that are convenient, hyper-palatable, and aggressively marketed (Monteiro et al., 2013). Broader changes in the food environment, including increased availability, marketing strategies, and urbanisation, have also contributed to altered dietary patterns worldwide (Swinburn et al., 2011). The Activity and Nutrition Aotearoa 2020 report recommends that the data on food and nutrition in NZ needs to be updated, and there is an urgent need for a regular, robust collection of data using accurate and reliable methods to monitor food and nutrition trends (Activity and Nutrition Aotearoa Connecting people and knowledge, 2020).

We recently reviewed the NZ school food environment and found that improved intake data are needed to evaluate the impact of government guidelines and policies (Pillay et al., 2022). Initiatives such as Healthy Active Learning and Ka Ora, Ka Ako (healthy school lunches) aim to reduce food insecurity and improve nutrition knowledge, behaviours, and overall wellbeing. Evidence suggests these programmes can enhance dietary quality, food security, fruit and vegetable intake, and education outcomes (Cohen et al., 2021). However, rigorous dietary assessment methods are required to determine whether such public investment is delivering meaningful health benefits.

Despite the need, no national or large-scale studies of nutrient intakes in NZ schoolchildren have been conducted in the past two decades, nor have tools been validated for methodological reliability in this population. The 24-hour dietary recall is widely used in nutrition epidemiology (Castell et al., 2015) and has been validated for children, including those whose caregivers report in-home intake (Foster & Bradley, 2018). Enhanced approaches, such as trained interviewers, food models, probing questions, and portion-size aids, can further improve accuracy (Douglass et al., 2013). Although under-reporting of energy remains a limitation, recalls provide contextual information on preparation methods and food combinations that biomarkers cannot (Foster & Bradley, 2018). Advances in self-reported methods continue to enhance their reliability for informing public health policy (Castell et al., 2015; Foster & Bradley, 2018).

Compared to the traditional 24-hour recall method, the 24-hour multiple-pass recall (24-MPR) strengthens the traditional method by guiding participants through quick recall, detailed recording, and final review to ensure all foods and drinks are accounted for. Interviewers can clarify ambiguous responses, adapt to comprehension levels, and improve portion size estimates with visual aids (Bradley et al., 2016). Studies show that a two-day 24-MPR, including a weekday and weekend day with parental input, provides the most accurate estimates of energy intake in children aged 4–11 years compared with doubly labelled water (Burrows et al., 2010).

This study aimed to evaluate the feasibility, validity and reliability of a modified interviewer-led 2×24-MPR (weekday and weekend day) for assessing dietary intake in NZ schoolchildren aged 9–13 years. We include the addition of a familiarisation trial, extensive interviewer training, portion-size prompts and photographs, and parental support during the final pass (FAO, 2018; Lacie Peterson, 2023). Caregiver input improved brand and preparation details while preserving the child's report of foods and quantities consumed. The method was tested against the gold-standard weighted food record (WFR) collected through full-day observations

(Thompson & Subar, 2017). The primary objective was to determine whether energy and nutrient intakes were equivalent between methods within acceptable bounds. Secondary aims included quantifying the standardised mean change and typical error between the 24-MPR and WFR.

6.2. Methods

6.2.1. Study design

A 24-MPR depends on memory and cognitive functions, making it challenging to administer to children under 10 years old (Foster & Adamson, 2014). Therefore, we included children aged 9-13 years in this study, as children from around 9 years are able to participate in dietary recall, although younger participants may still require support. Contributing primary (years 1-6), full primary (years 1-8), and intermediate (years 7-8) schools in Auckland, NZ, based on the NZ school year system, were invited to participate.

To estimate sample size, the average Intraclass Correlation Coefficient (ICC) for a WFR and combined 24-MPR of 0.98, 0.97, and 0.94 for energy, protein, and iron, respectively, were drawn from Nightingale et al. (2016). Therefore, assuming a conservative ICC for energy intake of 0.9 and an expected dropout rate of 10%, 25 children needed to be recruited (Borg et al., 2022). In an analysis of the expected validity of the 24-MPR vs. weighed record from the same study, the 149 kJ (2.8%) difference in energy between the measure and criterion, with SD 1706 kJ, SE 59 kJ, and within-subject SD (typical error) 196 kJ, required a sample size of 26 at 90% power and 5% type-1 error. Of the two sample sizes, the larger one (n=26) was selected to ensure statistical power and precision. Given an estimated 20% dropout rate, a sample size of 31 was selected for this study.

6.2.2. Ethical consideration

Children and parents or caregivers were informed about the study through written and verbal communication. Children provided verbal assent, while their parents or caregivers gave written consent. Researchers underwent police vetting to ensure the safety of children. All procedures were reviewed and approved by the Massey University Human Ethics Committee, accredited by the Health Research Council, under protocol application OMI 23/46 for the study. Students were recruited in approximately equal numbers of boys and girls (self-identified).

6.2.3. Study setting and participants

Thirty-four Auckland schools were randomly selected and contacted by email to request appointments to discuss the study. Four schools agreed to initial meetings, during which the study objectives were presented to school principals or designated school representatives, and support for participant recruitment was sought. Recruitment materials were distributed to parents and caregivers via letters sent home with children and school newsletters. Combined briefing sessions were then organised for interested parents, children, and teachers to outline study procedures and address questions. Following these sessions, 23 parents provided written consent for their children to participate.

In addition to school-based recruitment, invitations were circulated via social media and community notice boards, resulting in 16 positive responses. Individual appointments were arranged with these families to provide further information, resulting in written consent from 13 parents.

Inclusion criteria comprised children aged 9–13 years residing in Auckland and attending school, with a parent or caregiver able to provide informed consent and participate in study procedures. Children outside this age range, without parental consent, or with incomplete dietary data were excluded from the study to ensure data accuracy.

In total, 36 children (approximately equal numbers of boys and girls, self-identified) were enrolled. Verbal assent was obtained from all children, alongside written parental consent. Ethical approval was granted by the Massey University Human Ethics Ohu Matatika 1 Committee (Application OM1 23/46).

6.2.4. Data collection procedure

Data collection was conducted between January 2024 and July 2024. Each child and parent attended three appointments: one familiarisation session and two 24-MPRs within a week, covering one school day and one weekend day. Sessions lasted 30–45 min and were conducted either at school before class or at home.

The study used a modified interviewer-led triple-pass 24-MPR, adapted from the 2002 Children's Nutrition Survey (Ministry of Health, 2003), with the data collection sheet provided in Appendix 4.6. In the first pass, children listed all foods and drinks consumed. In the second pass, interviewers obtained detailed information (time, place, description, brand, and portion size) using prompts and aids including a photographic atlas previously adapted for use in *Life and Living to Advanced Age: a Cohort Study* in NZ (LiLACS NZ) (Nelson et al., 1997), standardised measures, and playdough models (Nightingale et al., 2016). The third pass included reviewing the detailed list with the child and parent to fill in gaps, with relevant recipes noted at the end (Ministry of Health, 2003). Parent support was sought only for cooking methods, recipes, and product brand names if the children failed to mention them (Baranowski et al., 2012).

One final-year Master of Nutrition and Dietetics student and a registered dietitian conducted all interviews after structured training and supervision from a senior dietitian. Training included practice recalls, use of standardised scripts, and fidelity checks, with random audits of completed recalls that were reviewed to minimise inter-rater variability. A familiarisation trial at the first appointment explained expectations and improved children's accuracy in reporting.

For the reference method, parents and caregivers completed weighted food records (WFRs), with the data collection sheet provided in Appendix 4.7, following written and video guidance and in-person instruction. They were provided with calibrated scales, household measures, and a record booklet, and asked to photograph foods and any leftover food. School-day intakes were documented by recording lunchbox contents before and after school or, for purchased meals, by having children draw. If not adequately explained, the researchers obtained the size and nutritional details of the ingested foods from the school canteen, based on the specific items reported or illustrated by each child, and then matched them to the individual participant's intake records. WFRs were collected independently of the 24-MPR sessions to minimise carryover bias.

6.2.5. Nutrient intakes analysis

Nutrient intake analysis was conducted using FoodWorks 10 (Xyris, Sydney, NSW, 2021), incorporating the NZ Food and Beverage Composition Database (Plant and Food Research and

Ministry of Health, 2022). Nutrients analysed included energy, macronutrients (carbohydrate, protein, fat), dietary fibre, selected minerals (calcium, iron, zinc etc.), fat-soluble vitamins (A, D, E), and water-soluble vitamins (B complex, C) following recommendations from Nightingale (Nightingale et al., 2016).

6.2.6. Statistical analysis

All statistical analyses were performed using purpose-designed spreadsheets based on the methods described by Hopkins (2017), including spreadsheets for comparison of means and estimation of effect sizes. Linear regression was used for validity evaluation. Uncertainty around the mean estimate was expressed as 90% confidence intervals. Both validity and reliability results were interpreted in accordance with established statistical guidelines for reliability (Atkinson & Nevill, 1998; Hopkins, 2000).

Validity assessment

The 24-MPR was validated against the WFR as the criterion using the same-day paired data. Accuracy was evaluated via 100*natural log of the 24-MPR/WFR ratio for each nutrient, which also provided for improved model fit to accommodate observed data heteroscedasticity; following analysis of the log-transformed data, outcomes were back-transformed and expressed as per cent differences (Hopkins, 2000; Hopkins, 2017). Systematic error was described as the mean difference (24-MPR minus WFR) in a percentage of WFR intake (parametric quantitative data), with standardisation applied to allow comparison across nutrients. Additionally, Pearson correlation coefficients measured linear association, while Bland–Altman analysis quantified limits of agreement. In this study, bias in the Bland–Altman analysis was defined as the mean difference between the two methods (24-MPR minus WFR), while limits of agreement were calculated as the bias ±1.65 standard deviations of the differences (90% limits of agreement). These complementary methods were used to assess different aspects of relative validity, including accuracy (bias), association, and agreement between the two dietary assessment methods.

Reliability assessment

The reliability of the 24-MPR was assessed using test-retest analysis, comparing data from separate administrations (weekday vs. weekend). Parametric data were analysed as 100*natural log of the ratio of the 24-MPR/WFR to enable proportional comparisons, while serving size was analysed using the raw difference measure and criterion. Reliability metrics included mean difference, typical error (expressed as coefficient of variation, CV%), and ICC. Acceptable reliability was defined as ICC > 0.90, CV% < 5%, and ICC precision within ±0.05 (Hopkins, 2000; Hopkins, 2017).

6.3. Results

We obtained more interest than expected so recruited 36 participants into the study, of which 32 completed the full protocol (Table 6.1). Two participants withdrew for personal reasons, while two were excluded for non-compliance with the study methodology.

Table 6.1. Characteristics of the study sample.

Characteristics	Girls (n=12)	Boys(n=20)	Total (n=32)
Age mean (SD) (y)	11 (0.9)	12 (1.3)	11 (1.2)
Height mean (SD) (cm)	153 (10)	150 (13)	152 (12)
Weight mean (SD) (kg)	46 (12)	40 (12)	43 (12)
BMI mean ± SD (kg/m^2)	19 (3.4)	18 (2.9)	18 (3.1)
Ethnicity			
Māori	1	2	3
Tongan	0	2	2
European	10	16	26
Arab	1	0	1

6.3.1. Validity of the modified 24-MPR compared to FWR

Table 6.2 summarises the validity of the modified 24-MPR against the WFR for energy, macronutrients, and relevant micronutrients. Mean bias was generally small for energy and macronutrients, with wider variability for micronutrients. Using Hopkins' thresholds (trivial <0.10, small 0.10–0.30, moderate 0.30–0.50, large 0.50–0.70, very large 0.70–0.90) (Hopkins, 2015), correlations ranged from trivial to large. Energy and carbohydrate showed moderate associations, while protein, dietary fibre, thiamin, vitamin A, and vitamin B_{12} reached large correlations. Most minerals (magnesium, potassium, zinc, phosphorus) and niacin were small or trivial, indicating weaker alignment. No nutrient achieved a very large or nearly perfect correlation. Bland–Altman plots indicated narrower limits of agreement for energy and macronutrients than for micronutrients.

Table 6.2. Validity of the Modified 24-MPR Method with WFR.

Parameter	WFR Mean (SD)	24-MPR Mean (SD)	Mean bias in raw units (90% CI)	Mean bias, % (90% CI)	Mean bias Standardised (90% CI)	Pearson Correlation (r)	Bland-Altman Limits of Agreement
Energy (kJ)	8964 (2390)	8926 (2351)	-38 (-588, 513)	-0.2 (-7.1, 7.2)	-0.0 (-0.3, 0.2)	0.43 (0.25, 0.59)	1.97
Carbohydrate (g)	250 (69)	249 (73)	-0.8 (-16, 14)	-0.7 (-7.4, 6.5)	-0.0 (-0.3, 0.2)	0.53 (0.36, 0.66)	1.93
Protein (g)	83 (34)	85 (31)	1.8 (-4.6, 8.3)	3 (-5.7, 13)	0.1 (-0.1, 0.3)	0.63 (0.48, 0.74)	2.30
Total fat (g)	85 (28)	83 (28)	-1.8 (-9.2, 5.7)	-2.1 (-13, 9.5)	-0.1 (-0.4, 0.3)	0.28 (0.08, 0.46)	2.86
Dietary fibre (g)	26 (10)	23 (9)	-2.1 (-3.7, -0.4)	-7.5 (-15, 1.1)	-0.2 (-0.4, 0.0)	0.61 (0.46, 0.72)	2.31
Calcium (mg)	1019 (494)	823 (458)	-196 (-298, -94)	-23 (-36, -6.4)	-0.5 (-0.9, -0.1)	0.44 (0.26, 0.60)	5.96
Iron (mg)	13 (4.7)	12 (6.0)	-0.8 (-2.2, 0.5)	-11 (-24, 4.0)	-0.3 (-0.6, 0.1)	0.36 (0.17, 0.53)	4.22
Magnesium (mg)	311 (120)	249 (96)	-0.9 (-88, -34)	-19 (-30, -5.8)	-0.5 (-0.9, -0.1)	0.26 (0.06, 0.45)	4.10
Potassium (mg)	2707 (1041)	2415 (935)	-292 (-526, -58)	-9.7 (-23, 5.3)	-0.2 (-0.5, 0.1)	0.27 (0.07, 0.45)	4.24
Zinc (mg)	9.9 (4.6)	8.7 (3.7)	-1.2 (-2.1, -0.2)	-9.9 (-34, 23)	-0.1 (-0.5, 0.3)	0.19 (-0.01, 0.39)	18
Phosphorus (mg)	1371 (521)	1198 (540)	-172 (-307, -38)	-12 (-35, 18)	-0.2 (-0.6, 0.2)	0.08 (-0.13, 0.28)	16
Iodine (μg)	179 (261)	130 (131)	-49 (-89, -9.4)	-21 (-45, 15)	-0.3 (-0.8, 0.2)	0.20 (-0.01, 0.39)	33
Selenium (μg)	57 (26)	50 (35)	-7.2 (-14, -0.4)	-23 (-39, -1.3)	-0.6 (-1.1, -0.0)	0.39 (0.20, 0.55)	9.9
Vitamin A (μg)	760 (528)	816 (738)	57 (-72, 185)	-6.9 (-25, 16)	-0.1 (-0.4, 0.2)	0.67 (0.53, 0.77)	7.54
Thiamin (mg)	2.0 (1.3)	1.8 1.3)	-0.2 (-0.4, -0.0)	-13 (-26, 2.8)	-0.2 (-0.4, 0.0)	0.63 (0.48, 0.74)	4.60
Riboflavin (mg)	2.0 (1.0)	1.7 (1.0)	-0.3 (-0.6, -0.1)	-19 (-32, -4.1)	-0.4 (-0.8, -0.1)	0.42 (0.23, 0.58)	5.06
Niacin (mg)	18 (7.8)	16 (8.2)	-1.6 (-3.6, 0.3)	-11 (-27, 7.9)	-0.2 (-0.6, 0.1)	0.24 (0.03, 0.42)	6.17
Vitamin B_6 (mg)	1.7 (0.8)	1.6 (0.8)	-0.1 (-0.3, 0.1)	-5.5 (-20, 11)	-0.1 (-0.4, 0.2)	0.42 (0.23, 0.57)	4.48
Vitamin B_{12} (μg)	4.9 (6.0)	3.6 (3.1)	-1.3 (-2.2, -0.4)	-23 (-40, -2.2)	-0.4 (-0.7, -0.0)	0.57 (0.41, 0.69)	9.83
Vitamin C (mg)	88 (70)	78 (86)	-9.9 (-29, 8.6)	-20 (-45, 17)	-0.2 (-0.7, 0.2)	0.42 (0.23, 0.58)	36
Vitamin E (mg)	10.3 (3.9)	7.7 (3.9)	-2.6 (-3.7, -1.5)	-23 (-36, -8.3)	-0.6 (-0.9, -0.2)	0.13 (-0.08, 0.33)	5.5

All data were derived from raw data. Data are mean estimates (90%CI). 24-MPR=24 hours Multiple-pass recall, WFR= Weighted Food Record, CI= confidence intervals, B-A= Bland-Altman in nutrient units, r=Pearson correlation.
Bias represents the mean difference between methods (24-MPR minus WFR). Limits of agreement were calculated as bias ± 1.65 SD of the differences and are presented on the ratio scale following log-transformation.

Figure 6.1 shows the mean Pearson correlation coefficients, ranging from 0.08 (phosphorus) to 0.67 (vitamin A), indicating trivial to large associations between methods. Protein and carbohydrate showed large correlations (r=0.53-0.63), whereas phosphorus, showed a trivial correlations ($r \leq 0.10$), and zinc (r=0.19) showed a small correlation (Hopkins, 2015).

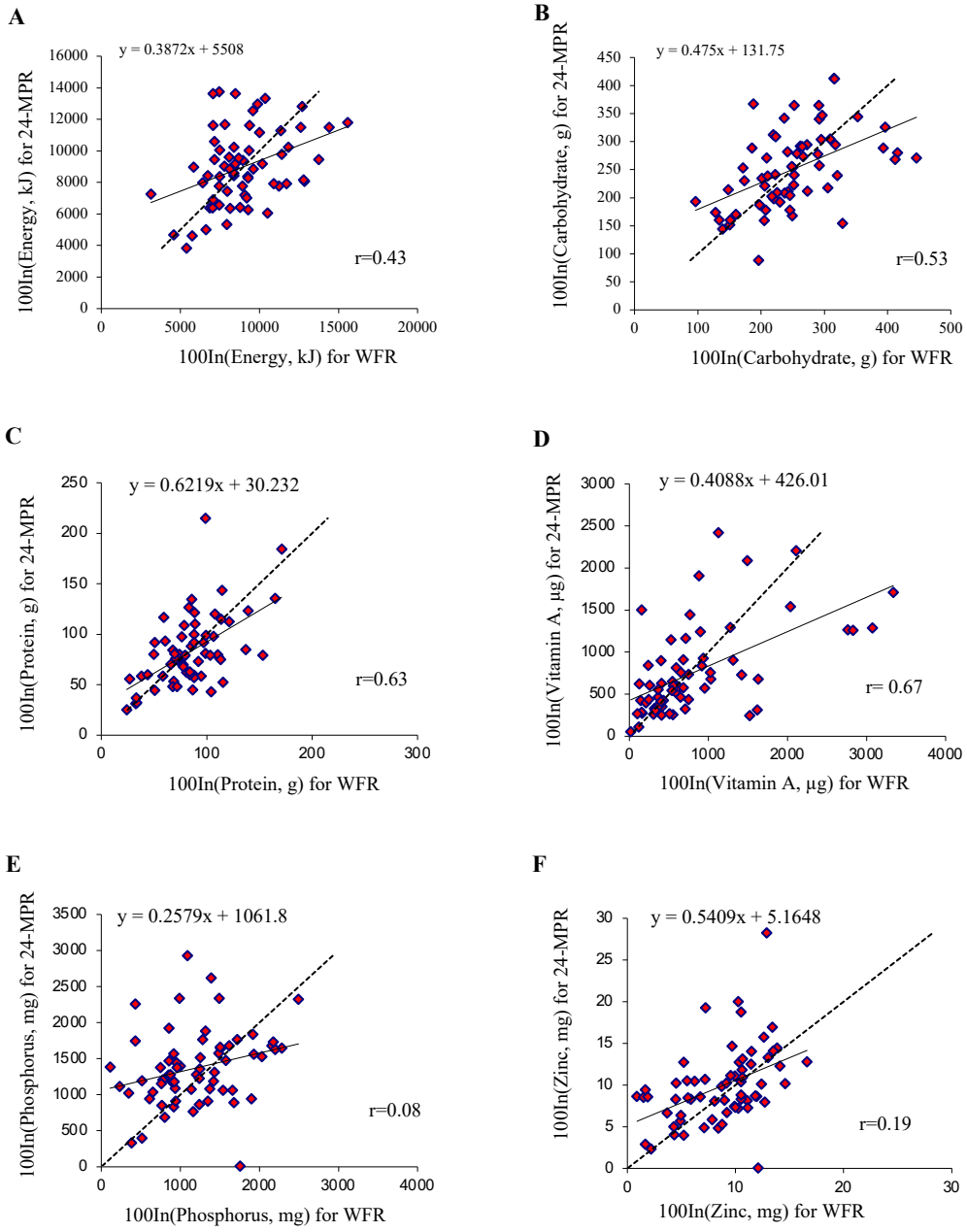


Figure 6.1. Nutrient correlation between log-transformed 24-MPR and WFR - Validity.
(A) Correlation between log-transformed 24-MPR and WFR – Energy.
(B) Correlation between log-transformed 24-MPR and WFR – Carbohydrate.
(C) Correlation between log-transformed 24-MPR and WFR – Protein.
(D) Correlation between log-transformed 24-MPR and WFR – Vitamin A.
(E) Correlation between log-transformed 24-MPR and WFR – Phosphorus.
(F) Correlation between log-transformed 24-MPR and WFR – Zinc
24-MPR–24 hours multiple-pass recall, WFR-weighted food record

Additional correlations between log-transformed 24-MPR and WFR for other nutrients are provided in Appendix 2.2

6.3.2. Reliability of the Modified 24-MPR Compared to FWR

Table 6.3 presents reliability metrics for the modified 24-MPR compared with the WFR. Changes in mean were generally small to moderate for energy and macronutrients, but larger and more variable for several micronutrients. Standardised changes in mean ranged from trivial (<0.20) for thiamine and riboflavin to moderate (0.60–1.20) for energy, carbohydrate, protein, and dietary fibre, and were very large (>2.00) for vitamin C (Hopkins, 2015). Standardised typical error values were generally large to very large, indicating substantial within-method variability for most nutrients. Intraclass correlation coefficients ranged from trivial (<0.10) for potassium, vitamin B_{12}, and vitamin C to small (0.10–0.30) for most micronutrients, and moderate (0.30–0.60) for calcium, magnesium, thiamine, riboflavin, and niacin (Hopkins, 2015). Overall, the 24-MPR demonstrated moderate reliability for some macronutrients and selected micronutrients, but poor reliability for potassium and several vitamins.

Table 6.3. Reliability assessment of modified 24-MPR method compared to WFR.

Parameter	Changes in mean, % (90%CI[a])	Typical error as a CV[b], % (90% CI)	Standardised change in mean (90% CI)	Standardised typical error (90% CI)	ICC (90% CI)
Energy (KJ)	-7.2 (-16, 2.8)	27 (22, 36)	-0.4 (-1.0, 0.2)	1.4 (1.2, 1.8)	0.34 (0.06, 0.58)
Carbohydrate (g)	-10.1 (-19, -0.2)	28 (23, 37)	-0.7 (-1.5, -0.0)	1.7 (1.4, 2.2)	0.26 (-0.03, 0.52)
Protein (g)	-12 (-22, -0.5)	34 (27, 44)	-0.7 (-1.3, -0.0)	1.5 (1.2, 1.9)	0.33 (0.04, 0.57)
Total Fat (g)	-1.5 (-16, 16)	47 (37, 62)	-0.1 (-0.9, 0.7)	1.9 (1.6, 2.4)	0.23 (-0.07, 0.49)
Dietary Fibre (g)	-9.6 (-21, 2.9)	36 (29, 48)	-0.6 (-1.3, 0.2)	1.7 (1.4, 2.2)	0.26 (-0.03, 0.52)
Calcium (mg)	-16 (-31, 0.7)	55 (44, 74)	-0.4 (-0.8, 0.0)	0.9 (0.8, 1.2)	0.56 (0.32, 0.73)
Iron (mg)	1.7 (-17, 25)	61 (49, 83)	0.1 (-0.7, 0.8)	1.7 (1.4, 2.1)	0.27 (-0.02, 0.52)
Magnesium (mg)	-16 (-29, 0.4)	51 (41, 69)	-0.5 (-1.0, 0.0)	1.2 (1.0, 1.5)	0.43 (0.16, 0.64)
Potassium (mg)	-15 (-32, 6.8)	71 (56, 97)	-1.2 (-2.9, 0.5)	4.0 (3.3, 5.0)	0.06 (-0.23, 0.35)
Zinc (mg)	10.5 (-23, 58)	133 (102, 192)	0.3 (-0.8, 1.3)	2.4 (2.0, 3.1)	0.15 (-0.15, 0.42)
Phosphorus (mg)	9.9 (-21, 53)	120 (92, 172)	0.2 (-0.6, 1.0)	1.9 (1.6, 2.5)	0.22 (-0.08, 0.48)
Iodine (μg)	-2.3 (-29, 34)	109 (85, 155)	-0.0 (-0.5, 0.4)	1.0 (0.9, 1.3)	0.50 (0.24, 0.69)
Selenium (μg)	2.6 (-21, 34)	86 (67, 120)	0.1 (-0.5, 0.6)	1.31 (1.1, 1.7)	0.38 (0.10, 0.60)
Vitamin A (μg)	-2.5 (-26, 29)	92 (72, 129)	-0.1 (-1.0, 0.9)	2.3 (1.9, 2.9)	0.17 (-0.13, 0.44)
Thiamin (mg)	-0.8 (-18, 20)	57 (46, 78)	0.0 (-0.6, 0.5)	1.3 (1.0, 1.6)	0.40 (0.13, 0.62)
Riboflavin (mg)	-15 (-30, 4.4)	61 (48, 83)	-0.4 (-1.0, 0.1)	1.3 (1.1, 1.6)	0.39 (0.11, 0.61)
Niacin (mg)	-12 (-28, 8.4)	63 (50, 85)	-0.3 (-0.7, 0.2)	1.1 (0.9, 1.4)	0.47 (0.21, 0.67)
Vitamin B_6 (mg)	-28 (-43, -9.0)	75 (59, 103)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	-0.05 (-0.34, 0.25)
Vitamin B_{12} (μg)	-8.8 (-34, 26)	115 (89, 164)	-0.6 (-2.9, 1.6)	5.3 (4.4, 6.7)	0.04 (-0.26, 0.32)
Vitamin C (mg)	-47 (-65, -21)	159 (120, 234)	-2.1 (-3.4, -0.8)	3.2 (2.6, 4.0)	0.09 (-0.20, 0.38)
Vitamin E (mg)	-5.4 (-23, 17)	65 (51, 88)	-0.2 (-0.7, 0.4)	1.3 (1.1,1.7)	0.38 (0.10, 0.60)

All Statistics were derived from raw data. Data are mean estimates (90%CI). Data are rounded to 2 significant figures.
24-hMPR=24 hours Multiple-pass recall, WFR= Weighted Food Record, CI[a] = confidence intervals, CV[b]= Coefficient of Variation, ICC[c]= Intra-class correlation coefficient.
Changes in mean (%) were calculated as (24-MPR − WFR), expressed relative to WFR.
For vitamin B6, standardised estimates were close to zero, likely reflecting minimal variation and the effects of rounding; these values should be interpreted cautiously.

Figure 6.2 shows correlations of log-transformed 24-MPR/WFR ratios between weekdays and weekends for selected nutrients. Reliability was moderate for energy and protein, indicating consistent ranking across days, and small for vitamin A and magnesium. Folate and vitamin C exhibited trivial correlations. Overall, reliability was stronger for macronutrients than for vitamins and minerals.

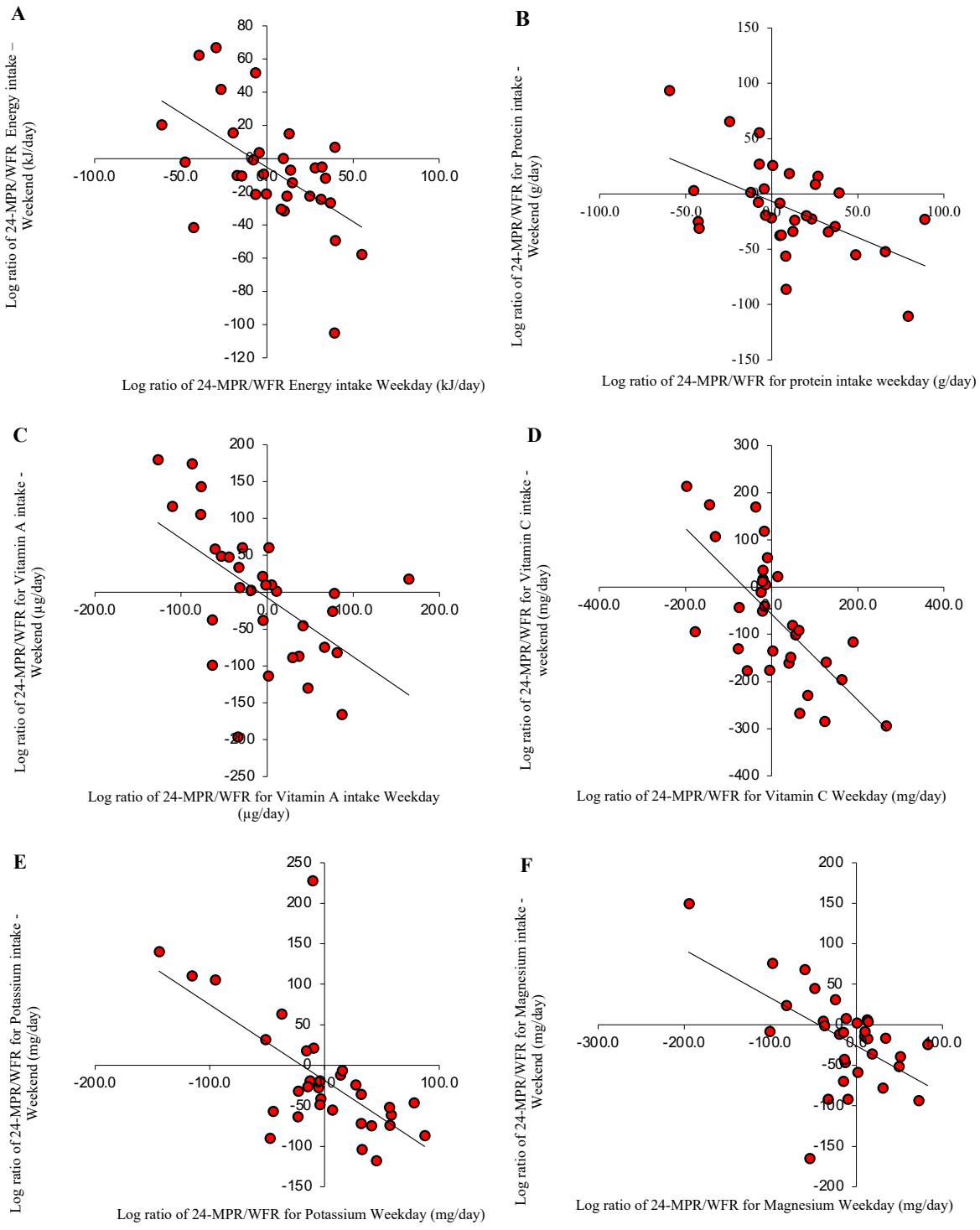


Figure 6.2. Nutrient correlation between the log-transformed ratio of 24-MPR/WFR - reliability

A. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Energy.
B. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Protein.
C. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Vitamin A.
D. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Vitamin C.
E. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Potassium.
F. Correlation between the log-transformed ratio of 24-MPR/WFR on weekends and weekdays for Magnesium
24-MPR–24 hours multiple-pass recall, WFR-weighted food record

6.4. Discussion

The present study evaluated the validity and reliability of a modified 24-MPR method relative to a caregiver-determined WFR in children aged 9-13 years. We found that whereas the modified 24-MPR technique performs well in estimating macronutrient intake, its validity and reliability in evaluating micronutrient intake is less precise.

6.4.1. Methodological enhancements

Several methodological refinements were implemented to improve the validity and reliability of dietary intake data. One of the key strengths was the supervision and intensive training provided to the interviewers. Although the impact of training on validity and reliability was not quantified, our anecdotal observation was that the intervention enhanced consistency of implementation, as suggested by Olukotun and Seal (2015).

To improve portion-size estimation and, therefore, the accuracy of quantification, we systematically used visual and household aids. Specifically, we used an adapted photographic atlas of food portion sizes (LiLACS NZ) (Nelson et al., 1997), alongside standardised household measures. These tools were selected to reduce errors in child-reported portion sizes, which are a common source of misreporting in paediatric dietary assessments.

Another significant modification was the structured inclusion of parental input during the third pass of the 24-MPR. Parents were invited to clarify cooking methods, brand names, and other details that children may not accurately recall. This method improved the completeness and accuracy of the dietary data (Trolle et al., 2011). It also aligns with guidelines to reduce proxy influence while utilising parental knowledge for specific details (Ortiz-Andrellucchi et al., 2010).

Finally, to further support accurate reporting, we conducted a familiarisation session with both children and parents prior to data collection. This session explained the study's purpose and the type of information required, helping participants understand the importance of attentive listening and accurate recall. The session was supported by measuring tools, detailed paper instructions, and educational videos, which collectively improved participants' understanding of the procedures. These additions likely contributed to the observed reductions in error rates for portion-size estimation and recall. However, a future study would be needed to quantify their impact on validity and reliability (Nightingale et al., 2016a).

6.4.2. Validity of the modified 24-MPR

The modified 24-MPR method showed strong validity for macronutrients, with minimal bias for energy and protein and moderate correlations for energy, carbohydrate, protein, and fibre, while weaker correlations were observed for total fat, suggesting lower agreement for fat intake, consistent with previous studies (Nightingale et al., 2016b; Rockett et al., 1997). These findings align with previous dietary validation studies, which have often shown stronger agreement for energy and macronutrients than for micronutrients (Arsenault et al., 2020; Ferguson et al., 1989; Nightingale et al., 2016b). A systematic review by Olukotun and Seal found that 24-hour recalls and food records were among the most valid tools for estimating macronutrient intake in children under 11. The review emphasised that while multiple days of data collection are needed to estimate usual intake, the 24-MPR method offers low participant burden and does not require literacy, making it suitable for diverse populations. (Olukotun & Seal, 2015). The review also highlighted that three to four repeated recalls are generally sufficient to estimate habitual macronutrient intake, and that trained interviewers using

structured protocols can enhance data quality (Olukotun & Seal, 2015). In our study we used of trained interviewers and oversighted by a senior dietitian aligns with these best practices. Further support comes from a meta-analysis that found that food frequency questionnaires (FFQs) had weak validity for estimating energy and macronutrient intake in children and adolescents, whereas 24-hour recalls and food records were more accurate—especially when supported by visual aids and interviewer training (Saravia et al., 2021). This reinforces the strength of our approach, which included visual tools for portion size and interviewer standardisation.

The modified 24-MPR method demonstrated variable validity across micronutrients when compared with WFR. Underreporting was most pronounced for several vitamins and minerals, particularly fat-soluble vitamins and trace elements, while others showed smaller discrepancies. Correlations ranged from trivial to large, with thiamine and vitamin A achieving large associations, calcium and vitamin C showing moderate associations, and nutrients such as vitamin E, phosphorus, and zinc exhibiting trivial correlations. These patterns indicate that while the method performs well for some micronutrients, accuracy is nutrient-specific and weaker for minerals and certain vitamins. These findings are consistent with Ortiz-Andrellucchi et al. (2009), who reviewed 32 validation studies in children and adolescents and found that 24-hour recalls and WFR generally outperformed FFQs for estimating micronutrient intake. Good correlations were reported for vitamin C ($r = 0.61$) and calcium ($r = 0.51$) using short-term reference methods, and WFRs were superior to FFQs when validated against biomarkers. Roman Viñas et al. (2011) within the EURRECA Network of Excellence, confirmed the utility of FFQs for vitamin C, calcium, and iron in older children but noted weaker validity for other micronutrients, underscoring the importance of population- and nutrient-specific tools. They also emphasised the need for repeated recalls or records to capture usual intake and reduce intra-individual variability. Similarly, Matsushita et al. (2021) an enhanced 24-hour recall with a portable camera and food atlas was validated in Japanese adults, reporting strong correlations with WFR for potassium ($r = 0.56$) and salt equivalents ($r = 0.58$). Although not in children, these findings suggest visual aids and structured protocols can improve micronutrient estimation.

6.4.3. Reliability of the modified 24-MPR

Reliability was stronger for macronutrients than micronutrients. The ICCs for macronutrients, particularly energy and protein, both at 0.3, indicate moderate reliability, although lower than previously reported. Prior research has reported ICCs ranging from 0.5 to 0.7 for repeated 24-hour recalls (Foster et al., 2019; Yuan et al., 2017). Variations in population characteristics, modifications to the recall method, and differences in weekday versus weekend reporting may explain these discrepancies (Foster & Bradley, 2018; Gibson et al., 2017).

In terms of micronutrients, the modified 24-MPR method showed moderate reliability for calcium, with small to moderate reliability for magnesium, iodine, selenium, and niacin. Most other micronutrients, including vitamin C, vitamin B_{12}, and potassium, demonstrated trivial reliability, indicating high day-to-day variability and limited consistency. Overall, reliability was nutrient-specific, with better performance for some minerals and B vitamins, but poor reproducibility for most vitamins and trace elements. This aligns with Bush et al. (2019), who found wide LOA and variable reliability for micronutrients in UK children and adolescents, often limited by recall days and proxy reporting. We addressed these issues through child-led recall, parental clarification, and interviewer training.

Strengths and Limitations

Overall, the modified 24-MPR method is a practical and structured approach for dietary assessment in children. Its design, incorporating interviewer training, visual aids, and parental input, supports validity for macronutrients and acceptable group-level estimates for many micronutrients. However, reliability for micronutrients was generally weak, reflecting high day-to-day variability and limitations for individual-level monitoring. In contrast, energy and macronutrients showed better reproducibility, reinforcing the method's suitability for population-level research rather than precise individual assessment.

The study nonetheless has limitations. Although the sample size met a priori criteria for a repeated-measures design, it may have been insufficient to yield precise micronutrient correlations. Using weighed food records as the comparator could have introduced bias through altered parental observation or reporting (Baxter, 2009). Still, alternatives such as in-person or video surveillance posed ethical and practical challenges. The updated LiLACS NZ Photographic Food Atlas, though useful, may not fully capture contemporary or multicultural diets. Day-to-day variability in intake, not accounted for in the design, may also have inflated within-subject variation (Palaniappan et al., 2003). Finally, inherent issues of dietary recall – memory dependence and under- or over-reporting – remain potential sources of error (Macdiarmid & Blundell, 1998).

6.5. Conclusions and future directions

We found that the modified 24-MPR method is a feasible and moderately reliable tool for assessing dietary intake in NZ children aged 9–13 years. While the macronutrient estimates and energy showed acceptable validity and fair reliability, micronutrient estimates were more variable, with nutrient-specific differences in recall accuracy, although some micronutrients such as calcium and riboflavin demonstrated relatively better validity. Methodological enhancements, including interviewer training, visual portion size aids, structured parental input, and participant familiarisation, contributed to improved data quality. Importantly, findings indicate that the modified 24-MPR is more suitable for assessing dietary intake at the group level, where average intake estimates are needed, rather than at the individual level, where precision and agreement between methods are more critical. This distinction is especially relevant for micronutrient intake, which showed greater variability and lower reproducibility. These findings support the use of structured recall methods in child nutrition research and highlight the need for continued refinement and validation, particularly for micronutrient assessment. Integrating biomarkers and additional recall days in future studies could further improve the accuracy of the modified dietary recall method.

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Chapter 7

Comparative Evaluation of Nutrient Intakes and Dietary Adequacy Among Schoolchildren Aged 9-13 in Sri Lanka and New Zealand: An Exploratory Analysis

This chapter presents a manuscript titled *"Comparative Evaluation of Nutrient Intakes and Dietary Adequacy Among Schoolchildren Aged 9–13 in Sri Lanka and New Zealand: An Exploratory Analysis"* authored by Harshani Perera, Ajmol Ali, Carol Wham, Ananda Chandrasekara, David S Rowlands. The manuscript is prepared in journal format and is intended for submission to *Nutrients*.

This chapter addresses **Research Objective 5 (Section 1.3.5)**. It assesses and compares the adequacy of energy and key nutrient intakes among schoolchildren aged 9–13 years in Sri Lanka and New Zealand using the 24-hour multiple-pass dietary recall (24-MPR) method, with the aim of identifying population-specific nutritional inadequacies. By highlighting differences and gaps in dietary adequacy between these two contexts, this chapter provides evidence to inform targeted nutrition interventions and policy development.

HP, AA, CW, and DR designed the research and obtained ethical approval. HP and CW developed all the data collection sheets, and CW assisted with training the research assistants. Participant recruitments, data collection and data entry for the Sri Lankan arm was led by HP with assistance from AC. HP, AA, and DR contacted schools and negotiated permission for participation in New Zealand. HP, VP, and AM were responsible for participant recruitment and data collection, while VP and SM assisted with data entry in New Zealand. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.

Abstract

Nutritional adequacy during childhood is critical for growth and long-term health. Evidence on dietary intake disparities across different national contexts remains limited. This study aimed to compare nutrient adequacy among schoolchildren in New Zealand (NZ) and Sri Lanka (SL) to explore context-specific differences between two distinct food environments. A cross-sectional analysis was conducted among schoolchildren aged 9–13 years in SL (n=99) and NZ (n=32). Dietary intake was assessed using a modified 24-hour multiple-pass dietary recall. Nutrient adequacy was evaluated against country-specific reference values, and differences were examined by country, gender and week versus weekend days. Children in NZ had significantly higher intakes of total energy and most nutrients than their SL counterparts (all $p<0.05$). Among NZ children, the intake of energy was 38% (mean difference; 95% CI: 592 kcal; 411, 773), protein 79% (+38 g; 27, 48), total fat 116% (+44 g; 36, 52) and dietary fibre intake 17 g; 14, 20) higher, relative to SL children. For micronutrients, NZ children consumed substantially more calcium (+611 g; 460, 763), zinc (+5.0 mg; 3.7, 6.2), iodine (+95 µg; 47, 142), and vitamin B_{12} (+2.5 µg; 1.3, 3.6) compared to SL children. In SL, inadequacy was widespread: 100% had intakes below recommendations for dietary fibre and magnesium, and >85% had inadequate calcium, zinc, and iodine intakes. In NZ, inadequacies of copper and vitamin A were evident, while protein intake approached three times the estimated average requirements (EAR). In both settings, weekday diets were more nutrient-dense than weekend diets. New Zealand schoolchildren consumed more energy and most nutrients than their SL peers, while SL children exhibited widespread nutrient inadequacies (notably fibre, magnesium, calcium, zinc, and iodine), with no consistent gender differences. The study identified country of residence as the dominant predictor of adequacy, with age and weekend days showing nutrient-specific effects, supporting targeted fortification/diet diversification in SL and diet-quality improvements in NZ.

Keywords: Dietary intake, Nutritional status, Micronutrients, Cross-cultural comparison, Child nutrition, SDG 2 – Zero Hunger, SDG 3 – Good Health and Well-being, SDG 10 – Reduced Inequalities

7.1. Introduction

Adequate nutrition in childhood promotes growth, development and long-term health, yet school-aged children remain understudied relative to under-fives and adolescents. (Centers for Disease Control and Prevention, 2024). Global nutrition research and policy have historically focused on children under five or adolescents aged above 15 years, leaving a significant gap in understanding the dietary adequacy of school-aged children (Saavedra & Prentice, 2023). Children aged 9 to 13 years, however, are in a developmental phase characterised by physical growth, the onset of puberty, and increased psychological and social independence regarding food choices (Spear, 2002). Children's diets are increasingly characterised by high consumption of energy-dense, nutrient-poor foods (e.g., processed snacks, sugar-sweetened beverages) and reduced intake of home-prepared meals, alongside behaviours such as skipping breakfast (Fryar et al., 2020; Lytle et al., 2000; Siega-Riz et al., 1998). These shifts lower diet quality and contribute to nutritional imbalances, which can impair growth and cognitive development and increase the risk of non-communicable diseases (Prentice, 2018; Roberts et al., 2022). Similar trends are evident in developing nations, where rapid nutritional transitions have driven a rise in childhood overweight and obesity, notably in India and China (Popkin, 2021; World Obesity Federation, 2023). Ensuring dietary adequacy during this stage is critical for lifelong health (Kehoe et al., 2022). Childhood overweight and obesity are associated with an increased risk of non-communicable diseases later in life, including type 2 diabetes, cardiovascular disease, and metabolic disorders, as well as the persistence of obesity into adulthood (WHO, 2025). Conversely, undernutrition during middle childhood can impair physical growth, delay cognitive development, and reduce educational attainment, with long-term consequences for health, productivity, and economic potential (Victora et al., 2008). Together, these contrasting risks highlight the importance of achieving balanced nutrition during this critical developmental period.

Dietary adequacy, defined as meeting recommended nutrient intake levels, is a fundamental element of public health nutrition (Castro-Quezada et al., 2014). Assessing adherence to these benchmarks offers insights into potential nutritional deficiencies or imbalances and aids in evaluating the effectiveness of existing dietary strategies (Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference, 2000). However, children's dietary patterns are influenced by multiple factors, including socioeconomic status, cultural practices, food availability, and public health infrastructure, which often vary considerably between high-income and low- to middle-income countries (Birhanu et al., 2024; Zarnowiecki et al., 2014). These differences in dietary adequacy become even more evident through factors such as temporal variations (weekend vs. weekday) (Esposito et al., 2022) and gender-related differences (Merkiel-Pawłowska & Chalcarz, 2017). While numerous studies have examined the nutritional intakes of schoolchildren in developed countries (high-income), fewer have explored these patterns in developing nations (low-to middle-income) using validated dietary assessment methods (Windus et al., 2025). Even fewer studies have conducted direct cross-country comparisons of dietary adequacy in schoolchildren, especially between developed and developing countries. Such comparative assessments are crucial for identifying global and local challenges and for directing resources effectively (Demmler et al., 2024).

Sri Lanka (SL) and New Zealand (NZ) were selected for this study because they represent distinctly different socioeconomic backgrounds, stages of nutrition transition, and cultural food

environments, offering valuable contrasts and insights into the challenges of child nutrition (Galgamuwa et al., 2017; Moll et al., 2025; Quan & Zhu, 2025). Current data on nutrient intake among 9-to-13-year-olds in NZ remain limited and outdated, with most comprehensive assessments conducted over two decades ago (Ministry of Health NZ, 2023), preceding substantial changes in food environments and consumption patterns driven by globalisation and the introduction of new products (Bandara et al., 2021; Mackay et al., 2025). New Zealand is a high-income country with a highly industrialised and commercialised food system characterised by widespread availability of food; however, it also faces high childhood overweight and obesity, and dietary imbalances, especially among disadvantaged groups, reflecting the influence of an obesogenic food environment and socioeconomic inequalities in access to healthy food (Men, 2024). Conversely, SL is a lower-to-middle-income country, undergoing a rapid nutrition transition characterised by persistent undernutrition, micronutrient deficiencies, and an increasing prevalence of overweight in urban populations (Weerahewa et al., 2020). Both countries exemplify different stages of global nutrition transition and highlight the diverse influences of socioeconomic status, food availability, cultural practices, and public health policies on child dietary adequacy. School-based nutrition programmes in both countries aim to improve dietary quality, yet the effectiveness of these initiatives varies, and monitoring of dietary adherence is inconsistent (de Seymour et al., 2022; Seneviratne et al., 2021). Comparing these nations, therefore, presents a unique opportunity to identify shared and context-specific risks, providing the necessary evidence to guide effective nutrition strategies for school-aged children in diverse contexts.

This study aimed to compare nutrient intakes and dietary adequacy among schoolchildren aged 9- to 13 years in SL and NZ using country-specific reference values (SL DRIs; AU/NZ NRVs), as detailed in Appendix 2.3 (Supplementary document for Chapter 7). Specifically, the study compared mean daily intakes of energy, macronutrients, and micronutrients between countries; quantified the prevalence of inadequacy for key nutrients against national thresholds; examined differences by gender (boys vs girls) and day type (weekday vs weekend); and identified independent predictors of adequacy (country, age, sex, day type) using multivariable models. While absolute nutrient intakes were directly compared between countries, dietary adequacy was assessed using country-specific reference standards to ensure contextually appropriate evaluation and avoid misclassification across populations (Institute of Medicine (US), 2000).

7.2. Methods

7.2.1. Study design

This is a cross-sectional evaluation of nutrient intake and dietary adequacy among school-aged children 9-to-13-year-olds in SL and NZ. Dietary intake data were collected using the 24-MPR method, administered by trained personnel in both countries. The recalls were conducted on school days and weekends, with the assistance of parents or guardians, as needed, to ensure accuracy in reporting.

7.2.2. Ethical consideration

Children and parents or caregivers were informed about the study through written and verbal communication. Children provided verbal assent, while their parents or caregivers gave written consent. Researchers underwent police vetting to ensure the safety of children. All procedures were reviewed and approved by the Massey University Human Ethics Committee, accredited by the Health Research Council, under protocols Application OMI 23/46 for the NZ study and

Application NOR22/16 for the SL study. Students were recruited in approximately equal numbers of boys and girls (self-identified).

7.2.3. Study setting and participants

To meet our exploratory research objectives, we adopted a feasibility-limited approach, based on the availability of participants and human fiscal resources. A minimum sample size of 31 participants per group was established for this research, assuming a minimum moderate correlation between groups of 0.5 for this cross-sectional design, consistent with commonly applied effect size assumptions in exploratory and behavioural research, as per the sample size estimation spreadsheet (Hopkins, 2000), and anticipating a dropout rate of 10%. Interest in study participation, coupled with resource limitations, permitted recruitment of n=32 in NZ and n=99 in SL.

Participants aged 9-to-13 years living in Auckland, NZ, were mainly recruited through schools and related networks, using advertising flyers in community locations and posts on Facebook community groups. This age group was chosen because evidence suggests that children from the age of nine can reliably complete a 24-MPR with minimal adult support (Burrows et al., 2010) , although previous research also indicates that children under 10 years may have limitations in self-report accuracy (Foster et al., 2019). Accordingly, interviewer guidance and limited parental assistance were incorporated in this study to support recall accuracy while maintaining consistency in data collection. Inclusion criteria comprised children residing in Auckland and attending school, along with a parent or caregiver willing and able to complete a weighted food record (WFR) after researcher training.

Recruitment initially focused on schools with high equity index values – indicating greater socioeconomic barriers to learning - as part of a purposive sampling strategy to capture variability in socioeconomic conditions within NZ. Although NZ is classified as a high-income country, it exhibits marked within-country disparities, and including schools with higher levels of socioeconomic disadvantage enabled a more meaningful comparison with the SL context. However, of the 10 high-EQI schools randomly selected and contacted, only two agreed to participate, yielding five participants from one school and none from the other. Consequently, without EQI restrictions, a further 34 Auckland schools were randomly selected and contacted, of which two agreed to support recruitment, resulting in 23 consenting parents. To increase sample size, recruitment was extended beyond schools through social media and community notice boards, generating 16 expressions of interest, of which 13 parents provided written consent. In total, 36 children were enrolled in the study.

In SL, randomly selected National Schools in the Ratnapura District were invited to participate. Permission was obtained from the Ministry of Education and the Sabaragamuwa Provincial Education Director. The principals of the selected schools were informed about the study, and ten schools agreed to participate. Each school held a parent meeting where the study objectives and methods were explained, questions were answered, and information sheets, along with consent forms, were distributed. Parents either gave their consent at the meeting or submitted their forms within a week. A total of 121 parents provided written consent.

7.2.4. Data collection procedures

Each consenting parent was contacted and briefed on the study, receiving measurement tools and documents at the first meeting. Two home visits were scheduled, one on a school day and

one on a non-school day. Two interviewers in NZ and six in SL were trained to use 24-MPR using a standardised protocol, ensuring consistency across countries. Interviews were conducted in the participants' native language (Sinhala/Tamil in SL; English in NZ) using the same transcript.

Dietary assessment using the 24-MPR involved three passes: (1) a quick food recall, (2) a detailed recall with prompts (time, place, brand, amount), and (3) reviewing the detailed list and filling in any gaps. To improve the accuracy of food portion size estimation the SL Food Atlas (Jayawardena, 2019), Play-Dough, and a photographic atlas of food portion sizes previously adapted for use in *Life and Living to Advanced Age: a Cohort Study* in NZ (LiLACS NZ) (Nelson et al., 1997) were used. Parent support was sought for cooking methods, recipes, and product brand names. Children who purchased their lunch drew their meals and kept a diary; missing details were obtained from canteens or suppliers.

7.2.5. Nutrient intake analysis

Reported food intake was converted into nutrient values using country-specific dietary analysis tools: FoodWorks for NZ (Foodworks 2.0, Xyris, Sydney, NSW) and FoodBase software for SL (FoodBase 2000; Institute of Brain Chemistry, University of London, UK). FoodWorks utilises the NZ Food Composition Database, a comprehensive and regularly updated resource maintained by the Ministry of Health and Plant and Food Research (Ministry of Health & Plant & Food Research, 2024). For SL, a nutrient analysis was conducted using FoodBase 2000 software, a locally adapted nutrition analysis software developed by the Department of Applied Nutrition at Wayamba University of SL. FoodBase is specifically designed to reflect the diversity and specificity of SL cuisine (Thamilini, 2014). The database is continuously updated with new data from laboratory analyses, standardised recipes, and nutrient profiles of commonly consumed cooked foods. It also incorporates international food composition databases (such as USDA, ASEAN, and Indian FCTs) and published and unpublished research findings (Thamilini, 2014). When a food item was not available in the respective databases, researchers employed strategies such as recipe calculations, substitution with similar foods, or manual entry of nutrient data from product labels or manufacturer websites to help minimise data gaps and ensure comprehensive nutrient profiling.

Nutrient Reference Values.

For SL, the Dietary Reference Intakes (DRI) (Department of Nutrition SL, 2022) include four reference standards: the Average Requirement (AR), the Recommended Dietary Allowance (RDA), the Adequate Intake (AI), and the Tolerable Upper Intake Level (UL), as detailed in appendix 2.3 (Supplementary document for Chapter 7). For NZ, the Nutrient Reference Values for Australia and NZ, published by the National Health and Medical Research Council (NHMRC) in 2017, provide comprehensive recommendations including estimated average requirement (EAR), Recommended Dietary Intake (RDI), Adequate Intake (AI), and Upper Intake Levels (UL) (National Health and Medical Research Council (NHMRC), 2017).

The EAR (the AR, equivalent to the EAR in international terminology) is the recommended standard for evaluating the daily intake level estimated to meet the requirements of 50% of healthy individuals in a specific age and gender group. In the absence of an EAR, the AI is used, with the understanding that intakes below the AI cannot be definitively classified as inadequate (Department of Nutrition SL, 2022; National Health and Medical Research Council (NHMRC), 2017).

This study primarily used EAR/AR to assess the inadequate nutrient intake among individual children 9-to-13-years-old, applying AI when necessary. Intake recommendations diverge by sex from age 9 (National Health and Medical Research Council (NHMRC), 2017), which was considered in the analysis. Nutrients for which individual dietary intake is not a reliable indicator of physiological status, such as sodium and vitamin D, were excluded from the analysis. Sodium intake cannot be accurately estimated from dietary recalls due to discretionary salt use and limitations in food composition databases (University of Otago and Ministry of Health NZ, 2011), while vitamin D status is primarily determined by sunlight exposure and best assessed using serum 25(OH)D concentrations (Delshad, 2019). Therefore, only relevant nutrients for which dietary intake is an appropriate proxy for adequacy were included.

7.2.6. Statistical analysis

Nutrient intake data from children 9-to-13-years-old in SL and NZ were analysed to explore differences across countries. Descriptive statistics, including means and standard deviations (SD), were calculated for each nutrient. Since data collection included one weekday and one weekend day per participant, the average daily intake was weighted: weekday intake was multiplied by 5, and weekend intake by 2. Independent samples t-tests were used to compare nutrient intakes between groups. (For each comparison, p-value (with statistical significance set at $p < 0.05$), mean difference, and the 95% confidence interval (CI) bounds were reported to assess statistical significance and the magnitude of differences.)

The following criteria were used to assess the percentage of recommendations met,

$$Percent\ of\ recomendation\ met = \frac{Actual\ Daily\ Intake}{Dietary\ Reference\ Intake} \times 100$$

If the percentage of criteria met was ≥100% (i.e., either met or exceeded the recommendation), it was classified as having met the recommendation; otherwise, it was classified as not meeting the recommendation, indicated by the percentage of risk-related intake (Refer to Appendix 7.A for NZ RDI values and Appendix 7.B for SL RDI values).

To examine the factors associated with nutrient adequacy, a multivariate logistic regression model was developed using nutrient intake-to-recommendation ratios, with adequate versus inadequate as the binary outcome. The model included four key predictor variables: gender (male/female), day of dietary recall (weekday/weekend), country (SL/NZ), and age (continuous).

Model fit was evaluated using McFadden's R^2 and the Akaike Information Criterion (AIC). McFadden's R^2 is a pseudo-R^2 metric commonly used in logistic regression, where values between 0.2 and 0.4 indicate an excellent fit (McFadden, 1974). AIC was used to assess model parsimony by balancing goodness of fit with model complexity; lower AIC values indicate a relatively better-fitting model (Akaike, 1974). Both metrics were considered together to provide a comprehensive evaluation of model performance. Odds ratios (OR) with 95% confidence intervals (CI) and p-values were reported for each predictor, with statistical significance set at $p < 0.05$. To explore potential effect modification by country, interaction terms (Gender × Country, Age × Country, and Day × Country) were incorporated into the models, and coefficients for these interactions were examined to determine whether the associations between predictors and nutrient adequacy differed between SL and NZ. Analyses were conducted using R software, version 4.4.1 (R Core Team, 2024).

7.3. Results

A total of 121 students from SL schools initially provided informed consent to participate in the study. However, eight participants were excluded as their parents could not schedule appointments within the designated data collection period. An additional 14 participants were excluded due to incomplete data collection, resulting in a final sample of 99 participants from SL.

In NZ, 36 participants were initially enrolled. Of these, 32 completed the full study protocol. Two participants withdrew for personal reasons, and two were excluded for non-compliance with the study methodology. Table 7.1 summarises the general demographic of the final sample included in the analysis from both SL and NZ.

Table 7.1. Participant demographics (aged 9–13 years), by country.

	SL (n=99)	**NZ (n=32)**	**Total (n=131)**
Female	58 (59%)	12 (38%)	70 (53%)
Male	41 (41%)	20 (62%)	61 (47%)

NZ-New Zealand, SL-Sri Lanka

Notes: Values are n (%). Between-country comparison of sex distribution: $\chi^2(1)=3.52$, $p=0.061$.

Table 7.2 presents a comparison of nutrient intake between NZ and SL schoolchildren, revealing statistically significant differences for most nutrients assessed ($p < 0.05$). Children in NZ had significantly higher intakes of energy, protein, total fat, dietary fibre, calcium, iron, magnesium, potassium, zinc, iodine, selenium, thiamine, riboflavin, niacin, vitamin B_6, vitamin B_{12}, vitamin C, and vitamin E. In contrast, SL children had significantly higher intakes of copper. No significant differences in carbohydrate or vitamin A intake were observed between the two cohorts.

Weekday–weekend comparisons showed distinct patterns within each country (Table 7.2). Among SL schoolchildren, intakes of protein, total fat, potassium, copper, thiamine, and vitamin E were significantly higher on weekdays compared to weekends ($p<0.05$). For NZ schoolchildren, calcium, thiamine, riboflavin, and vitamin B_6 intakes were also significantly higher on weekdays than weekends ($p<0.05$). For energy and most other nutrients, including carbohydrates, and several vitamins and minerals, no significant differences were found across weekdays and weekends in either context.

The prevalence of nutrient intake below the EAR or AI among schoolchildren aged 9–13 years is presented in Table 7.3. A high proportion of SL schoolchildren had inadequate intakes of several nutrients (Table 7.3). Among 7–10-year-olds, energy inadequacy affected 87% of females and all males, while inadequacies in dietary fibre, calcium, magnesium, potassium, zinc, and iodine were nearly widespread (>90%). Iron inadequacy was also significant (71–83%). Similar patterns were seen in 11–14-year-olds, with energy inadequacy exceeding 97% and widespread shortfalls in fibre, calcium, magnesium and potassium. In contrast, NZ children showed no inadequacy in total energy intake and protein. However, notable inadequacy showed in dietary fibre (42–45%) and calcium (42–50%). Magnesium and potassium inadequacy ranged from 20–67%, while vitamin A inadequacy was relatively high (80–92%). Overall, nutrient intake patterns and the prevalence of inadequacies were broadly similar between males and females in both SL and NZ (Appendix 2.3 supplementary documents for Chapter 7, Tables

7C and 7D), with only minor differences observed, such as slightly higher vitamin B_6 intake among SL males compared to females.

Significant cross-national differences were observed in nutrient adequacy ratios, with NZ children consistently achieving higher intake-to-recommendation (EAR or AI) than their SL counterparts for most nutrients (Table 7.4). The most significant disparities were evident for protein, iron, several B vitamins, and vitamin C. In contrast, SL children had relatively higher adequacy for copper, while vitamin A showed no meaningful difference between countri

Table 7.2. Day-wise comparison of daily nutrient intake among SL and NZ schoolchildren.

Nutrient	(Weekday – Weekend) SL (n=99)				(Weekday – Weekend) NZ (n=32)				(NZ – SL)			
	Weekday Mean (SD)	Weekend Mean (SD)	Mean Dif (95% CI: Lower, Upper)	p-value	Weekday Mean (SD)	Weekend Mean (SD)	Mean Dif (95% CI: Lower, Upper)	p-value	NZ Mean (SD)	SL Mean (SD)	Mean Dif (95% CI: Lower, Upper)	p-value
Energy (kcal)	1566 (396)	1500 (392)	67 (-29, 162)	0.17	2145 (514)	2126 (615)	20 (-199, 238)	0.86	2140 (471)	1547 (331)	592 (411, 773)	<0.01
Carbohydrate (g)	250 (67)	246 (69)	3.6 (-14, 21)	0.69	253 (60)	245 (84)	7.8 (-18, 34)	0.54	251 (60)	249 (55)	2.2 (-22, 26)	0.85
Protein (g)	50 (14)	45 (15)	4.7 (1.0, 8.5)	0.01	88 (31)	82 (31)	5.3 (-5, 16)	0.32	86 (28)	48 (12)	38 (27, 48)	<0.01
Total fat (g)	40 (17)	36 (15)	3.8 (0.2, 7.4)	0.04	81 (26)	85 (30)	-3.9 (-17, 9.5)	0.56	82 (21)	38 (14)	44 (36, 52)	<0.01
Dietary fibre (g)	6.7 (4.3)	6.7 (4.8)	0.0 (-1.1, 1.1)	0.98	25 (9.8)	22 (8.7)	2.9 (-1.1, 6.9)	0.15	24 (8.1)	6.7 (3.7)	17 (14, 20)	<0.01
Calcium (mg)	258 (147)	259 (189)	-1.8 (-42, 38)	0.93	932 (493)	714 (399)	218 (45, 391)	0.02	869 (415)	258 (132)	611 (460, 763)	<0.01
Iron (mg)	9.2 (5.0)	9.0 (6.0)	0.1 (-1.1, 1.3)	0.85	13 (6.5)	11 (5.6)	0.8 (-1.7, 3.3)	0.51	12 (5.4)	9.1 (4.6)	2.7 (0.6, 4.8)	0.01
Magnesium (mg)	115 (58)	105 (64)	10.0 (-7.1, 27)	0.25	261 (98)	238 (95)	23 (-9.4, 55)	0.16	254 (88)	112 (46)	142 (109, 175)	<0.01
Potassium (mg)	1280 (516)	1143 (496)	137 (15, 260)	0.03	2591 (1025)	2239 (813)	351 (-25, 727)	0.07	2490 (847)	1241 (428)	1249 (933, 1565)	<0.01
Zinc (mg)	3.9 (1.8)	3.7 (2.0)	0.2 (-0.2, 0.7)	0.33	8.9 (3.8)	8.5 (3.7)	0.4 (-1.0, 1.8)	0.58	8.8 (3.3)	3.8 (1.6)	5.0 (3.7, 6.2)	<0.01
Iodine (µg)	40 (37)	35 (35)	5.0 (-2.3, 12)	0.18	139 (173)	120 (72)	19 (-41, 79)	0.52	134 (131)	39 (32)	95 (47, 142)	<0.01
Selenium (µg)	37 (25)	33 (23)	4.4 (-1.7, 10.4)	0.16	50 (38)	49 (32)	1.6 (-10.2, 13)	0.79	50 (33)	36 (20)	14 (1.5, 27)	0.03
Copper (mg)	0.7 (0.3)	0.6 (0.3)	0.1 (0.0, 0.2)	0.02	0.1 (0.2)	0.1 (0.1)	0.1 (0.0, 0.1)	0.20	0.1 (0.1)	0.7 (0.3)	-0.5 (-0.6, -0.4)	<0.01
Vitamin A (µg)	245 (225)	209 (244)	36 (-18, 90)	0.19	276 (221)	185 (164)	92 (-7.3, 190)	0.07	250 (165)	235 (195)	15 (-55, 86)	0.67
Thiamin (mg)	0.7 (0.4)	0.6 (0.3)	0.1 (0.0, 0.2)	0.04	2.0 (1.5)	1.5 (1.0)	0.5 (0.1, 1.0)	0.03	1.9 (1.2)	0.6 (0.3)	1.2 (0.8, 1.7)	<0.01
Riboflavin (mg)	1.1 (2.0)	1.1 (2.1)	0.0 (-0.4, 0.5)	0.89	1.9 (1.1)	1.5 (0.8)	0.5 (0.1, 0.8)	0.01	1.8 (1.0)	1.1 (1.8)	0.7 (0.2, 1.2)	0.01
Niacin (mg)	13 (3.8)	12 (4.9)	1.0 (0.0, 2.1)	0.06	17 (8.2)	16 (8.3)	1.2 (-2.2, 4.5)	0.48	16 (7.1)	12 (3.4)	4.1 (1.5, 6.7)	<0.01
Vitamin B_6 (mg)	1.1 (1.4)	1.3 (1.8)	-0.2 (-0.6, 0.3)	0.45	1.9 (0.9)	1.4 (0.7)	0.5 (0.1, 0.8)	0.01	1.7 (0.7)	1.2 (1.2)	0.6 (0.2, 0.9)	<0.01
Vitamin B_{12} (µg)	1.5 (1.1)	1.3 (1.5)	0.2 (-0.1, 0.6)	0.23	4.2 (3.8)	3.1 (2.1)	1.1 (-0.1, 2.4)	0.08	3.9 (3.0)	1.4 (1.0)	2.5 (1.3, 3.6)	<0.01
Vitamin C (mg)	30 (34)	30 (42)	-0.1 (-11, 10.4)	0.98	82 (60)	74 (108)	8.3 (-33, 50)	0.69	80 (56)	30 (28)	50 (29, 71)	<0.01
Vitamin E (mg)	3.3 (4.8)	2.2 (3.5)	1.1 (0.0, 2.1)	0.05	8.1 (4.6)	7.3 (3.2)	0.8 (-0.9, 2.6)	0.34	7.9 (3.6)	3.0 (3.8)	4.9 (3.4, 6.4)	<0.01

SL- Sri Lanka, NZ- New Zealand, SD – Standard Deviation, Mean Dif – Mean Difference, CI – Confidence Interval

Table 7.3. Selected nutrient intake at risk among SL and NZ schoolchildren.

Nutrient	SL schoolchildren aged 7- 10			SL schoolchildren aged 11- 14			NZ schoolchildren aged 9 – 13 (n=32)		
	Female - SL % Intake at Risk (AI or EAR) (SE)	Male - SL % Intake at Risk (AI or EAR) (SE)	p-value	Female - SL % Intake at Risk (AI or EAR) (SE)	Male -SL % Intake at Risk (AI or EAR) (SE)	p-value	Female - NZ % Intake at Risk (AI or EAR) (SE)	Male - NZ % Intake at Risk (AI or EAR) (SE)	p-value
Energy (kcal)	87 (5.7)	100 (0.0)	0.54	97 (3.4)	100 (0.0)	1.00	NA	NA	NA
Protein (g)	3.5 (3.4)	0.0 (0.0)	1.00	0 (0)	7.4 (5.0)	0.44	0.0 (0.0)	0.0 (0.0)	NA
Dietary fibre (g)	100 (0.0)	100 (0.0)	NA	100 (0.0)	100 (0.0)	NA	42 (14)	45 (11.1)	1.00
Calcium (mg)	97 (3.4)	93 (6.9)	1.00	100 (0.0)	100 (0.0)	NA	42 (14)	50 (11.2)	0.93
Iron (mg)	83 (7.0)	71 (12)	0.65	83 (7.0)	89 (6.1)	0.79	8.3 (8.0)	10.0 (6.7)	1.00
Magnesium (mg)	100 (0.0)	100 (0.0)	NA	97 (3.4)	96 (3.6)	1.00	42 (14)	20 (8.9)	0.36
Potassium (mg)	93 (4.7)	93 (6.9)	1.00	97 (3.4)	96 (3.6)	1.00	67 (14)	65 (10.7)	1.00
Zinc (mg)	90 (5.7)	93 (6.9)	1.00	100 (0.0)	100 (0.0)	NA	17 (10.8)	10.0 (6.7)	1.00
Iodine (µg)	90 (5.7)	86 (9.4)	1.00	100 (0.0)	100 (0.0)	NA	25 (13)	15 (8.0)	0.82
Selenium (µg)	55 (9.2)	50 (13)	1.00	79 (7.5)	78 (8.0)	1.00	33 (14)	65 (10.7)	0.17
Copper (mg)	93 (4.7)	86 (9.3)	0.83	97 (3.4)	96 (3.6)	1.00	100 (0.0)	100 (0.0)	NA
Vitamin A (µg)	66 (8.8)	71 (12)	0.97	93 (4.7)	93 (5.0)	1.00	92 (8.0)	80 (8.9)	0.71
Thiamine (mg)	59 (9.2)	57 (13)	1.00	93 (4.7)	89 (6.1)	0.93	8.3 (8.0)	0.0 (0.0)	0.79
Riboflavin (mg)	66 (8.8)	71 (12)	0.97	76 (8.0)	89 (6.1)	0.36	8.3 (8.0)	10.0 (6.7)	1.00
Niacin (mg)	34 (8.8)	14 (9.4)	0.31	34 (8.8)	62 (9.3)	0.06	25 (13)	10.0 (6.7)	0.53
Vitamin B_6 (mg)	66 (8.8)	79 (11.0)	0.60	59 (9.1)	74 (8.4)	0.35	17 (10.8)	5.0 (4.9)	0.64
Vitamin B_{12} (µg)	83 (7.0)	100 (0.0)	0.25	97 (3.4)	89 (6.1)	0.55	17 (10.8)	15 (8.0)	1.00
Vitamin C (mg)	72 (8.3)	86 (9.4)	0.56	90 (5.7)	89 (6.1)	1.00	17 (10.8)	10.0 (6.7)	1.00

SL-Sri Lanka, NZ-New Zealand, AI- Adequate Intake, EAR – Estimated Average Requirement, DRI – Dietary Reference Intake, SE- Standard Error
Note: Values indicate the percentage of children with intake below the DRI. Percent at risk was calculated as: Actual Daily Intake/DRI×100.
Intake <100% of DRI was classified as "at risk." Inadequacy was assessed using EAR, or AI where EAR was unavailable.

Table 7.4. Cross-national comparison of nutrient adequacy using intake-to-recommendation ratios based on EAR or AI.

Nutrient	Intake-to-Recommendation Ratios			
	NZ (n=32) Mean (SD)	SL (n=99) Mean (SD)	Mean Dif: (95% CI Lower, Upper)	p-value
Protein (g)	3.1 (1.1)	2.0 (0.6)	1.1 (0.7, 1.5)	<0.01
Dietary fibre (g)	1.1 (0.3)	0.4 (0.2)	0.7 (0.6, 0.8)	<0.01
Calcium (mg)	1.1 (0.5)	0.4 (0.2)	0.7 (0.5, 0.9)	<0.01
Iron (mg)	2.0 (0.9)	0.7 (0.3)	1.3 (0.9, 1.6)	<0.01
Magnesium (mg)	1.3 (0.4)	0.5 (0.2)	0.8 (0.6, 0.9)	<0.01
Potassium (mg)	0.9 (0.3)	0.6 (0.2)	0.3 (0.2, 0.4)	<0.01
Zinc (mg)	1.8 (0.7)	0.5 (0.2)	1.2 (1.0, 1.5)	<0.01
Iodine (µg)	1.8 (1.7)	0.4 (0.3)	1.4 (0.8, 2.0)	<0.01
Selenium (µg)	1.2 (0.8)	0.8 (0.5)	0.4 (0.1, 0.7)	0.01
Copper (mg)	0.1 (0.1)	0.6 (0.2)	-0.5 (-0.6, -0.4)	<0.01
Vitamin A (µg)	0.6 (0.4)	0.6 (0.6)	0.0 (-0.2, 0.1)	0.65
Thiamin (mg)	2.7 (1.7)	0.8 (0.4)	1.9 (1.3, 2.5)	<0.01
Riboflavin (mg)	2.2 (1.2)	1.1 (1.8)	1.1 (0.5, 1.6)	<0.01
Niacin (mg)	1.8 (0.8)	1.1 (0.3)	0.7 (0.5, 1.0)	<0.01
Vitamin B_6 (mg)	2.2 (0.9)	1.1 (1.1)	1.1 (0.7, 1.5)	<0.01
Vitamin B_{12} (µg)	2.6 (2.0)	0.5 (0.3)	2.1 (1.4, 2.8)	<0.01
Vitamin C (mg)	2.9 (2.0)	0.6 (0.6)	2.2 (1.5, 3.0)	<0.01

SL-Sri Lanka, NZ-New Zealand, EAR – Estimated Average Requirement, AI – Adequate Intake, SD – Standard Deviation, Mean Dif – Mean Difference, CI – Confidence Interval, DRI – Dietary Reference Intake
Note: Intake-to-recommendation ratio was calculated as: Actual Daily Intake/DRI
DRI was based on the EAR for most nutrients and AI where EAR was unavailable. Ratios >1 indicate intake met or exceeded the recommendation; ratios <1 indicate intake below the recommendation.

The regression analysis (Table 7.5) showed that country was the most consistent predictor of nutrient intake, with SL significantly associated with lower intakes across most nutrients compared to NZ. Age and day type (weekday vs weekend) were also significant predictors for selected nutrients, indicating some variation in intake patterns by age group and day of consumption. Overall, these findings highlight that cross-country differences were the primary driver of variation in nutrient intake, with additional contributions from behavioural and demographic factors.

Table 7.5. Summary of logistic regression models fit evaluation for nutrient adequacy

Nutrient	McFadden R^2	AIC	Significant Predictors	Interpretation
Protein (g)	0.07	32	None	Weak model fit.
Dietary fibre (g)	0.28	173	CountrySL	Excellent model fit.
Calcium (mg)	0.15	236	CountrySL	Moderate model fit.
Iron (mg)	0.23	283	Age, CountrySL	Excellent model fit.
Magnesium (mg)	0.38	174	CountrySL	Excellent model fit.
Potassium (mg)	0.12	205	Age, CountrySL	Moderate model fit.
Zinc (mg)	0.36	208	CountrySL	Excellent model fit.
Iodine (µg)	0.37	191	Age, CountrySL	Excellent model fit.
Selenium (µg)	0.00	361	None	Weak model fit.
Copper (mg)	0.11	124	DayWeekend	Moderate model fit.
Vitamin A (µg)	0.01	259	None	Weak model fit.
Thiamin (mg)	0.17	312	CountrySL	moderate model fit.
Riboflavin (mg)	0.17	304	CountrySL	Moderate model fit.
Niacin (mg)	0.04	326	CountrySL, DayWeekend	Weak model fit.
Vitamin B_6 (mg)	0.23	282	Age, CountrySL	Excellent model fit.
Vitamin B_{12} (µg)	0.31	227	CountrySL	Excellent model fit.
Vitamin C (mg)	0.17	278	CountrySL	Moderate model fit.

Each model examines the association between nutrient adequacy (based on intake-to-recommendation ratios) and the predictors: gender (male/female), day of dietary recall (weekday/weekend), country (SL/NZ), and age. A value between 0.2 and 0.4 is generally considered an excellent fit; however, values below 0.2 may still be acceptable, especially in fields such as social or health sciences, where predicting outcomes is more complex. A value of 0 indicates the model is no better than the null model, while a value of 1 suggests perfect prediction (McFadden, 1974).
AIC - Akaike Information Criterion

The heatmap (Figure 7.1) illustrates which predictors were statistically significant ($p < 0.05$) in multivariate logistic regression models for different nutrients, with detailed model outputs provided in Appendix 2.3 Supplementary documents for Chapter 7, Table 7E. Country (SL) emerged as the most consistent and strongest predictor, with children in SL showing a higher likelihood of nutrient inadequacy across most nutrients compared to NZ. Age was a significant predictor for selected nutrients (including iron, potassium, iodine, and vitamin B_6), with older children generally exhibiting higher risk of inadequacy. Day type (weekday vs weekend) was significant only for a limited number of nutrients, with weekend intake associated with a slightly higher likelihood of inadequacy for nutrients such as copper and niacin. Gender was not a significant predictor for any of the nutrients.

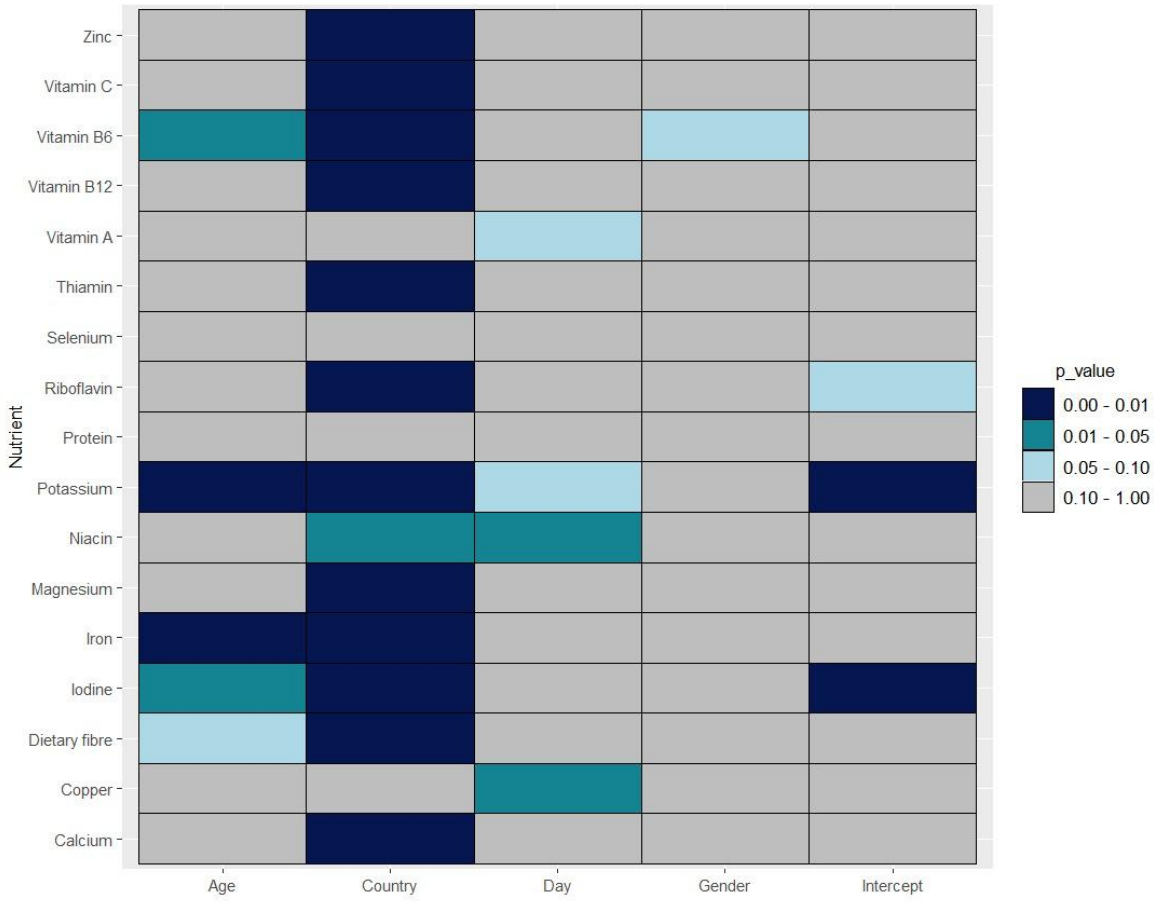


Figure 7.1. Heatmap of nutrient adequacy predictors among schoolchildren in SL and NZ.

Note: The heatmap displays p-value categories for associations between nutrients and predictors (Age (9-13 years), Country (SL-Sri Lanka and NZ-New Zealand), Day type (Weekend and Weekday), Gender (male and female)). Darker shades indicate stronger significance ($p < 0.01$), lighter shades indicate weaker significance. This figure summarises statistical significance patterns; however, p-values do not reflect the magnitude or direction of associations, and detailed effect estimates are presented in Appendix 2.3 (Table 7E).

7.4. Discussion

This study compared the nutrient intake and dietary adequacy of schoolchildren from SL and NZ, two countries representing distinct socioeconomic and nutrition-transition contexts. In this

bi-national convenience sample of 9–13-year-olds, NZ children consumed substantially more total energy and several key nutrients than SL peers, with the largest absolute differences observed for total fat (~+44 g/day), protein (~+38 g/day), fibre (~+17 g/day), calcium (~+611 mg/day), zinc (~+5 mg/day), iodine (~+95 µg/day), and vitamin B_{12} (~+2.5 µg/day). Prevalence of inadequacy in SL was widespread, particularly for fibre, magnesium, calcium, zinc, and iodine, whereas NZ inadequacies were apparent for vitamin A and copper despite high protein intakes. Diets were more nutrient-dense on weekdays than weekends in both settings, with weekend intake generally associated with a higher likelihood of nutrient inadequacy for selected nutrients. Multivariable models further identified country of residence as the dominant predictor, with children in SL consistently showing a higher risk of nutrient inadequacy compared to those in NZ. Age also exerted nutrient specific effects, with older children generally exhibiting a greater likelihood of inadequacy for selected nutrients, while no consistence differences were observed by sex. These findings illustrate the global "double burden" of malnutrition, with persistent nutrient deficiencies in developing contexts and nutrient excesses alongside diet-quality gaps in developed settings.

The adequacy of most nutrients among NZ children was higher than SL children, reflecting disparities between high- and low-income contexts. This pattern aligns with global evidence showing that children in high-income countries often meet or exceed energy intake requirements (Diethelm et al., 2014; Kutbi, 2021; López-Sobaler et al., 2019), while those in LMICs frequently fall short (Poh et al., 2013; Rojroongwasinkul et al., 2013; Sandjaja et al., 2013). In our study, across most nutrients, NZ children exceeded the EAR, consistent with the country's diverse food supply and widespread fortification policies (Ministry of Health & Plant & Food Research, 2024). But persistence gaps in copper, potassium, calcium, fibre and vitamin A inadequacy affected most children, aligning with previous reports highlighting insufficient fruit, vegetable, and dairy intake among NZ children (Metcalf et al., 2006). Soil-related deficiencies (selenium, iodine) and dietary patterns dominated by processed foods contribute to these gaps (Health New Zealand, 2024). Despite being a high-income country, food insecurity affects 25% of NZ households with children, influencing diet quality (Katiforis et al., 2023).

In contrast, SL children showed widespread inadequacy across nearly all micronutrients, with universal shortfalls for dietary fibre, and magnesium and over 85% inadequacy for calcium, zinc, and iodine. These shortages align with national surveys reporting persistent micronutrient deficiencies (Medical Research Institute, 2023). These findings indicate limited dietary diversity, a reliance on rice, and low intake of dairy and fortified foods in SL. The 2022 economic crisis and 95% food inflation worsened dietary deficiencies by reducing access to nutritious foods. (Selvarasa & Kalainathan, 2025). Despite adequate carbohydrate intake, total energy intake in SL children was frequently below recommended levels, while protein intake, although lower than in NZ, generally remained adequate. These findings suggest that dietary challenges among SL children are driven more by overall energy deficits and micronutrient inadequacies than by insufficient protein intake. Such inadequacies have implications for growth, immune function, and cognitive performance (Kehoe et al., 2022; Saavedra & Prentice, 2023).

In both countries, weekday diets were more nutrient-dense than weekend diets, reflecting the positive influence of structured school-day meals (Esposito et al., 2022). In SL, protein, fat, potassium, thiamine, and vitamin E were significantly higher mid-week, likely due to home-prepared lunches aligned with school meal policies (Ministry of Education Sri Lanka, 2024).

New Zealand children showed higher weekday intakes of calcium, thiamin, riboflavin, and vitamin B_6, suggesting the stabilising effect of school environments where fruit, dairy, and grain snacks are encouraged (Ministry of Health New Zealand, 2021).

These findings align with global evidence. Australian children consume more fruits and vegetables on weekdays (Esposito et al., 2022); Danish adolescents have higher micronutrient intakes during school days (Rothausen et al., 2013); and better overall diet quality with lower discretionary food intake is observed mid-week (Dutch et al., 2021). Sugar-sweetened beverage intake doubles on weekends among Norwegian adolescents (Bjelland et al., 2011). Structured environments, scheduled meals, and regulated food options support balanced diets, while weekends often lack this structure, leading to irregular and less nutritious choices. School-based interventions further improve food choices and reduce diet-related risks (Mohammadi & Koo, 2025), highlighting the need to extend structured nutrition programmes into home and community settings (Sliwa et al., 2023).

Logistic regression analyses identified "country" as the most consistent predictor of nutrient adequacy across models, with children in SL demonstrating a higher likelihood of nutrient inadequacy compared to those in NZ, underscoring the influence of national food systems and socioeconomic conditions. Day type was significant for selected nutrients, such as niacin and copper, with weekend intake generally associated with a higher likelihood of inadequacy, reflecting temporal variations in diet quality. Age also emerged as a statistically significant predictor for specific nutrients; however, the direction of this association varied depending on the nutrient, although older children often showed a higher likelihood of inadequacy, potentially reflecting increased nutritional requirements during early adolescence.

Interpretation of the age effect should be made cautiously, as body weight and pubertal stage, both important determinants of nutrient requirements and metabolism, were not assessed. Given that the study population spans a transitional age range, including both prepubescent children and those at different stages of puberty, these unmeasured factors may confound the observed age-related associations. This developmental heterogeneity may also explain why no consistent gender differences were identified, as sex-specific nutritional needs tend to become more pronounced only in later stages of adolescence. Future studies should incorporate weight and other anthropometric measures better to isolate the independent effect of age on nutrient deficiencies. At the same time, gender was not a significant predictor for any of these nutrients. These associations reflect both biological and environmental influences, with younger SL children particularly vulnerable to multiple deficiencies. The relatively high McFadden R^2 values for dietary fibre, magnesium, and zinc models (0.28–0.38) suggest robust discrimination, indicating that differences between SL and NZ were strongest for these nutrients.

The pronounced disparities between SL and NZ children highlight divergent stages of nutrition transition. Sri Lanka faces a triple burden of malnutrition, characterised by the coexistence of undernutrition, micronutrient deficiencies, and overweight/obesity (World Food Programme, 2018). Diets remain heavily cereal-based and low in animal-source foods and fortified products (Weerahewa et al., 2020). Conversely, NZ reflects the later phase of the transition, characterised by high energy and insufficient micronutrient density despite overall dietary abundance (Men, 2024). Interventions should therefore be context-specific: in SL, prioritising school-meal fortification, dairy and legume promotion, and community-based nutrition education; in NZ, food-literacy programmes and increased consumption of nutrient-rich whole foods.

The modified interviewer-led 24-MPR used here was designed to support culturally appropriate and comparable data collection across contexts. This standardised approach enhances cross-country comparability, addressing limitations of previous studies that employed different dietary-assessment methods (Cade et al., 2017; Windus et al., 2025). However, while the 24-MPR is widely used in paediatric populations, its application across different cultural settings requires careful consideration, as variations in food practices, portion estimation, and familiarity with reporting tools may influence accuracy (Almiron-Roig et al., 2017; Amoutzopoulos et al., 2020). In addition, the method is subject to limitations, including recall bias and within-person variability, which should be considered when interpreting cross-country comparisons (Gibson et al., 2017a; Nel et al., 2022).

We recognised that some pupils were unfamiliar with brand names or cooking methods, which could compromise recall reliability; therefore, parental assistance was allowed only during the third pass of the 24-MPR to clarify these details without influencing portion sizes or adding foods. Additionally, familiarisation sessions were conducted before data collection to reinforce accurate food recall and portion estimation; measures that have been shown to enhance validity in paediatric nutrition research while reducing interviewer burden (Nightingale et al., 2016).

While the 24-MPR is widely regarded as appropriate for estimating dietary intake at the population level, its ability to accurately assess individual level intake, particularly for micronutrients, is limited due to day-to-day variation and recall error. Therefore, it is most suitable for group-level analyses, such as comparing mean intakes and identifying population-level differences between countries. In this study, estimates of nutrient inadequacy were derived from individual intake data; however, these prevalence estimates should be interpreted with caution, as they may be influenced by within-person variation and measurement error inherent in single-day recalls. Multiple-day assessments or biomarker validation would improve the precision of individual-level adequacy classification in future research.

The findings underscore the urgent need for school-based nutrition strategies that are tailored to the local socioeconomic contexts. For SL, improving dietary diversity and fortification (particularly of calcium, zinc, and iodine) within school-meal programmes could mitigate widespread deficiencies. Partnerships with agricultural and food industries to integrate fortified milk, eggs, and pulses into school lunches may yield sustainable benefits (Seneviratne et al., 2021). In NZ, strategies should focus on promoting balanced diets and reducing excessive energy and fat intake through reformulation and portion control (Ministry of Health NZ, 2020). Integrating nutrition education into the curriculum may also enhance food literacy and long-term dietary behaviours (Follong et al., 2022).

Strengths and Limitations

This study has several strengths. Using two context-specific nutrient databases improved accuracy by capturing both traditional SL and western-style foods. The standardised 24-MPR minimised recall bias, and the cross-national design offered insights into nutrient adequacy across distinct cultural and economic settings. Logistic regression further identified key predictors of adequacy.

Limitations include recruitment challenges in NZ, resulting in a small sample and reduced generalisability. As a cross-sectional analysis based on two recall days, intra-individual variability and recall bias remain possible (Baxter, 2009). Unequal sample sizes limited subgroup analyses, and the absence of biochemical validation restricts the interpretation of

functional adequacy. Differences between nutrient databases may have introduced variability, and reliance on a single recall per participant may not reflect usual intake. Finally, some models showed a weak fit, suggesting the need for additional predictors or repeated measures. Gender difference cannot be evaluated due to insufficient statistical power. While some international studies report higher intakes among boys (Galloway, 2007; Merkiel-Pawłowska & Chalcarz, 2017), others, such as Kutbi (2021), suggest that gender may not universally influence dietary intake during middle childhood. More adequately powered research is required to determine the nutrient adequacy in gender-wise comparisons between countries.

Although vitamin D and sodium intake were not assessed in this study because dietary intake is not a valid proxy for their physiological status, these nutrients remain critically important for public health investigation. Globally, vitamin D deficiency affects nearly half the population: 48% have serum 25(OH)D levels below 50 nmol/L, and 16% below 30 nmol/L, posing risks to bone and non-skeletal health outcomes (Cui et al., 2023). Similarly, excess sodium intake is a widespread concern, with the global average intake (4310 mg/day) more than double the WHO recommendation of less than 2000 mg/day, contributing to nearly 1.89 million deaths annually from cardiovascular and related diseases (World Health Organisation, 2023).

7.5. Conclusions and future directions

This comparative analysis highlights the coexistence of nutritional deficiency and excess across contrasting socioeconomic environments. While this convenience sample of NZ schoolchildren consumed more total energy and most nutrients than their SL counterparts, SL children demonstrated widespread inadequacy, most notably for fibre, magnesium, calcium, zinc, iodine and several vitamins, including vitamin A, vitamin B_1, vitamin B_2, vitamin B_6, vitamin B_{12} and vitamin C, reflecting pervasive dietary insufficiency rather than isolated nutrient deficiencies. Across both settings, weekday diets were more nutrient-dense than weekend diets, with no consistent differences by sex. Multivariable analyses identified country of residence as the principal determinant of dietary adequacy, with children in SL consistently showing a higher likelihood of nutrient inadequacy compared to those in NZ. Age and day type exerted nutrient-specific effects, with older children generally showing a higher likelihood of inadequacy for selected nutrients and weekend intake associated with increased risk of inadequacy for certain nutrients. Collectively, these findings support targeted fortification and diet diversification in SL and diet-quality improvements in NZ, alongside strategies that extend school-day nutrition supports into weekends. Future research should prioritise robust methods, such as incorporating biomarkers (e.g., 24-hour urinary sodium and serum 25(OH)D), to assess these nutrients, given their significant global burden.

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Chapter 8

General Discussion

This thesis aimed to evaluate and compare selected aspects of school food environments and physical activity (PA) behaviours among children aged 5–13 years in the Rathnapura District, Sri Lanka (SL) and the Auckland Region, New Zealand (NZ).

The primary research questions were:
(1) How do school food environments and PA behaviours differ between SL and NZ?
(2) How adequate are children's diets in these contexts?

Addressing these questions is important for informing school health policies and interventions in SL and NZ and may provide guidance for similar settings. Overall, this research demonstrates the feasibility of adapting tools and protocols developed in high-income settings for use in low- and middle-income contexts, providing valuable insights for future cross-country studies and policy development.

The research was linked to the Healthy Active Learning (HAL) initiative in NZ and explored the feasibility of conducting a complementary study in SL to enable cross-country comparisons. In addition to the HAL-related components, the study incorporated a dietary assessment using a modified 24-hour multiple-pass dietary recall (24-MPR) method, which was first validated for NZ children for reliability and accuracy. This validated tool was subsequently used in the SL context for the same age group (9–13 years) to ensure consistency in dietary data collection.

The study adopted a multi-component approach that included objective accelerometer-based PA measurement, assessment of children's subjective PA experiences, analysis of school food policies and practices, evaluation of food availability, and assessment of dietary adequacy. A methodological contribution was the validation and reliability testing of a modified 24-MPR protocol for NZ children.

This chapter synthesises findings across all studies, discusses implications for school health policy and practice, acknowledges limitations such as the pilot nature and sampling approach, and outlines directions for future research.

8.1. Summary of research questions and key findings

To achieve the overall research, aim of this thesis, five interconnected studies were conducted, each focusing on different aspects of school food environments, PA behaviours, and dietary adequacy in NZ and SL.

Research Question 1: What are the methodological challenges and gaps in using accelerometers to measure PA in Asian children?

The first literature review analysis study (**Chapter 3:** Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions: A Narrative Review) examined methodological challenges in using accelerometers to measure PA in Asian children. Most accelerometer cut-points and protocols were developed for Western

populations, with limited validation for Asian contexts, highlighting the need for culturally adapted measurement methods and informing the design of the SL component of this thesis.

Research Question 2: How do objectively measured PA patterns and children's perceptions of physical education differ between NZ and SL?

The first original research study (**Chapter 4**: Physical Activity Measurement and Perception in Schoolchildren in NZ and SL: a Pilot Study of a Developed vs a Developing Nation) compared objectively measured PA patterns and children's perceptions of physical education between a convenience sample of NZ and SL children. Sri Lankan children accumulated more moderate-to-vigorous physical activity (MVPA), while NZ children recorded higher step counts and greater sedentary time. NZ children also reported more positive attitudes toward PE and greater access to structured activities, whereas SL children relied on informal play and reported fewer opportunities. These findings demonstrate cross-country differences in PA behaviours and perceptions, informing context-specific strategies for school-based PA promotion.

Research Question 3: What are the differences in school food policies, practices, and food availability between NZ and SL schools?

The second original research study (**Chapter 5**: School Food Environment in Focus: Availability and Policy Practices in New Zealand and Sri Lanka – An Exploratory Study) examined school food policies, practices, and food availability in NZ and SL schools. New Zealand schools reported having written food policies, although updates were infrequent, while SL schools followed national canteen guidelines with weak compliance. Sri Lankan school canteens offered deep-fried foods and confectionery, whereas NZ schools provided packaged snacks and limited fruit. These findings identify policy and implementation gaps that influence school food environments in both countries.

Research Question 4: Is the modified 24-MPR recall valid and reliable for assessing dietary intake in NZ schoolchildren?

The third original research study (**Chapter 6**: Reliability and Validity of a Modified 24-MPR in New Zealand Schoolchildren) assessed the validity and reliability of a modified 24-MPR for NZ schoolchildren. The method showed good validity for energy and macronutrients and moderate reliability for some micronutrients, and its successful adaptation for SL demonstrated feasibility for cross-country comparability.

Research Question 5: How do nutrient intakes and dietary adequacy compare between NZ and SL schoolchildren aged 9–13 years?

The fourth original research study (**Chapter 7:** Comparative Evaluation of Nutrient Intakes and Dietary Adequacy Among Schoolchildren Aged 9-13 in Sri Lanka and New Zealand: An Exploratory Analysis) compared nutrient intakes and dietary adequacy among schoolchildren aged 9–13 years in NZ and SL. New Zealand children consumed more energy and most nutrients, whereas SL children showed widespread inadequacies in fibre, calcium, magnesium, zinc, and iodine. New Zealand's inadequacies were concentrated in vitamin A and fibre.

Collectively, addressing these research questions provided several key insights. The initial review of accelerometer-based PA assessment highlighted methodological challenges in

applying protocols developed for Western populations to Asian contexts, emphasising the need for culturally adapted approaches. Physical activity behaviours differed between countries: NZ children recorded higher step counts and had structured PA opportunities but also greater sedentary time, whereas SL children accumulated more MVPA through informal play. School food environments also varied; NZ schools had written food policies and healthier options, while SL schools followed national guidelines with weak compliance and offered more energy-dense foods. Dietary adequacy analysis revealed nutrient gaps in both contexts, with widespread inadequacies in fibre, calcium, iron, zinc, and iodine among SL children, and shortfalls in vitamin A and fibre among NZ children. A methodological contribution was the validation and reliability testing of a modified 24-MPR for NZ children, which was successfully adapted for SL, enabling cross-country dietary assessment. Overall, this research demonstrates the feasibility of adapting tools from high-income settings for use in low- and middle-income contexts and provides evidence to guide school health policies and interventions in both countries.

8.2. Advancing current understanding

This thesis advances knowledge on how school environments shape children's health behaviours by providing the first systematic comparison of PA behaviours, food environments, and dietary adequacy between a lower-middle-income South Asian country (SL) and a high-income Pacific nation (NZ). Research on school environments and children's health behaviours has predominantly focused on high-income countries (HIC), with limited attention to low- and middle-income contexts (LMIC) (Larson et al., 2020). This geographic bias limits understanding of how school climate influences student outcomes across diverse settings. Evidence suggests that schools shape students' health behaviours through factors such as supervision, teacher-student relationships, and students' sense of inclusion, all of which influence their response to health messages (Jamal et al., 2013). For example, studies in New South Wales, Australia, show that supportive school environments and positive teacher relationships are associated with healthier student behaviours (McLellan et al., 1999). Although international initiatives such as the Health Behaviour in School-aged Children survey include multiple countries, rigorous research on school climate in LMICs remains scarce, underscoring the need for more diverse, cross-cultural investigations (Inchley et al., 2020; Larson et al., 2020).

This thesis moves beyond traditional single-country or HICs-focused research by employing an integrated, multi-method approach. Combining objective PA measures, student PA perceptions and behaviours, school food environment policies and practices, and validated dietary assessment provides a broader view of child health within contrasting socio-economic contexts. This design aligns with global recommendations for extensive strategies to address childhood health disparities (Langford et al., 2015; World Health Organisation, 2021). A key methodological advance is the validation and cross-cultural application of a modified 24-MPR, enabling accurate and culturally relevant dietary data collection in both NZ and SL. This innovation not only addresses a critical gap in paediatric nutrition research but also establishes a framework for future comparative studies across diverse settings (Burrows et al., 2010; Thompson & Subar, 2017).

8.3. Integration of findings across themes

Cross-context differences in PA behaviours were evident. Sri Lankan children accumulated more MVPA, whereas NZ children recorded higher step counts but also greater sedentary time. These findings contrast with other research findings suggesting that adolescents in LMICs generally exhibit low PA (Li et al., 2024). Despite diverse opportunities for structured activities and active travel in NZ schools, sedentary time remained high, consistent with research linking modern schooling and screen exposure to reduced movement (Chaput et al., 2020; Smith et al., 2024). A notable pattern was the inverse relationship between infrastructure and activity: countries with poorer infrastructure demonstrate higher PA and lower sedentary behaviour than those with better infrastructure (Tremblay et al., 2014). In SL, higher MVPA likely reflects informal play and flexible classroom routines, although structured PE opportunities were scarce, similar to other LMICs where resource constraints hinder formal PE delivery (Hardman, 2008; Hasson et al., 2023).

According to the World Health Organisation, there are significant gender and age disparities in PA participation across different populations. Among youth, boys are consistently more active than girls, though gender differences in overall PA are modest (World Health Organisation, 2020). Physical activity levels decline rapidly with age during childhood and adolescence, with the largest decreases occurring between grades 1-3 and 4-6 (Trost et al., 2002; World Health Organisation, 2020). In our study, these patterns were evident in NZ, where older children and girls engaged in less MVPA, aligning with international trends. In contrast, in SL children there were minimal gender and age variation, suggesting that uniformly limited opportunities for structured PA may reduce socio-cultural differences. This finding highlights the role of environmental constraints in shaping activity patterns (Laddu et al., 2021). It emphasises the need for interventions that address both gender equity and age-related declines in PA across diverse contexts.

Self-reported data revealed marked cross-national differences in children's PA behaviours, consistent with global evidence that environmental and cultural contexts strongly shape activity patterns (Haug et al., 2021). In our study, active travel was more common in NZ than SL, aligning with international findings that walkable neighbourhoods and shorter school distances facilitate active commuting (Mandic et al., 2023; Oliver et al., 2014), while traffic safety concerns and urban design limit such opportunities in SL (Damsara et al., 2021). NZ children reported greater engagement in PA before school and during recess, supporting systematic reviews showing recess contributes significantly to daily MVPA when schools provide adequate space and equipment (Pulido Sánchez & Iglesias Gallego, 2021; Reilly et al., 2016). Conversely, SL children's reliance on light activity reflects similar patterns observed in resource-constrained settings where PE is undervalued and opportunities for structured play are limited (Hardman, 2005). According to our study, NZ schoolchildren engaged in organised activities on weekends, whereas SL schoolchildren engaged in informal family-based play. This reflects international trends where structured days, such as school weekdays, are associated with higher MVPA than weekends. For example, Canadian youth engage in approximately 30% less MVPA on weekends (Comte et al., 2013). Sri Lankan schoolchildren predominantly engage in informal physical activities on weekends due to systemic barriers, including limited access to sports facilities, a lack of structured programmes, and resource constraints within schools and communities (Wickramasinghe et al., 2009). Cultural norms and socioeconomic factors further restrict opportunities for organised sport, reinforcing reliance on family-based or home-centred play rather than structured, vigorous activity (Gulzar et al., 2025). Finally, teacher influence and cultural diversity in PE emerged as critical factors; our

findings are similar to other research in the literature, which emphasises culturally responsive curricula and teacher encouragement as predictors of positive attitudes and sustained participation (Vita, 2025). These results underscore the need for context-specific strategies that address infrastructural, cultural, and policy barriers to equitable PA opportunities.

Research demonstrates that effective school food policy implementation requires all-inclusive stakeholder engagement and robust monitoring frameworks (Nelson & Breda, 2013). The Avison and Joint Consortium for Schol Health (2010) study highlights that stakeholder involvement is critical throughout the policy process, including among school personnel, students, parents, health professionals, and industry representatives. In this study, school food policy frameworks in SL and NZ differ markedly, yet both face similar implementation challenges that reflect worldwide patterns. Sri Lanka's centralised school canteen policy was designed to restrict foods high in sugar, fat, and salt, but compliance was weak. Although most schools reported having food committees, these were largely inactive, with minimal monitoring or reporting. Similar enforcement gaps have been observed in India and Brazil, where resource limitations and profit-driven models undermine policy effectiveness (Gaetani & Ribeiro, 2015; Rathi & Worsley, 2021). In contrast, NZ schools operate under a decentralised system in which food policies are developed locally and adherence to national guidelines is voluntary. While over half of schools reported having a policy in our study, updates were infrequent, and enforcement mechanisms were absent, a pattern consistent with findings from Australia, where voluntary guidelines resulted in poor compliance (Woods et al., 2014; Yoong et al., 2016). These findings align with international evidence showing that policy design alone is insufficient; success depends on strong monitoring, stakeholder engagement, and adaptation to socio-economic realities (Durão et al., 2023; World Health Organisation - food policy, 2021). Persistent barriers such as limited resources, financial dependence on unhealthy food sales, and parental preferences highlight the need for stronger accountability systems and culturally tailored strategies in both contexts.

Food availability patterns reflected these policy gaps and revealed contrasting challenges across contexts. In SL, deep-fried snacks, confectionery, and sweetened dairy beverages were widely available despite policy restrictions, similar to findings from other LMICs, where enforcement failures allow unhealthy foods to dominate school menus (Ronto et al., 2020). In NZ, fried foods and confectionery were absent, yet packaged snack foods were highly prevalent, and fruit availability was limited. This reliance on ultra-processed items suggests that voluntary guidelines and school autonomy, where schools retain discretion over food choices and implementation, are insufficient to fully restrict unhealthy options, a concern reflected in HICs where discretionary foods remain common despite policy intentions (Bell & Swinburn, 2004; Pillay et al., 2023).

These patterns indicate that structural and cultural factors, such as convenience, affordability, and taste preferences, shape food environments as much as policy frameworks. International reviews confirm that effective interventions require mandatory standards, sustainable funding models, and education initiatives to promote healthier choices (Matela et al., 2024; World Health Organisation - food policy, 2021). In the context of SL, this may involve strengthening monitoring and enforcement mechanisms for existing policies, improving canteen vendor training, and ensuring affordability and accessibility of healthier food options within schools. In contrast, in NZ, where policy implementation is more decentralised, stronger national-level regulatory frameworks, along with incentives for schools to prioritise fresh and minimally processed foods, may be required to reduce reliance on ultra-processed items. Across both

settings, integrating nutrition education with practical food provision strategies and ensuring consistent policy implementation may be critical to achieving sustained improvements in children's dietary environments. Without these measures, schools in both contexts risk continuing exposure to energy-dense, nutrient-poor foods and declining overall nutrition targets for children.

Accurate dietary assessment in school-aged children requires consideration of cognitive ability and food knowledge (Pérez-Rodrigo et al., 2015). Children aged 8 years or younger often struggle to recall what they have consumed, estimate portion sizes, and understand preparation details, thereby increasing reliance on proxy reporting by parents or caregivers (Livingstone & Robson, 2000). While parental input can improve accuracy, it introduces complexity and potential bias, particularly when meals are consumed outside the home (Klesges et al., 1987). Given these limitations and evidence from previous studies recommending self-reporting for older children, the current research focused on children aged 9–13 years, who have greater cognitive capacity and familiarity with common foods, thereby enabling more reliable recall.

To improve the accuracy of dietary recalls among children aged 9–13 years, our study included a familiarisation process and a photographic specific food atlas for both countries (Lazarte et al., 2012; Nightingale et al., 2016). Visual tools aimed at reducing cognitive burden and improving confidence, addressing a major source of error in dietary assessment (Lazarte et al., 2012). Training of children ensured they could accurately match their consumed portions to the closest image, enhancing recall reliability. Evidence from previous research supports the use of photographic food atlases as an effective strategy to improve portion-size estimation in children, particularly when combined with age-appropriate prompts and interviewer guidance (Gibson et al., 2016). Integrating these tools into the modified 24-MPR strengthened the validity of nutrient intake estimates and facilitated accurate assessment of dietary adequacy. This thesis contributes a validated, culturally adapted 24-MPR protocol for NZ children, demonstrating good validity for energy and macronutrients and moderate reliability for selected micronutrients. Its successful application in SL establishes the feasibility of cross-country comparability, addressing a major gap in paediatric nutrition research, where heterogeneous methods hinder synthesis (Olukotun & Seal, 2015). This methodological advancement was conducted outside the HAL initiative, addressing a critical gap in dietary research for this age group.

The study, reported in Chapter 7, revealed marked cross-national differences in dietary intake and adequacy among schoolchildren in SL and NZ, reflecting global patterns of the nutrition transition (Global Nutrition Report, n.d.). Our study's evidence shows that children often meet energy requirements but fail to achieve optimal micronutrient intake, increasing long-term health risks (Gibson et al., 2016; World Health Organisation - food policy, 2021). New Zealand children consumed significantly more energy and key nutrients, protein, fat, fibre, calcium, zinc, iodine, and vitamin B_{12}, while SL children showed widespread inadequacies, particularly for calcium, zinc, magnesium, iodine, and fibre, consistent with LMIC trends (Poh et al., 2013; Rojroongwasinkul et al., 2013; Sandjaja et al., 2013). These findings illustrate the "double burden" of malnutrition: nutrient excesses and diet-quality gaps in high-income contexts, versus severe micronutrient deficiencies in resource-constrained settings (Men, 2024; Weerahewa et al., 2020).

This contrast has critical implications for intervention design. In high-income countries such as NZ, strategies may include strengthening school food policies to limit ultra-processed foods,

increasing the provision and accessibility of fresh fruits and vegetables within schools, and integrating nutrition education with practical food-based initiatives such as school meal programmes and food literacy programmes. In contrast, in SL, interventions may need to prioritise improving access to affordable, nutrient-rich foods through school feeding programmes, fortification initiatives (e.g., iodine or iron fortification), and strengthening supply chains to increase availability of diverse foods in school canteens. In addition, targeted nutrition education for both children and caregivers may be necessary to address dietary behaviours shaped by cost and cultural preferences. Across both contexts, aligning policy implementation with local food environments and ensuring consistent monitoring mechanisms may be essential to improve dietary quality and address both excess and deficiency-related risks. Addressing both ends of the spectrum is essential to prevent long-term health risks and achieve global nutrition targets.

Weekday diets were more nutrient-dense than weekends in both countries, consistent with evidence that structured school environments, through policies and initiatives such as HAL, promote healthier eating patterns by shaping food availability and choices (Esposito et al., 2022; Green et al., 2025; Nicholls et al., 2025; Rothausen et al., 2013). Predictors of adequacy highlighted the country as the dominant factor, underscoring the role of national food systems and socioeconomic conditions. Interventions should therefore be context-specific. Sri Lanka requires school-meal fortification, dairy and legume promotion, and nutrition education (Medical Research Institute, 2023; Selvarasa & Kalainathan, 2025). In NZ, evidence from dietary intake data shows that while energy intake is adequate, intakes of key micronutrients such as calcium and vitamin A are often below recommendations. Therefore, strategies should focus on improving micronutrient density and food literacy to address gaps in fruit, vegetable, and dairy intake (Katiforis et al., 2023; Metcalf et al., 2006). Multivariable analysis of our data showed that 'country' was the strongest predictor of nutrient adequacy, highlighting how differences in food systems and socioeconomic contexts shape children's diets. The use of this culturally adaptable dietary assessment method addresses international demand for better tools to evaluate school-aged children's nutrition and provides a foundation for future cross-national research (Gibson et al., 2017b; Langford et al., 2015).

Overall, our analysis showed that SL children had high levels of MVPA but severe dietary inadequacy, while NZ children had structured opportunities for PA yet spent considerable time sedentary. These findings verify global trends of declining PA and rising sedentary time among children in high-income settings (Guthold et al., 2020) and persistent micronutrient deficiencies in LMICs undergoing nutrition transition (Weerahewa et al., 2020). However, the coexistence of high MVPA in SL with severe dietary inadequacy contrasts with patterns reported in other LMICs, where both PA and diet quality are often poor (Sandjaja et al., 2013). Similarly, NZ's combination of structured PA opportunities and high sedentary time reflects the "structured-day hypothesis" (Brazendale et al., 2021), highlighting the complexity of translating opportunities into active behaviours. These findings underscore the need for integrated interventions addressing both movement and nutrition within school systems.

8.4. Strengths, limitations, and implications

Strengths and limitations specific to studies reported in each chapter have been highlighted; however, there are also some wider strengths and limitations relevant to all four empirical research chapters. These should be taken into consideration when interpreting the overall findings of this research. This thesis offers several notable strengths.

- First, this thesis addresses a critical evidence gap by providing the first systematic comparison of school food environments, PA behaviours, and dietary adequacy between a LMIC South Asian country (SL) and a HIC Pacific nation (NZ).

- The multi-component design**,** integrating objective PA measurement using accelerometers, subjective perceptions of PE, school policy analysis, and dietary intake assessment, ensures a broader evaluation of child health environments.

- The objective measurement of PA is another strength of this study. Accelerometer data collection in a free-living setting, spanning a whole 24-hour period and a week, was necessary given the variability in activities performed within a day and across a week. This method may have improved wear-time compliance.

- This study utilised triaxial accelerometers (ActiGraph GT3X+) to measure PA among school-aged children objectively. To our knowledge, this is the first study in SL to employ accelerometry to assess PA in schoolchildren, addressing a significant methodological gap in paediatric research in South Asian contexts.

- The NZ arm of the study included a relatively large sample of more than 1,300 children from Auckland primary and intermediate schools, strengthening the findings and enabling more reliable subgroup analyses.

- Methodological innovations include the development and validation of a modified 24-MPR protocol for NZ children, subsequently applied in SL to maintain consistency, and the cultural adaptation of PA behaviour tools for use in SL schools. These contributions advance methodological rigour in paediatric health research and enhance cross-cultural comparability.

- Furthermore, the thesis provides policy-relevant evidence by identifying gaps and opportunities within school environments, offering actionable insights for interventions tailored to contrasting socioeconomic and cultural contexts.

Despite these strengths, several limitations warrant consideration.

- The study employed convenience sampling, resulting in unequal sample sizes and limited representation of socioeconomic and cultural diversity, especially in the SL arm, which constrains generalisability.

- The cross-sectional design of this thesis limits the ability to capture day-to-day variability in behaviours, particularly for dietary intake data, which is known to fluctuate substantially across days.

- Measurement challenges include the potential for wrist-worn accelerometers to overestimate PA compared to hip placement, as wrist devices capture additional arm movements that may not reflect whole-body activity.

- Accelerometer cut-points used to classify PA intensity have primarily been validated in European populations and may not accurately reflect movement patterns in Asian children. Furthermore, there are no female-specific cut-points and no validation studies

for SL children, meaning the thresholds applied in this study may introduce misclassification bias.

- Contextual factors also influenced findings; Data collection in SL occurred during 2021–2022, immediately following COVID-19 lockdowns and amid a severe economic crisis. These circumstances disrupted school food environments and temporarily suspended food programmes, potentially leading to the observed food availability not reflecting typical conditions.

- Food environment data in SL were collected only from school canteens, excluding external food outlets such as retail shops commonly operating around schools. This may not fully represent the actual food availability and purchasing options accessible to students.

- Due to participant burden and the need to maintain engagement, dietary intake data collection was limited to two days (one weekday and one weekend), which may not fully capture habitual intake patterns. Additionally, the absence of biochemical validation limits the accuracy of micronutrient adequacy estimates.

Implications for research, practice and policy include:

- Research: Future research should employ larger, representative samples and longitudinal designs to confirm these findings and explore causal pathways. Incorporating biomarkers would strengthen dietary adequacy assessments by validating self-reported intake and identifying deficiencies that recall alone cannot capture. Further psychometric validation of adapted PA and food policy tools is recommended to ensure cross-cultural reliability.

- Practice: Practitioners should design inclusive school programmes that integrate structured and informal PA opportunities, supported by teacher training and culturally responsive resources. Nutrition interventions should prioritise diversity and affordability of healthy foods, particularly in resource-limited settings.

- Policy: In SL, enforcement of school canteen guidelines requires legal backing, monitoring mechanisms, and sustainable funding models to reduce reliance on unhealthy food sales. In NZ, voluntary compliance should be replaced with mandatory minimum standards for school food policies, alongside strategies to address persistent gaps in fruit, vegetable, and dairy intake. Both countries should extend structured nutrition and PA supports beyond school hours, promote active travel, and engage families to align home and school environments.

8.5. Conclusion

This thesis provides a multi-dimensional evaluation of school health environments in two contrasting national contexts, SL and NZ, focusing on PA behaviours of schoolchildren aged 5-13 years, school food environments, and dietary adequacy among children aged 9–13 years.

The findings reveal significant cross-country differences shaped by socioeconomic, cultural, and policy factors.

Objective accelerometer data showed that children in both countries exceeded the WHO recommendations for MVPA, challenging the assumption of widespread inactivity. Sri Lankan children accumulated higher MVPA, while NZ children recorded greater step counts but also higher sedentary time, indicating differences in activity patterns and intensity. Self-reported data highlighted more positive attitudes toward PE and a greater diversity of opportunities in NZ schools. In contrast, SL schools offered fewer structured options and relied heavily on informal play.

Marked disparities in nutrient intake were observed between the two countries. Sri Lankan children exhibited widespread inadequacies in calcium, magnesium, zinc, iodine, and dietary fibre, reflecting limited dietary diversity and reliance on staple foods. In contrast, NZ children consumed higher energy and most nutrients but showed persistent gaps in vitamin A, calcium, and fibre, indicating concerns about diet quality even in high-income settings. Weekday diets were generally more nutrient-dense than weekend diets in both countries, underscoring the stabilising influence of structured school environments.

Food availability and policy practices also differed substantially. Sri Lankan schools adhered to a centralised school canteen policy, yet enforcement was weak, and deep-fried foods, confectionery, and sweetened beverages remained common. In NZ, voluntary guidelines led to the absence of fried foods and confectionery, but to widespread availability of packaged snacks and sweet baked goods. Both contexts face structural barriers: economic constraints and monitoring gaps in SL, and reliance on voluntary compliance in NZ. Notably, the SL assessment excluded external food outlets surrounding schools, which are common and likely influence children's choices, indicating that actual food exposure may be broader than reported.

Collectively, these findings highlight the interplay between school environments, cultural norms, and socioeconomic conditions in shaping child health behaviours. They underscore the need for integrated, context-specific strategies that address both PA and nutrition within and beyond school settings. Methodologically, this thesis makes significant contributions by introducing accelerometry for school-aged children in SL and validating a modified 24-MPR protocol for NZ, advancing paediatric health research in diverse contexts.

8.6. Future research direction

Building on the findings and limitations of this thesis, several areas warrant further investigation:

- Future studies should include larger, nationally representative samples across diverse regions to improve generalisability. Inclusion of rural and urban schools, as well as socio-economic strata, will provide a more comprehensive understanding of school health environments.
- Cross-sectional designs limit causal inference. Longitudinal research is needed to examine temporal trends and the impact of school-based interventions on PA, dietary behaviours, and health outcomes.
- Incorporating biomarkers such as serum 25-hydroxyvitamin D [25(OH)D] for vitamin D, urinary sodium for salt intake, and iron status indicators (e.g., serum ferritin and

haemoglobin) will strengthen the validity of nutrient adequacy assessments and overcome limitations of self-reported intake.

- Formal psychometric testing of adapted PA questionnaires is essential to ensure reliability and construct validity across cultural contexts.
- Develop and validate ethnic- and sex-specific accelerometer cut-points, particularly for South Asian children, to improve accuracy in classifying PA intensity.
- Future research should capture external food outlets surrounding schools and home-packed meals to reflect the full spectrum of food availability influencing children's choices. Some recent studies have begun mapping these environments using tools such as Google Street View, offering a more comprehensive approach.
- Examine the effectiveness of school food and PA policies through controlled trials and implementation research, with a focus on enforcement mechanisms and stakeholder engagement.
- Explore digital dietary assessment tools and advanced wearable technologies to reduce participant burden, improve compliance, and enhance data accuracy.
- Test fortification strategies and culturally tailored nutrition programs in SL and diet quality improvement initiatives in NZ, addressing identified gaps in micronutrient intake and food diversity.

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Chapter 9

Critical reflection on research ethics and study design in a cross-national school-based health study

Abstract

This chapter presents a critical reflection on the ethical and methodological considerations underpinning a cross-national doctoral study examining physical activity (PA), school food environments, dietary assessment, and dietary intake among schoolchildren in Sri Lanka (SL) and New Zealand (NZ). Conducted across the education and health sectors, the study required navigation of multiple ethical, institutional, cultural, and methodological challenges associated with undertaking research involving children in two contrasting national contexts. The first part of the chapter critically examines ethical issues encountered throughout the research process, including ethical governance, institutional access, informed consent and assent, research involving children, and the adaptation of research procedures across diverse linguistic and cultural settings. Particular attention is given to the distinction between ethical review and administrative approvals, the complexities of obtaining access to schools and participants, and the challenges associated with ensuring meaningful participation in cross-country research. The second part reflects on the research design and the methodological decisions that shaped the doctoral study. This includes consideration of the evolution of the research programme, application of the Social Ecological Model (SEM) and supporting frameworks, selection of narrative review methodologies, and the implementation of a cross-country comparative design. The strengths and limitations of conducting multiple embedded studies across two countries are critically evaluated, together with challenges relating to methodological consistency, cultural adaptation, and contextual comparability. The chapter concludes by reflecting on the limitations of the overall research programme, lessons learned, and recommendations for future international research. Collectively, the reflection highlights the importance of balancing ethical responsibility, methodological rigour, cultural responsiveness, and practical feasibility when conducting cross-national school-based health research involving children.

9.1 Introduction

This chapter provides a critical reflection on the ethical and methodological considerations supporting this doctoral study, which examined school food environments, dietary habits, and physical activity (PA) environments among school-aged children in Sri Lanka (SL) and New Zealand (NZ). The research was undertaken across two countries and covered both the health and education sectors, requiring engagement with diverse participant groups, multiple institutional stakeholders, and varied regulatory and ethical frameworks. As a result, the planning and implementation of the research involved complexities extending beyond those typically encountered in single-country studies (Spector et al., 2015).

Reflective evaluation is recognised as an important component of doctoral research, providing opportunities to critically examine the decisions, assumptions, strengths, and limitations that have shaped the research process and knowledge produced through it (Finlay, 2002). The purpose of this chapter is not to restate procedures already described in previous chapters but rather to critically evaluate the rationale underpinning key ethical and methodological decisions, consider the challenges encountered during implementation, and reflect on lessons learned throughout the research process. Rather than describing study procedures already presented in previous chapters, this chapter considers how ethical requirements, methodological choices, and theoretical perspectives influenced the design, conduct, and outcomes of the research. Such reflection is particularly relevant in cross-national studies, where differences in cultural, educational, administrative, and policy contexts may influence research processes and the interpretation of findings.

This doctoral study was undertaken using a thesis-by-publication approach and consisted of multiple interconnected studies that collectively addressed the overall aim of evaluating and comparing school food environments, dietary habits, and PA environments among children in SL and NZ. These studies included literature reviews, school environment assessments, dietary intake investigations, and methodological studies examining the validity and reliability of dietary assessment approaches. While each study was designed to address a specific research question, all were guided by a shared conceptual framework and contributed evidence towards the broader research objectives. Conducting these studies required careful consideration not only of ethical requirements but also of methodological decisions relating to sampling, measurement tools, cultural adaptation, theoretical frameworks, and data collection approaches.

This chapter is organised into two main sections. The first presents a critical reflection on research ethics, focusing on ethical approval processes, institutional access requirements, informed consent and assent procedures, participant protection, and considerations relating to language, culture, and diverse communities. The second examines the research design, including the application of the Social Ecological Model (SEM), methodological decisions made across the embedded studies, and the strengths and limitations of the literature review approaches employed throughout this doctoral study. Attention is also given to challenges associated with conducting comparative research across countries and to methodological issues identified during the examination process. Through this analysis, the chapter highlights lessons learned and offers recommendations for future cross-national research involving school-aged children within the health and education sectors. By critically reflecting on these areas, the chapter provides a deeper understanding of how ethical and methodological considerations shaped the conduct, quality, and outcomes of the research.

9.2 Part 1: Reflection on research ethics

Conducting research across national boundaries introduces complex ethical considerations that extend beyond standard institutional ethical approval processes. In the present study, which involved schoolchildren aged 5–13 years in both NZ and SL, ethical governance required navigating multiple regulatory systems, institutional structures, and socio-cultural contexts. This section critically reflects on the ethical frameworks, approval processes, participant engagement procedures, and contextual challenges encountered in implementing research across education and health sectors in two distinct countries.

9.2.1 Ethical governance and approval processes

Ethical governance is fundamental to protecting participant rights, wellbeing, dignity, and autonomy throughout the research process. International frameworks, including the Declaration of Helsinki and the Council for International Organisations of Medical Sciences (CIOMS) guidelines, emphasise independent ethical review, informed consent, risk minimisation, and participant protection, particularly in cross-national research involving diverse regulatory and cultural contexts (CIOMS, 2016; World Medical Association, 2025; "World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects," 2013).

A key issue in cross-national research is that ethical review processes are not standardised globally (CIOMS, 2016; Spector et al., 2015). In many international research contexts, ethical approval is obtained from the primary academic institution, while additional approval or permissions from host-country authorities facilitate local implementation and compliance with national requirements (de Onis et al., 2004).

In this doctoral study, ethical approval was obtained from the Massey University Human Ethics Committee through two applications: NOR 22/16 for the SL component and OM1 23/46 for the NZ dietary assessment study. These approvals provided oversight of participant recruitment, informed consent, confidentiality, and participant protection. In addition, institutional permissions were obtained from relevant educational and health authorities in SL, including the Ministry of Education, Provincial Education Department, and regional education offices, to facilitate access to schools and participants. School-level approval functioned as an important gatekeeping mechanism in both countries.

Critical reflection

A key ethical issue arising from this study was the distinction between formal ethical review and administrative permission. Ethical review undertaken by the Massey University Human Ethics Committee provided independent scrutiny of participant protection, informed consent procedures, confidentiality, and risk management. Administrative approvals obtained from educational and institutional authorities also considered many of these issues, particularly those relating to the welfare of children and the appropriateness of research activities within school settings. However, their primary function was to determine whether the research could be conducted within their institutions and whether access to schools and participants should be

granted. The need to obtain approvals from multiple stakeholders across two countries highlighted the complexity of conducting research involving children across both the education and health sectors.

Although institutional permissions enabled access to schools and participants, they did not provide the same level of independent scrutiny as formal ethical review. Consequently, the absence of an independent host-country ethical review process for the SL component may be considered a limitation of the study. Local ethical review could have provided additional consideration of context-specific cultural and institutional factors influencing research implementation.

Obtaining approvals across multiple authorities also created practical challenges, including extensive documentation requirements, differing approval procedures, and delays to data collection. Similar challenges have been reported in multinational research (de Onis et al., 2004). Future inter-country studies should carefully consider both home-institution and host-country ethical review requirements while also advocating for more harmonised approaches to ethical governance where appropriate.

9.2.2 Institutional access and gatekeeping

Access to participants in school-based research required engagement with multiple institutional stakeholders in both SL and NZ, although approval pathways differed considerably between the two countries. In SL, access followed a hierarchical process involving approvals from the Ministry of Education, Provincial Education Offices, and individual schools. This multi-layered structure influenced both the feasibility and scope of data collection. In NZ, recruitment procedures varied according to the study component. For the PA study, schools were recruited through the HAL initiative via Sport NZ and Regional Sport Trusts, whereas the dietary assessment study required direct recruitment by the researcher. When school participation proved challenging, additional recruitment was undertaken through community networks and social media platforms.

Critical reflection

Institutional gatekeepers played an important role in protecting schools and students by reviewing research activities before participant recruitment. However, they also influenced participation opportunities because researchers could only approach children and parents after institutional approval had been granted. Consequently, participant access depended not only on individual willingness to participate but also on organisational decisions made by educational authorities and school leaders.

The contrasting approval processes in SL and NZ demonstrated how governance structures can influence recruitment, sample composition, and inclusiveness. The multi-layered system in SL increased administrative requirements, whereas the more decentralised approach in NZ provided greater flexibility but relied heavily on school-level participation decisions. These experiences highlighted the need to balance institutional requirements with equitable

opportunities for participation, particularly when alternative recruitment strategies are required.

Overall, this experience reinforced the importance of early engagement with gatekeepers and transparent communication regarding research aims, procedures, and participant protections. Careful consideration of access pathways is essential for both ethical research practice and inclusive participation in cross-national studies involving children.

9.2.3 Participant information and informed consent

Obtaining informed consent is a fundamental ethical requirement in research involving children. International ethical guidelines emphasise that participants and their legal guardians should receive clear information about the purpose, procedures, risks, and benefits of the research to support voluntary and informed decision-making (CIOMS, 2016). In addition to parental consent, children should provide assent appropriate to their age, recognising that children may not fully understand the implications of participation despite parental agreement. Consequently, assent was viewed as an ongoing process rather than a single event.

In the present study, participant information and consent procedures were adapted to suit the institutional and cultural contexts of SL and NZ, while maintaining adherence to ethical principles. In SL, information sheets and consent forms were distributed through schools and supported by face-to-face meetings with parents and children. Additional meetings were conducted for study components requiring complex procedures, such as dietary assessment and accelerometer use. In NZ, consent procedures varied according to the study component, with participant information provided either directly to parents or through schools. In the case of the HAL study, participant recruitment was facilitated through schools.

Critical reflection

Although formal consent procedures were followed, ensuring that consent was genuinely informed remained challenging. Written information assumes a level of literacy and familiarity with research that may vary across participants. Face-to-face meetings in SL improved opportunities for clarification, but school-mediated communication may not have reached all parents equally.

The study also highlighted tensions between participant autonomy and recruitment pathways. Direct recruitment in NZ may have enhanced voluntary participation but increased the likelihood of selection bias, whereas school-based recruitment provided broader access but may have influenced perceptions of voluntariness through institutional endorsement. Similarly, children may have felt obliged to participate because of the involvement of teachers and schools despite formal opportunities to decline participation.

Overall, the experience reinforced that informed consent and assent are continuous ethical processes rather than administrative requirements. Ensuring that participation is genuinely understood, voluntary, and inclusive remains a key challenge in cross-national research involving children.

9.2.4 Ethical considerations in research with children

The inclusion of children aged 5–13 years introduced additional ethical complexities due to their status as a vulnerable population. Ethical guidelines emphasise the need for heightened protection for child participants, including minimisation of risk, age-appropriate communication, and the safeguarding of autonomy (CIOMS, 2016; World Medical Association, 2025).

In this study, data collection methods included accelerometer-based PA measurement, questionnaires, and dietary recall methods, all of which required careful adaptation to ensure suitability for children of different developmental stages. In particular, the PA questionnaire was designed to be age-appropriate and cognitively accessible. Two versions of the questionnaire were developed and applied consistently in both SL and NZ.

For younger children aged 5–8 years, a shorter questionnaire was used, incorporating simplified questions with direct response options and graphical illustrations to support understanding and engagement. For older children aged 9–13 years, a more detailed questionnaire was administered, including elements such as approximate time estimation and activity recall, supported by representative visual aids to facilitate comprehension. This differentiation in questionnaire design aimed to align data collection methods with children's cognitive abilities while maintaining consistency across both study contexts.

Critical reflection

The adaptation of data collection tools according to age group reflects an important ethical consideration in research involving children, specifically ensuring that methods are appropriate, understandable, and not cognitively burdensome. However, despite these adaptations, younger children may still have experienced difficulties in fully understanding study procedures, particularly in relation to dietary recall and time-based questionnaire responses. This may have influenced the accuracy and reliability of self-reported data.

The use of accelerometers also introduced practical and social challenges. Wearing a device continuously for seven days required sustained participant compliance and may have caused discomfort or inconvenience. Additionally, the visibility of the device in school settings may have affected children's willingness to comply due to concerns about peer attention or social acceptability.

Although these risks were considered minimal, they highlight the importance of accounting for both physical and psychosocial dimensions of participation when designing research protocols for children. Furthermore, the requirement for sustained engagement and adherence to study protocols (e.g., repeated meetings, device usage, and data recording) may have influenced participation patterns, favouring children and families with higher levels of commitment and support.

Overall, these considerations emphasise that ethical research with children extends beyond formal consent procedures to include careful design and implementation of age-appropriate methodologies that minimise burden while maximising understanding and meaningful participation.

9.2.5 **Language, cultural context, and diverse communities**

The cross-country nature of this doctoral study required engagement with populations from diverse linguistic, cultural, educational, and socioeconomic backgrounds. Although several data collection tools were originally developed within the NZ context through the HAL initiative, implementing these instruments within the SL context required more than direct translation.

For the PA study, the PA questionnaires developed for HAL were reviewed by a multidisciplinary panel comprising physical education lecturers, public health academics, school teachers, sports scientists, nutritionists, and Ministry personnel. Activities that were not culturally relevant to SL children, such as beach-based activities and fishing, were removed or replaced with more locally appropriate examples while retaining the underlying constructs being measured. Similarly, questionnaires used in the school food environment study required adaptation to reflect SL food culture, school canteen practices, and regulatory structures. Food items commonly available in NZ schools, such as sushi, Edam cheese, and multigrain bread products, were replaced with culturally relevant alternatives. Questions relating to governance structures were also modified to align with SL school food committee systems and government circulars rather than NZ Board of Trustees arrangements.

Dietary assessment required further adaptation because food practices, meal patterns, preparation methods, and commonly consumed foods differed substantially between countries. To improve accuracy and cultural relevance, portion-size estimation in SL was supported through the use of the SL Food Atlas alongside other visual aids. Nutrient intake analysis was conducted using country-specific food composition databases to ensure that local foods and recipes were appropriately represented. These adaptations aimed to minimise cultural bias while maintaining methodological consistency across countries.

Following cultural adaptation, all participant materials and questionnaires were translated into Sinhala and Tamil. Forward translation and back-translation procedures were undertaken by language specialists to improve linguistic accuracy and consistency between versions. Expert review was subsequently used to assess item clarity, relevance, and cultural appropriateness before data collection commenced.

Critical reflection

The adaptation of instruments across countries highlighted that translation alone is insufficient in cross-cultural research. While linguistic translation can address language differences, it does not necessarily ensure conceptual equivalence. Several examples encountered during this study demonstrated that questions developed within the NZ context could not always be directly transferred to SL participants because educational systems, regulatory frameworks, food environments, and daily activities differed substantially.

The process also revealed an ongoing tension between maintaining methodological consistency and achieving cultural relevance. Excessive modification of questionnaires risks reducing comparability between countries, whereas insufficient adaptation may result in participant confusion or misinterpretation of questions. Throughout this study, efforts were made to

preserve the original constructs while modifying contextual examples and wording to improve relevance for SL participants. However, it remains possible that some concepts were interpreted differently despite these adaptations.

Differences in socioeconomic conditions between SL and NZ also influenced participant experiences and access to resources. Variations in food availability, transport systems, technology access, and school infrastructure may have affected how participants responded to questionnaire items and engaged with study procedures. These contextual differences represent an inherent challenge in cross-country comparative research and should be considered when interpreting findings.

Reflecting on this process, cultural adaptation was not simply a methodological requirement but also an ethical responsibility. Ensuring that research instruments were understandable, relevant, and respectful of local contexts helped promote meaningful participation and reduce the risk of misunderstanding. Future inter-country studies should allocate sufficient time and resources for cultural adaptation, expert review, pilot testing, and linguistic validation to strengthen both the ethical and methodological quality of comparative research.

9.3 Part 2: Reflection on research design

This section critically reflects on the methodological decisions underpinning this doctoral study and the rationale for adopting a programme of interconnected studies to address the overall research aim. Conducted across two countries and spanning the health and education sectors, the research required balancing methodological consistency with responsiveness to different cultural, institutional, and policy contexts. The section examines the evolution of the research design, the application of the theoretical framework, the literature review methodologies that informed the empirical studies, and the strengths and limitations of conducting cross-country comparative research. Particular attention is given to how methodological decisions shaped the scope, implementation, and interpretation of the research, and to the lessons learned through undertaking a complex programme of cross-national research involving school-aged children.

9.3.1 Overview of the research programme and design rationale

The doctoral study was originally developed around participation in the NZ HAL initiative, which provided opportunities to examine school-based PA behaviours and school food environments (Massey University, n.d.). The original intention was to utilise data generated through the HAL project to examine factors influencing children's health behaviours within NZ school settings.

However, the COVID-19 pandemic and delays associated with international relocation altered the circumstances under which the doctoral study was conducted (Royal Commission of Inquiry into COVID-19 Lessons Learned, 2025). During the early stages of candidature, an extended period was spent in SL. Following discussions with the supervisory team, this situation was viewed as an opportunity to broaden the scope of the research through the inclusion of comparable studies in SL. Consequently, the study evolved from a predominantly

NZ-focused investigation into a cross-national research programme involving schoolchildren in both SL and NZ.

While the PA and school food environment components were closely aligned with the objectives of the HAL initiative, the inclusion of a dietary assessment study represented a deliberate extension of the original research scope. This decision was based on recognition that understanding school health environments required examination not only of PA opportunities and food environments, but also of children's actual dietary intake and nutritional adequacy. However, obtaining accurate dietary data from children presents well-recognised methodological challenges, particularly among children aged 9-13 years, due to limitations in memory, recall accuracy, and portion size estimation (Livingstone & Robson, 2000). Consequently, the dietary component of the research incorporated an additional methodological study aimed at improving dietary assessment procedures for this population. A modified 24-hour multiple-pass dietary recall (24-MPR) protocol was developed and subsequently evaluated for validity and reliability among NZ schoolchildren using parent-completed weighed food records as the reference method (Livingstone & Robson, 2000). The validated dietary assessment approach was then applied in the subsequent cross-national dietary assessment study, which was used to evaluate energy and nutrient adequacy among schoolchildren in SL and NZ. This sequential process strengthened the methodological rigour of the dietary investigations and enabled a more comprehensive evaluation of factors influencing children's health behaviours, extending the research beyond environmental assessment to include dietary outcomes.

The final research programme consisted of five interconnected studies that collectively addressed the overall doctoral aim of evaluating and comparing school PA environments, school food environments and dietary adequacy among school-aged children. Table 9.1 summarises the individual studies included in the doctoral programme.

Table 9.1. Overview of the doctoral research programme

Study	Purpose	Design
Chapter 3	Examine methodological issues relating to accelerometer-based PA assessment in Asian children	Narrative review
Chapter 4	Compare PA behaviours and perceptions between NZ and SL	Cross-sectional comparative study
Chapter 5	Compare school food environments, policies, and practices between NZ and SL	Cross-sectional comparative study
Chapter 6	Assess validity and reliability of a modified 24-MPR protocol for NZ children	Validation study
Chapter 7	Compare nutrient intake adequacy between NZ and SL	Cross-sectional comparative study

Critical reflection

Reflecting on the overall design, the research evolved substantially from its original conception. The inclusion of SL was not part of the initial research plan but emerged in response to circumstances created by the COVID-19 pandemic and associated logistical constraints. While these disruptions initially appeared to represent significant challenges, they ultimately created opportunities to strengthen the doctoral study by enabling a comparative international perspective that would otherwise not have been achieved.

A key strength of the final design was its multidisciplinary and multi-component nature. Rather than focusing exclusively on one aspect of health behaviour, the programme examined PA, school food environments, dietary assessment methodology, and nutrient adequacy. This broader approach enabled findings from individual studies to be interpreted within a wider context and facilitated a more comprehensive understanding of children's health behaviours than would have been possible through a single-study design.

However, the expanded scope also increased methodological and logistical complexity, requiring additional institutional approvals, ethical approval, participant recruitment, data collection, instrument adaptation, and project management requirements, and careful consideration of contextual differences between countries. Furthermore, the cross-sectional nature of the empirical studies limited the ability to establish causal relationships between school environments and children's health behaviours. While associations could be identified, conclusions regarding causality remained beyond the scope of the research design.

Overall, the evolution of the doctoral study demonstrated the importance of flexibility in research design. Rather than viewing unexpected disruptions as limitations, the research programme adapted to changing circumstances and ultimately produced a broader and more meaningful contribution to understanding school health environments across contrasting national contexts. These experiences reinforced the value of adapting research designs to emerging circumstances while maintaining alignment with the overarching research aim.

9.3.2 Application of the theoretical framework

This doctoral study was guided by the SEM, which served as the overarching theoretical framework for understanding the multiple influences on children's health behaviours. The SEM recognises that health behaviours are shaped by interactions occurring across individual, interpersonal, organisational, community, and policy levels (Graif et al., 2021). This perspective was considered particularly appropriate because the study examined PA behaviours, dietary intake, and school food environments across two national contexts.

As illustrated in Figure 9.1, the SEM provided the overall conceptual structure linking the embedded studies within the doctoral research programme. The individual level informed investigation of children's PA and dietary intake, while organisational and policy levels informed the assessment of school food environments and school food policies. To provide greater specificity, the Youth Physical Activity Promotion Model (YPAPM) was applied within the PA component of the study to examine factors influencing children's participation in PA (Welk, 1999). Similarly, the School Food Environment Dimensions Framework guided the assessment of physical, socio-cultural, economic, and policy influences on school food

environments (Turner et al., 2018). Together, these frameworks enabled examination of both individual health behaviours and the environmental contexts in which they occurred.

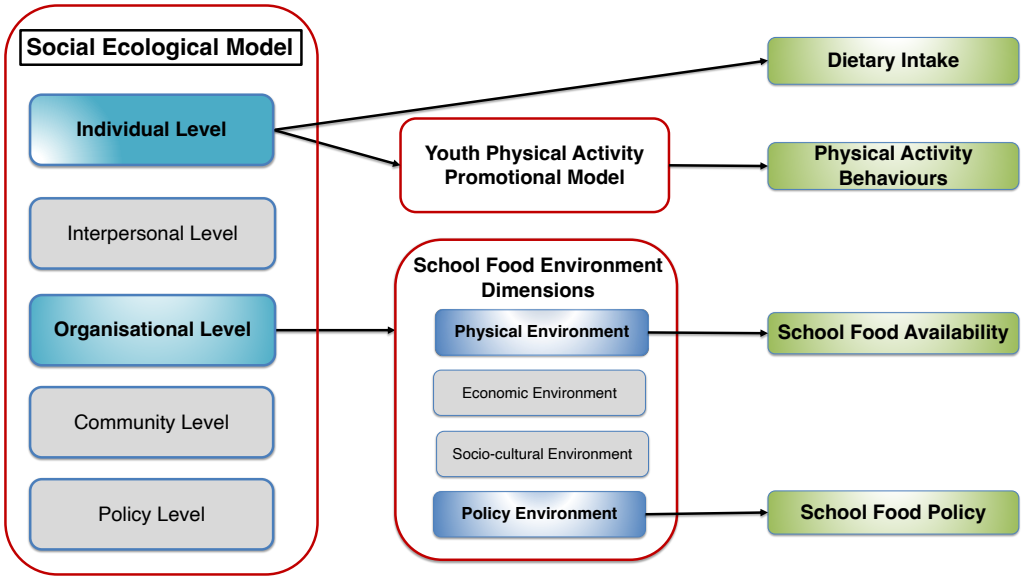


Figure 9.1. Conceptual framework of the study

Critical reflection

A major strength of the theoretical approach was its ability to support a multi-level understanding of children's health behaviours. Rather than focusing solely on individual behaviours, the frameworks recognised the influence of social relationships, community and policy contexts. This was particularly valuable in a cross-national study because it enabled findings from SL and NZ to be interpreted within their broader environmental and policy settings.

The integration of the YPAPM and School Food Environment Dimensions Framework strengthened the application of the SEM by providing more specific guidance for examining PA and food-related behaviours. This contributed to greater coherence across the embedded studies and supported alignment with the overall doctoral research aim.

A limitation of the theoretical approach was that the frameworks were applied selectively rather than in their entirety. Within the SEM, the research focused primarily on individual and organisational influences, while interpersonal, community, and policy levels were beyond the scope of the study. Similarly, only selected components of the YPAPM were used to examine PA behaviours. For the School Food Environment Dimensions Framework, the study focused mainly on physical and policy dimensions, whereas economic and socio-cultural dimensions were not comprehensively explored. Consequently, the findings provide insight into selected influences on children's dietary and PA behaviours rather than all factors represented within the three frameworks.

9.3.3 Reflection on literature review methodologies

Two literature review approaches were utilised within this doctoral study. Chapter 2 provided the theoretical and methodological foundation for RQ2-RQ5 through a series of focused narrative mini-reviews, while Chapter 3 consisted of a standalone narrative review addressing RQ1. Unlike the reviews presented in Chapter 2, the Chapter 3 review was developed as an independent manuscript and subsequently published as a journal article. Consequently, it was retained as a separate chapter within the thesis rather than being incorporated into the broader literature review chapter. Together, these reviews provided the conceptual and methodological foundation for the embedded studies undertaken throughout the doctoral study.

Table 9.2. Alignment of literature reviews with research questions and embedded studies

Literature review chapter section	Related RQ(s) / Chapter(s)	Focus of review	Contribution to the doctoral study
Section 2.2	RQ2 (Chapter 4)	PA behaviours, children's perceptions of PA, determinants of participation, and PA trends in SL and NZ	Provided the theoretical foundation for investigating objectively measured PA and children's subjective experiences of PE and PA participation.
Section 2.3 Chapter 3 (Published Narrative Review)	RQ1 (Chapter 3)	Accelerometer-based PA assessment among Asian children, including accelerometer selection, validation procedures, cut-points, and interpretation of PA data	Identified methodological challenges and evidence gaps relating to objective PA measurement in Asian children and provided methodological context for the PA component of the doctoral study.
Section 2.4	RQ3 (Chapter 5)	School food environments and policy frameworks, including physical and policy dimensions of school food environments and factors influencing policy implementation	Informed the investigation of school food availability and policy implementation within school settings.
Section 2.5	RQ4 and RQ5 (Chapters 6&7)	Dietary assessment methodologies in children, validity and reliability considerations, the multiple-pass recall approach, dietary reference standards, and nutritional adequacy among school-aged children	Provided the methodological foundation for the dietary assessment validation study and the theoretical basis for evaluating dietary intake and nutrient adequacy among children in SL and NZ.

As shown in Table 9.2, separate narrative reviews were undertaken because the research questions addressed distinct behavioural, environmental, methodological, and nutritional domains (Baumeister & Leary, 1997). Different search strategies, eligibility criteria, and study selection processes were therefore required to ensure that evidence relevant to each research question was identified and synthesised. This approach enabled each embedded study to be supported by a focused evidence base while maintaining alignment with the overall doctoral aim of understanding PA behaviours, dietary intake, and school environments among children in SL and NZ.

Critical reflection

The choice of literature review methodology was guided by the objectives of the doctoral study and the nature of the available evidence. Systematic reviews are designed to answer clearly

defined research questions using comprehensive and reproducible search strategies, explicit eligibility criteria, and formal quality appraisal procedures (Aromataris & Pearson, 2014). In contrast, narrative reviews are more appropriate when the purpose is to develop conceptual understanding, synthesise diverse evidence, explore methodological issues, and identify knowledge gaps within complex research areas (Baumeister & Leary, 1997).

For Chapter 2, a narrative review approach was considered more appropriate than a systematic review because the purpose was not to answer a single narrowly defined research question. Rather, the review was designed to provide the theoretical and methodological foundation for four embedded studies addressing PA behaviours, school food environments, dietary assessment methodology, and dietary adequacy. Conducting separate systematic reviews for each topic would have been beyond the scope of the doctoral study and may have limited the integration of evidence across related domains.

An additional consideration was the limited availability of directly comparable evidence examining children's health behaviours across both developed and developing country contexts (Inchley et al., 2020). Much of the available literature originated from high-income countries, while evidence from SL and other low- and middle-income countries was comparatively limited. Furthermore, studies varied considerably in terms of methodological approaches, health outcomes, and sociocultural settings (Inchley et al., 2020). The narrative review therefore allowed evidence from diverse geographical and disciplinary contexts to be synthesised while also highlighting important gaps in knowledge relevant to the cross-country comparison undertaken in this thesis.

Similarly, the narrative review conducted in Chapter 3 was selected because its objective was exploratory and methodological rather than evaluative. The literature relating to accelerometer use among Asian children was highly heterogeneous, involving different accelerometer models, validation procedures, wear protocols, cut-points, study populations, and analytical approaches (Perera et al., 2024). A narrative review provided the flexibility required to examine methodological inconsistencies, identify knowledge gaps, and critically evaluate factors influencing the interpretation of accelerometer-derived PA data. Given the exploratory nature of the research question, a narrative approach enabled examination of issues that may have been overlooked in a more narrowly focused systematic review.

A major strength of the narrative review approach was its ability to provide broad synthesis and conceptual understanding across diverse bodies of literature. The reviews informed methodological decisions, identified evidence gaps, and provided context for interpreting the findings of the empirical studies. However, narrative reviews are inherently limited by reduced transparency and reproducibility compared with systematic reviews and are more susceptible to selection bias because they do not require exhaustive search procedures or formal quality appraisal (Aromataris & Pearson, 2014). Consequently, the findings should be interpreted as providing contextual and methodological understanding rather than exhaustive summaries of all available evidence.

Overall, the narrative review methodologies represented a pragmatic and appropriate approach for addressing the aims of this doctoral study. While they sacrificed some of the transparency and reproducibility associated with systematic reviews, they provided the flexibility necessary to synthesise diverse evidence, identify methodological challenges, and establish the conceptual foundations for the subsequent embedded studies.

9.3.4 Reflection on cross-country comparative research design

A central feature of this doctoral study was the comparison of school food environments, dietary adequacy, and PA environments between SL and NZ. The decision to undertake a cross-country comparison emerged following changes to the original study design during the COVID-19 pandemic and the opportunity to conduct research in SL while maintaining involvement with the HAL initiative in NZ.

The selection of SL and NZ provided an opportunity to examine children's health behaviours within two countries that share a commitment to promoting healthy eating and PA through schools, but differ substantially in their socioeconomic, educational, and policy contexts. Both countries have implemented school-based health promotion initiatives and nutrition-related policies, although these operate within different systems and resource environments. Comparing these settings enabled exploration of how similar public health goals are translated into practice and how contextual differences may influence children's PA behaviours, dietary practices, and school food environments.

A key consideration in the comparative design was the need to maximise methodological consistency while remaining responsive to local contexts. Wherever possible, common measurement frameworks were applied across both countries. For example, objectively measured PA was assessed using accelerometers, and similar age groups were recruited in both settings. The PA study adopted procedures based on the HAL protocol, with contextual adaptations made where necessary for implementation in SL. Similarly, the school food environment study utilised a common assessment framework to facilitate comparison of school food availability and policy implementation. For the dietary component, the same modified 24-MPR methodology was subsequently applied in both countries following validation among NZ schoolchildren. These decisions were intended to enhance comparability while maintaining methodological feasibility across diverse settings.

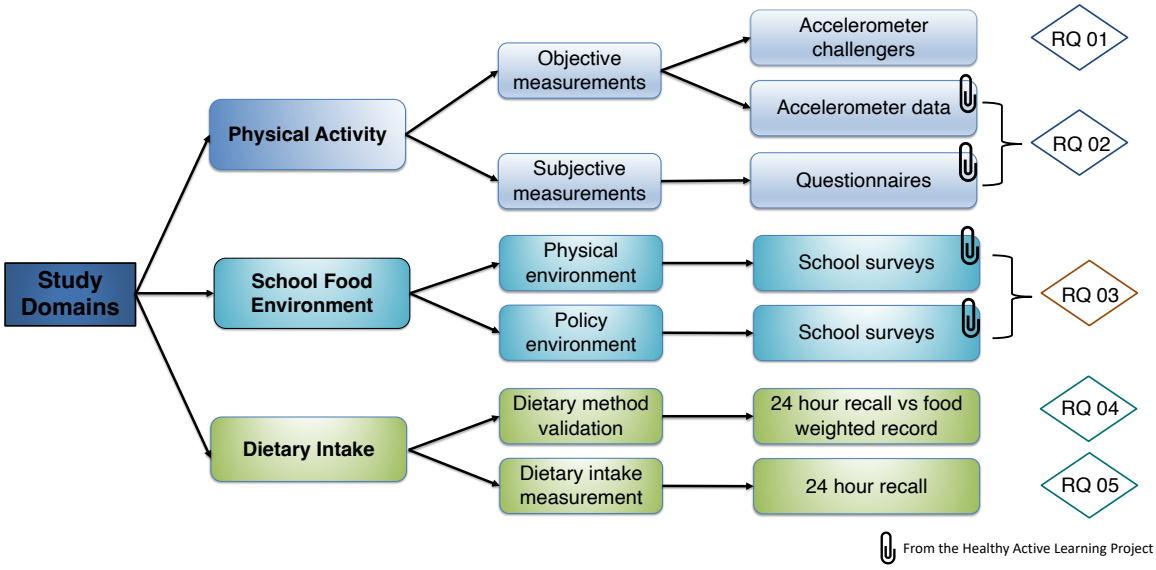


Figure 9.2. Overview of study domains, data collection methods, and alignment with RQs.

Despite efforts to standardise measurement approaches, some aspects of implementation necessarily differed between countries. In NZ, participant recruitment occurred through schools participating in the HAL initiative, which provided established relationships between Sport NZ, Regional Sports Trusts, schools, and the research team. In contrast, the SL

component required separate engagement with education authorities and individual schools before participant recruitment could commence. Furthermore, while the PA questionnaires developed for HAL provided the basis for assessing children's perceptions of PA and PE in both countries, cultural adaptation, translation, and content validation were required before implementation in SL. These adaptations were considered essential to ensure that questionnaire items remained relevant, understandable, and culturally appropriate for SL schoolchildren.

Critical reflection

A major strength of the cross-country design was its ability to generate insights that would not have been possible within a single-country study. Comparative studies enable researchers to identify contextual influences on health outcomes, distinguish setting-specific factors from more universal influences, and generate knowledge relevant to policy transfer and international learning (Bowden et al., 2024). Comparing NZ and SL enabled examination of how children's health behaviours are influenced by differing environmental and policy contexts while addressing a significant gap in the literature, as relatively few studies have compared school health environments across developed and developing countries. The design also provided opportunities for policy learning, allowing strengths and challenges within each country's school health system to be considered in relation to the other.

The comparison further improved the transferability of findings and created opportunities for policy learning. Comparative research can support the identification of successful practices, implementation barriers, and policy approaches that may be adapted across different settings while recognising contextual differences (Bowden et al., 2024). Examining school environments across countries therefore provided opportunities to consider how strategies implemented within one context may inform future initiatives in another. For example, schools in both NZ and SL experienced difficulties in translating school food policies into consistent practice and maintaining healthy school food environments. Similarly, concerns relating to insufficient PA opportunities and suboptimal dietary behaviours were evident despite differences in economic development and educational structures. These findings suggest that some barriers to healthy behaviours may extend beyond national income level and reflect broader implementation challenges within school environments.

An additional limitation relates to the representativeness of the study samples. The participating schools and students were drawn from the Auckland region in NZ and Rathnapura District in SL and were therefore not intended to be nationally representative of either country. Comparative research conducted within selected regions can provide valuable contextual insights; however, findings should be interpreted cautiously when considering broader national populations because regional, socioeconomic, cultural, and educational differences may exist within countries (Rodgers et al., 2025). Consequently, the findings of this doctoral study are more appropriately viewed as reflecting the experiences and characteristics of the participating schools and communities rather than all schoolchildren in NZ or SL. Furthermore, substantial contextual differences existed between the two countries, including differences in culture, food systems, school structures, socioeconomic conditions, and policy implementation processes. Although considerable effort was made to adapt data collection tools and ensure conceptual equivalence, some differences in interpretation and response patterns may have remained.

Another challenge involved balancing methodological consistency with cultural appropriateness. Standardisation was necessary to support meaningful comparisons, yet excessive standardisation risked overlooking important contextual differences. Conversely, extensive adaptation could have reduced comparability across settings. Throughout the study,

efforts were made to maintain this balance by retaining core constructs while culturally adapting examples, terminology, and data collection procedures.

The cross-sectional nature of the embedded studies also limited interpretation of comparative findings. While the design enabled examination of similarities and differences between countries at a particular point in time, it could not determine how school environments influenced behavioural outcomes over time. Longitudinal approaches may have provided stronger evidence regarding causal pathways linking school environments, PA participation, and dietary behaviours. However, such designs would have required substantially greater resources and extended follow-up across both countries, making them difficult to implement within the scope of a doctoral study.

Reflecting on the overall design, a major lesson learned was that successful cross-country research requires balancing methodological consistency with contextual adaptation. Meaningful comparison does not necessarily depend on identical implementation procedures; rather, it depends on ensuring that comparable constructs are measured appropriately within each setting. In retrospect, the comparative design became one of the most significant strengths of this doctoral study. Although it increased methodological complexity and logistical demands, it provided insights that would not have been achievable through a single-country investigation. The experience highlighted both the value and the challenges of conducting cross-national school-based research and reinforced the importance of context-sensitive approaches when examining children's health behaviours across diverse educational and cultural environments.

9.4 Limitations, lessons learned and recommendations for future research

While this doctoral study generated important insights into PA behaviours, school food environments, dietary assessment, and dietary intake among schoolchildren in SL and NZ, several limitations should be considered when interpreting the findings. At the same time, these challenges provided valuable methodological and practical lessons that may inform future cross-country research involving children.

A key limitation was the use of convenience sampling across several study components. Schools and participants were recruited based on accessibility and willingness to participate rather than through nationally representative sampling procedures. Furthermore, the samples were drawn from the Auckland region in NZ and Rathnapura District in SL, limiting the extent to which findings can be generalised to all schoolchildren in either country. Although the study included participants from diverse school settings, caution is required when interpreting the findings at a national level. Future studies would benefit from larger and more geographically representative samples drawn from multiple regions within each country.

The cross-sectional nature of the empirical studies also limited interpretation of the findings. The research design enabled examination of PA, school food environments, and dietary outcomes at a single point in time but did not permit assessment of causal relationships or changes over time. Consequently, while associations between environmental factors and health behaviours could be explored, the direction of these relationships could not be determined. Future research incorporating longitudinal or intervention-based designs would strengthen

understanding of the pathways linking school environments, dietary behaviours, and PA outcomes.

Several external events influenced the conduct of the study. The COVID-19 pandemic affected the original research plan and delayed relocation to NZ, requiring adaptation of the study design. Although these circumstances ultimately contributed to the development of the cross-country comparative component, they also created logistical challenges relating to planning and coordination. Similarly, the economic crisis in SL occurred during the study period and may have influenced food availability, household purchasing practices, and school food environments. These circumstances highlighted the importance of flexibility and adaptation in international research. A major lesson learned was that research undertaken across countries must be designed with sufficient flexibility to accommodate unexpected contextual changes while preserving the integrity of the overall study.

Differences in sample size between countries represented another limitation. The NZ component benefited from participation in the HAL initiative and access to a substantially larger number of participants, whereas recruitment in SL relied on independently selected schools and available resources. Although consistent measurement approaches were applied wherever possible, unequal sample sizes may have influenced statistical power and the precision of some cross-country comparisons. Future multi-country studies should consider recruitment strategies that enhance sample comparability across participating countries.

The dietary assessment component also had limitations. Although the modified 24-MPR method was validated prior to implementation, dietary intake data remained dependent on participant recall and reporting accuracy. In addition, biomarker measures were not included within the study. Biomarkers may have provided objective information relating to nutritional status and strengthened interpretation of dietary adequacy findings. Future studies should consider integrating biological measures, where feasible and ethically appropriate, to complement self-reported dietary data and provide a more comprehensive assessment of nutritional outcomes.

Despite these limitations, several important lessons emerged. First, an important ethical and methodological lesson arising from this doctoral study related to the complexity of ethical governance in international research. While ethical approval was obtained from the Massey University Human Ethics Committee and administrative permissions were secured from relevant authorities in SL, the absence of independent host-country ethical review represented a limitation of the study and highlighted broader challenges associated with ethical governance in international research. While the absence of host-country ethical review may be considered a limitation, the experience also highlighted broader challenges associated with conducting multi-country research across different regulatory systems. Multiple ethics applications often require substantial time, resources, and administrative coordination, and the requirements of ethics committees may vary considerably between countries. These processes can create delays and increase the complexity of international research without necessarily improving participant protection when similar ethical issues are being reviewed repeatedly.

Reflecting on this experience, it became evident that clearer guidance and more harmonised approaches to ethical review are needed for multi-country studies. International frameworks that facilitate mutual recognition of ethical review decisions or provide standardised guidance for cross-national research may help reduce unnecessary administrative burden while maintaining high ethical standards. They may also facilitate earlier engagement with key stakeholders and improve coordination between participating institutions.

Second, the adaptation and validation of research instruments highlighted the importance of ensuring cultural and contextual relevance when transferring measurement tools between countries. Maintaining conceptual consistency while allowing appropriate local adaptation proved essential for meaningful cross-country comparisons.

The doctoral study also highlighted several methodological priorities for future research. The development and validation of population-specific accelerometer calibration studies and cut-points for Asian children would strengthen the accuracy and contextual relevance of objective PA assessment. Similarly, continued validation of dietary assessment methods for children is needed to improve data quality and comparability across studies. More broadly, future international research would benefit from stronger collaborative governance arrangements, standardised measurement protocols, and long-term partnerships between researchers, schools, and policymakers. Such approaches may enhance methodological consistency while remaining responsive to local contexts.

Overall, the limitations encountered throughout this doctoral study reinforced important lessons regarding the conduct of cross-country research. While methodological consistency remains essential, successful international studies also require flexibility, stakeholder engagement, cultural responsiveness, and careful adaptation to changing circumstances. These experiences provide valuable guidance for future research seeking to examine children's health behaviours across diverse educational, social, and policy environments.

9.5 Conclusion

This chapter has critically reflected on the ethical and methodological considerations underpinning this doctoral study. Conducting research across the education and health sectors in SL and NZ required navigation of multiple ethical, institutional, cultural, and methodological challenges. The study highlighted the importance of viewing ethics as an ongoing process that extends beyond formal approval procedures and requires continuous attention to participant welfare, informed consent, cultural appropriateness, and institutional relationships throughout the research process.

The chapter also reflected on key methodological decisions that shaped the study, including the adoption of a series of embedded studies, the use of narrative review methodologies, the application of common measurement frameworks across countries, and the incorporation of dietary assessment method validation prior to dietary data collection. Together, these decisions enabled examination of children's health behaviours across behavioural, environmental, methodological, and nutritional domains.

A major lesson arising from this doctoral study was the importance of balancing methodological consistency with contextual adaptation in cross-country research. While

standardised protocols were essential for comparability, adaptations were often necessary to ensure cultural relevance and feasibility within different settings. The experience demonstrated that meaningful international comparisons depend not on identical procedures, but on the careful application of equivalent concepts across diverse contexts.

Although challenges such as convenience sampling, cross-sectional designs, unequal sample sizes, the COVID-19 pandemic, the SL economic crisis, and the complexities of ethical governance influenced the research process, these experiences strengthened the overall study and generated valuable methodological and practical insights. Ultimately, this doctoral study demonstrated that conducting cross-country school health research extends beyond methodological implementation and requires ongoing ethical reflection, methodological flexibility, and responsiveness to contextual realities. These lessons provide a valuable foundation for future international research seeking to improve children's health through school-based interventions and policies.

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Appendices

Appendix 1 - Publication, conference presentations and grants

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Appendix 1.2.2 Peer-reviewed journal publication
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Appendix 1.3.2 Peer-reviewed journal publication
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Appendix 1.5 DRC 16 form for Chapter 5
Appendix 1.6 DRC 16 form for Chapter 6
Appendix 1.7 DRC 16 form for Chapter 7
Appendix 1.8.1 IPASH
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Appendix 2 – Supplementary documents

Appendix 2.1 Supplementary Document for Chapter 4
Appendix 2.2 Supplementary document for Chapter 6
Appendix 2.3 Supplementary Document for Chapter 7

Appendix 3 - SL Data Collection

3.1 Ethics approval letter from Massey University, New Zealand
3.2 Permission letter from the Ministry of Education, Sri Lanka
3.3 Permission letter from the Sabaragamuwa Provincial Education Office, Sri Lanka
3.4 Information letter – Parents
3.5 Information letter – Food Suppliers
3.6 Information letter – Food Committee members
3.7 Consent form – Parents
3.8 Consent form – Key informant
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3.10 Data collection Sheet – Physical Activity (Grade 1-3)
3.11 Data collection Sheet – Physical Activity (Grade 4-8)
3.12 Data collection Sheet – Food Availability
3.13 Data collection sheet – Food policy and practice
3.14 Characteristics of Schools in Rathnapura District
3.15 Characteristics of the study population

Appendix 4 - NZ Data Collection

4.1 Ethics approval letter from Massey University, New Zealand
4.2 Permission request letter
4.3 Research advertisement
4.4 Information sheet
4.5 Consent form
4.6 Data collection sheet – 24 hours Multiple Pass Dietary Recall
4.7 Food-Weighted Record Booklet
4.8 Veggie Meter Questionnaire

Appendix 1
Publication, conference presentations and grant

Appendix 1.1. – Publication, Presentation, and Awards List

Peer-reviewed Journal Publications
Perera T. S. H., David S. Rowlands, Ananda Chandrasekara, Scott Duncan, & Ajmol Ali. (2024). Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions. *Asian Society of Kinesiology*, *2*(1), 15-31. https://doi.org/10.63020/pa.2024.2.1.15
Patel, V. V., Perera, T. S. H., Rush, E., McArley, S., Wham, C., & Rowlands, D. S. (2025). Reliability of a Modified 24 h Dietary Recall and Veggie Meter to Assess Fruit and Vegetable Intake in New Zealand Children. *Nutrients*, *17*(20), 3293. https://www.mdpi.com/2072-6643/17/20/3293
Publications under review or to be submitted
Chapter 4 - Physical Activity Measurement and Perception in Schoolchildren in New Zealand and Sri Lanka: a Pilot Study of a Developed vs a Developing Nation
Chapter 5 - School Food Environment in Focus: Availability and Policy Practices in New Zealand and Sri Lanka – An Exploratory Study
Chapter 6 - Reliability and Validity of a Modified 24-hour Dietary Recall in New Zealand Schoolchildren
Chapter 7 - Comparative Evaluation of Nutrient Intakes and Dietary Adequacy Among Schoolchildren Aged 9-13 in Sri Lanka and New Zealand: An Exploratory Analysis
Conference presentations
TSH Perera, David S. Rowlands, Ajmol Ali, Carol Wham, Ananda Chandrasekara. Cross-National Comparison of School-Age Physical Activity: New Zealand and Sri Lanka. Sport and Exercise Science New Zealand Conference, 2025, Massey University, Auckland, New Zealand, 19th to 21st November 2025
TSH Perera, David S. Rowlands, Ajmol Ali, Carol Wham, Ananda Chandrasekara, VCR De Mel. Comparative Analysis of Physical Activity and Sedentariness in Schoolchildren from New Zealand and Sri Lanka. 10th International Society for Physical Activity and Health Congress (ISPAH) – 2024. Palais des Congrès de Paris, France, 28th to 31st October 2024
Abstract Publication "Measuring PA in Children using Accelerometer" published at the 2nd ASK global symposium, monitoring PA and Motor Skills in Children: The evidence Base in Asia, organized by the Asian Society of Kinesiology which was held on 4th November 2022
Grants
Recipient of the Massey University Doctoral Conference Grants 2024

Appendix 1.2.1. - DRC 16 form for Chapter 3 - Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions

MASSEY UNIVERSITY
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UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Thalagalage Shalika Harshani Perera
Name and title of main supervisor:	David S Rowlands, Professor
In which chapter is the manuscript/published work?	Chapter 3 - Accelerometer-Based Assessment of PA

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

As a PhD student, I was responsible for drafting the manuscript, including synthesizing relevant literature, structuring the content, and articulating the key challenges, trends, and future directions in accelerometer-based physical activity assessment among Asian children. The manuscript was subsequently reviewed and approved by all co-authors, ensuring collaborative input and academic rigor.

Please select one of the following three options:

- (●) The manuscript/published work is published or in press

  Please provide the full reference of the research output:

  Perera T. S. H., David S. Rowlands, Ananda Chandrasekara, Scott Duncan, & Ajmol Ali. (2024). Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions. Asian Society of Kinesiology, 2(1), 15-31. https://doi.org/10.63020/pa.2024.2.1.15

- ( ) The manuscript is currently under review for publication

  Please provide the name of the journal:

- ( ) It is intended that the manuscript will be published, but it has not yet been submitted to a journal

Student's signature:	Harshani Perera Digitally signed by Harshani Perera DN: CN=Harshani Perera, E=shalika.harshani@gmail.com Reason: I am the author of this document Location: Date: 2026-02.13 23:17:30+13'00' Foxit PDF Reader Version: 12.1.0	Main supervisor's signature:	David Rowlands Digitally signed by David Rowlands DN: cn=David Rowlands, o=Massey University, ou=School Sport Exercise Nutrition, email=d.s.rowlands@massey.ac.nz Date: 2025.12.09 17:02:19 +01'00'

This form should be placed at the beginning of each relevant thesis chapter.

[1] Refer to the Massey University Publishing and Authorship guidelines (OneMassey for staff, Stream for students) and/ or Contributor Roles Taxonomy (CRediT) guidelines for guidance.

Appendix 1.2.2. – Peer-reviewed journal publication Chapter 3 - Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions

Physical Activity 2(1) 2024: 15—31 | https://doi.org/10.63020/pa.2024.2.1.15

REVIEW PAPER

Accelerometer-Based Assessment of Physical Activity in Asian Children: Challenges, Trends, and Future Directions

Perera, TSH[1,2]; David S. Rowlands[1]; Ananda Chandrasekara[3]; Scott Duncan[4]; Ajmol Ali[1]

[1] School of Sport, Exercise and Nutrition, Massey University, Auckland, New Zealand
[2] Department of Sport Sciences and Physical Education, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka
[3] Department of Applied Nutrition, Wayamba University of Sri Lanka
[4] School of Sport and Recreation, Auckland University of Technology, Auckland, New Zealand

ABSTRACT

Introduction: The rise of sedentary lifestyles and increasing rates of obesity among Asian children have raised concerns regarding public health. Accelerometer-based physical activity (PA) evaluation provides an objective, quantitative method with acceptable validity and reliability to quantify PA in the child, and currently, there is increasing popularity in the use of accelerometers in PA studies in Asia.

Objective: This review aims to examine the factors that need to be considered before conducting accelerometer-derived studies in Asian children while exploring the utility of accelerometers in assessing PA and sedentary behaviours.

Method: This narrative review was undertaken using publications retrieved from PubMed, Google Scholar, Sci-Hub, and MEDLINE databases. The publications contained a combination of words related to accelerometry-based assessment of PA, sedentary behaviour, and PA in Asian children.

Result: Despite the recognised benefits of PA, accurate measurement remains challenging. Accelerometer-based devices offer objective and quantitative data, yet their use in Asian countries is underexplored compared to Western nations because of wearing reluctance, fear of damage, stigma, and overemphasis on academic achievement. Challenges such as cultural preferences, socioeconomic factors, and technical limitations hinder the widespread adoption of accelerometers in PA research. Moreover, existing cut-points for defining PA levels are primarily based on Western populations, raising questions about their applicability to Asian children. This review highlights the need for culturally specific and age-appropriate PA guidelines and emphasises the importance of validating accelerometer-based measurements for accurate PA assessment in Asian children.

Conclusion: When assessing PA, consideration needs to be given to specific challenges within the Asian context, including ethnicity, body composition, diet, and seasonal variation. Future research should focus on assessing the validity and reliability of accelerometer-derived cut-points tailored to the Asian population to advance our understanding of PA behaviours and inform targeted interventions to promote active lifestyles in this demographic.

Keywords:
Calibration,
Cut points,
Movement,
Reliability,
Validity

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***CORRESPONDENCE:** Prof Ajmol Ali; School of Sport and Exercise Massey University Albany, Auckland, New Zealand; Tel: +64 (0)9 2136414; Email: a.ali@massey.ac.nz

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Introduction

Since the dawn of time, humans have created new technologies that make daily tasks less physically demanding, more effective, and consequently more sedentary[103]. Low levels of physical activity (PA) and rising obesity rates are significant public health concerns in Asia, affecting both developed and developing nations as a result of an increase in sedentary lifestyles and growing academic pressure on children[109]. However, this socioeconomic change is linked to dietary and lifestyle changes that lead to reduced PA and, when combined with the increased consumption of energy-dense foods, the results have been an average increase in body weight and the onset of obesity[68, 5]. However, to intervene, first, it is necessary to generate accurate and reliable metrics of PA by use of practical and economically accessible tools. PA domains include all types of activities performed during free time or leisure time, transportation activities, all tasks performed in the home environment, physical education sessions, and break-time at school[71]. Further, PA behaviour can be characterised according to the dimensions of type, intensity, frequency, and duration[90]. It is vital to have legitimate and trustworthy methods that are capable of encompassing all significant dimensions and domains to measure PA behaviour effectively.

Accelerometer-based devices are often used to collect reliable data on free-living PA behaviours in diverse studies[93]. Typically, the accelerometer is an unobtrusive small machine that is placed on the hip, hand, or ankle using an elastic belt or strap[66, 76]. Accelerometers provide precise, reliable, and accurate communicable data for measuring PA in children and adolescents relative to other conventional methods[27, 64, 42]. Accelerometers are used in various studies to assess PA in different population sizes. The use of accelerometers in a nationally representative sample of Americans aged 6 and older as part of the National Health and Nutrition Examination Survey serves as an example of the viability of using accelerometers in large-scale research (NHANES)[27].

As a result of the rapid economic growth and changing living conditions over the past 20 years, there are significantly more Asian children and adolescents in developed and developing countries who are mostly physically inactive or often too inactive to fulfil PA recommendations[30, 59]. However, numerous studies have been conducted to collect reliable and accurate data for the evaluation of PA in children and adolescents around the world (USA, German, Belgium, Greece, Hungary, the Netherlands, and Switzerland and UK) based on the time of wearing, intensity[17], age[26], position[49], seasonal variations[78], and body weight[98, 65]. However, there is a notable lack of data from Asia, the eastern Mediterranean, and Arab countries in the PA assessment relative to Western countries[91, 25]. Several studies have revealed that South Asian children living in the United Kingdom exhibited greater levels of sedentary behaviour and lower levels of PA when compared to native white British children[8, 25, 87, 102]. These discrepancies are frequently attributed to cultural preferences, socioeconomic considerations, a lack of intrinsic drive, ignorance about the advantages of PA, and an inability to incorporate PA into regular activities[43]. According to Nagy *et al*., (2019), ethnicity, sex, BMI, and local socioeconomic position are key children-specific characteristics linked to PA behaviours and cutpoints, while weekends, school breaks, and seasonality of nations are significant temporal factors.

However, population studies based on selfreports reveal that Asian people tend to exercise infrequently, and self-reported surveys account for most of the data on the low prevalence of PA in Asian individuals[102]. These measurements have known drawbacks, including imperfect recall, bias in social desirability, and difficulty in accurately estimating the frequency, duration, and intensity of activities. Also, since some parents reported that their children were reluctant to wear accelerometers at school and during sports owing to the potential of stigma and bullying, measuring PA with an accelerometer has a plethora of challenges[30]. Additionally, among school children (7-11 years old), the major problem was a perception that the accelerometer was perceived to be *seeing them* and that it featured a webcam or microphone[82]. Furthermore, children may not use the device

during specific activities, like swimming and contact sports[79]. The impact of a humid subtropical environment in some Asian countries on daily activity behaviour measurements is another hurdle and remains unknown[108]. Thus, sedentary time and actual PA energy expenditure are frequently overestimated or underestimated in Asian countries[4]. To measure current and fluctuating sedentary time and PA levels and to assess the efficacy of interventions intended to increase activity levels, an accurate assessment is essential. When determining the measurement method based on the purpose of the research, factors such as the measurement tool's reliability and validity, acceptability by individuals, group size, age, gender, education, time, cost, and comorbidity must be considered. Accelerometers offer accurate estimations of sedentary time, PA, and sleep, and their use has significantly increased in developed nations[19]. However, accelerometer methods are almost always designed for Western populations, making their applicability to nonWestern populations questionable.

Asian children, in particular, are underresearched given the proportion of the world population. Additionally, the data we have may be misleading if the methods are not appropriate. Therefore, the purpose of this review is to examine the factors that need to be considered before conducting accelerometer-derived studies in Asian children. In this review, selected publications were discovered by searching PubMed, Google Scholar, Sci-Hub, and MEDLINE databases, which contain the following combinations of words: PA assessment of Asian children, drawbacks of PA measurement, accelerometer measurements, cut-points, and accelerometry-based assessment of PA.

Methods of Physical Activity Assessment

There are numerous methods for measuring PA, both subjective and objective. Pedometers and accelerometers are categorised as objective methods among frequently used techniques, while survey questions and logs belong to the category of subjective techniques[89]. Generally, PA assessment can be categorised into five groups: behavioural observation, self-reported methods, physiological markers, calorimetry, and motion sensors[101]. Each of these methods has its own strengths and limitations <Table 1>. The lack of a suitable standard to which procedures can be compared has been the biggest barrier to the validation of laboratory and field methods of quantifying PA in individuals. Although there may be some benefits in how different methods interact, it is hard to identify which method is truly the gold standard because all methods have flaws[58] <Table 1>.

The most promising technology for measuring PA in recent years is accelerometers. Free-living subjects can be exposed to sensors for extended periods[44]. They can also be used to study patterns of PA over time when empowered with a memory space to store information on body movement. Different sensors, including mechanical devices and electronic accelerometers, have been developed. The total amount, frequency, intensity, and duration of PA can be determined using accelerometers[54].

Table 1. Advantages and limitations of physical activity (PA) measuring approaches.

Approaches	Advantages	Limitations	References
Direct observation	• Provides relevant information • low cost	Time-consuming Limited monitoring time • The observer's appearance may affect the subject's behaviour during the activity.	Pate *et al*., (2010), Plasqui and Westerterp, (2009)
Self-reporting (Questionnaires and daily activity log)	• Affordable • Applicable in epidemiological studies • Suitable for use with large populations • valid for overweight cataloguing of PA level	Poor reliability and validity for regular PA assessment No comprehensive data on PA	Cain *et al*., (2013); Sylvia *et al.,* (2014)
Heart rate monitoring	• Energy expenditure pattern is obtained • Used in validation studies at observation • intervals of 7 to 14 days for 2-4 days.	Only valid for a specific range of heart rate Poor validity in long-term free-living behaviours of PA Some factors (hydration, temperature, emotion) • could limit the use	yang *et al*., (2020), and Sylvia *et al.,* (2014)
Calorimetry	• Measuring short-term energy expenditure • reliably and accurately. •	Expensive Usually restricted to laboratory conditions unless using portable devices • Device calibration takes significant time	Chen and Bassett, (2005)
Motion sensors (pedometer, and accelerometer)	• A lightweight, portable, simple, and device • inexpensive • Non-reactive • Monitor free-living subjects for extended periods. • Track patterns of movement over time	Inadequate validity for energy expenditure assessment No information on precise behaviours	Plasqui and Westerterp, (2009); Ke, (2019)

Evolution of the Accelerometer and Utilisation in Physical Activity Measurement

The body part where the sensor is attached experiences accelerations that are measured by wearable accelerometers. Accelerometers are in the category of motion sensors, widely used to detect movements in terms of acceleration and estimate PA. The monitor typically filters and pre-processes the signal to produce activity counts, or accelerations brought on by body movement[105]. By classifying activity counts that have been accumulated over a given amount of time (epoch length) with a set of *cut-points*, or intensity thresholds for PA intensity classification, it is possible to determine the quantity and intensity of regular sedentary activities and PA[3]. Applying algorithms to objectively determine activity counts can also be used to estimate PA energy expenditure or sleep-related behaviour[28]. Instead of using activity counts, new techniques have been developed to evaluate these factors from raw acceleration signals[105].

In the 1980s, the first accelerometry-based PA evaluation was conducted[93]. Because of the conventional device's high production cost, as well as issues with consistency, authentication, and calibration, a novel accelerometry-based research device was created in the 1990s[58, 23]. Generally, the number of peer-reviewed papers reporting PA or exercise monitoring using an accelerometer grew from <10 per year from 1981-1996 to ~90 per year in 2003-2004 with the development of calibration of the accelerometer[92]. As a result of the reliability and validity of accelerometry-derived data, the practice of accelerometry to collect PA data in children over multiple regular days has improved exponentially in the early 2000s with ~30 publications per year. over 300 research articles were published in 2010 based on the accelerometer-derived PA research, while more than 1100 papers were published in 2017[83].

Initially, accelerometer-based PA devices had many drawbacks, including short battery

life, limited storage capacity, low sensitivity, and less connectivity with other equipment[85]. owing to remarkable technical advances in accelerometers in PA monitoring since 2004, researchers have access to raw acceleration PA data using wearable accelerometry devices[22]. However, advances in activity monitor technologies are connected to the sampling frequency (acceleration rate detected every second) and modern activity monitors can reach 100 Hz, as opposed to the 10 Hz of earlier monitors. Updated models offer several gigabytes of storage space, allowing them to save data for many days or weeks whereas older models were only able to store data for a few hours. Furthermore, battery life enables activity sensors to gather data for more than 29 days without recharging. In addition to collecting raw acceleration data in three axes rather than counts, modern activity monitors may also have wireless connections to computers, tablets, and heart rate belts through WiFi and Bluetooth[16, 85]. Recent activity trackers also feature screens where the devices may provide consumers with immediate feedback. other sensors have been integrated with accelerometry to offer data on ambient light, global location, body posture, and a variety of physiological indicators to researchers. Wearable triaxial accelerometers and multi-sensor devices that measure several physiological activities have grown from basic pedometers to these sensors[74]. The current ActiGraph accelerometer is the only type that can be utilised to identify sleep patterns as well as measure the PA of children[41]. Such varied sensor deployment is not only helpful in enhancing PA and sedentary behaviour predictions but also enables simultaneous data gathering of several health-related parameters[28, 85].

Types of Accelerometers for Assessing Physical Activity

Accelerometers can be categorised into three types based on the number of axes <Table 2>. Triaxial accelerometers, found in devices like the RT3, Actigraph, GENEA, and, GENEActive, detect acceleration along three orthogonal axes, as opposed to omnidirectional accelerometers, found in devices like the MiniMitter and Actical, which measure acceleration in all directions but are particularly sensitive to movement in the vertical plane. Microelectromechanical systems (MEMS) accelerometer chips are often used in modern accelerometers[88].

To measure acceleration along a certain axis, accelerometers can use a variety of technologies, such as piezoelectricity, piezoresistance, micromechanical springs, and capacitance changes[100]. Primarily, accelerometers can be categorised into three types; piezoelectric,

Table 2. Different types of axes in accelerometers

Axis type	Description
A. Single axis	The most common type is a single-axis accelerometer. These are often used to calculate the magnitude of simple vibration points. A single-axis device is a piezoresistive accelerometer, for instance.
B. Two-axis	Accelerometers are intended to measure acceleration/vibration along both the x and y axes.
C. Three-axis	The vertical z-axis augments the device's two-axis accelerometer. Triaxial devices can monitor complex three-dimensional positioning and measurements.

Resource: Strong *et al*., 2005

Table 3. Types of Accelerometers.

Type	operation Principle and aspects	Technical advantages	Limitations
1. Piezoelectric Accelerometers	• Rely on a piezoelectric substance to perceive changes in acceleration, such as quartz crystal or polycrystalline ceramic. • The change in the material's electric charge is comparable to the force applied to accelerate mass.	Conscience Electronic output Basic interface circuit Outstanding base deflection and temperature isolation High resonance frequency High linearity	• Unable to monitor impulses with zero frequency • The poor responsiveness of piezoelectric materials to direct current (DC) • The size of the gadget is considerable.
2. Piezoresistive Accelerometer	• Resistance changes are used to gauge reading output. • It consists of semiconductors with several unique resistive circuits for all measurement axes.	Appropriate design architecture • Easy manufacturing procedure Simple readout circuit. Possess silicon micro- • accelerometers. • Tiny in scale • Low electricity usage	Minimal sensitivity Extremely sensitive to temperature Huge and hefty appearance high shock wave measurements to low-frequency readings with sensitivity DC
3. Capacitive accelerometer	• A silicon mass linked to four chains serves as a spring • system in this semiconductor • sensing device. • Polar-distance-variable • capacitive sensors are provided • using the capacitance theory.	Hypersensitivity Effective DC efficiency Low frequency • Small drift Sensitivity to low temperatures Simple circuit design linearity of under 1%; Reliable results Minimal measurement erroneous	• sensitive to electromagnetic interference (EMI) Range is restricted A high-impedance signal source is a capacitive sensor. • Low-frequency measurement adaptation Expensive equipment

piezoresistive, and capacitive accelerometers. There are many accelerometers accessible that assess PA, and the majority of them also record step counts. The study objectives, the target demographic, the activity aspect of interest, the limitations of the device as well as the budget and logistics, all influence the choice of the monitoring device <Table 3>.

A variety of practical considerations impacting monitor selection, such as the size, weight, stability, and strength of the accelerometer and how tamper-proof the device is, may be particularly pertinent for monitoring PA in children[24]. Although triaxial and omnidirectional accelerometers theoretically have an advantage over uniaxial monitors for assessing young children's distinct PA behaviour, the topic has garnered little study attention in 3-11 years old children[32, 48]. Uniaxial monitors may also fail to recognise issues such as walking slowly up a 5% elevation may consume more energy than walking quicker on level ground[56]. None of these technical parameters discussed above is likely to be different in Asian children.

Cut-Points for Accelerometry

Cut-points can change depending on the findings of studies that calibrated accelerometers by defining counts per minute about the intensity of PA. Calibration studies have been conducted in laboratories and the field using a range of methodologies[100]. The use of published threshold values or cut-points to convert accelerometer counts into minutes of PA has resulted in an ongoing debate about which cut-points to use in research[27]. often, calibration studies are undertaken to provide techniques for converting accelerometer data into physically significant measurements like metabolic equivalents (METs) in health-related assessment of children[15], energy expenditure ($kcal \cdot min^{-1}$) in PA and sedentary behaviour assessment[34] or oxygen uptake (vo_2) in the validation of accelerometer related to PA assessment[45]. over the past 20 years researchers have undertaken multiple calibration experiments to find optimal cut-points for preschoolers and school-aged children[52, 10, 33, 55]. The classification of children's PA levels according to existing cut-points may be improved, which could benefit subsequent intervention and observational studies, with the development of a low-cost, scalable fieldbased protocol to produce population-specific accelerometer cut-points that are behaviourally valid[53].

Additionally, data for *specificity* (proportion of actual non-wear events correctly identified by

the model) and *sensitivity* (the ratio of change in acceleration (input) to change in the output signal) of the accelerometer revealed that the established cut-points correctly recognised PA and that children's minutes of activity was rarely mistakenly classified as inactive[63]. Indirect calorimetry was employed by Lynch *et al*., (2019) to examine the reliability of triaxial and omnidirectional accelerometers in 570 participants (aged 3 to 18). The mean specificity varied from 71% to 96% and the mean sensitivity varied from 46% to 96% across all trials and the range of the average area under the curve was 69% to 98%. Additionally, Lynch *et al.,* (2019) were able to determine that accurate measurement was optimal when monitoring inactivity and poorest when monitoring light PA. Montoye *et al*., (2016) explained how the accelerometer performed more accurately when it was worn on the hip as opposed to the wrist. Also, according to the available data, triaxial and omnidirectional accelerometers can measure children's levels of PA and sedentary with accuracy. According to Cauwenberghe *et al*., (2011), accelerometer cut-points with strong discriminating power were created to differentiate between PA levels in preschoolers, although the choice of the cutpoints might result in considerable variances. Furthermore, the calibration and cut-points of several accelerometers were evaluated for various PA levels, age-specific investigations, and wearing postures in children all over the world <Table 4>. These studies included clinical trials of children with cerebral palsy[47] and cystic fibrosis[13], which also focused on cut-points for light PA and sedentary behaviour. Romanzini *et al*., (2014) concluded that cut-points of three different accelerometers in their studies can be used to screen PA in adolescents.

According to Duncan *et al*., (2020), triaxial accelerometry cut-points developed for calibration, placed on wrists, waist, and ankles, have an excellent capacity to discern children's sedentary behaviour and moderate intensity PA-encompassing motor skill exercise. However, others suggest that existing cut-points for evaluating PA in children are only valid for the population rather than for individual children[21, 53]. In addition to selecting cut-points for different levels of PA and sedentary behaviour, the calibration of the accelerometer takes into account the accelerometer model, epoch length, concept of non-wear time within a day, interpretation of a valid day, and the necessary number of valid wear days[18].

The Healthy China 2030 concept states that school-aged children should engage in at least 1 hour of PA every day, and more than 25% of them should have an "outstanding" fitness grade[110]. Zhu *et al.,* (2019) reported MvPA, screen time, and age- and sex-specific BMI using 131,859 children (aged 7 to 19) from 986 public China schools in 2017. The lack of culturally specific and age-appropriate PA and intervention guidelines for school-aged children and adolescents are all significant obstacles to PA measuring[109]. <Table 5> shows that most Indian school-age children are just moderately active. According to the worldwide recommendations, MvPA, as measured with an accelerometer in vietnam is on average 28 min/d, implying a significant occurrence of physical inactivity. Children from South Korea and China had daily step counts that were less than the recognised cut-points. Müller *et al*., (2013) showed

Table 4. Evaluation of cut-points, specification, and sensitivity of different accelerometers in physical activity studies

Reference	Country	Age (# participants)	BMI (kg/ m2)	Accelerometer type	Place	PA Type	Specificity (%)	Sensitivity (%)	Cut-point		
									SD	MPA	VPA
Mackintosh et al., (2012)	UK	10-11 y (n=28) Healthy	20 ±4.7	GT1M ActiGraph (Uniaxial)	Hip	Drawing, DVD Watching, Brisk Walking, Jogging, Playground Games, Free-choice Games	96-97	89-99	≤372 counts/m	>2160 counts/m	>4806 counts/m
Cauwenberghe et al., (2011)	Belgium	5.8 ± 0.4 y (n=18) Healthy	16.4 ±1.1.	GT1M ActiGraph	Hip, wrist	Free playing, standing, sitting, drawing, walking, and jogging on the treadmill	82-91	86-88	373 counts/15 s	585 counts/15 s	881 counts/15 s
Duncan et al, (2020)	UK	8-12 y (n=20) Healthy boys	17.3 ±1.9	GENEActiv monitor	Nondominant, Wrist,	Football	66.2-84.8	84.4-84.7	4.5	16.5	-
					Dominant, Wrist,		53.3-84.6	67.5-84.7	4.4	12.5	-
					waist		88.1-97.2	86.8-87.8	4.0	8.9	-
					Dominant Ankle		66.8-95.9	73.1-74.2	3.5	39.3	-
					Nondominant Ankle		81.2-96.4	76.3-82.5	4.0	81.7	-
Chandler et al., (2016)	USA	8-12 y (n=45) Healthy	-	ActiGraph GT3X+,	Wrist	Resting, Coloring, Walking, Playground, Splash Pad, Swimming, and Progressive Aerobic Cardiovascular Endurance Run	61.7-86.6	60.3-61.7	<113	114-372	777+
Keawutan et al., (2016)	Australia	4-5 y (n=84) With cerebral palsy	-	GT3X ActiGraph and GT3X+ ActiGraph	lower back close to the center of mass of the body	Sedentary behaviour	27-37	65-81	40 counts/5S	-	-
Bianchim et al., (2022)	UK	7-17 y (n=63) with 35 cystic fibrosis girls	18.0 ± 4.2	ActiGraph GT9X Link	Wrist	Video, Writing, playing with the device, walking, Stairs	63.3-85.4	76.5-92.9	74.2	82.5	262.7
				GENEActiv			66.8-84.4	91.7-98.0	74.6	85.3	222.5
Romanzini et al., (2014)	Brazil	10-15 y (n=79) Healthy	-	ActiGraph GT3X	waist	Rest, DVD watching, Writing, playing video games, walking, running, playing volleyball and basketball, and soccer	84.9-93.9	97.9-98.3	46 counts/15 s	607 counts/15 s	818 counts/15 s
				RT3			84.9-94.2	91.2-98.3	5.6 counts/s	20.4 counts/s	32.2 counts/s
				Actical			85.1-94.2	98-98.3	17 counts/15 s	441 counts/15 s	873 counts/15 s

*SD- sedentary behaviour; MPA- moderate-intensity physical activity; VPA- vigorous-intensity physical activity
*Sensitivity refers to the ratio of change in acceleration (input) to change in the output signal.
*Specificity refers to the proportion of actual non-wear events correctly identified by the model.

Table 5. Accelerometry-derived measurements of physical activity (PA) in Asian children

Reference	country	No: of applicants	Male	Female	Device	output
Corder *et al*., (2010)	India	30	15	15	Accelerometer [7 days, obtain average movement in counts per minute (CPM)]	Ø337.7 CPM (light active) MvPA=37.5 min/d (average of the whole group) MvPA for at least more than 30 mins per day- 31% of boys, 0% of girls
Lachat *et al*., (2008)	vietnam	227	Not ment	ioned	Accelerometer (8 days, total counts and time of MvPA measured)	ØMvPA=28 min/day MPA for at least 30 min/day=46% MPA for at least 60 min/day=16%
yamauchi *et al*., (2007)	South Korea and China	159	80	79	Accelerometer (7 days, provide TEE, STP, and PAL)	STP=10,946 (male: 11,388; female: 10,504) (below cut-points) TEE=1.54 kcal/d (male: 1.5; female: 1.57)
Tudor-Locke *et al*., (2003)	Philippines	1629	756	873	Accelerometer (1 day, energy expenditure on PA of 1 day recorded)	EEPA(24h)=378 ± 164.5 kcal (male); EEPA(24h)=271 ± 105.4 kcal (female)
Nguyen *et al*., (2010)	vietnam	617	333	284	Accelerometer (7 days, average time spent with MvPA calculated)	Ø MvPA=60.3 min/day
Rowlands *et al*., (2002)	Hong Kong	50	24	26	Accelerometer [5 weekdays and 1 weekend day, obtain average movement in counts per day (cpd)]	Ø 299,407 ± 147,075 cpd (moderately active) (averaged over 5 weekdays)

EE= Energy Expenditure; MvPA=moderate to vigorous PA; PAL=Physical Activity Level; STP=Daily step frequency; TEE=Total Energy Expenditure; Ø=Arithmetic means

that the majority of Asian children did not exceed the PA standards, and the minimal PA guidelines of 30 minutes, 3 days per week, were only reached by less than 50% of the samples examined.

Wang *et al*., (2013) outlined the findings of a national survey of Chinese city children and adolescents, which used accelerometers to objectively measure the PA and sedentary time of Chinese city children and youth aged 9 to 17 and to investigate for differences by sex, age, grade, and body weight. Based on cut-points specially designed for Chinese children and adolescents, Wang et al (2013) concluded that only 9.4% of boys and 1.9% of girls achieved recommended level (60 min/day) of MAPA, boys were more active than girls, children were more active on weekdays than weekends, and based on the BMI of children, variations in PA and sedentary behaviour were not found. However, Wang *et al*., (2013) concluded the inadequacy of PA, the excess of sedentary behaviour in Asian children and, one of the challenges of measuring PA in Asian children is limited evidence on accelerometer-based PA assessment in Asian children.

There is a dearth of information with regard to calibration and cut-points of accelerometers for Asian children based on body composition, geographical, nutritional, seasonality, cultural and socioeconomic gaps. For Chinese children and teenagers, Zhu *et al.,* (2013) conducted research to create new ActiGraph cut-points for moderateto-vigorous PA (MvPA) and vigorous PA (vPA) and to assess the classification accuracy against a set of preexisting cut-points. Zhu *et al.,* (2013) suggested using CPM ≥2,800 as the cut-point value for MvPA and CPM ≥4,000 as the cut-point for vPA for Chinese kids and teenagers. Moreover, yates *et al*., (2015) observed variations in self-reported and objectively recorded PA levels between white and South Asian groups. However, there have been few studies in the previous decade evaluating existing cut-points, validations, and reliability of accelerometers paired with PA in Asian children with varying gaps such as BMI, body composition, sex, and age.

Validity and Reliability of

Accelerometer-Based Physical Activity Measurements

validity is measured by taking into account how accurately the procedure can be simulated. Reliability is the capacity of technology to produce the same outcome from day to day when no intervention is utilised[29]. Numerous examples of the usage of various accelerometer types to analyse PA in various disciplines can be found. The many types of accelerometers and their technical specifications that were

burden[1]. There are certain drawbacks to the approach, such as the inability to quantify the mode, intensity, or duration of activities when calculating total energy expenditure over a selected number of days[39]. Based on those limitations, several studies have made major contributions to manufacturing improved versions of the accelerometer as a self-monitoring tool for PA assessment.

It is crucial for researchers studying sedentary behaviour and PA to assess both the validity of the observed behaviour and the

Table 6. Technical specifications of the different accelerometers used in physical activity (PA) assessment

Name of accelerometer	Country	No. of axes	Accelerometer Type	Wearing place	Frequency response (Hz)	Sampling frequency (Hz)	Size (mm)	Weight (g)
RT3 (Jacob *et al.*, 2007; Maddison *et al.et al.*, 2009)	USA	3	Piezo-resistive	Waist	-	-	68 × 48 × 18	63
Tritrac (Jacob *et al.*, 2007)	USA	3		Waist	-		120 × 65 × 22	168
Actigraph (model 7164) (Pomeroy *et al.*, 2011; Corder *et al.*, 2009)	No longer available	1	Piezoelectric	Waist	0.25-2.5	10	51 × 41 × 15	43
Tracmor (Bonomi *et al.*, 2009)	Netherlands	3	Piezo-capacitive	Lower back	-	20	80 × 35 × 10	35
Tracmor (Bonomi *et al.*, 2010)	Netherlands	3	Piezo-capacitive	Lower back	-	-	32 × 32 × 5	13
Actigraph (GT1M) (Farooq *et al.*, 2018)	USA (no longer available)	1	Capacitive	Waist	0.25-2.5	30	38 × 37 × 18	27
Actiheart (Bonomi *et al.*, 2010)	UK	1	Piezoelectric	Chest	1-7	32	7 ×33; 100-mm length wire	8
Lifecorder (ohkawara et al., 2011; Lim *et al.*, 2018)	Japan	1	Piezoelectric	Waist	-	32	62 × 46 × 26	42
3dNX (Carter *et al.*, 2008; Konstabel *et al.*, 2019)	UK	3	Piezoelectric	Hip/ lower back	0.2-10	100	125 × 58 × 8	93
ActivPAL (Skipworth *et al.*,2011)	UK	1	Capacitive	Thigh	-	10	35 × 53 × 7	15
Actigraph GT3X+ (Skipworth *et al.*,2011)	USA	3	Piezoelectric	Wrist	0.25-2.5	30–100 Hz	46 × 33×15	19

evaluated against doubly labeled water (DLW) methods are listed in <Table 6>[75]. The DLW method, which is normally evaluated over a 7- to 14-day period, is still the gold standard for calculating total energy expenditure[104]. It is noteworthy because the approach is acceptable for usage in a free-living setting, is non-intrusive, and requires minimal participant

instrument's reliability[9]. According to van *et al*., (2011), the validity evaluation demonstrated a substantial and positive correlation between mean ActiGraph accelerometer activity counts and average observational System for Recording PA in Children-Preschool (oSRAC-P) activity intensity (r = 0.66; p 0.001; n = 31).

Furthermore, the sedentary cut-points revealed low to good classification accuracy, whereas the light PA and MvPA cutpoints showed poor classification accuracy in identifying sedentary behaviour, light PA, and MvPA, respectively. valkenet and veenhof, (2019) demonstrated the validity of three different accelerometers in PA <Figure 1>.



Figure 1. Validity of different accelerometers (sensitivity and specificity ratings) were established for each activity. Error bars are denoted standard deviation. (valkenet and veenhof, 2019)

According to Pedišić and Bauman (2015), there are four potential factors of concern that could weaken the validity of accelerometerbased estimation methods of PA and sedentary behaviour in children: (1) technical issues, such as some accelerometers cannot be utilised to evaluate aquatic activities[37] and overestimate the amount of energy required for a variety of other regular tasks and leisure activities like climbing stairs and playing tennis[51]; (2) periods of nonwearing time i.e., most children do not have accurate accelerometer data for complete days[81], and children avoid wearing accelerometers due to aesthetic concerns and physical pain[70]; (3) participant interference with the results like accelerometer data interfere by purposefully choosing not to wear the device, changing their usual behaviour, moving the device, or shaking it[6], and also 12-16-year-olds were worried about losing or destroying the gadget[69]; and (4) use of intensity cut-points such as MvPA estimation may derive from alternative methods like pattern recognition rather than employing cut-points[36]. variable sets of cut-points have been devised for various accelerometer models and are recommended to be used since they can produce significantly different prevalence estimates and intensity-specific PA levels[7].

According to Pedišić. and Bauman, (2015), metrics employed for PA monitoring should be sufficiently reliable to generate valid estimates at the group level. Also, errors from technological human-related factors might influence the reliability of an accelerometer. Baumgarter (1989) distinguished two categories of reliability: relative and absolute. The degree to which participants maintain their place in a sample after repeated assessments is known as relative reliability, whereas the level of individual variation in repeated measurements is known as absolute reliability. Accelerometers revealed strong intrainstrument and inter-instrument constancy in lab conditions, with coefficients of variation (CV) typically below 5% and 10%, respectively[77]. In freeliving situations, the inter-instrument reliability of accelerometers varied from moderate for RT3 accelerometers (Cv 9.8-39.8%) to a sufficient level for Actigraph 7164 and GT1M models (Cv 0.9-15.5%)[69, 97]. The high reliability of the accelerometer acquired over two 7-day periods in free-living situations was demonstrated by a test-retest reliability study (ICCs 0.77–0.90;[69]. According to Helmerhorst *et al*., (2012), the reliability of accelerometer-based estimations of PA and sedentary behaviour could be appropriate for public health surveillance. Conversely, there are positive developments in reliability that wristworn accelerometer compliance is higher than that of hip-mounted accelerometers[35].

Mindell *et al*., (2014) emphasised several practical issues of accelerometers in PA assessment such as no devices recognise loadcarrying, which also underestimates energy expenditure when carrying a big school bag, for instance, and because most accelerometers are not waterproof, they must be taken off before swimming. Although accelerometers are excellent at capturing time spent doing nothing and time spent engaging in dynamic activity, such as running or walking up to a particular speed, they are less effective at monitoring static activity and non-wear period, which is frequently crucial for total energy expenditure assessment[81, 88]. Additionally, some ethical committees could set limitations, such as advising athletes to take their devices off before engaging in contact sports[56].

Future Directions

This review explored PA monitoring using an accelerometer for Asian children but several concerns still require further investigation. Due to the absence of detailed investigation, methodologies for the use of accelerometers in different age groups could not be established.

We suggest further extended studies to assess the specific validity and reliability of cut-points in accelerometer measurements in Asian children are needed for the accurate evaluation of PA when choosing an accelerometer. Thus, based on the seasonality, BMI, age, sex, and type of PA, extended research on assessing suitable parameters such as validity, reliability, sensitivity, and specificity of the accelerometer is further required to measure the sedentary and physically active behaviours of Asian children, due to the majority of existing cut-points only being valid for children in Western countries.

Conclusion

Extended and accurate measurement of PA in Asian children is crucial to evaluate and intervene in the changing lifestyles leading to reduced inactivity and increased risk of non-communicable diseases stemming from increasing rates of obesity in children living in Asian countries. The accelerometer is a feasible, accurate, and selfmonitoring device that can be used to measure children's PA. The validity of accelerometer outputs depends on the validity and reliability of cut-points for the targeted population and it changes with body composition, age, sex, BMI, geographical area, seasonality, and cultural behaviour of children. However, the majority of existing cut-points for monitoring PA in children have been developed using data based on Western countries, and more data is required for Asian countries. The current validity and reliability values of accelerometer measures of PA in Asian children are less precise due to variance body composition, BMI, sex, and age-specific cut-point gaps. Although few studies were undertaken relating to Asian children, further validity and reliability assessment studies of cut-points in accelerometer measurements in Asian children are requisite for the accurate evaluation of PA.

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Appendix 1.3.1. - DRC 16 form for additional publication - Reliability of a Modified 24 h Dietary Recall and Veggie Meter to Assess Fruit and Vegetable Intake in New Zealand Children

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Student name:	Thalagalage Shalika Harshani Perera
Name and title of main supervisor:	Prof David S Rowlands
In which chapter is the manuscript/published work?	This work is related to chapter 6 and Chapter 7

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

HP, CW, VP, and DR designed the research and obtained ethical approval. HP and CW developed all the data collection sheets, and CW assisted with training the research assistants. HP, AA, and DR contacted schools and negotiated permission for participation. HP, VP, and AM were responsible for participant recruitment and data collection, while VP and SM assisted with data entry. VP, HP and DR conducted data analysis and interpreted the results. VP drafted the manuscript, and all authors reviewed and approved the final version.

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Appendix 1.3.2. - Additional publication - Reliability of a Modified 24 h Dietary Recall and Veggie Meter to Assess Fruit and Vegetable Intake in New Zealand Children

nutrients

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Article

Reliability of a Modified 24 h Dietary Recall and Veggie Meter to Assess Fruit and Vegetable Intake in New Zealand Children

Varshika V. Patel [1], Thalagalage Shalika Harshani Perera [1,2], Elaine Rush [3,4], Sarah McArley [1], Carol Wham [1] and David S. Rowlands [1,4,*]

[1] School of Sport, Exercise and Nutrition, Massey University, Auckland 0632, New Zealand; varshika.vpatel@gmail.com (V.V.P.); shalika.harshani@gmail.com (T.S.H.P.); s.m.mcarley@massey.ac.nz (S.M.); c.a.wham@massey.ac.nz (C.W.)
[2] Department of Sport Sciences and Physical Education, Sabaragamuwa University, Belihuloya 70140, Sri Lanka
[3] Office of the Vice-Chancellor, AUT University, Auckland 1010, New Zealand; elaine.rush@aut.ac.nz
[4] Riddet Institute, Massey University, Palmerston North 4442, New Zealand
* Correspondence: d.s.rowlands@massey.ac.nz; Tel.: +64-272099383

Abstract

Adequate intake of fruits and vegetables (F + V) supports healthy growth and development in children, yet many New Zealand children do not meet national dietary recommendations, and methods to evaluate intake require good reliability. **Objectives:** To establish the validity and reliability of a modified 24 h multiple pass recall (MPR) for evaluating F + V and carotenoid intakes in children aged 9–13 years. The reliability of the Veggie Meter® (VM®), a non-invasive reflection spectrometer to estimate skin carotenoid scores and derive blood carotenoid concentrations, was also examined. **Methods:** Thirty-two children (20 boys, 12 girls) completed three 24 h MPRs and parent-assisted weighed food diaries (WFDs) on randomised weekdays and weekends. Skin carotenoid scores were assessed using the VM®. The validity of the MPR was evaluated against WFDs using log-transformed Pearson correlations and mean x-axis bias. The reliability was assessed by the coefficient of variation (CV) and Pearson correlations. **Results:** Participants did not meet recommended F + V intakes (5–5.5 servings/day): MPR (mean fruit 1.3 servings/day; vegetables 2.0), WFD (fruit 1.3; vegetables 1.9). The MPR was a valid tool to estimate fruit and vegetable daily servings (combined-day Pearson coefficients > 0.71) with only trivial–small standardized mean bias-offset vs. WFD; however, the reliability was poor for the MPR-estimated carotenoid intake (CV 126%) and F + V intake. In contrast, the VM® was reliable (Pearson correlation 0.97–0.99) with low measurement error (CV 4.0–5.2%). **Conclusions:** The modified 24 h MPR was valid but unreliable for estimating F + V and carotenoid intake. The VM® demonstrated high reliability as a biomarker of skin carotenoid status in children.

Keywords: dietary intake assessment; 24 h multiple pass recall; weighed food diary; fruit and vegetable; Veggie Meter®; carotenoid

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1. Introduction

The last National Children's Nutrition Survey in New Zealand was conducted over 20 years ago [1]. Since then, substantial demographic and socioeconomic changes have occurred, including increased ethnic diversity—with a growing proportion of the population identifying as Māori, Pacific, and Asian [2]—along with shifts in food availability, food preferences, and the affordability of healthy food options [3]. These shifts may substantially affect the current dietary habits and nutritional health of children [3]. Therefore, an

updated understanding of children's food intake, particularly fruit and vegetable (F + V) consumption, is urgently needed.

Fruits and vegetables are essential components of a healthful diet and have been consistently associated with improved growth and reduced risk of obesity, heart disease, diabetes, and certain cancers [4,5]. Despite this, most New Zealand children aged 9–13 years do not meet national F + V intake recommendations of 5–5.5 servings of vegetables and at least 2 servings of fruit each day [6]. The most recent New Zealand Health Survey (2022/23) found that only 5.4% of children met the vegetable intake recommendation, while 70.9% met the fruit intake recommendation [7], pointing to the need for further evaluation with valid and reliable tools.

The 2002 National Survey used a 24 h multiple pass recall (MPR) to assess dietary intake [1]. While the MPR is widely used in nutrition surveillance, its accuracy depends on the age and recall ability of the participant. Children may lack knowledge of brand names, preparation methods, and portion sizes. To address these limitations, we have developed a modified 24 h MPR that includes parental input to improve completeness and accuracy and visual aids such as standardised household measures and a 'Photographic Atlas of Food Portion Sizes' [8]. Herein, we aim to determine if the current modified 24 h MPR improves the reliability and validity of F + V intake estimates in children.

In addition to recall-based dietary assessments, non-invasive biomarker tools such as the Veggie Meter® (VM®) may offer objective measures of F + V intake. The VM® uses reflection spectroscopy to quantify skin carotenoid scores (SCSs), which correlate directly with the concentration of carotenoid in the blood and strongly with habitual F + V intake [9–13]. Carotenoids are a biomarker for F + V consumption due to the high concentrations in these foods and their inability to be synthesised by the body. Although the VM® has shown promise in adult populations, its intra- and inter-day reliability and feasibility for use in school-aged children has not yet been established. This question provides the second primary aim of the current study and, together with the first aim, will provide information for the design of larger-scale dietary assessments in children and yield updated estimates of F + V quantitative intake and variability, aiding in sample size calculations for future research.

Materials and Methods

Study Design

This study was a randomised observational study comprising a weekday and weekend

(a) modified 24 h MPR completed by the child, (b) a WFD for the same 24 h period completed by the child's parent or caregiver, and (c) VM®

assessments (Figure 1). The WFD provided the only practical way to qualitatively and quantitatively assay free-living food intake of the children and therefore was used as the criterion reference method to establish an estimate of the validity and reliability of the modified 24 h MPR.

Following information and consent, the child–parent/caregiver pair were familiarised with the procedures and tools (Figure 1). Thereafter, each pair was randomly assigned to the assessment of either a weekday school-day first, followed by a weekend day, or vice versa over a one-to-three-week period. Participating children and schools received NZD 75 and NZD 200 vouchers, respectively, on completion, as a koha/gift of gratitude and in part to reimburse for school staff time contributions and the use of their facilities for interviews.

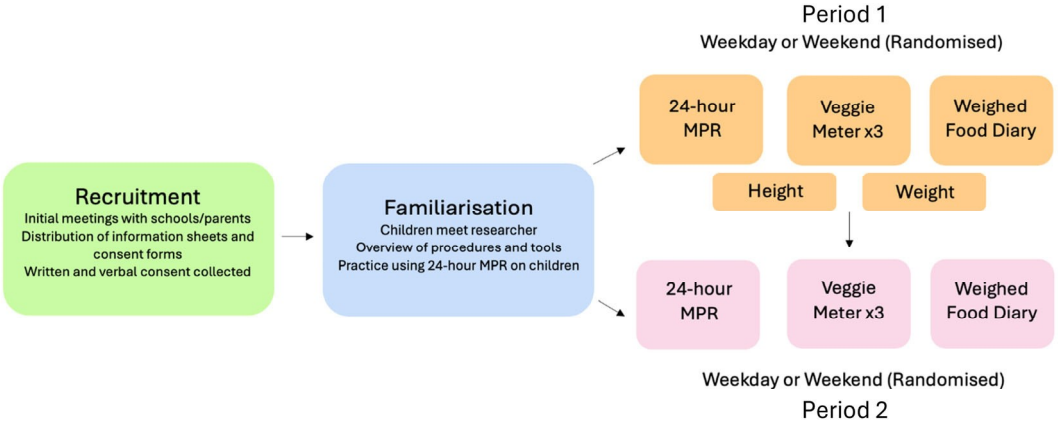


Figure 1. Research design, sampling days, and assessment procedures in both arms (Periods 1 and 2) of the crossover. 24 h MPR, modified 24 h multipass recall.

Ethics

Children and parents/caregivers were informed of the study through written and verbal discourse. Children gave verbal and their parents/caregivers written consent. Researchers underwent police vetting to ensure child safety. All procedures were reviewed and approved by the Health Research Council accredited Massey University Human Ethics Committee, Ohu Matatika 1, Application OMI 23/46.

Participants, Sample Size, and Recruitment

Participants aged 9–13 years living in Auckland, New Zealand, were primarily recruited through schools and affiliated networks, as well as flyers in community locations and posts on Facebook community groups. This age range was selected as evidence suggests that from the age of nine, children can reliably complete a 24 h MPR with minimal adult support [14]. Inclusion criteria included residence and school attendance in Auckland and a parent/caregiver willing and able to

complete a WFD following researcher training. Recruitment initially targeted schools with high equity index values—indicative of greater socioeconomic barriers to learning—but all except two declined participation; one yielded five volunteers, and the other yielded none. Additional schools were subsequently contacted by email and phone. A minimum sample size of 31 participants for this study was determined based on the intraclass correlation coefficient (ICC) for weighed and modified 24 h MPRs of 0.98 for energy, 0.97 for protein, and 0.94 for iron [15]. Assuming the minimum acceptable ICC of 0.9 [16,17], 25 children would be required [18]. In an analysis of the expected validity of the 24 h MPR vs. WFD, the 36 kcal (2.8%) difference in energy between the measure and criterion, with SD 409 kJ, SE 14 kJ, and within-subject SD (typical error) 47 kJ, required a sample size of 26 at 90% power and 5% type-1 error. Out of the two sample sizes, the larger one was selected (n = 26) to ensure statistical power and precision. Accommodating an estimated 20% dropout, a minimum sample size of 31 was selected.

Familiarisation

Familiarisation was led by trained registered or student dietitians and comprised introducing and familiarising the child with the modified 24 h MPR and training the parent in completing the WFD that included the extent of detail required for qualitative and quantitative accuracy. Parents were also asked to fill out a VM® questionnaire regarding their child's intake of F + V, supplements, and other foods high in vitamin A (Supplementary File S1). Following familiarisation, child–parent/caregiver pairs were offered the opportunity to ask questions and then were provided with the measuring equipment, as described below.

Modified 24 h MPR

The modified 24 h MPR was adapted from the National Children's Nutrition Survey [1]. The modifications included the following: (a) a familiarisation process prior to the interviews, (b) parental support in the third phase of the recall, (c) the use of the Photographic Atlas of Food Portion Sizes [8] adapted for use in Life and Living in Advanced Age: A Cohort Study in New Zealand (LiLACS NZ), and (d) standardised measuring equipment to assist with portion estimations and conducting the recall without computer assistance.

The modified 24 h MPRs were undertaken with the children at either the home, school classroom, or in a meeting room at the University. The first 24 h MPR session also included measuring the participating child's weight and height using a portable weight scale and stadiometer. Each session took approximately 20–30 min.

One weekday and one weekend modified 24 h MPR were completed on the day after each respective WFD. In the first pass (Supplementary File

S2), the researcher interviewed the child and recorded an uninterrupted quick list of their food and drink intake. In the second pass (Supplementary File S3), a detailed list of the child's food and drink intake was recorded; this included specifics such as time, place, brand, and amount, which was aided using the Photographic Atlas and measuring equipment. The third pass consisted of reviewing the food and drink intake with the child and parent/caregiver to fill in any gaps by asking open-ended questions and recording any recipes or brands that were provided.

Weighed Food Diary

Following recruitment and familiarisation, parents or caregivers were provided with written instructions, scales, measuring spoons and cups, and a printed copy of the data entry booklet (Supplementary File S4). In addition, digital photographs of all the food and drinks (including uneaten food) were taken and later forwarded to the independent researchers. Information on food and drinks purchased at school was obtained by asking the children to explain what they ate or to retain packaging for their parents to record. The WFD results were discussed and collected following the completion of both modified 24 h MPRs to minimise carryover bias.

Veggie Meter®

The VM® measures SCSs in the fat pad under the skin [19]. Before use, the VM® was calibrated using dark and light reference materials; repeat calibrations occurred every hour. Participants were required to wash and dry their hands thoroughly. Their right index finger pad was then placed facing down on the bulb of the VM®. The average of three VM® SCS samples were collected providing scans between 0 and 800 with an allowance of less than 10% variability between each score and used to assess the accuracy of the modified 24 h MPR and WFDs for assessing dietary F + V intake. The VM® SCSs were converted to plasma carotenoid concentration VM® dCC (μmol/L) through the following equation:

0.0056 VM® SCS [20].

Data Processing and Analysis

Ingested food and drink items within the diaries were processed within FoodWorks V.2.0 [21] by two different researchers independent of those conducting the MPRs. Foods unavailable within the software were manually entered using nutrition panels. The New Zealand food and nutrition guidelines for healthy children and young people aged 2–18 years were used to determine F + V serving size [22]. Examples of one serving size

of F+V included 130 g of apple, banana, or orange; 135 g of canned fruit; 50–80 g of cooked vegetables; 135 g of potato or kumara; and 60 g salad [22]. The total carotenoid intake was calculated from the sum of lycopene, lutein, zeaxanthin, β-carotene, α-carotene, and β-cryptoxanthin generated within the software [21].

Statistical Analysis

The validity and reliability for outcomes was estimated in a spreadsheet [17]. The validity of the modified 24 h MPR to estimate fruit, vegetable, and carotenoid intake was compared against the criterion values obtained from the WFD. All data except F + V servings due to zero values were 100*Ln-transformed to manage heteroscedasticity apparent on visual inspection and examination of skewness and kurtosis of the residuals, where >±2 and >±7 were considered nonnormal [23], and to promote uniformity of error and validity estimated by Pearson correlation and standardised bias at *x* (axis) derived from regression analysis [24]. Standardised bias at x evaluated the magnitude of the difference between the modified 24 h MPR and WFDs. It was calculated by dividing the mean bias of the modified 24 h MPR by the standard deviation of the WFD; this measure indicated overestimation when the bias was positive, while a negative bias suggested underestimation, with the magnitude interpreted using a modified Cohen scale [25]. The Pearson correlation measures the similarity between two variables [24]. The magnitude thresholds for Pearson correlations were ≥0.1 = small, ≥0.3 = moderate, ≥0.5 = large, ≥0.7 = very large, and ≥0.9 = extremely large [25].
The reliability of the modified 24 h MPR fruit, vegetable, and total F + V serving intake was expressed as the inter-day (weekday vs. weekend days) difference between the within-day 24 h MPR serving minus WFD serving estimates (i.e., difference of the difference); this approach was taken over log-transformation because of the zero values for some samples between the two forms of diaries and the fact that zero cannot be logtransformed. The inter-day reliability of the modified 24 h MPR carotenoid intake (µg/day) was estimated from the 100*Ln of the 24 h MPR/WFD ratio. The inter-day values for the VM® dCC were also log-transformed. The derived reliability statistics were the percentage change in the mean, mean typical error as a CV (%), and Pearson correlation. The CV is presented as the mean error score of the estimated intake and measures the within-subject variability present within repeated measurements [17]. A smaller typical error indicated more consistency, while a larger typical error indicated greater inconsistencies [16]. The standardised typical error of estimate was calculated by taking the single estimate divided by the sample variation (standard deviation); due to brevity, these data are not shown in the main text (see worksheets in Supplementary File S14) but were used to

qualify the effect magnitude to aid in inferential description of the statistic.
The modified Cohen scale was used to interpret the magnitude as follows: for standardised typical error <0.1 = trivial, 0.1–0.3 = small, 0.3–0.6 = moderate, 0.6–1.0 = large, 1.0–2.0 = very large, and >2.0 = extremely large. The thresholds for the mean x-axis bias and the standardised raw change in mean and standardised raw typical error for reliability were 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large, and 4.0 = extremely large [26].

Results

Participants and Data

We obtained more interest than expected, resulting in thirty-seven participants being recruited and enrolled in this study, which, after dropout, left 32 completing the study. Three participants dropped out due to personal reasons, and the data from two participants were removed due to incorrect procedures (Supplementary File S5). All data and analysis have been provided in Supplementary Files S12–S15.
Carotenoids

The recommended average daily carotenoid intake is 5340 µg/day for boys and 5040 µg/day for girls [27]. With 24 h MPR intakes of (mean ± SD) 3045 ± 3535 µg/day for boys and 2493 ± 3698 µg/day for girls and WFD intakes of 2816 ± 2983 for boys and 1974 ± 2263 for girls on average, neither boys nor girls met the requirement, but there was wide interindividual variation. Three girls met the carotenoid intake for the weekday and weekend 24 h MPR, while seven boys met it. For the weekday and weekend WFD intakes, two girls and six boys met the recommended intake.

Vegetable Intake

Both boys and girls had an average intake of less than 5–5.5 vegetable servings/day, although boys had a higher vegetable intake than girls (Figure 2A). Vegetable intake was overestimated in the modified 24 h MPR when compared to the WFD (Figure 2A). Children's vegetable intake for the weekday modified 24 h MPR and WFDs was higher than their vegetable intake for the weekend (Supplementary Files S6–S11).

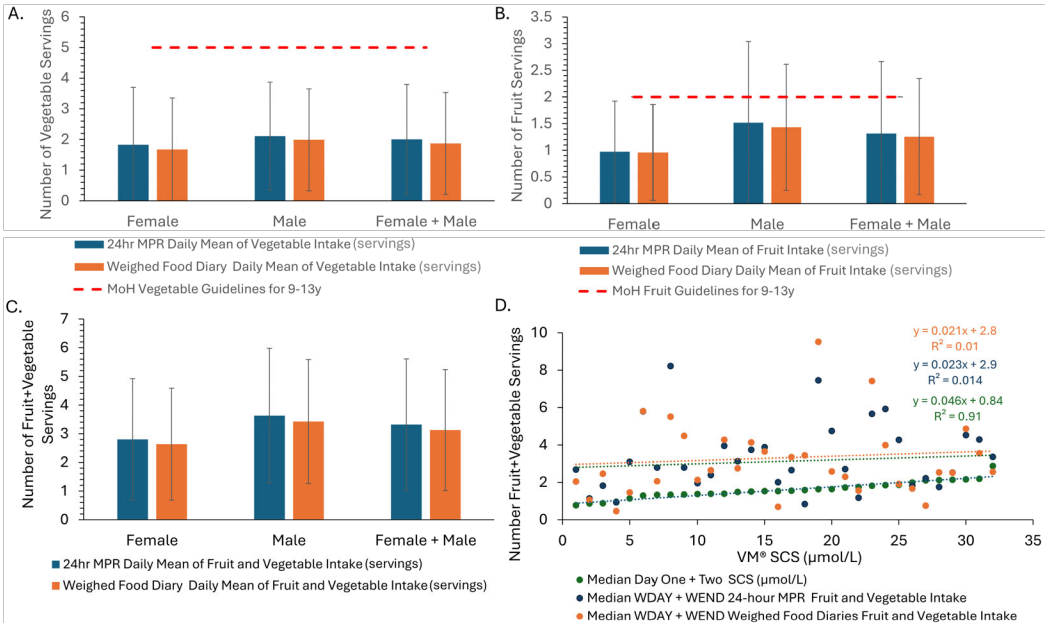


Figure 2. (**A**) Mean daily vegetable intake as estimated from the modified 24 h multipass recall (MPR) and WFD. (**B**) Mean daily of fruit intake as estimated from the modified 24 h MPR and WFD. For panels A and B, the red dashed line is the NZ Ministry of Health Guidelines for Vegetable Servings for 9- to 13-year-olds [28]. (**C**) Daily mean fruit and vegetable intake as estimated from the modified 24 h MPR fruit and WFD. (**D**) VM® dCC vs. median child-sample value for fruit and vegetable intake estimated from the modified 24 h MPR and WFDs. Histograms are raw means, and error bars represent standard deviations. MOH, Ministry of Health; WFD, weighed food diary; VM®, Veggiemeter spectrophotometer; dCC, derived carotenoid concentration.

Fruit Intake

On average, boys and girls had an intake of less than two fruit servings a day for the weekday and weekend modified 24 h MPR and WFDs; however, boys had an overall higher fruit intake than girls (Figure 2B). Fruit intake was overestimated by both girls and boys when comparing the modified 24 h MPR to the WFD (Figure 2B).

Total Fruit and Vegetable Intake

Total F + V intake for the weekday modified 24 h MPR and WFD had an overall higher estimated intake than the weekend (Supplementary Files S6–S11). Boys had an overall higher F + V intake than girls, but neither group met the recommended intake (Figure 2C). Total F + V intake was overestimated in both girls and boys for the modified 24 h MPR (Figure 2C).

Skin Carotenoid Score vs. Median F + V Intake from the Modified 24 h Multiple Pass Recalland Weighed Food Diaries

Figure 2D shows that there was no relationship between VM® dCC, the modified 24 h

MPR, and the WFD F + V intake. The relationship between the modified 24 h MPR and WFD shows some similarity (Figure 2D).

Validity of the Modified 24 h Multiple Pass Recall

There were large to very large mean positive correlations between the 24 h MPR and WFD for carotenoid intake, total fruit servings, vegetable servings, and total F + V servings (Table 1; Figure 3A–L). The 24 h MPR consistently showed trivial–small positive bias for fruit and vegetable intake and carotenoids across all days (Table 1).

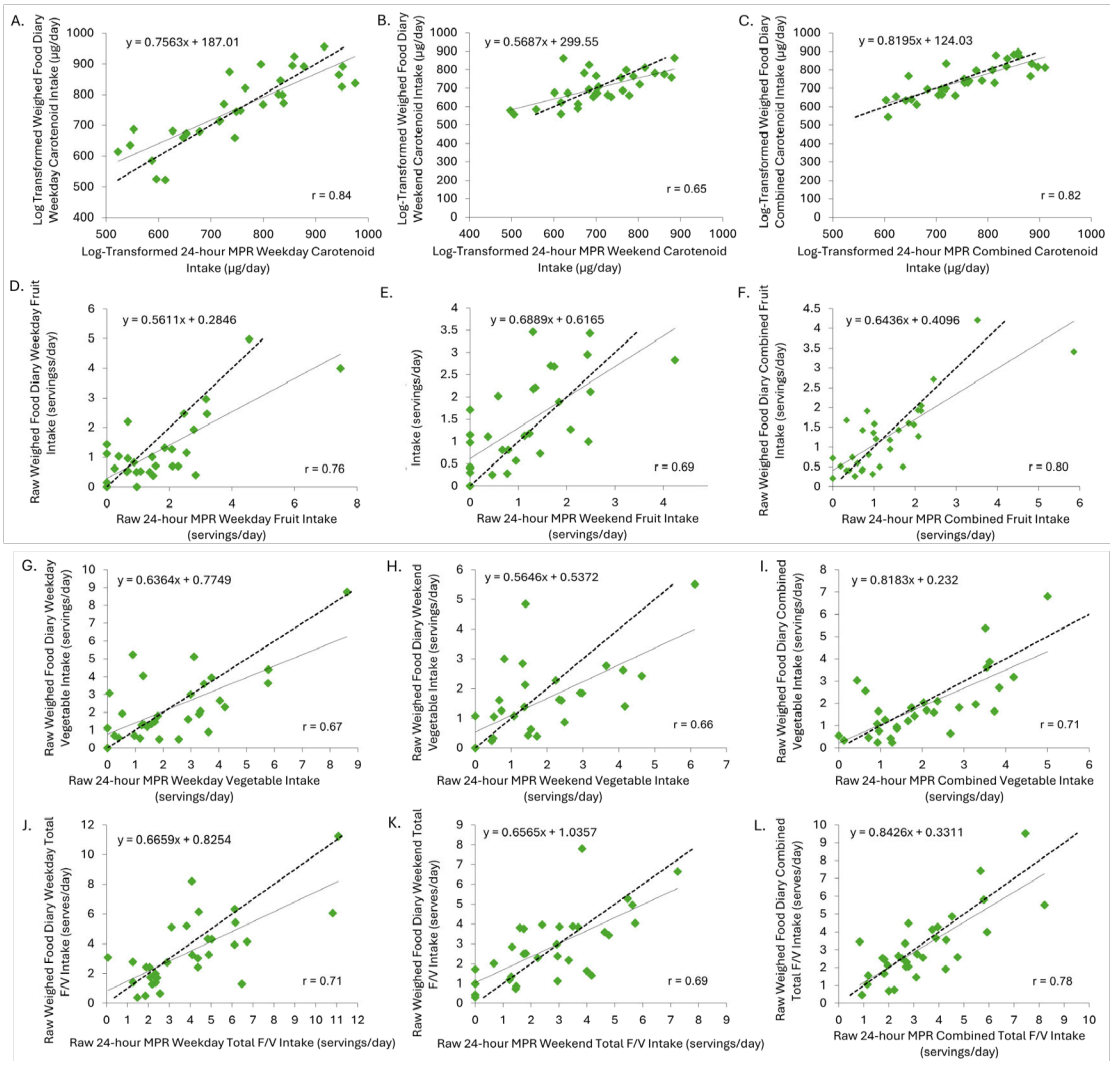


Figure 3. (**A**) Correlation between log-transformed 24h MPR and weighed food weekday carotenoid intake (µg/day). (**B**) Correlation between log-transformed 24 h MPR and weighed food weekend carotenoid intake (µg/day). (**C**) Correlation between log-transformed 24 h MPR and weighed food combined carotenoid intake (µg/day). (**D**) Correlation between raw 24 h MPR and weighed food weekday fruit intake (servings/day). (**E**) Correlation between raw 24 h MPR and weighed food weekend fruit intake (servings/day). (**F**) Correlation between raw 24 h MPR and weighed food

combined fruit intake (servings/day). (**G**) Correlation between raw 24 h MPR and weighed food weekday vegetable intake (servings/day). (**H**) Correlation between raw 24 h MPR and weighed food weekend vegetable intake (servings/day). (**I**) Correlation between raw 24 h MPR and weighed food combined vegetable intake (servings/day). (**J**) Correlation between raw 24 h MPR and weighed food weekday total F + V intake (servings/day). (**K**) Correlation between raw 24 h MPR and weighed food weekend total F + V intake (servings/day). (**L**) Correlation between raw 24 h MPR and weighed food combined total F + V intake (servings/day). Dashed line is line of identity. Solid line is the model regression line. 24 h MPR, 24 h multiple pass recall.

Table 1. Validity measures for estimates of fruit, vegetable, and carotenoid intake derived from the 24 h MPR.

Attribute	Sample	Pearson Coefficient	Mean Standardised Bias at x (Predictor) Value
Total Fruit (servings)	WDAY:	0.76 (0.61, 0.86)	0.35 (0.09, 0.61)
	WEND:	0.69 (0.49, 0.82)	−0.28 (−0.51, −0.04)
	COMB:	0.80 (0.66, 0.89)	0.06 (−0.16, 0.29)
Total Vegetable (servings)	WDAY:	0.67 (0.46, 0.81)	0.04 (−0.21, 0.29)
	WEND:	0.66 (0.45, 0.80)	0.14 (−0.14, 0.41)
	COMB:	0.71 (0.53, 0.83)	0.09 (−0.13, 0.30)
Total Fruit + Vegetable (servings)	WDAY:	0.71 (0.52, 0.83)	0.20 (−0.03, 0.44)
	WEND:	0.69 (0.50, 0.82)	−0.06 (−0.30, 0.18)
	COMB:	0.78 (0.63, 0.88)	0.10 (−0.09, 0.29)
Carotenoids (µg)	WDAY:	0.84 (0.72, 0.91)	−0.02 (−0.29, 0.24)
	WEND:	0.65 (0.44, 0.79)	0.06 (−0.35, 0.47)
	COMB:	0.82 (0.69, 0.90)	0.15 (−0.09, 0.39)

Fruit, vegetable, and fruit + vegetable statistics were derived from raw data, and carotenoid statistics were derived from log-transformed raw data. Data are mean estimates (90% CLs). WDAY, weekday; WEND, weekend; COMB combined (average of weekday and weekend); MPR; multiple pass recall. Thresholds for mean standardised raw bias at x value for validity were as follows: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large 2.0–4.0 = very large, and >4.0 = extremely large.

3.8. Reliability of the Modified 24 h MPR and Veggie Meter®

The modified 24 h MPR showed large typical error for carotenoid intake and moderate to large error for fruit, vegetable, and total F + V intake (Table 2), with varied reliability outcomes. There was a weak negative correlation for carotenoid intake and weak positive correlations for fruit, vegetable, and total F + V intake (Table 3). The modified MPR showed poor positive Pearson correlations for carotenoid intake and poor Pearson correlations for fruit, vegetable, and total F + V intake overall (Tables 2 and 3; Figure 4A–D). Vegetable intake showed a small change in mean, whereas total F + V intake exhibited a very large standardised raw change in mean (Table 2). For the VM®, the percentage change in mean for weekday, weekend, combined, and between-day dCC was small, indicating excellent reproducibility. Typical error was small for the VM® across all time points (Table 3). The Pearson correlations reinforced these findings (Table 3; Figure 4A–D).

Table 2. Reliability measures for the modified 24 h MPR.

Attribute (Servings)	Standardised Raw Change in Mean	Standardised Mean Raw Typical Error (90% CL)	Mean Raw Pearson Correlation
Modified 24 h MPR vs. Weighed Fruit Intake	−2.2 (−3.4, −1.0)	0.94 (0.78, 1.2)	0.12 (−0.18, 0.40)
Modified 24 h MPR vs. Weighed Vegetable Intake	−0.2 (−0.8, 1.2)	0.92 (0.76, 1.2)	0.16 (−0.14, 0.44)
Modified 24 h MPR vs. Weighed F + V Intake	−1.0 (−2.2, 0.1)	0.94 (0.78, 1.2)	0.13 (−0.18, 0.41)

Data are mean estimates (90% CLs). WDAY, weekday; WEND, weekend; COMB, combined (average of weekday and weekend); MPR, multiple pass recall. Thresholds for raw change in mean and raw typical error for reliability were as follows: 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large, and 4.0 = extremely large.

Table 3. Reliability Measures for the Veggie Meter® and the carotenoid intake estimated from the modified 24 h MPR.

	Statistic		
Attribute	Change in Mean (%)	Typical Error as a CV (%)	Pearson Correlation
Modified 24 h MPR Carotenoid Intake (µg)	8 (−23, 53)	126 (97, 181)	−0.20 (−0.47, 0.10)
Weekday VM® SCS	2-1: 1.0 (−0.6, 2.7)	2-1: 4.0 (3.3, 5.1)	2-1: 0.97 (0.97, 0.99)
	3-2: 1.0 (−1.5, 3.6)	3-2: 6.2 (5.1, 8.0)	3-2: 0.96 (0.93, 0.98)
Weekend VM® dCC (µmol/L)	2-1: 1.0 (−0.7, 2.7)	2-1: 4.1 (3.4, 5.2)	2-1: 0.98 (0.97, 0.99)
	3-2: 1.2 (−0.4, 2.8)	3-2: 3.8 (3.2, 4.9)	3-2: 0.99 (0.97, 0.99)
Combined VM® dCC (within day) (µmol/L)	2-1: 1.0 (−0.6, 2.7)	2-1: 4.0 (3.3, 5.1)	2-1: 0.98 (0.97, 0.99)
	3-2: 1.0 (−1.5, 3.6)	3-2: 6.2 (5.1, 8.0)	3-2: 0.96 (0.93, 0.98)
	4-3: −0.5 (−3.2, 2.3)	4-3: 6.7 (5.5, 8.5)	4-3: 0.96 (0.92, 0.98)
	5-4: 1.0 (−0.7, 2.7)	5-4: 4.1 (3.4, 5.2)	5-4: 0.98 (0.97, 0.99)
	6-5: 1.2 (−0.4, 2.8)	6-5: 3.8 (3.2, 4.9)	6-5: 0.99 (0.97, 0.99)
Between Weekday and Weekend VM® dCC (µmol/L)	2-1: 1.5 (−0.2, 3.3)	2-1: 4.2 (3.5, 5.3)	2-1: 0.98 (0.97, 0.99)
	3-2: −0.5 (−2.2, 1.2) 4-3: 1.5 (0.0, 3.0)	3-2: 4.2 (3.5, 5.4)	3-2: 0.98 (0.97, 0.99)
		4-3: 3.5 (2.9, 4.5)	4-3: 0.99 (0.98, 0.99)
	5-4: −0.5 (−2.9, 2.1)	5-4: 6.2 (5.1, 7.9)	5-4: 0.96 (0.93, 0.98)
	6-5: 1.7 (−0.7, 4.1)	6-5: 5.8 (4.8, 7.4)	6-5: 0.97 (0.94, 0.98)

All statistics were derived from log-transformed raw data. Number contrasts (e.g., 2-1) denote the number of the repeated test. WDAY, weekday; WEND, weekend; COMB, combined (average of weekday and weekend); VM®, Veggie Meter®; dCC, derived carotenoid concentration. Thresholds for log-transformed raw change in mean for reliability were as follows: 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large, and 4.0 = extremely large. Values are 90% CI. #-# = VM® dCC test compared to each other.

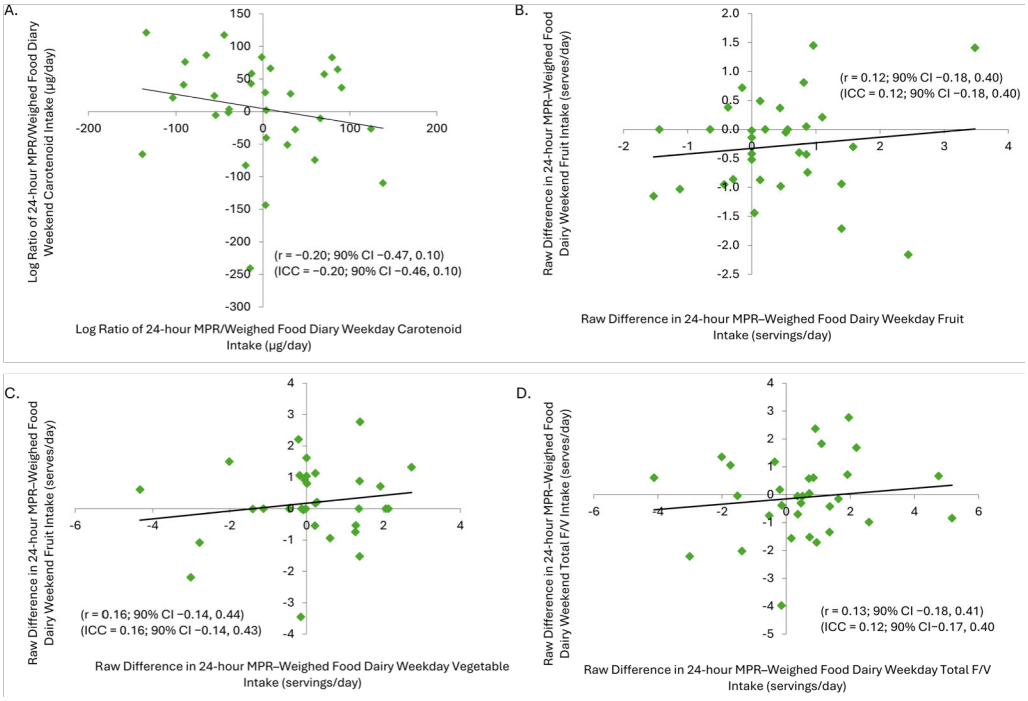


Figure 4. (**A**) Correlation between log-transformed ratio of 24 h MPR/WFD on weekday and weekend for carotenoid intake as a measure of reliability. (**B**) Correlation between raw difference in 24 h MPR– WFD servings on weekday and weekend for fruit intake as a measure of reliability. (**C**) Correlation between raw difference in 24 h MPR–WFD diary on weekday and weekend for vegetable intake. (**D**) Correlation between raw difference in 24 h MPR–WFD on weekday and weekend for total F + V intake. The black line is the regression line. 24 h MPR, 24 h multiple pass recall; WFD, weighed food diary.

Discussion

The current study evaluated the validity and reliability of a modified 24 h MPR for assessing fruit, vegetable, and carotenoid intake in New Zealand children aged 9–13 years. Additionally, the inter-day reliability of the VM®, a non-invasive spectrophotometric tool for assessing SCSs and dCC, was examined. The key findings were that the modified 24 h MPR was a valid but not very reliable tool for assessing F + V and carotenoid intake, while the VM®, in contrast, demonstrated excellent reliability across all tested parameters.

Validity of the Modified 24 h MPR

Large to very-large positive correlations and trivial–small positive bias against the WFD values for carotenoid, fruit, vegetable, and total F + V intake (Table 1) confirmed the validity of the modified 24 h MPR as a dietary assessment tool for our sample of children aged 9–13 years. These findings are consistent with previous literature showing that multiple 24

h recalls improve validity compared to single-day recalls in children [29].

Correlation Between F + V Intake and Skin Carotenoid Scores

In contrast to prior studies that demonstrated positive associations between SCSs and F + V intake using food frequency questionnaires (FFQs) [12,13], our study found no clear correlation between SCSs measured by the VM® and F + V or carotenoid intake estimated by the 24 h MPR. Sampling variability is one explanation; another is the disparity in measurement time windows. The VM® measures the SCS as a chronic biomarker reflecting the stable skin carotenoid reservoir [30]. Carotenoids are slowly incorporated into the skin (detectable increase after 2 to 6 weeks of sustained intake [31]) and clear slowly, with a half-life of several months [32]. Furthermore, while FoodWorks is a widely used food composition database standard [integrating Australian (AUSNUT) and United States (USDA) food composition data], the inherent measurement variability of nutrient values in these databases vs. ingested, coupled with the 24 h MPR method's acute nature, may have further compromised the accuracy [33]. Additionally, some carotenoids such as lycopene are found in few foods, with most coming from tomatoes and tomato products [34], making the top food sources of lycopene pizza, spaghetti, lasagna, and ketchup. Thus, lycopene is not considered a biomarker of total fruit and vegetable intake but rather tomato product intake [31], with implications for inference to dietary prescription to raise carotenoid intake.

Meanwhile, other authors reported small but significant correlations between SCSs and total F + V intake in larger cohorts of preschool-aged children [12,13]. These findings highlight the need for replication in larger New Zealand samples and suggest that pairing the VM® with an FFQ or more days of sampling, rather than 1 or 2 MPRs, may enhance convergent validity. Despite the lack of observed correlation in this study, our observed high reliability and other existing research supports the use of the VMR as a valid biomarker of chronic carotenoid intake [4,9–11].

Reliability of the Modified MPR

The modified 24 h MPR showed poor inter-day reliability for estimated F + V and carotenoid intakes (Table 2). Large changes in mean and moderate to very-large high typical error reflected inconsistency in children's reporting, likely due to their limited role in meal selection and recall. The Pearson and intraclass correlations were weak for all intake outcomes, suggesting low day-to-day reproducibility.

These findings are supported by St. George, et al. [35], who reported that even three repeated 24 h dietary recalls yielded low reliability in children. They estimated that up to 21–32 recalls would be needed to

achieve 80% accuracy for fruit intake—clearly not practical in field research. In this study, the unreliability could also reflect natural intake variation between weekdays and weekends. During the week, many children have a set lunch box routine that usually consists of a main meal, fruit, and snacks, However, on weekends at home, meals may vary more, and fruit is offered less consistently, making intake less structured and controlled. Additionally, there will be some additional error associated with the WFD assessment, but this was not quantified in the current methodology.

Despite poor reliability, the magnitude of measurement error provides useful information for sample size estimation in future intervention studies. Based on within-subject standard deviations (TEE = 126%) and between-subject SDs for carotenoid intake (µg), a parallel-groups trial designed to detect moderate effects (0.6 × SD) would require 41 participants per group using standard alpha = 5% and beta = 80% error rates, which is a feasible target depending on study resources.

Reliability of the Veggie Meter®

In contrast to the MPR, the VM® demonstrated excellent inter-day reliability for SCS and dCC values. Log-transformed Pearson correlations were high (0.97–0.99), and typical errors as CVs were low across all conditions (Table 3), confirming the VM® as a consistent measure of tissue carotenoids. These findings align with previous studies in children and adolescents.

Interestingly, in this study, girls had higher SCSs than boys, despite reporting lower F + V and carotenoid intake. This is inconsistent with prior research showing that boys generally consume more F + V and have higher SCSs [36]. Our findings were more consistent with Takeuchi, et al. [37], who reported higher SCSs in girls. This discrepancy may reflect the need for a longer-duration of MPR sampling as noted above, sampling variability, gender differences in body composition, or behavioural factors not captured in dietary assessment and warrants further exploration.

Overestimation and Reporting Bias

Overestimation of F + V intake was observed in both boys and girls, reflecting a desire to appear healthier, a known limitation of self-reported dietary assessment [38,39]. Despite training and visual aids, children in this age group may lack the attention to detail or interest in recording intake accurately, especially when foods are prepared for them; additionally, the data may also point to another contribution in that most parents either do not know or are unable to provide the appropriate number of F + V portions. This suggests that the modified 24 h MPR, while feasible and valid, may still require adjustment for overreporting or need to be supplemented with objective tools such as the VM® or wearable cameras.

Strengths and Limitations

A strength of this study was the structured use of portion estimation tools, including the LiLACS NZ Photographic Atlas of Food Portion Sizes and standardised household measures. The inclusion of parental input also helped improve data completeness.
The limitations include the small although a priori adequate sample size, which reduced the power for detecting correlations, and the reliance on WFDs as a reference method—subject to its own biases such as parental over-observation, which meant that there was a high likelihood of alterations being made to the children's diet to make their intake more healthy or appealing. Various items in the LiLACS NZ Photographic Atlas of Food Portion Sizes may also be outdated and not fully reflective of current food environments or multicultural diets in New Zealand. Additionally, natural day-to-day variability in diet was not controlled, which may have inflated within-subject variation. Another limitation to be noted is that carotenoid intake is not only influenced by fruits and vegetables; therefore, a high VM® SCS does not necessarily mean a high F + V intake.

Conclusions and Future Directions

This study found that the modified 24 h MPR was a valid but poorly reliable tool for estimating F + V and carotenoid intakes in a sample of New Zealand children aged 9–13 years. The tool showed excellent precision for serving size estimation, but the low reliability suggests its use should be approached cautiously with an adequate sample size. In contrast, the VM® demonstrated high reliability, suggesting its utility as a noninvasive biomarker of low carotenoid status and, therefore, carotenoid-containing fruits and vegetables, within this age group. Future research should assess the modified 24 h MPR's reliability in larger and more diverse cohorts. Comparisons with FFQs and the integration of emerging technologies— such as wearable cameras— may enhance intake tracking but raise ethical and logistical considerations. Food nutrient composition databases require updating as the fundamental biomarker of intake. Differences in F + V intakes between genders also merit further investigation. Finally, large-scale studies are needed to validate the VM® as a tool to track dietary intervention effects and to further refine child-specific protocols for its application.

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T.S.H.P.; formal analysis, V.V.P., S.M. and D.S.R.; resources, C.W., T.S.H.P. and E.R.; data curation,

V.V.P. and S.M.; writing—original draft preparation, V.V.P. and D.S.R.; writing—review and editing,
V.V.P., D.S.R. and E.R.; visualisation, V.V.P. and D.S.R.; supervision, D.S.R.; project administration, D.S.R., C.W. and T.S.H.P.; funding acquisition, D.S.R., C.W. and T.S.H.P. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Written parental and verbal child informed consent was obtained from all participants involved in the study.

Data Availability Statement: The analysis outcomes are in Supplementary Data Files S1–S11. The data spreadsheets are in Supplementary File S12; the validity and reliability analysis spreadsheets are in S13 and S14, respectively; and the VM® data spreadsheet is in Supplementary File S15.

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Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body Mass Index
CV	Coefficient of Variation
FFQ	Food Frequency Questionnaire
F + V	Fruits and Vegetables
ICC	Intraclass Correlation Coefficient
MUHEC	Massey University Human Ethics Committee
MELAA	Middle Eastern, Latin American, African
MPR	Multiple Pass Recall
WFD	Weighed Food Diary
NSLP	National School Lunch Program
NCDs	Noncommunicable diseases
RS	Reflection Spectroscopy
RRS	Resonance Rama Spectroscopy
SPAN	School Physical Activity and Nutrition
STEAM	Science, Technology, Engineering, Arts, and Math
SCS	Skin Carotenoid Score
dCC	Derived Carotenoid Concentration
TEE	Typical Error of Estimate
VM®	Veggie Meter®

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Appendix 1.4. - DRC 16 form for Chapter 4 - Physical Activity Measurement and Perception in Schoolchildren in New Zealand and Sri Lanka: a Pilot Study of a Developed vs a Developing Nation

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Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1] HP, AA, CW, AC, and DR designed the research and obtained ethical approval. AA coordinated with the Healthy Active Learning (HAL) initiation and sought guidance from the special HAL committee regarding the use of HAL data. Data collection for the Sri Lankan arm was led by HP with assistance from AC. HP was responsible for participant recruitment and data entry for the Sri Lankan arm, while AA supported HAL data extraction and cleaning of accelerometer data for both countries. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.			
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Appendix 1.5. - DRC 16 form for Chapter 5 - School Food Environment in Focus: Availability and Policy Practices in New Zealand and Sri Lanka – An Exploratory Study

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Student name:	Thalagalage Shalika Harshani Perera
Name and title of main supervisor:	Prof. David S. Rowlands
In which chapter is the manuscript/published work?	Chapter 5

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

HP, AA, CW, AC, and DR designed the research and obtained ethical approval. AA coordinated with the Healthy Active Learning (HAL) initiation and sought guidance from the special HAL committee regarding the use of HAL data. Data collection for the Sri Lankan arm was led by HP with assistance from AC. HP was responsible for participant recruitment, data collection and data entry for the Sri Lankan arm. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.

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Appendix 1.6 - DRC 16 form for Chapter 6 - Reliability and Validity of a Modified 24-hour Dietary Recall in New Zealand Schoolchildren

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Name and title of main supervisor:	Prof. David S. Rowlands
In which chapter is the manuscript/published work?	Chapter 6

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

HP, CW, and DR designed the research and obtained ethical approval. HP and CW developed all the data collection sheets, and CW assisted with training the research assistants. HP, AA, and DR contacted schools and negotiated permission for participation. HP was responsible for participant recruitment and data collection. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript, and all authors reviewed and approved the final version.

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Appendix 1.7 - DRC 16 form for Chapter 7 - Comparative Evaluation of Nutrient Intakes and Dietary Adequacy Among Schoolchildren Aged 9-13 in Sri Lanka and New Zealand: An Exploratory Analysis

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Name and title of main supervisor:	Prof. David S. Rowlands
In which chapter is the manuscript/published work?	Chapter 7

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

HP, CW, and DR designed the research and obtained ethical approval. HP and CW developed all the data collection sheets, and CW assisted with training the research assistants. HP, AA, and DR contacted schools and negotiated permission for participation in New Zealand. HP contacted and recruited participants and conducted data collection in Sri Lanka under the supervision of AC. HP was responsible for participant recruitment and data collection. HP completed data entry and dietary analysis for the Sri Lankan arm. HP and DR conducted data analysis and interpreted the results. HP drafted the manuscript and all authors reviewed and approved final version.

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- ○ The manuscript/published work is published or in press
  Please provide the full reference of the research output:
- ○ The manuscript is currently under review for publication
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Appendix 1.8.1 – ISPAH Poster

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Comparative Analysis of Physical Activity and Sedentariness in Schoolchildren from New Zealand and Sri Lanka

TSH Perera[1,2], David S. Rowlands[1], Ajmol Ali[1], Carol Wham[1], Ananda Chandrasekara[3], VCR De Mel[4]

[1]School of Sport, Exercise and Nutrition, Collage of Health, Massey University, New Zealand
[2]Department of Sport Sciences and Physical Education, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka
[3]Department of Applied Nutrition, Wayamba University of Sri Lanka
[4]Department of Mathematics, University of Sri Jayawardenepura, Sri Lanka

Background

- Childhood obesity is a growing global public health concern, with similar trends observed in Sri Lanka (SL) and New Zealand (NZ), driven mainly by declining physical activity (PA) and rising sedentary behaviours linked to modern lifestyles and academic pressures.
- Accurately measuring PA is essential, and accelerometers offer a practical, cost-effective way to obtain reliable data on activity and sedentary behaviour. This data is vital for assessing children's PA patterns and guiding public health interventions.
- This study is significant as it marks the first time accelerometers have been used to measure PA levels in SL students, providing essential data for addressing these public health concerns.

Research goal

- This study examines and compares the objectively measured PA levels and sedentary behaviour of schoolchildren from a convenience sample of schools in NZ and SL.
- Through this comparative analysis, the research aims to identify differences and similarities in PA patterns and sedentary lifestyles between the two countries, providing valuable insights for public health interventions aimed at reducing obesity and promoting active lifestyles among children.

Methodology

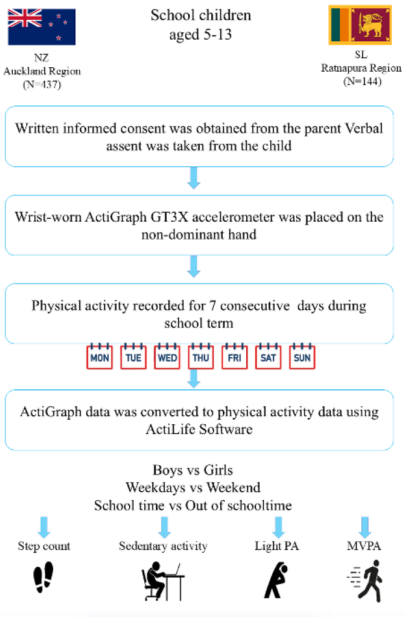


Figure 1: Methodology of the Study

- The research team fitted and removed the accelerometer after seven days during school.
- PA data were presented on weekdays (times in and out of school) and weekends. The outcome variables were percentages of time spent in sedentary, light PA, and moderate-to-vigorous PA (MVPA).

Results

- Students from NZ (13,273) and SL (13,511) met the recommended 12000 daily step count. However, during school hours, SL children completed fewer steps than NZ children (SL: 5140 steps; NZ: 6816 steps).

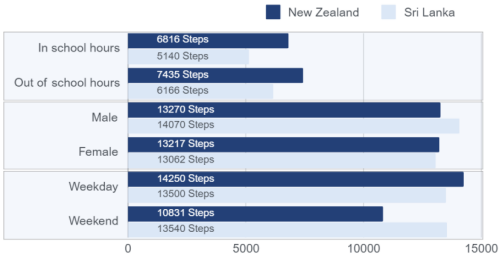


Figure 2: Average step count

- SL children had lower sedentary behaviour (18.7%) than NZ children (28%) during school hours (p<0.001), with higher light PA (SL: 51.3%; NZ: 44%) (p<0.001).
- Overall, NZ schoolchildren were more active than SL children, showing less sedentary behaviours (NZ: 37.9%; SL: 45.9%, p<0.001) and higher levels of light PA (NZ: 37.6%; SL: 33.8%, p<0.001) and MVPA (NZ: 24.5%; SL: 20.3%, p<0.001).

Table 1: Comparison of Physical Activity Intensities

	NZ			SL			Comparison - t test p value		
	Sedentary%	Light PA%	MVPA%	Sedentary%	Light PA%	MVPA%	Sedentary%	Light PA%	MVPA%
School hours									
In school hours	28	44	28	18.7	51.3	29.9	p<0.001*	p<0.001*	0.4952
Out of school hours	40	36	24	29.7	41.2	29.1	p<0.001*	p<0.001*	p<0.001*
Gender									
Male	38	38	24	45.3	33.8	20.9	0.0002*	0.0006*	0.0010*
Female	38	38	24	46.3	33.9	19.8	0.0002*	0.0016*	p<0.001*
Day									
Weekday	35	39	26	45.4	34.6	20.1	p<0.001*	p<0.001*	p<0.001*
Weekend	45	34	21	47	32	21	0.155	0.0344*	0.8312
Overall	37.9	37.6	24.5	45.9	33.8	20.3	p<0.001*	p<0.001*	p<0.001*

Conclusions

- Children from both countries met the recommended daily step counts.
- Weekend sedentary behaviour was consistent across both countries.
- Gender and day-specific patterns highlight the variability in activity levels, emphasising the need for tailored interventions to promote physical activity among children in different settings.

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1. Bailey et al. (2013). Choice of activity-intensity classification thresholds impacts upon accelerometer-assessed physical activity-health relationships in children. PLoS One, 8(2):e57101.
2. Jurado-Castro et al. (2022). Methods recently used for the assessment of physical activity in children and adolescents. *Current Opinion in Clinical Nutrition and Metabolic Care*, 25(5):298-303.
3. Lynch et al. (2019). Accuracy of accelerometers for measuring physical activity and levels of sedentary behaviour in children: A systematic review. *Journal of Primary Care and Community Health*, 10:2150132719874252.

Acknowledgement

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Healthy Active Learning

Harshani.Perera.1@uni.massey.ac.nz

Appendix 1.8.2. – SESNZ Conference Poster

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Cross-National Comparison of School-Age Physical Activity: New Zealand and Sri Lanka

TSH Perera[1,2], David S. Rowlands[1], Ajmol Ali[1], Carol Wham[1], Ananda Chandrasekara[3]
[1]School of Sport, Exercise and Nutrition, Collage of Health, Massey University, New Zealand
[2]Department of Sport Sciences and Physical Education, Sabaragamuwa University of Sri Lanka
[3]Department of Applied Nutrition, Wayamba University of Sri Lanka

Background

- Children's perceptions strongly influence physical activity (PA) engagement, enjoyment, competence, and inclusion, which shape motivation and participation.
- Perceptions vary across cultural and school contexts, shaping how children interpret opportunities for movement and physical education.
- Comparing New Zealand (NZ) and Sri Lanka (SL) provides insight into how cultural and school contexts influence children's PA perceptions, enabling identification of context-specific barriers and opportunities for intervention.

Research goal

- To examine and compare children's self-reported perceptions of PA and school-based opportunities in NZ and SL using questionnaires.

Methodology

- Cross-sectional pilot study comparing children's PA perceptions in NZ and SL to explore cultural and school-context differences.
- Schools were selected using convenience sampling: primary and intermediate schools in Auckland, NZ, and schools in the Rathnapura district, SL, with grades 1–8 and more than 500 students.
- The Healthy Active Learning (HAL) initiative in NZ developed PA questionnaires adapted for the SL context; two versions for two age groups.
- Children completed the questionnaires with assistance, on iPads via Qualtrics in NZ and on printed questionnaires in SL.
- Data for the NZ component were drawn from the HAL baseline evaluation in the Auckland region.
- Multivariable logistic regression was used to estimate adjusted odds ratios and 95% CI for perceptions and opportunities by country, gender, and age.

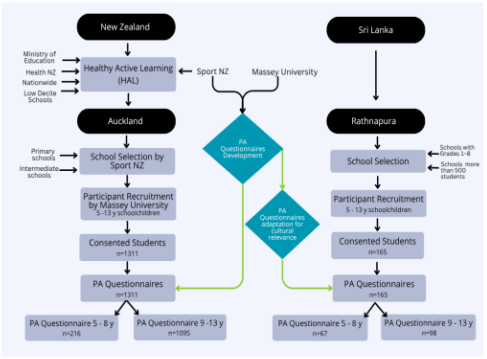


Figure 1. Flow of school selection, participant recruitment, and questionnaire development in New Zealand and Sri Lanka

Results

Table 1. Adjusted Odds Ratios for perception of physical activity by Country, Gender, and Age Category

Dependent Variable	Country (NZ vs SL) aOR (95% CI)	Gender (Female vs Male) aOR (95% CI)	Age (9-13 vs 5-8 years) aOR (95% CI)
Perceptions of Physical Education (PE)			
I feel I am making progress in PE	1.71 (1.22-2.39)**	0.62 (0.50-0.77)***	0.90 (0.69-1.19)
I am good at PE	2.28 (1.62-3.19)***	0.62 (0.50-0.77)***	1.28 (0.96-1.70)
I feel I learn lots during PE	2.68 (1.92-3.76)***	0.87 (0.69-1.10)	1.04 (0.77-1.39)
Most of my PE involves playing sports	2.74 (1.95-3.85)***	0.79 (0.63-1.00)*	0.52 (0.39-0.68)***
Physical activity practice			
My teachers give helpful feedback to improve in PE or sports	1.63 (1.11, 2.41)*	1.22 (0.91, 1.64)	0.45 (0.33, 0.63)***
At school I learn games, dance or movement from different cultures	0.46 (0.31, 0.70)***	1.38 (1.10, 1.73)**	0.67 (0.50, 0.89)**
I learn that team members have different skills to use	1.72 (1.15, 2.57)**	0.99 (0.74, 1.33)	0.46 (0.33, 0.64)***
At school people encourage me to be active	0.42 (0.27, 0.65)***	1.04 (0.82, 1.32)	0.87 (0.65, 1.17)
opportunities for being physically active			
At school, I can try many sports and activities	2.67 (1.86 - 3.83)***	1.18 (0.90 - 1.54)	1.06 (0.76 - 1.48)
We have lots of equipment to create games at lunchtime	1.01 (0.69 - 1.48)	1.05 (0.82 - 1.33)	1.62 (1.21 - 2.16)***

SL- Sri Lanka, NZ- New Zealand, PE- physical education, CI- confidence interval, aOR- adjusted odds ratio, * indicates statistical significance: *p < 0.05, **p < 0.01, ***p < 0.001.

Conclusions and future direction

- Sri Lankan children reported fewer positive experiences and opportunities for PA than their NZ peers, with girls in both countries showing lower participation and enjoyment.
- Significant disparities highlight the need for school-based programmes that offer a wider range of PA options, ensure equal participation opportunities for all students, and actively address gender-related barriers to engagement.
- Validate these findings in larger, representative samples and explore longitudinal trends to understand causal relationships.

Acknowledgement
The Healthy Active Learning project, which is supported by the NZ Ministries of Health, Sport, and Education contributed to this study.

References
1. Perera et al. (2022). *PLoS ONE*, 17(6):e0268817.
2. Laukkanen et al. (2020). *Int J Environ Res Public Health*, 17(7):2315.

To download this poster

For more information:

Appendix 2
Study Supplementary document

Appendix 2.1 Supplementary Document for Chapter 4

Supplementary for Table 4.2

Table A. Comparison of PA Metrics per hour Between SL and NZ Schoolchildren (Aged 5–13 Years).

Variable	Time Segment	NZ Mean (SD)	SL Mean (SD)	Mean difference	Std err mean diff	t-value	df	p-value	95%CI Lower	95%CI Upper
Step Count (steps/hour)	Overall	992 (168)	873 (169)	119	17	-7.0	586	<0.01	86	153
	Weekdays	1034 (167)	867 (167)	167	17	-9.9	586	<0.01	134	201
	Weekends	885 (249)	890 (249)	-4.7	25	0.2	571	0.85	-55	45
	In-school	1082 (187)	925 (189)	157	19	-8.3	586	<0.01	120	194
	Out-of-school	1004 (219)	851 (191)	153	22	-7.1	586	<0.01	111	196
	Male	1031 (179)	894 (180)	137	27	5.1	257	<0.01	190	84
	Female	965 (154)	855 (159)	110	21	5.1	313	<0.01	152	68
	Age 5-8	1052 (145)	837 (131)	215	32	6.7	142	<0.01	278	152
	Age 9-13	971 (171)	881 (177)	90	20	4.6	442	<0.01	128	51
Sedentary Time (min/hour)	Overall	34 (2.7)	31 (3.1)	2.8	0.3	-10.1	586	<0.01	2.3	3.4
	Weekdays	33 (2.5)	31 (3.1)	2.3	0.3	-7.7	170	<0.01	1.7	2.9
	Weekends	35 (4.2)	31 (5.1)	4.1	0.5	-9.1	571	<0.01	3.2	5.0
	In-school	33 (2.7)	29 (3.3)	3.9	0.3	-13	586	<0.01	3.3	4.4
	Out-of-school	33 (3.4)	32 (3.6)	1.3	0.4	-3.9	586	<0.01	0.7	2.0
	Male	34 (2.7)	31 (3.1)	3	0.4	7.2	257	<0.01	2.2	3.8
	Female	33 (2.6)	31 (3.0)	2.6	0.4	6.9	313	<0.01	1.8	3.3
	Age 5-8	32 (2.4)	32 (3.2)	0.8	0.6	1.5	142	0.1	-0.3	2
	Age 9-13	34 (2.6)	31 (3.0)	3.4	0.3	11.1	442	<0.01	2.8	4
Light Activity (min/hour)	Overall	19 (1.5)	18 (1.7)	1.2	0.2	7.7	586	<0.01	0.9	1.5
	Weekdays	19 (1.6)	18 (1.7)	1.2	0.2	7.7	586	<0.01	0.9	1.6
	Weekends	19 (2.3)	17 (2.7)	1.3	0.2	5.1	571	<0.01	0.7	1.7
	In-school	20 (1.8)	20 (2.0)	-0.3	0.2	-1.8	586	0.1	-0.7	0.0
	Out-of-school	19 (1.9)	17 (1.8)	2.3	0.2	12	586	<0.01	1.9	2.7
	Male	19 (1.5)	18 (1.7)	1.3	0.2	5.4	257	<0.01	0.8	1.7
	Female	19 (1.5)	18 (1.7)	1.1	0.2	5.6	313	<0.01	0.8	1.6
	Age 5-8	20 (1.3)	18 (2.1)	1.7	0.3	5.0	142	<0.01	1	2.3
	Age 9-13	19 (1.5)	18 (1.6)	1.1	0.2	6.0	442	<0.01	0.7	1.4
Moderate-to-Vigorous (MVPA) (min/hour)	Overall	7 (2.5)	11 (2.8)	4.0	0.3	14	177	<0.01	4.6	3.5
	Weekdays	7.5 (2.5)	11.1 (2.8)	3.6	0.3	13	181	<0.01	4.1	3.0
	Weekends	6.8 (3.1)	12 (4.2)	5.3	0.4	13	160	<0.01	6.1	4.5
	In-school	7.4 (2.6)	10.9 (3.3)	3.5	0.3	11	168	<0.01	4.2	2.9
	Out-of-school	7.8 (3.0)	11.5 (3.1)	3.7	0.3	12	586	<0.01	4.3	3.1
	Male	7.4 (2.4)	11.6 (3.0)	4.2	0.4	-9.9	77	<0.01	5.1	3.4
	Female	7.4 (2.6)	11.1 (2.7)	3.7	0.4	-10.4	313	<0.01	4.5	3.0
	Age 5-8	8.0 (2.5)	10.5 (2.5)	2.5	0.5	-4.5	142	<0.01	3.6	1.4
	Age 9-13	7.1 (2.4)	11.5 (2.9)	4.4	0.3	-14	143	<0.01	5.1	3.8

For NZ: Sleep time: 9pm to 7am, in school time: 9am to 3pm, out of school time: 7am-9am and 3pm-9pm

For SL: Sleep time: 9pm to 6am, in school time: 8am to 2pm, out of school time: 6am-8am and 2pm-9pm

Supplementary for Table 4.3

Table B. Differences in PA Levels by Day Type, Setting, Gender, and Age in NZ and SL

Country	Variable (steps/hour)/ (min/hour)	Mean (SD)	Mean (SD)	Mean dif	t-value	df	p-value	95%CI Lower	95% CI Upper
		Weekday	**Weekend**						
NZ	Step Count	1034 (167)	885 (249)	149	14	449	<0.01	127	167
	Sedentary	33 (2.5)	35 (4.2)	-1.6	-9.6	449	<0.01	-1.9	-1.3
	Light Activity	19 (1.6)	19 (2.3)	0.9	8.7	449	<0.01	0.7	1.1
	MVPA	7.5 (2.5)	6.8 (3.1)	0.7	6.9	449	<0.01	0.5	1.0
SL	Step Count	867 (167)	890 (249)	-23	-1.2	122	0.22	-60	14
	Sedentary	31 (3.1)	31 (5.1)	0.1	-3.5	122	0.73	-0.7	1.0
	Light Activity	18 (1.7)	17 (2.7)	0.8	3.8	122	<0.01	0.39	1.2
	MVPA	11.1 (2.8)	12 (4.2)	-0.9	-3.1	122	<0.01	-1.6	-0.3
		In school	**Out of school**						
NZ	Step Count	1082 (187)	1004 (219)	78	7.1	463	<0.01	56	99
	Sedentary	33 (2.7)	33 (3.4)	-0.7	-3.9	463	<0.01	-1.0	-0.3
	Light Activity	20 (1.8)	19 (1.9)	1.1	11.1	463	<0.01	0.9	1.3
	MVPA	7.4 (2.6)	7.8 (3.0)	-0.4	-3.7	463	<0.01	-0.6	-0.2
							<0.01		
SL	Step Count	925 (189)	851 (191)	74	5.0	123	<0.01	45	103
	Sedentary	29 (3.3)	32 (3.6)	-3.2	-10.8	123	<0.01	-3.8	-2.6
	Light Activity	20 (2.0)	17 (1.8)	3.7	25	123	<0.01	3.4	4.0
	MVPA	10.9 (3.3)	11.5 (3.1)	-0.6	-2.1	123	0.04	-1.1	-0.0
		Male	**Female**						
NZ	Step Count	1031 (179)	965 (154)	67	-4.2	399	<0.01	-98	-35
	Sedentary	34 (2.7)	33 (2.6)	0.4	-1.4	428	0.15	-0.9	0.1
	Light Activity	19 (1.5)	19 (1.5)	-0.4	2.4	423	0.02	0.1	0.6
	MVPA	7.4 (2.4)	7.4 (2.6)	-0.02	0.1	442	0.94	-0.4	0.5
SL	Step Count	894 (180)	855 (159)	39	-1.3	113	0.20	-100	21
	Sedentary	31 (3.2)	31 (3.0)	-0.1	0.1	117	0.92	-1.0	1.2
	Light Activity	18 (1.7)	18 (1.8)	-0.4	1.4	120	0.16	-0.2	1.1
	MVPA	12 (3.0)	11 (2.7)	0.5	-0.96	113	0.34	-1.5	0.5
		5-8 years	**9-13 years**						
NZ	Step Count	1052 (145)	971 (171)	81	5.0	243	<0.01	49	113
	Sedentary	32 (2.4)	34 (2.6)	-1.6	-6.3	226	<0.01	-2.1	-1.1
	Light Activity	20 (1.3)	19 (1.5)	0.7	4.5	233	<0.01	0.4	1.0
	MVPA	8.0 (2.5)	7.1 (2.5)	0.97	3.7	208	<0.01	0.5	1.5
SL	Step Count	837 (131)	881 (177)	-44	-1.4	46	0.18	-108	21
	Sedentary	32 (3.2)	31 (3.0)	0.9	1.3	34	0.20	-0.5	2.4
	Light Activity	18 (2.1)	18 (1.6)	0.05	0.1	30	0.91	-0.9	1.0
	MVPA	10.55 (2.5)	11.54 (2.9)	-0.99	-1.7	39	0.10	2.2	0.2

NZ-New Zealand, SL-Sri Lanka, MVPA-Moderate to vigorous physical activity,
Mean Dif– Mean difference, df - degree of freedom, CI-confidence interval

DiD Analysis

Table C. Difference-in-differences comparison of mean PA levels and step counts between SL and NZ children, stratified by weekday vs. weekend and in-school vs. out-of-school periods.

	Variable (steps/hour)/ (min/hour)	NZ mean	SL mean	DiD	t-value	df	P value	95%CI Lower	95%CI Upper
Weekday-Weekend difference	Step Count	149	-23	170 (21)	7.96	201	<0.01	128	212
	Sedentary	-1.6	0.1	-1.8 (0.5)	-3.91	164	<0.01	-2.7	-0.9
	Light Activity	0.9	0.8	0.1 (0.2)	0.28	180	0.78	-0.4	0.5
	MVPA	0.7	-0.9	1.6 (0.3)	5.17	153	<0.01	1.1	2.3
In school-out of school difference	Step Count	78	74	3.7 (18)	0.20	273	0.84	-32	40
	Sedentary	-0.7	-3.2	2.5 (0.3)	7.46	207	<0.01	1.9	3.2
	Light Activity	1.1	3.7	-2.7 (0.2)	-15	232	<0.01	-3.0	-2.3
	MVPA	-0.4	-0.6	0.1 (0.3)	0.45	171	0.65	-0.4	0.7

NZ-New Zealand, SL-Sri Lanka, MVPA-Moderate to vigorous physical activity,
Mean Dif– Mean difference, df - degree of freedom, DiD- Difference of the mean Difference

Table D. Mode of travel to school

Mode of travel to school	NZ (n=1311)	SL (n=165)
	N (%)	N (%)
Active	581 (44%)	27 (16%)
Public transport	61 (5%)	87 (53%)
Private motorised transport	628 (48%)	51 (31%)
NA	41 (3%)	0

Multiple responses permitted.

N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand

Active transport: walk, bike, skateboard, or scooter (by bike only in SL)

Public transport: by bus or train (NZ), by bus, van or train (SL)

Private motorised transport: by car or motorbike

Table E. Physical Activities Before School class Start Among Students by Age Group in NZ and SL								
Activity	**NZ**				**SL**			
	5-8 years (n=387)		**9-13 years (n=923)**		**5-8 years (n=64)**		**9-13 years (n=101)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Sit Around	124	32	421	46	52	81	87	86
Stand Around	35	9	316	34	52	81	90	89
Walk around	173	45	565	61	50	78	85	84
Active things like games, dance and sport	189	49	503	55	8	13	15	15
Multiple responses permitted. N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand								

Table F. Physical Activities During Lunch/Tea Time Among Students by Age Group in NZ and SL								
Activity	**NZ**				**SL**			
	5-8 years (n=64)		**9-13 years (n=101)**		**5-8 years (n=64)**		**9-13 years (n=101)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Sit Around	118	31	314	34	43	67	95	94
Stand Around	40	10	261	29	47	73	82	81
Walk around	124	32	563	61	54	84	84	83
Active things like games, dance and sport	267	69	606	66	15	23	13	13
Multiple responses permitted. N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand								

Table G. Physical Activities during PE/ Sports time among students aged over 8 years in NZ and SL				
Activity	**NZ (n=923)**		**SL (n=101)**	
	N	**%**	**N**	**%**
Playing with ball	769	83	31	31
Walking/jogging/running	509	55	65	64
others	361	39	4	4
Tag/Playing on the playground	322	35	84	83
Swimming	200	22	10	10
Aerobics/dancing/skipping	182	20	4	4
Riding a bike	131	14	5	5
Multiple responses permitted. N - count of responses**,** % - percentage of respondents (calculated based on the total sample size for that country), n - sample size, SL- Sri Lanka, NZ - New Zealand				

Table H. Physical Activities During Weekends Among Students aged below 8 years				
Activity	**NZ (n=387)**		**SL (n=64)**	
	N	**%**	**N**	**%**
Active things with friends or by oneself	238	63	58	91
Active things with my family	222	57	52	81
Watching TV, movies, or DVDs	255	66	45	70
Playing on computer or cell phone	226	58	32	50

Table I. Physical Activities During Weekends Among Students aged over 8 years in SL and NZ				
Activity	**NZ (n=923)**		**SL (n=101)**	
	N	**%**	**N**	**%**
Walking with friends and family or pets	289	31	65	64
Playing at the beach/park	418	45	47	47
Swimming or diving	208	23	18	18
Climbing trees	176	19	25	25
Riding a bike	189	20	48	48
Fun run	181	20	53	52
Sports	505	55	10	10

Appendix 2.2 Supplementary document for Chapter 6

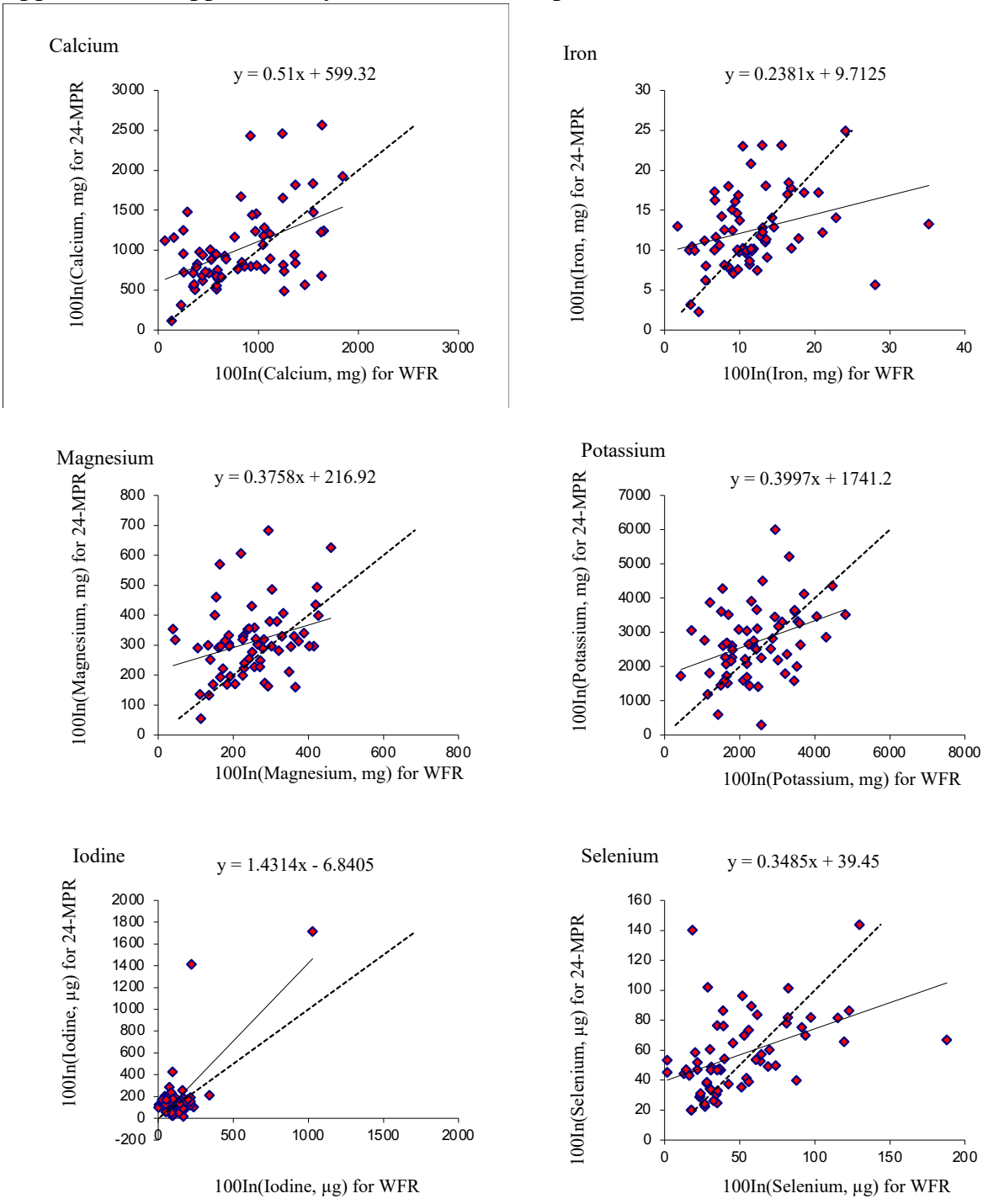


Figure 6. A. Nutrient correlation between log-transformed 24-MPR and WFR.
(A) Correlation between log-transformed 24-MPR and WFR – Calcium
(B) Correlation between log-transformed 24-MPR and WFR – Iron
(C) Correlation between log-transformed 24-MPR and WFR – Magnesium
(D) Correlation between log-transformed 24-MPR and WFR – Potassium
(E) Correlation between log-transformed 24-MPR and WFR – Iodine
(F) Correlation between log-transformed 24-MPR and WFR – Selenium

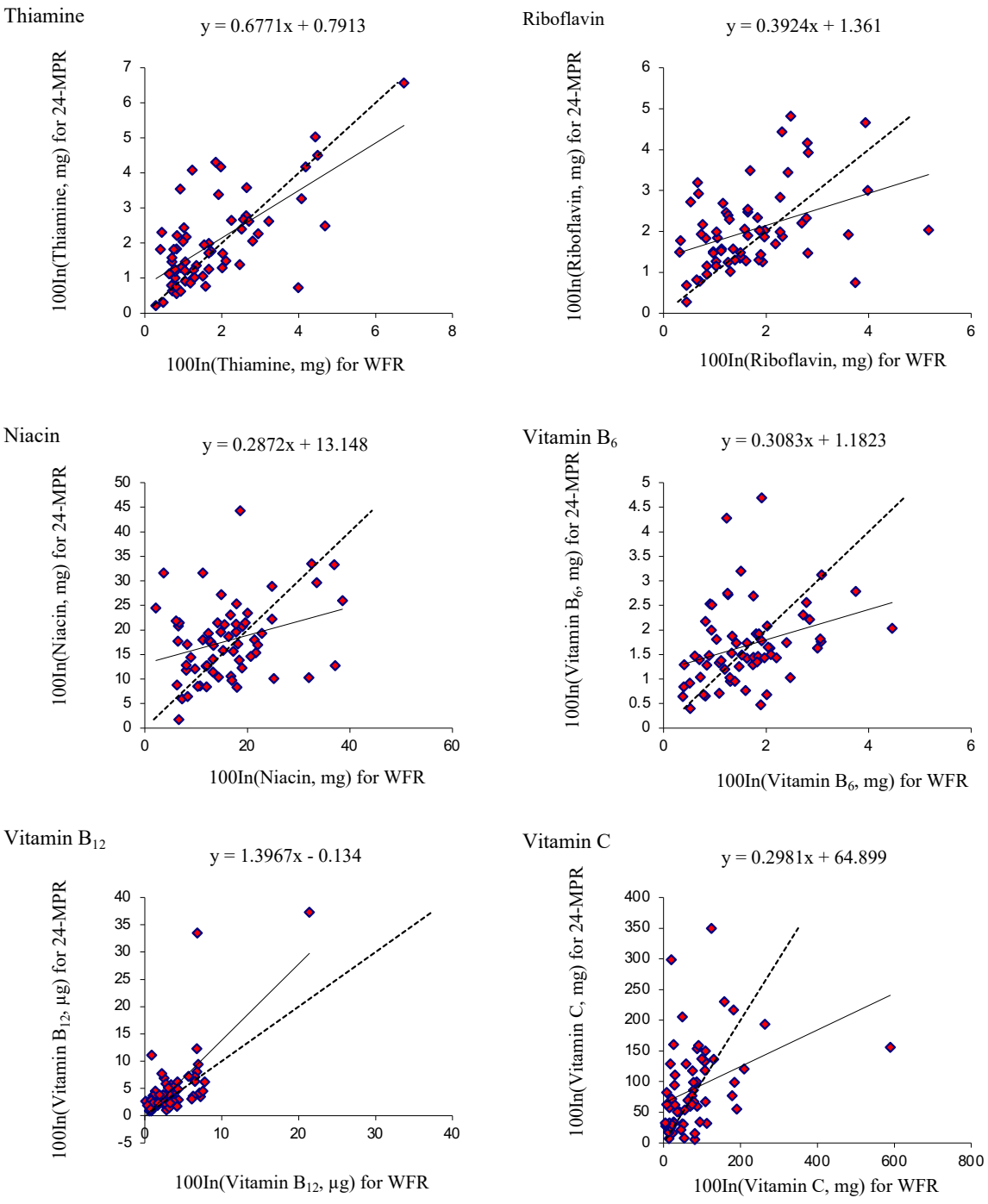


Figure 6. B. Nutrient correlation between log-transformed 24-MPR and WFR.
(A) Correlation between log-transformed 24-MPR and WFR – Thiamine
(B) Correlation between log-transformed 24-MPR and WFR – Riboflavin
(C) Correlation between log-transformed 24-MPR and WFR – Niacin
(D) Correlation between log-transformed 24-MPR and WFR – Vitamin B_6
(E) Correlation between log-transformed 24-MPR and WFR – Vitamin B_{12}
(F) Correlation between log-transformed 24-MPR and WFR – Vitamin C

Appendix 2.3 – Supplementary document for Chapter 7

Dietary Reference Intakes

To evaluate the adequacy of nutrient intakes among individual children aged 9–13 years, the Estimated Average Requirements (EARs) from the Dietary Reference Intakes (DRIs) were used as the primary reference values. The EAR represents the daily intake level estimated to meet the requirements of 50% of healthy individuals in a specific age and sex group. According to the National Academies of Sciences, Engineering, and Medicine, the EAR is the most appropriate reference value for assessing the adequacy of nutrient intakes for individuals, particularly when multiple days of intake data are available. If an individual's intake falls below the EAR, it is likely to be inadequate; if it is equal to or above, adequacy is more probable.

For nutrients where an EAR is not established, the Adequate Intake (AI) was used. While AI values are based on observed or experimentally determined approximations, they do not allow for precise determination of inadequacy. Therefore, intakes at or above the AI were considered likely adequate, but intakes below the AI could not be definitively classified as inadequate.

(Source: National Academies of Sciences, Engineering, and Medicine. (2006). Dietary Reference Intakes: The Essential Guide to Nutrient Requirements. Washington, DC: The National Academies Press. https://doi.org/10.17226/11537)

Table 7.A. New Zealand DRI for children aged 9 to 13.

NZ								
	Male				Female			
Nutrient	AI	EAR	RDI	UL	AI	EAR	RDI	UL
Energy kcal								
Protein g/day	--	31	40	NA	--	24	35	NA
Dietary Fiber g/day	24	--	--	NA	20	--	--	NA
Vitamin A µg/day	--	445	600	1700	--	420	600	1700
Thiamin mg/day	--	0.7	0.9	NA	--	0.7	0.9	NA
Riboflavin mg/day	--	0.8	0.9	NA	--	0.8	0.9	NA
Niacin mg/day	--	9	12	20	--	9	12	20
Vitamin B_6 mg/day	--	0.8	1.0	30	--	0.8	1.0	30
Vitamin B_{12} µg/day	--	1.5	1.8	NA	--	1.5	1.8	NA
Vitamin C mg/day	--	28	40	NA/1000	--	28	40	NA/1000
Vitamin D µg/day	5.0	--	--	80	5.0	--	--	80
Calcium mg/day 9-11	--	800	1000	2500	--	800	1000	2500
Calcium mg/day 12-13	--	1050	1300	2500	--	1050	1300	2500
Copper mg/day	1.3	--	--	5	1.1	--	--	5
Iodine µg/day	--	75	120	600	--	75	120	600
Iron mg/day	--	6	8	40	--	6	8	40
Magnesium mg/day	--	200	240	350		200	240	350
Potassium mg/day	3000	--	--	NA	2500			NA
Selenium µg/day	--	40	50	280	--	40	50	280

Sodium mg/day	400-800	--	--	2000	400-800	--	--	2000
Zinc mg/day	--	5	6	25	--	5	6	25

Table 7.B. Sri Lanka DRI for children aged 9 to 13.

SL																
	Male								Female							
Nutrient	AI 7-10	AI 11-14	EAR 7-10	EAR 11-14	RDI 7-10	RDI 11-14	UL 7-10	UL 11-14	AI 7-10	AI 11-14	EAR 7-10	EAR 11-14	RDI 7-10	RDI 11-14	UL 7-10	UL 11-14
Energy kcal	--	--	1920	2390	1920	2390	--	--	--	--	1920	2180	1920	2180	--	--
Protein g/day	--	--	20	30	24	37	--	--	--	--	20	31	24	38	--	--
Dietary Fiber g/day	RI 16	RI 19	--	--	--	--	NA		RI 16	RI 19	--	--	--	--	NA	
Vitamin A µg/day	--	--	320	480	400	600	1500	2000	--		320	480	400	600	1500	2000
Thiamin mg/day	--	--	0.6	1.0	0.8	1.0	NA		--	--	0.6	1.1	0.8	0.9	NA	
Riboflavin mg/day	--	--	0.8	1.1	1.4	1.4	NA		--	--	0.8	1.1	1.4	1.4	NA	
Niacin mg/day	--	--	10.4	13.0	12.7	15.8	350	500	--	--	10.4	11.9	12.7	14.4	350	500
Vitamin B_6 mg/day	--	--	0.9	1.2	1.0	1.4	10	15	--	--	0.9	1.2	1.0	1.4	10	15
Vitamin B_{12} µg/day	2.5	3.5	--	--	--	--	NA		2.5	3.5	--	--	--	--	NA	
Vitamin C mg/day	--	--	40	60	45	70	800	1050	--	--	40	60	45	70	800	1050
Vitamin D µg/day	15.0	15.0	--	--	--	--	50	100	15	15	--	--	--	--	50	100
Calcium mg/day			500	800	650	1000	NA		--	--	500	800	650	1000	NA	
Copper mg/day	1.0	1.3	--	--	--	--	3	4	1.0	1.1	--	--	--	--	3	4

Iodine µg/day	90	120	--	--	--	--	300	450	90	120	--	--	--	--	300	450
Iron mg/day			10	14	15	17	NA				10	17	15	30	NA	
Magnesium mg/day	230	230	--	--	--	--	250	250	230	230	--	--	--	--	250	250
Potassium mg/day	1800	2700	--	--	--	--	NA		1800	2700	--	--	--	--	NA	
Selenium µg/day	35	55	--	--	--	--	130	200	35	55	--	--	--	--	130	200
Sodium mg/day	1700	2000	--	--	--	--	NA		1700	2000	--	--	--	--	NA	
Zinc mg/day	--	--	6.2	8.9	7.4	10.7	13	18	--	--	6.2	8.9	7.4	10.7	13	18

Table 7.C. Gender-wise comparison of daily nutrient intake among SL children.

Nutrient	Female Mean (SD)	Male Mean (SD)	t-value	df	p-value	Mean Dif	SED	95% CI Lower	95% CI Upper
Energy (kcal)	1538 (350)	1561 (304)	-0.35	93	0.73	-23	66	-155	108
Carbohydrate (g)	247 (61)	252 (45)	-0.46	97	0.65	-4.8	10.6	-26	16
Protein (g)	49 (12)	48 (10.9)	0.64	92	0.52	1.5	2.3	-3.1	6.2
Total fat (g)	38 (13)	39 (14)	-0.28	82	0.78	-0.8	2.9	-6.5	4.9
Dietary fibre (g)	6.3 (3.5)	7.3 (3.9)	-1.37	80	0.17	-1.1	0.8	-2.6	0.5
Calcium (mg)	254 (126)	263 (147)	-0.32	76	0.75	-9.0	28	-65	47
Iron (mg)	9.6 (5.0)	8.5 (3.7)	1.25	97	0.21	1.1	0.9	-0.6	2.8
Magnesium (mg)	111 (47)	114 (45)	-0.27	88	0.79	-2.5	9.3	-21	16
Potassium (mg)	1244 (440)	1237 (416)	0.09	89	0.93	7.7	87	-165	181
Zinc (mg)	3.8 (1.8)	3.9 (1.3)	-0.42	97	0.68	-0.1	0.3	-0.7	0.5
Iodine (µg)	39 (29)	39 (36)	-0.07	74	0.95	-0.4	6.8	-14	13
Selenium (µg)	37 (20)	34 (20)	0.59	86	0.56	2.4	4.0	-5.7	10.4
Copper (mg)	0.6 (0.3)	0.7 (0.2)	-0.62	90	0.54	0.0	0.1	-0.1	0.1
Vitamin A (µg)	253 (213)	210 (166)	1.12	96	0.27	43	38	-33	118
Thiamine (mg)	0.6 (0.3)	0.7 (0.3)	-0.59	85	0.56	0.0	0.1	-0.2	0.1
Riboflavin (mg)	1.2 (1.9)	0.9 (1.7)	0.73	93	0.47	0.3	0.4	-0.5	1.0
Niacin (mg)	13 (3.6)	12 (3.1)	0.94	93	0.35	0.6	0.7	-0.7	2.0
Vitamin B_6 (mg)	1.4 (1.3)	0.9 (0.9)	2.02	97	0.05	0.5	0.2	0.0	0.9
Vitamin B_{12} (µg)	1.5 (1.0)	1.3 (1.0)	1.01	85	0.32	0.2	0.2	-0.2	0.6
Vitamin C (mg)	29 (19)	32 (38)	-0.55	54	0.58	-3.5	6.4	-16	9.2
Vitamin E (mg)	3.1 (3.7)	2.9 (3.9)	0.16	84	0.87	0.1	0.8	-1.4	1.7

SDE- Standard Error Difference, SD – Standard Deviation, df – degree of freedom, Mean Dif – Mean Diffrence CI – Confidence Interval

Gender-based comparisons of nutrient intake among SL schoolchildren revealed no statistically significant differences across the nutrients assessed ($p > 0.05$ for all) (Table 7.C). Although some nutrients, such as vitamin B_6, showed borderline significance ($p = 0.05$), the overall pattern suggests that dietary intake was broadly similar between male and female participants. These findings indicate that gender may not be a significant determinant of nutrient consumption in this population. And most importantly sample size is not enough statistical power to give solid conclusion.

Table 7.D. Gender wise comparison **of** daily nutrient intake among NZ children.

Nutrient	Female Mean (SD)	Male Mean (SD)	t-value	df	p-value	Mean Dif	SED	95% CI Lower	95% CI Upper
Energy (kcal)	2083 (368)	2173 (530)	-0.57	29	0.58	-90	159	-416	235
Carbohydrate (g)	251 (54)	251 (65)	0.02	27	0.99	0.3	21	-43	44
Protein (g)	86 (27)	86 (30)	-0.06	25	0.96	-0.6	10.2	-22	20
Total fat (g)	77 (14)	85 (24)	-1.18	30	0.25	-8.1	6.9	-22	5.9
Dietary fibre (g)	22 (6.9)	25 (8.7)	-1.28	28	0.21	-3.5	2.8	-9.2	2.1
Calcium (mg)	801 (438)	911 (407)	-0.71	22	0.49	-110	156	-433	213
Iron (mg)	12 (4.0)	12 (6.2)	-0.25	30	0.80	-0.5	1.8	-4.1	3.2
Magnesium (mg)	235 (101)	266 (80)	-0.89	19	0.39	-30	34	-102	41
Potassium (mg)	2241 (839)	2640 (837)	-1.30	23	0.21	-399	306	-1031	234
Zinc (mg)	8.3 (3.5)	9.1 (3.3)	-0.59	22	0.56	-0.7	1.3	-3.3	1.9
Iodine (µg)	106 (57)	150 (159)	-1.13	26	0.27	-44	39	-125	36
Selenium (µg)	56 (38)	46 (30)	0.71	19	0.49	9.2	13	-18	36
Copper (mg)	0.1 (0.0)	0.1 (0.2)	-1.70	8.4	0.13	-0.1	0.1	-0.2	0.0
Vitamin A (µg)	214 (186)	272 (153)	-0.92	20	0.37	-59	64	-191	74
Thiamine (mg)	1.9 (1.4)	1.9 (1.1)	0.13	19	0.90	0.1	0.5	-0.9	1.1
Riboflavin (mg)	1.5 (0.7)	1.9 (1.1)	-1.17	29	0.25	-0.4	0.3	-1.0	0.3
Niacin (mg)	16 (7.2)	17 (7.2)	-0.15	23	0.88	-0.4	2.6	-5.8	5.0
Vitamin B_6 (mg)	1.7 (0.9)	1.7 (0.7)	0.02	19	0.98	0.0	0.3	-0.6	0.6
Vitamin B_{12} (µg)	3.3 (1.7)	4.2 (3.6)	-0.88	29	0.38	-0.8	0.9	-2.8	1.1
Vitamin C (mg)	69 (43)	87 (63)	-0.93	29	0.36	-18	19	-56	21
Vitamin E (mg)	6.9 (4.0)	8.5 (3.3)	-1.20	20	0.24	-1.7	1.4	-4.5	1.2

SDE- Standard Error Difference, SD – Standard Deviation, df – degree of freedom, Mean Dif – Mean Diffrence CI – Confidence Interval

Gender-based comparisons of nutrient intake in NZ schoolchildren revealed no statistically significant differences between male and female children across all nutrients assessed (Table 7.D). Although mean intakes varied slightly between genders, for example, males tended to have higher average intakes of energy, fat, calcium, and riboflavin, these differences were not statistically significant ($p > 0.05$). This suggests that, within the study sample, nutrient intake patterns were broadly similar between boys and girls. And most importantly sample size is not enough statistical power to give solid conclusion.

Table 7.E. Multivariate Logistic Regression Analysis of Predictors on Nutrient Adequacy Among School-Aged Children

	Intercept		Age		GenderMale[a]		CountrySL[b]		DayWeekend[c]	
Nutrient	Odds Ratio (95%CI)	P-value	Odds Ratio (95%CI)	p-value	Odds Ratio (95%CI)	p-value	Odds Ratio (95%CI)	p-value	Odds Ratio (95%CI)	**p-value**
Protein (g)	8.41 (0.00, 33)	0.75	0.56 (0.16, 1.91)	0.35	0.92 (0.05, 16.6)	0.96	0.26 (0.01, 4.84)	0.37	1 (0.06, 16.35)	1.00
Dietary fibre (g)	12 (0.35, 380)	0.17	0.77 (0.57, 1.05)	0.10	1.5 (0.66, 3.43)	0.33	19.8 (8.45, 46.4)	0.00*	1.5 (0.68, 3.32)	0.32
Calcium (mg)	2.21 (0.13, 38)	0.59	0.94 (0.74, 1.21)	0.65	0.74 (0.38, 1.45)	0.39	7.06 (3.6, 13.83)	0.00*	1.19 (0.61, 2.29)	0.61
Iron (mg)	3.32 (0.29, 38)	0.34	0.74 (0.60, 0.92)	0.01*	1.53 (0.83, 2.83)	0.17	19.21 (8.52, 43.28)	0.00*	0.84 (0.47, 1.5)	0.55
Magnesium (mg)	3.26 (0.10, 103)	0.50	0.86 (0.64, 1.17)	0.34	0.58 (0.26, 1.29)	0.18	30.16 (13.46, 67.59)	0.00*	1.28 (0.58, 2.83)	0.54
Potassium (mg)	241 (8.49, 6858)	0.00	0.66 (0.49, 0.88)	0.00*	0.66 (0.32, 1.38)	0.27	3.49 (1.66, 7.31)	0.00*	1.84 (0.88, 3.83)	0.10
Zinc (mg)	0.42 (0.02, 9.25)	0.58	0.95 (0.73, 1.25)	0.71	1.09 (0.52, 2.29)	0.83	33.4 (15.31, 72.86)	0.00*	1 (0.48, 2.07)	1.00
Iodine (µg)	0.01 (0.00, 0.29)	0.01	1.43 (1.05, 1.95)	0.02*	0.78 (0.36, 1.68)	0.53	34.93 (15.28, 79.86)	0.00*	1 (0.47, 2.13)	1.00
Selenium (µg)	1.31 (0.16, 10.83)	0.80	1.00 (0.83, 1.20)	0.97	0.93 (0.56, 1.55)	0.79	1.23 (0.69, 2.2)	0.49	1.14 (0.69, 1.87)	0.61
Copper (mg)	2070503.21 (0, Inf)	0.99	0.97 (0.68, 1.38)	0.88	1.48 (0.52, 4.2)	0.46	0.00 (0.00, Inf)	0.99	3.93 (1.24, 12.4)	0.02*
Vitamin A (µg)	1.88 (0.13, 26)	0.64	1.07 (0.85, 1.34)	0.58	0.96 (0.51, 1.81)	0.89	0.88 (0.41, 1.87)	0.74	1.75 (0.93, 3.31)	0.08
Thiamin (mg)	0.3 (0.03, 3.11)	0.31	0.91 (0.75, 1.11)	0.33	0.77 (0.44, 1.33)	0.35	14.14 (5.78, 34.59)	0.00*	1.36 (0.79, 2.34)	0.27
Riboflavin (mg)	0.12 (0.01, 1.31)	0.08	1.05 (0.85, 1.29)	0.65	0.94 (0.53, 1.66)	0.83	12.25 (5.9, 25.46)	0.00*	1.13 (0.65, 1.98)	0.67
Niacin (mg)	0.99 (0.1, 9.44)	0.99	0.85 (0.70, 1.04)	0.11	1.13 (0.66, 1.95)	0.65	2.21 (1.1, 4.43)	0.03*	1.79 (1.05, 3.06)	0.03*
Vitamin B_6 (mg)	1.02 (0.09, 12)	0.99	0.81 (0.65, 1.00)	0.05	1.78 (0.96, 3.32)	0.07	20.4 (9.01, 46.18)	0.00*	1.25 (0.7, 2.25)	0.46
Vitamin B_{12} (µg)	0.35 (0.02, 6.45)	0.48	0.94 (0.73, 1.21)	0.64	1.48 (0.72, 3.04)	0.29	25.82 (12, 55.52)	0.00*	1.63 (0.81, 3.26)	0.17
Vitamin C (mg)	2.31 (0.19, 28)	0.52	0.86 (0.69, 1.07)	0.18	0.9 (0.49, 1.64)	0.72	9.29 (4.84, 17.83)	0.00*	1.26 (0.69, 2.29)	0.45

Each logistic regression model estimates the log odds of a nutrient deficiency based on predictors.
age (continuous)
[a] - binary dummy variable; reference is likely Female
[b] - binary dummy variable; reference is likely New Zealand
[c]- binary dummy variable; reference is likely weekday
Coefficients represent the effect of each predictor on the likelihood of meeting nutrient adequacy. Statistically significant predictors ($p < 0.05$) are marked with an asterisk (*).

Table 7.F.. Interaction Effects of Gender, Age, and Day with Country on Nutrient Adequacy Among School-Aged Children from logistic regression models

		Gender*Country			Age*Country			Day*Country		
	Nutrient	**Coefficient (Standard Error)**	**p value**	**95%CI**	**Coefficient (Standard Error)**	**p value**	**95%CI**	**Coefficient (Standard Error)**	**p value**	**95%CI**
1	Protein (g)	-39.99 (26609.96)	1.00	NA, 4359.85	-17.93 (4651.19)	1.00	NA, 751.13	-40.55 (23933.2)	1.00	NA, 3916.7
2	Dietary fibre (g)	-0.58 (0.86)	0.50	-2.27, 1.15	-0.56 (0.34)	0.10	-1.26, 0.08	-1.35 (0.85)	0.11	-3.08, 0.29
3	Calcium (mg)	-0.22 (0.7)	0.75	-1.59, 1.15	-0.22 (0.26)	0.41	-0.74, 0.3	-0.84 (0.68)	0.22	-2.19, 0.49
4	Iron (mg)	-0.54 (0.92)	0.56	-2.62, 1.15	-0.67 (0.34)	0.05	-1.38, -0.03	0.1 (0.81)	0.90	-1.48, 1.74
5	Magnesium (mg)	0.72 (0.84)	0.39	-0.92, 2.4	0.2 (0.31)	0.53	-0.42, 0.82	-0.79 (0.83)	0.34	-2.45, 0.84
6	Potassium (mg)	0.22 (0.8)	0.78	-1.33, 1.84	0.24 (0.33)	0.46	-0.38, 0.91	-1.58 (0.8)	0.05	-3.21, -0.05
8	Zinc (mg)	0.21 (0.8)	0.79	-1.39, 1.78	-0.13 (0.3)	0.67	-0.73, 0.46	-0.3 (0.78)	0.70	-1.84, 1.22
9	Iodine (µg)	0.18 (0.78)	0.82	-1.36, 1.73	0.45 (0.32)	0.16	-0.18, 1.11	0 (0.77)	1.00	-1.52, 1.52
10	Selenium (µg)	-0.96 (0.61)	0.12	-2.18, 0.24	0.43 (0.24)	0.08	-0.04, 0.92	0.53 (0.6)	0.38	-0.64, 1.72
11	Copper (mg)	0.39 (2165.17)	1.00	-59.26, 58.81	-0.03 (914.27)	1.00	-26.04, 25.99	1.37 (2122.22)	1.00	-59.02, 61.75
12	Vitamin A (µg)	1.5 (0.93)	0.11	-0.19, 3.59	0.48 (0.33)	0.14	-0.14, 1.17	-0.18 (0.8)	0.82	-1.81, 1.36
13	Thiamin (mg)	-0.65 (0.98)	0.51	-2.81, 1.21	-0.7 (0.43)	0.11	-1.67, 0.08	-0.53 (0.96)	0.58	-2.65, 1.3
14	Riboflavin (mg)	0.41 (0.75)	0.58	-1.09, 1.89	0.01 (0.29)	0.97	-0.58, 0.59	-0.68 (0.76)	0.37	-2.23, 0.78
15	Niacin (mg)	0.68 (0.71)	0.34	-0.73, 2.08	-0.55 (0.29)	0.06	-1.15, 0.01	0.98 (0.7)	0.16	-0.4, 2.38
16	Vitamin B_6 (mg)	1.2 (0.84)	0.15	-0.48, 2.86	0.09 (0.32)	0.78	-0.54, 0.75	-1.46 (0.92)	0.11	-3.53, 0.21
17	Vitamin B_{12} (µg)	0.8 (0.78)	0.30	-0.73, 2.34	-0.38 (0.29)	0.19	-0.98, 0.18	-0.06 (0.75)	0.93	-1.55, 1.4
18	Vitamin C (mg)	1.08 (0.69)	0.12	-0.26, 2.46	0.27 (0.27)	0.31	-0.25, 0.8	-0.57 (0.68)	0.40	-1.92, 0.75

Table 7.F presents the summary interaction effects from logistic regression models for nutrient adequacy, including Country × Gender, Country × Age, and Country × Day. Most interaction terms between predictors and country were not statistically significant ($p > 0.05$), indicating limited moderation effects. However, the age × country interaction for iron ($p = 0.05$) and niacin ($p = 0.06$) approached significance, suggesting that the influence of age on adequacy may differ by country. Similarly, day type x country interaction for potassium was marginally significant ($p = 0.05$), indicating possible variation in weekend versus weekday intake patterns between countries. No other interactions showed meaningful effects.

Appendix - 3
Study documents
Sri Lankan Study

Appendix 3.1- Ethics approval Letter from Massey University, New Zealand

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

7/06/2022

Dear: Harshani Perera

Re: Ethics Application - NOR 22/16 - Evaluating the healthy food and physical activity environment in schools in Sri Lanka: A study using 5-13 years old children

Thank you for the above application that was considered by the Massey University Human Ethics Committee:

Human Ethics Northern Committee at their meeting held on **Thursday, 31 March 2022**

On behalf of the Committee I am pleased to advise you that the ethics of your application are approved.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely



Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Appendix 3.2.- Permission letter from the Ministry of Education, Sri Lanka

ENGLISH TRANSLATION

"Isurupaya", Battaramulla,

MINISTRY OF EDUCATION Sri Lanka

My No. ED/01/09/11/01/09 Your No. Date – 29.11.2021

Mrs. T.S. Harshani Perera,
Senior Lecturer,
Sabaragamuwa University

Regarding the approval to carry out a research

This refers to your letter dated 07.07.2021, sent to the Ministry of Education regarding the above matter. Through that letter you have requested to obtain permission to collect the data from school children in order to carry out the related project studies in relation to your postgraduate course.

In this regard, I kindly inform you that in accordance with the recommendations given by the Director of Education (School Health and Nutrition), subject to the following conditions, the approval will be given to obtain the required data from the students of the school for the above academic work .

1. Prior to obtaining data from the relevant schools, an ethical clearance should be obtained from a board of a university in connection with the research.
2. If provincial schools are contacted, approval should be obtained from the relevant Provincial Director of Education.
3. Activities should be carried out only with the full consent of the Principal of the relevant colleges.
4. The assistance of an experienced school teacher should be sought when gathering information.
5. Parental permission must be obtained to obtain information from students.
6. At the end of the research a copy of the research report should be submitted to the Health and Nutrition Council of the Ministry of Education.
7. In order to be safe from Covid -19 , the instructions provided by the Director General of Health Services should be followed.

ENGLISH TRANSLATION

8. No photographs or recordings shall be made at the school.
9. The information obtained should be kept confidential.
10. Relevant work should be done in a manner that protects the accepted ethics of the school system.

Sgd / illegibly
P.W.Amaradivakara
Director of Education
(School Affairs)

Signed by /L.M.D.Dharmasena,
Additional Secretary(School Affairs)
For Secretary, Ministry of Education.

Copies :

1. Director of Provincial Education, ……..Provincial Department of Education
2. Director of Education (National Schools)
3. Director of Education (School Health and Nutrition)

I, D.K.L. Gunathilaka, Sworn Translator appointed by the Ministry of Justice Sri Lanka do hereby certify that the above is a true English translation of the original letter which was in Sinhala medium.

23.02.2022

D.K.L. GUNATHILAKA
Attorney - at - law & Notary Public
Sworn Translator
(District Court, Ratnapura)
3/9,Naputugala Road,
Gorokgoda, Ratnapura, Sri Lanka
Mobile:071-4401982

Appendix 3.3.- Permission letter from the Sabaragamuwa Provincial Education Office, Sri Lanka

අධ්‍යාපන අමාත්‍යාංශය
கல்வி அமைச்சு
Ministry of Education

'ඉසුරුපාය', බත්තරමුල්ල, ශ්‍රී ලංකාව.
'இசுருபாய', பத்தரமுல்ல, இலங்கை.
'Isurupaya', Battaramulla, Sri Lanka.
+94112785141-50 +94112785818
info@moe.gov.lk www.moe.gov.lk

මගේ යොමුව අංකය இல. My Ref. ED/01/09/11/01/09

ඔබේ යොමුව உமது இல. Your Ref.

දිනය திகதி Date 2021.11. 29.

ටී.එස්.හර්ෂනී පෙරේරා මිය
ජ්‍යෙෂ්ඨ කථිකාචාර්ය
සබරගමුව විශ්වවිද්‍යාලය

පර්යේෂණයක් සිදුකිරීම සඳහා අනුමැතිය ලබාදීම සම්බන්ධවයි

උක්ත කරුණ සම්බන්ධයෙන් ඔබ විසින් අධ්‍යාපන අමාත්‍යාංශය වෙත යොමුකළ 2021.07.07 දිනැති ලිපිය හා බැඳේ.

එමඟින්, ඔබගේ පශ්චාත් උපාධි පාඨමාලාවට අදාළව සිදුකිරීමට නියමිත ව්‍යාපෘති අධ්‍යයනය සඳහා පාසල් සිසුන් සම්බන්ධ කරගනිමින් දත්ත ලබාගැනීමට අනුමැතිය ලබාදෙන මෙන් ඉල්ලීමක් කර ඇත.

ඒ සම්බන්ධයෙන් අධ්‍යාපන අධ්‍යක්ෂ(පාසල් සෞඛ්‍ය හා පෝෂණ) විසින් ලබාදී ඇති නිර්දේශ අනුව, පහත සඳහන් කොන්දේසිවලට යටත් ව, පාසල් සිසුන්ගෙන් උක්ත අධ්‍යයන කාර්යය සඳහා අවශ්‍ය දත්ත ලබාගැනීමට අනුමැතිය ලබාදෙන බව කාරුණිකව දන්වමි.

1. අදාළ පාසල්වලින් දත්ත ලබාගැනීමට පෙර පර්යේෂණය සිදුකිරීම සම්බන්ධව විශ්වවිද්‍යාලයක මණ්ඩලයක් මඟින් ලබාදෙන ලද සදාචාරාත්මක කරුණු පිළිබඳ අනුමැතිය (ethical clearance) ලබා ගත යුතු ය.
2. පළාත් පාසල් සම්බන්ධකරගන්නේ නම් අදාළ පළාත් අධ්‍යාපන අධ්‍යක්ෂ වෙතින් අනුමැතිය ලබා ගත යුතු ය.
3. අදාළ විද්‍යාලයන්හි විදුහල්පතිගේ පූර්ණ එකඟතාවය මත පමණක් කටයුතු කළ යුතු ය.
4. තොරතුරු රැස්කිරීමට යාමේදී පාසලේ ප්‍රවීන ගුරු මහත්මයකුගේ / මහත්මියකගේ සහයෝගය ලබා ගත යුතු ය.
5. සිසුන්ගෙන් තොරතුරු ලබා ගැනීම සඳහා දෙමාපිය අවසරය ලබා ගත යුතු ය.
6. පර්යේෂණය අවසානයේදී පර්යේෂණ වාර්තාවේ පිටපතක් අධ්‍යාපන අමාත්‍යාංශයේ සෞඛ්‍ය හා පෝෂණ ශාඛාව වෙත ලබා දිය යුතු ය.
7. Covid-19 උවදුරෙන් ආරක්ෂාවීම සඳහා, සෞඛ්‍ය සේවා අධ්‍යක්ෂ ජනරාල් විසින් ලබාදී ඇති උපදෙස්වලට අනුකූලව කටයුතු කළ යුතු ය.
8. පාසල තුළ කිසිදු ඡායාරූප ලබාගැනීමක් හෝ පටිගත කිරීමක් සිදු නොකළ යුතු ය.
9. ලබාගත් තොරතුරුවල රහස්‍යභාවය සුරැකිය යුතු ය.
10. පාසල් පද්ධතියේ පිළිගත් ආචාරධර්ම ආරක්ෂාවන අන්දමින් අදාළ කාර්යයන් සිදු කළ යුතු ය.

PWAmaradeera

පී.ඩබ්.අමරදිවාකර
අධ්‍යාපන අධ්‍යක්ෂ
(පාසල් කටයුතු)

අත්.කළේ/එල්.එම්.සී.ධර්මසේන
අතිරේක ලේකම්
(පාසල් කටයුතු)
අධ්‍යාපන ලේකම් වෙනුවට

පිටපත්:
1. පළාත් අධ්‍යාපන අධ්‍යක්ෂ, ... පළාත් අධ්‍යා. දෙපාර්තමේන්තුව
2. අධ්‍යාපන අධ්‍යක්ෂ(ජාතික පාසල්)
3. අධ්‍යාපන අධ්‍යක්ෂ(පාසල් සෞඛ්‍ය හා පෝෂණ)

කරු.දැ.ගැ.ස

ගරු අමාත්‍යතුමා
கௌரவ அமைச்சர்
Hon. Minister
+94112784832
+94112784825
minister.education@moe.gov.lk

ලේකම්
செயலாளர்
Secretary
+94112784811
+94112785162
secretary.education@moe.gov.lk

Appendix 3.4.- Information letter – Parents

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

SABARAGAMUWA UNIVERSITY OF SRI LANKA

PARTICIPANT INFORMATION SHEET

PARENTS OF THE CHILDREN

Research Project Title
Evaluating the healthy food and physical activity environment in schools in Sri Lanka: A study using 5-13-year-old children.

Researcher Introduction
I am T.S.H. Perera, Senior lecturer in Sabaragamuwa University of Sri Lanka. I am also a PhD candidate at Massey University, New Zealand. I am a member of a team of researchers from the Sabaragamuwa University of Sri Lanka and Massey University in New Zealand, with physical activity and nutrition expertise.

Invitation
You are being invited to take part in this research project. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.
Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

1. **Background to study**
   A healthy, balanced diet and regular physical activity make an important contribution to children's growth and development, their educational performance and attainment and their long-term health and well-being. Therefore, this study has been designed to evaluate the food environment and physical activity practices in primary schools in Rathnapura District, Sri Lanka. The main outcome expected through this study is to understand the food and physical activity environment in selected Sri Lankan schools.

   We would like to invite you/your child to take part in this evaluation.

2. **Participant recruitment**
   We are collecting data from schoolchildren in grades 1 to 8 of selected schools across the Rathnapura district. Data will be collected from the schoolchildren in a variety of ways and we will be inviting students from different classes to take part in different aspects of the evaluation. Sometimes, students alone may be unable to provide details about their diet and physical activity, and therefore we ask you, as their parents, to help them throughout the data collection (especially students in grades 1 to 3). You and your child can use the preferred language medium (Sinhala/Tamil/English) for the questionnaires or interviews or discussions.
3. **Project Procedures and Participant Involvement**

If you agree to take part,

1. 24 hours dietary recall interview
   The date and time will be arranged according to the agreement of the particular parent and student considering their availability.

   For grades 1 to 3 students
   Students in grades 1-3 may not able to provide details of or understand what they have eaten the day before. Therefore, parents of the students in grades 1-3 will be interviewed to collect dietary information about the child.

   For grades 4 to 8 students
   Students will be invited to participate in an interview. It may be a face-to-face meeting or an online meeting according to the preference of the parents and students. If you wish to have a face-to-face meeting, we will meet you in the classroom after school. If you wish to have an online meeting, we will arrange it according to your available time.

2. Accelerometer
   Your child will be asked to wear a watch-like device on their wrist for 7 days. This device contains an accelerometer which records movement and allows the evaluation team to accurately record physical activity (amount, intensity, duration and patterns of activity). As the strap is waterproof, the device should stay on your child's wrist for the full 7-day duration (including shower/bath time, and swimming). The device will be fitted by a member of the research team. We will also show you/your child how to put on the device and provide a set of instructions for parents and caregivers (and make this information available for teachers as well) in case it must be removed at any stage (e.g., for sports like football).

   These accelerometers are also able to monitor sleep patterns, so should continue to be worn once your child goes to bed. We will be providing you with a sleep diary so that you can tell us the times your child went to bed and the times they woke up during the 7 days. This will help us understand your child's sleep pattern.

   Please be informed that the accelerometer may become damaged during the trial, but you will not be held liable nor have to pay to replace the equipment. But we hope that you will give special attention to your child during the period of wearing and return us as it is.

3. Questionnaires
   The research team will be asking your child to complete two questionnaires on the following topics:
   • Physical activity knowledge
   • Motivation/behaviour related to being physically active

   Trained evaluators will attend one session for a 40-minute data collection session.

   For grades 1–3 students
   We will ask questions relating to the physical activity behaviour of each selected student in grade 1-3 class because they may find it difficult to read and understand the questions on their own. Research assistants will help them to explain the question and select the most appropriate answer.

For grade 4-8 students
We will ask students in each class to complete two questionnaires.

Each questionnaire will take approximately 10 minutes to complete but we will allow some time to distribute hard copies of questionnaires, explain the testing procedures, answer any questions they may have, and collect filled questionnaires. We will work with schools to get a range of classes to obtain enough completions of the questionnaires.

Your child will be placed in a draw to win a $50 supermarket gift voucher as a small token of our appreciation (one draw for each selected school).

4. **Data analysis**
We would like to investigate the links between physical activity, nutrition intake and student engagement and therefore we will be using a unique identifier to connect the responses for each student. However, consistent with the confidentiality and non-identity of a participant, we will not provide personal data to the School, the Ministry of Education, (Sri Lanka) or any other external party who will receive the dataset or results. All data will be deidentified and the participant connected by a unique study code.

5. **Participant's Rights**
You or your child are under no obligation to accept this invitation. Your child's participation or non-participation will not influence his/her standing in the school. If you give consent for your child to participate, they have the right to:

- Decline to answer any particular question
- Withdraw from the evaluation at any time, even after you have signed a consent form (if you or your child choose to withdraw, you cannot withdraw his/her data from the analysis after the data collection has been completed.)
- Ask any questions about the evaluation at any time during participation
- Provide information on the understanding that your child's name will not be used in any publications
- Be given access to a summary of the project findings when it is concluded

6. **Good Practice and Cultural Safety for Evaluations**
The research was discussed with the Director/School Affairs, Ministry of Education, Sri Lanka. We acknowledge the concept of respecting the participant`s inherent dignity and acting in a caring manner towards them by way of:

- Taking full responsibility to perform the data collection in a safe and ethical manner
- Providing the participant with all of the critical information regarding the study in a clear way, so they can make informed decisions
- An awareness of the cultural significance and sensitivity to culturally safe implementation of the project
- Respect for the privacy and confidentiality of participants
-

7. **Confidentiality**
All data collected will be used solely for evaluation and research purposes. Reports will be provided to the Ministry of Education (Sri Lanka) and may be presented at conferences and

submitted for publication in journals. All personal information will be kept confidential by assigning numbers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with confidentiality and will be stored in a secure location for five years at the Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. After this time, it will be disposed of by an appropriate staff member from the Department of Sport Sciences and Physical Education or the School of Sport, Exercise and Nutrition.

8. **Project Contacts**

If you have any questions regarding this evaluation, please do not hesitate to contact either of the following people for assistance:

Name	Title	email Address	Contact Number
Ms.T.S.H. Perera Department of Sport Sciences and Physical Education, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka; School of Sport, Exercise and Nutrition, Massey University	Investigator (PhD Candidate)	Shalika.harshani@gmail.com	+94717800060
Prof David Rowlands School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Supervisor Professor of Nutrition, Metabolism and Exercise	D.S.Rowlands@massey.ac.nz	+6449793295
Prof Aj Ali School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Co-Supervisor Professor of Sport and Exercise Science/Associate Dean - International - School of Sport, Exercise and Nutrition	A.Ali@massey.ac.nz	+6492136414
Prof Carol Wham School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Co-Supervisor Professor of Public Health Nutrition - School of Sport, Exercise and Nutrition	C.A.Wham@massey.ac.nz	+6492136644
Dr.Ananda Chandrasekara Department of Applied Nutrition, Wayamba University of Sri Lanka	Co-Supervisor Senior Lecturer	ananda.ch@wyb.ac.lk	+94777030558

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 22/16. If you have any concerns about the conduct of this research, please contact A/Prof Fiona Te Momo, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800, x 43347, email humanethicsnorth@massey.ac.nz .

Thank you for taking part in this research.

Appendix 3.5.- Information letter – Food Suppliers

PARTICIPANT INFORMATION SHEET -

FOOD ENVIRONMENT – FOOD SUPPLIERS QUESTIONNAIRES

Research Project Title
Evaluating the healthy food and physical activity environment in schools in Sri Lanka: A study using 5-13-year-old children.

Researcher Introduction
I am T.S.H.Perera, Senior lecturer in Sabaragamuwa University of Sri Lanka. I am also a PhD candidate at Massey University, New Zealand. I am a member of a team of researchers from the Sabaragamuwa University of Sri Lanka and Massey University in New Zealand, with physical activity and nutrition expertise.

Invitation
You are being invited to take part in this research project. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.
Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

1. Background to study

A healthy, balanced diet and regular physical activity make an important contribution to children's growth and development, their educational performance and attainment and their long-term health and well-being. Therefore, this study has been designed to evaluate the food environment and physical activity practices in primary schools in Rathnapura District, Sri Lanka. The main outcome expected through this study is to understand the food and physical activity environment in selected Sri Lankan schools.

We will be conducting an evaluation of the food environment in schools. Hence, we would like to invite you to take part in this evaluation.

9. Participant recruitment

We are collecting data about the food environment of selected schools across the Rathnapura district. Data will be collected from the food suppliers using the questionnaire; this information sheet relates to the school food environment- food supplier's questionnaire. The participant can select the questionnaire according to their preferred language – Sinhala, Tamil, or English-and use the preferred language medium for the discussion.

10. Project Procedures and Participant Involvement

If you agree to take part, you will be invited to complete the questionnaire relating the foods and drink availability in your stall or canteen.

A trained evaluator will provide the questionnaire and ask you to fill it out during your free time. The questionnaire will take approximately 10 minutes to complete. But we will take some time to explain the testing procedures and answer any questions they may have. The filled questionnaire will be collected after completing the task in the agreed time later.

11. Data analysis

We aim to examine the food environment of the school. However, consistent with the confidentiality and non-identity of a participant, we will not provide personal data to the School, the Ministry of Education, Sri Lanka or any other external party who will receive the dataset or results. All data will be deidentified and the participant connected by a unique study code.

12. Participant's Rights

You are under no obligation to accept this invitation. Your participation or non-participation will not influence your standing in the school. If you give consent to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the evaluation at any time, even after you have signed a consent form (if you or your child choose to withdraw you/they cannot withdraw their data from the analysis after the data collection has been completed)
- Ask any questions about the evaluation at any time during participation
- Provide information on the understanding that your name will not be used in any publications
- Be given access to a summary of the project findings when it is concluded

13. Good Practice and Cultural Safety for Evaluations

The evaluation was discussed with the Director/School Affairs, Ministry of Education, Sri Lanka. We acknowledge the concept of respecting the participant`s inherent dignity and acting in a caring manner towards them by way of:

- Taking full responsibility to perform the evaluation in a safe and ethical manner
- Providing the participant with all of the critical information regarding the evaluation in a clear way, so they can make informed decisions
- An awareness of the cultural significance and sensitivity for culturally safe implementation of the evaluation
- Respect for the privacy and confidentiality of participants

14. Confidentiality

All data collected will be used solely for evaluation and research purposes. Reports will be provided to the Ministry of Education (Sri Lanka) and may be presented at conferences and submitted for publication in journals. All personal information will be kept confidential by assigning numbers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with confidentiality and will be stored in a secure location for five years at the Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. After this time, it will be disposed of by an appropriate staff member from the Department of Sport Sciences and Physical Education or school of Sport, Exercise and Nutrition.

15. Project Contacts

If you have any questions regarding this evaluation, please do not hesitate to contact either of the following people for assistance:

Name	Title	email Address	Contact Number
Ms.T.S.H. Perera Department of Sport Sciences and Physical Education, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka; School of Sport, Exercise and Nutrition, Massey University	Investigator (PhD Candidate)	Shalika.harshani@gmail.com	+94717800060
Prof David Rowlands School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Supervisor Professor of Nutrition, Metabolism and Exercise	D.S.Rowlands@massey.ac.nz	+6449793295
Prof Aj Ali School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Co-Supervisor Professor of Sport and Exercise Science/Associate Dean - International - School of Sport, Exercise and Nutrition	A.Ali@massey.ac.nz	+6492136414
Prof Carol Wham School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Co-Supervisor Professor of Public Health Nutrition - School of Sport, Exercise and Nutrition	C.A.Wham@massey.ac.nz	+6492136644

Dr.Ananda Chandrasekara Department of Applied Nutrition, Wayamba University of Sri Lanka	Co-Supervisor Senior Lecturer	ananda.ch@wyb.ac.lk	+94777030558

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 22/16. If you have any concerns about the conduct of this research, please contact A/Prof Fiona Te Momo, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800, x 43347, email humanethicsnorth@massey.ac.nz .

Thank you for taking part in this research.

Appendix 3.6. - Information Letter – Food Committee members



PARTICIPANT INFORMATION SHEET

FOOD ENVIRONMENT – SCHOOL ADMINISTRATORS QUESTIONNAIRES

Research Project Title

Evaluating the healthy food and physical activity environment in schools in Sri Lanka: A study using 5-13 years old children

Researcher Introduction

I am T.S.H.Perera, Senior lecturer in Sabaragamuwa University of Sri Lanka. I am also a PhD candidate at Massey University, New Zealand. I am a member of a team of researchers from the Sabaragamuwa University of Sri Lanka and Massey University in New Zealand, with physical activity and nutrition expertise.

Invitation

You are being invited to take part in this research project. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.
Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

1. Background to study

A healthy, balanced diet and regular physical activity make an important contribution to children's growth and development, their educational performance and attainment and their long-term health and well-being. Therefore, this study has been designed to evaluate the food environment and physical activity practices in primary schools in Rathnapura District, Sri Lanka. The main outcome expected through this study is to understand the food and physical activity environment in selected Sri Lankan schools.

We will be conducting an evaluation of the food environment in schools. Hence, we would like to invite you to take part in this evaluation.

16. Participant recruitment

We are collecting data about the food environment of selected schools across the Rathnapura district, Sri Lanka. Data will be collected from the members of the food committee using the questionnaire; this information sheet relates to the school food environment- administrators questionnaire. The participant can select the questionnaire according to their preferred language – Sinhala, Tamil, or English-and use the preferred language medium for the discussion.

17. Project Procedures and Participant Involvement

If you agree to take part, you will be invited to complete the questionnaire relating to the foods and drink policy of your school.

A trained evaluator will provide the questionnaire and ask you to fill it out during your free time. The questionnaire will take approximately 10 minutes to complete. But we will take another 10 minutes to explain the testing procedures and answer any questions they may have. The filled questionnaire will be collected after completing the task in the agreed time later.

18. Data analysis

We aim to examine the food environment of the school. However, consistent with the confidentiality and non-identity of a participant, we will not provide personal data to the School, the Ministry of Education, Sri Lanka or any other external party who will receive the dataset or results. All data will be deidentified and the participant connected by a unique study code.

19. Participant's Rights

You are under no obligation to accept this invitation. Your participation or non-participation will not influence your standing in the school. If you give consent to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the evaluation at any time, even after you have signed a consent form (if you choose to withdraw you cannot withdraw your data from the analysis after the data collection has been completed)
- Ask any questions about the evaluation at any time during participation
- Provide information on the understanding that your name will not be used in any publications
- Be given access to a summary of the project findings when it is concluded

20. Good Practice and Cultural Safety for Evaluations

The evaluation was discussed with the Director/School Affairs, Ministry of Education, Sri Lanka. We acknowledge the concept of respecting the participant`s inherent dignity and acting in a caring manner towards them by way of:

- Taking full responsibility to perform the evaluation in a safe and ethical manner
- Providing the participant with all of the critical information regarding the evaluation in a clear way, so they can make informed decisions
- An awareness of the cultural significance and sensitivity for culturally safe implementation of the evaluation
- Respect for the privacy and confidentiality of participants

21. Confidentiality

All data collected will be used solely for evaluation and research purposes. Reports will be provided to the Ministry of Education and may be presented at conferences and submitted for publication in journals. All personal information will be kept confidential by assigning numbers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with confidentiality and will be stored in a secure location for five years at the Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. After this time, it will be disposed of by an appropriate staff member from the Department of Sport Sciences and Physical Education or school of Sport, Exercise and Nutrition.

22. **Project Contacts**

If you have any questions regarding this evaluation, please do not hesitate to contact either of the following people for assistance:

Name	Title	email Address	Contact Number
Ms.T.S.H. Perera Department of Sport Sciences and Physical Education, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka; School of Sport, Exercise and Nutrition, Massey University	Investigator	Shalika.harshani@gmail.com	+94717800060
Prof David Rowlands School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Supervisor Professor of Nutrition, Metabolism and Exercise	D.S.Rowlands@massey.ac.nz	+6449793295
Prof Aj Ali School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Supervisor Professor of Sport and Exercise Science	A.Ali@massey.ac.nz	+6492136414
Prof Carol Wham School of Sport, Exercise and Nutrition, College of Heath, Massey University, New Zealand	Supervisor Professor of Public Health Nutrition	C.A.Wham@massey.ac.nz	+6492136644
Dr.Ananda Chandrasekara Department of Applied Nutrition, Wayamba University of Sri Lanka	Supervisor Senior Lecturer	ananda.ch@wyb.ac.lk	+94777030558

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 22/16. If you have any concerns about the conduct of this research, please contact A/Prof Fiona Te Momo, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800, x 43347, email humanethicsnorth@massey.ac.nz .

Thank you for taking part in this research.

Appendix 3.7. - Consent Form – Parents

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

SABARAGAMUWA UNIVERSITY OF SRI LANKA

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CONSENT FORM

This consent form will be held for a minimum period of five (5) years

This consent form covers three different research methods: Children's questionnaires, 24 hours dietary recall and accelerometry

I have read the Information Sheet and have had the details of the evaluation explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

☐Yes ☐No

I understand that I have the right to withdraw my child from the evaluation, and to decline to answer any particular questions (if I/they choose to withdraw I/we cannot withdraw his/her data from the analysis after the data collection has been completed).

☐Yes ☐No

I agree for my child to provide information to the researcher on the understanding that his/her name will not be used without my permission (the information will be used only for this project and publications arising from this study).

☐Yes ☐No

I agree for my child to participate in the children's questionnaires under the conditions set out in the Information Sheet.

☐Yes ☐No

Child in grades 4-8 only: I agree for my child to participate in the 24 hours dietary recall interview under the conditions set out in the Information Sheet.

☐Yes ☐No

Child in grades 1-3 only: I agree to give my child's dietary information during the 24 hours dietary recall interview under the condition set out in the Information Sheet.

☐Yes ☐No

I agree for my child to participate in the physical activity data collection (using accelerometry) under the conditions set out in the Information Sheet.

☐Yes ☐No

Signature: _____Date: _____

Full Name: _____

Phone Number:_____

School:_____

Class: _____

Appendix 3.8. - Consent Form – Key informant







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CONSENT FORM

This consent form will be held for a minimum period of five (5) years

This consent form covers questionnaires for School administration and food suppliers

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

☐Yes ☐No

I understand that I have the right to withdraw my input from the study, and to decline to answer any particular questions (if I choose to withdraw, I cannot withdraw data from the analysis after the data collection has been completed).

☐Yes ☐No

I agree to provide information to the researcher on the understanding that my name will not be used without my permission. The information will be used only for this study and publications arising from this project.

☐Yes ☐No

I agree to participate in this study under the conditions set out in the Information Sheet.

☐Yes ☐No

Signature: _____ Date: _____

Full Name: _____

Phone Number:_____

School:_____

Appendix 3.9. - Data Collection Sheet – 24 – hour multiple pass recall



Assessment of Dietary Intake of School-Aged Children (5-13) in Sri Lanka

DIETARY ASSESSMENT: 24 HOUR MULTIPLE PASS RECALL

Sample Person ID _____ Interviewer ID: ……..

Recall Number: 1 or 2

Day of Recall Day: Mon / Tue / Wed / Thu / Fri / Sat / Sun

Date of interview: …….. Time Started: ……. (am/pm)
Time Completed: ……. (am/pm) Date of intake: ……

1. Was the amount of food that you had yesterday about what you usually have, less than usual or more than usual?

Usual amount.....	
Less than usual.....	
More than usual.....	
Don't know.....	
Refused to answer.....	
Not asked.....	

2. What is the main reason the amount you ate yesterday was <u>less than usual</u>?

1	Sickness	
2	Traveling	
3	At a social function, special meal/ on a special day	
4	On vacation	
5	Too busy	
6	Not Hungry	
7	Other reason: …….	

3. What is the main reason the amount you ate yesterday was more than usual?

1	Travelling	
2	At a social function, special meal/ on a special day	
3	On vacation or day off	
4	Very hungry	
5	Other reason: …….	

4. Was the amount of drink that you had yesterday about what you usually have, less than usual or more than usual?

Usual amount.....	
Less than usual.....	
More than usual.....	
Don't know.....	
Refused to answer.....	
Not asked.....	

5. Did you or the respondent have difficulty with this interview?

Yes.....		(Go to Question 6)
No.....		(Go to Question 7)
Not asked.....		

6. What was the reason for this difficulty?

Did not understand the questions.....	
Poor memory of food.....	
Did not prepare food.....	
Sick.....	
Visual impairment.....	
Hearing impairment.....	
Language barrier.....	
Other (specify).....	
Not applicable.....	
Item not completed.....	

7. Overall, how well do you think the record reflects what the respondent ate and drank over this 24 hour period?

Good.....	
Moderate.....	
Poor.....	
Item not completed.....	

8. Please add any additional comments below:

Quick List	Time (24 hour)	Description of food or drink (as much detail as possible)	Homemade / retail (H.R.NA) If H: Prompt for recipes	Cooking method Oven – O Fried – F Grilled – G Boiled – B Steamed – S Not Applic. - NA	Brand	Amount served Preface with W: Weight P: Photo H: Household	Leftover Preface with W: Weight P: Photo H: Household	To be completed by nutritionist	
								Food Group	Weight

RECIPE 1:
Name of home-made dish:_____

Ingredients	Amount
Cooking method	

Occasion: 1) Breakfast 2) Brunch 3) Lunch 4) Evening tea 5) Dinner 5) Late night meal

Remind them about anything else eaten yesterday that hasn't already been mentioned.

Thank you for being so cooperative!

Time ended: ……..

Interviewer Observation

A. Did you or the respondent have difficulty with this intake interview? No Yes

B. What was the reason for this difficulty?

3.10. Appendix - Data Collection Sheet – Physical Activity (Grade 1-3)

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COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

SABARAGAMUWA UNIVERSITY OF SRI LANKA

Physical activity survey Grade 1 – 3

Thanks for agreeing to help the evaluation team by completing this survey. You may skip any parts that you do not want to answer, but we hope you will answer all of the items. There are no right or wrong answers; this is all about your views. The survey is private – no one will know your answers.

This survey is about being physically active at school and at home. The survey asks questions about PE classes (Physical Education or Phys-Ed), lunch and break times, and activities before and after school. PE is the learning you do when you are practicing skills, learning how to move your body or work as a team. Our questions will ask you about your sport, games, dance or activities that you do that make you sweat, make your legs feel tired or make you breathe hard.

If you are happy to take part in this survey, please circle the smiley face. If you do not want to take part, please circle the Red Cross.



1. School Name ……
……
……

2. Grade ……..

3. I am a
Boy ☐
Girl ☐

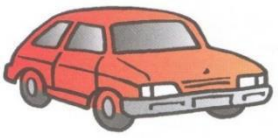
4. Age
5 years old ☐
6 years old ☐
7 years old ☐
8 years old ☐
9 years old ☐
10 years old ☐
11 years old ☐
12 years old ☐
13 years old ☐

5. Which ethnic group or groups do you identify with or belong to? *(you can pick more than one group)*

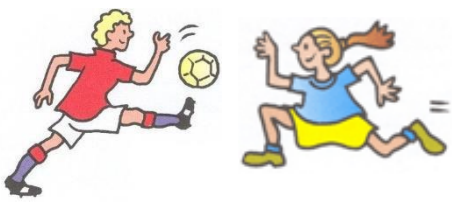
Sinhalese ☐
Sri Lankan Tamil ☐

Sri Lankan Moors	☐
Indian Tamils	☐
Sri Lankan Malays	☐
Burghers	☐
Indian Moors	☐
Others (please specify)	…….

6. How did you get to school last week? *(Select all of the ways you used to get to school)*

			
walk	By bike	By bus, van or train	By car or motorbike

7. In the **last week,** what physical activities have you done **before** school?

			
Sit around	Stand around	Walk around	Active things like games, dance, sports

8. In the **last week,** which activities have you done **during your morning tea or lunchtime?**

			
Sit around	Stand around	Walk around	Active things like games, dance, sports

9. In the last week, which activities did you do **after school?**

Playing ball ☐

Walking with friends ☐

Fun run ☐

Riding a bike ☐

Climbing trees ☐

Playing at the park (or on the playground) ☐

Playing at the beach ☐

Swimming ☐

Other (please tell us) .....

None of these ☐

10. Did you do each of these activities **last weekend?**

Activities	Yes	No
Active things with friends or by myself (like playing ball, swimming, climbing trees)	☐	☐
Active things with my family (like biking, walking or playing ball)	☐	☐
Watched TV, movies, or DVDs	☐	☐
Played on the computer or cell phone (like on a tablet, PlayStation, Xbox)	☐	☐

11. Questions about your experiences with PE

	Heaps	Quite a lot	A bit	Not at all
I like doing PE at school	☐	☐	☐	☐
I feel I am making progress in PE	☐	☐	☐	☐
I am good at PE	☐	☐	☐	☐
I feel I learn lots during PE	☐	☐	☐	☐
I feel included and don't get left out in PE	☐	☐	☐	☐
Most of my PE involves playing sports (eg. Foodball, basketball)	☐	☐	☐	☐
I feel included and don't get left out in physical activities	☐	☐	☐	☐

Some children agree with these statements and others do not. If you strongly agree with a statement, choose the 'two thumbs up' picture. If you agree a little, choose the 'one thumb up' picture. If you strongly disagree with a statement, choose the 'two thumbs down' picture. If you disagree a little bit with a statement, choose the 'one thumb down' picture. You might find you don't agree or disagree with a statement; if that happens, choose the middle option

12. At school, we get to make up our own active games, rules, or movement patterns.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

13. My teachers give me good feedback about how I could get better at PE or sports.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

14. I learn how to solve problems that happen when we are playing active games or moving.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

15. At school, I learn games, dance, or movement from different cultures

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

16. I understand that families and cultures have lots of different ways of being active.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

17. I learn that people in a team have different skills that we can use.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

18. At school people encourage me to be active.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

19. Please write the three most important things you have learnt in

_____

_____

_____

_____

_____

20. At school there are lots of different sports and active things I can try out.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

21. At lunchtime we are encouraged to play in lots of different ways (like making up games, climbing, running).

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

22. There are lots of things we can play with to make up games at lunchtime.

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

23. At school there's lots of active events we can do (like sports meet, tournaments, cultural events including dance).

Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree
				

Data collection sheet – Physical activity motivation
Data Collection Sheet – Food Availability
Data collection sheet – Food policy and practice
Characteristics of Schools in Rathnapura District
Characteristics of the study population

3.11. Appendix - Data Collection Sheet – Physical Activity (Grade 4-8)

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Physical activity survey Grade 4 – 8

Thanks for agreeing to help the evaluation team by completing this survey. You may skip any parts that you do not want to answer, but we hope you will answer all of the items. There are no right or wrong answers, this is all about your views. The survey is private – no one will know your answers.

This survey is about being physically active at school and at home. The survey asks questions about PE classes (Physical Education or Phys-Ed), lunch and break times, and activities before and after school. PE is the learning you do when you are practicing skills, learning how to move your body or work as a team. Our questions will ask you about your sport, games, dance or activities that you do that make you sweat, make your legs feel tired or make you breathe hard.

If you are happy to take part in this survey, please circle the smiley face. If you do not want to take part, please circle the red cross.



1. School Name ……
……
……

2. Grade ……..

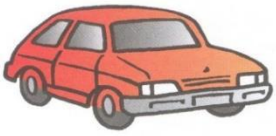
3. I am a
Boy ☐
Girl ☐

4. Age
5 years old ☐
6 years old ☐
7 years old ☐
8 years old ☐
9 years old ☐
10 years old ☐
11 years old ☐
12 years old ☐
13 years old ☐

7. Which ethnic group or groups do you identify with or belong to? *(you can pick more than one group)*

Sinhalese	☐
Sri Lankan Tamil	☐
Sri Lankan Moors	☐
Indian Tamils	☐
Sri Lankan Malays	☐
Burghers	☐
Indian Moors	☐
Others (please specify)	……

8. How do you <u>usually</u> get to school? (Circle all of the ways you use to get to school)

			
walk	By bike	By bus, van or train	By car or motorbike

9. How long does it take you to get to school?

Less than 15 minutes ☐

15 - 30 minutes ☐

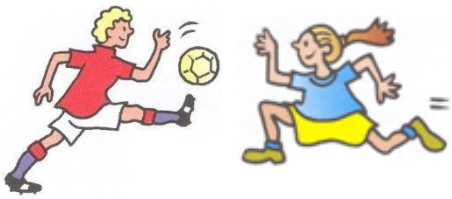
30 - 45 minutes ☐

45 - 60 minutes ☐

More than 60 minutes ☐

I don't know ☐

10. In the last week, which of these physical activities have you done before school? (Circle all of the activities you have done)

			
Sit around	Stand around	Walk around	Active things like games, dance, sports

11. In the last week, which activities have you done **during your morning tea or lunchtime?** (Circle all of the activities you have done)

			
Sit around	Stand around	Walk around	Active things like games, dance, sports

12. In the last week, what types of physical activity did you do at school during PE or sports time? (Tick all of the activities you have done)

Playing on the playground ☐

Riding a bike ☐

Walking/jogging/running ☐

Aerobics/dancing ☐

Swimming ☐

Throwing a ball ☐

Kick a ball ☐

Skipping ☐

Other(please specify) ……

None of these ☐

13. In the last week, which of these activities have you done after school? (Tick all of the activities you have done)

playing on the playground ☐
Riding a bike ☐
Walking/jogging/running ☐
Aerobics/dancing ☐
Cricket ☐
Volleyball/Basketball/Netball ☐
Badminton/tennis/TT ☐
Soccer/football ☐
Hockey/ Rugby ☐
Swimming ☐
Elle/traditional games ☐
Martial Arts (Karate/Taekwondo/Wushu) ☐
None of these ☐
Other: …….

14. Which activities did you do last weekend? (Select all of the activities you have done)

Playing at the beach/park ☐
Swimming ☐
Climbing trees ☐
Riding a bike ☐
Fun run ☐
Walking ☐
Rugby/ Hockey ☐
Badminton/tennis/TT ☐

Soccer/football ☐

Netball/Basketball/Volleyball ☐

Elle/traditional games ☐

Martial Arts (Karate/Taekwondo/Wushu) ☐

None of these ☐

other .....

Fill the next question only if you are 11 years or older

Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. Physical activity can be done in sports, school activities, playing with friends or walking to school. Some examples of physical activity are running, walking quickly, playing tag, cycling, dancing, swimming, football and going to the gym. For the next question, add up all the time you spend on physical activity each day.

15. Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?

0 days ☐

1 day ☐

2 days ☐

3 days ☐

4 days ☐

5 days ☐

6 days ☐

7 days ☐

16. Questions about your experiences with PE

	Heaps	Quite a lot	A bit	Not at all
I like doing PE at school	☐	☐	☐	☐
I feel I am making progress in PE	☐	☐	☐	☐
I am good at PE	☐	☐	☐	☐
I feel I learn lots during PE	☐	☐	☐	☐
I feel included and don't get left out in PE	☐	☐	☐	☐
Most of my PE involves playing sports (eg. Football, basketball)	☐	☐	☐	☐
I feel included and don’t get left out in physical activities	☐	☐	☐	☐

Some children agree with these statements and others do not. If you strongly agree with a statement, choose the ‘two thumbs up’ picture. If you agree a little, choose the ‘one thumb up’ picture. If you strongly disagree with a statement, choose the ‘two thumbs down’ picture. If you disagree a little bit with a statement, choose the ‘one thumb down’ picture. You might find you don’t agree or disagree with a statement, if that happens choose the middle option.

Physical Activity Practices

17. At school we get to make up our own active games, rules or movement patterns.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

18. My teachers give me good feedback about how I could get better at PE or sports.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

19. I learn how to solve problems that happen when we are playing active games or moving.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

20. At school I learn games, dance or movement from different cultures

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

21. I understand that families and cultures have lots of different ways of being active.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
👎👎	👎	▬	👍	👍👍

22. I learn that people in a team have different skills that we can use.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
👎👎	👎	▬	👍	👍👍

23. At school people encourage me to be active.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
👎👎	👎	▬	👍	👍👍

24. Please write the three most important things you have learnt in PE this year.

_____

_____

_____

_____

<u>Opportunities to be Active</u>

25. At school there are lots of different sports and active things I can try out.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
👎👎	👎	▬	👍	👍👍

26. At lunchtime we are encouraged to play in lots of different ways (like making up games, climbing, running).

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

27. There are lots of things we can play with to make up games at lunchtime.

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

28. At school there's lots of active events we can do (like sports meets, tournaments, cultural events).

Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
				

3.12. Appendix - Data Collection Sheet – Food Availability



Food availability – Food Suppliers

Healthy Food Environment in Schools

This survey aims to examine Sri Lankan students' access to healthy food in school settings.

The topics covered in this survey include your school's food environment - especially food availability around the school.

This questionnaire should be completed by a member of the food provider relevant to the food arrangement in a school.

This survey should take approximately 10 minutes to complete.

Your answers in this survey will be anonymous. It is important you answer questions as accurately as you can. Any data published from this survey will not identify you or your school by name.

Thank you for taking part in this survey.

1. Name of school:

_____

2. What is your job title?

Canteen operator ☐

Outside food provider ☐

Food Stall owner ☐

Other (specify): ……

3. What type of items do you sell as the main meal?

Rice and Curry ☐

Wheat flour-based food items (string hoppers, noodles, pittu, lavariya) ☐

Rice flour-based food items (String hoppers, roti, noodles, idly, those and other traditional food items) ☐

Boiled chickpea, green grams, cowpea ☐

Boiled yams (sweet potatoes, manioc, innala) ☐

White bread ☐

Wheat flour-based bakery items ☐

Buns with processed meat items (sausages bun, burger etc.) ☐

Pastries and puffs ☐

Other (Please specify): …….

4. Do you follow the model recipes of the menu set by the Ministry of Education?

Yes ☐

No ☐

5. How many breakfast menu variations do you usually make available to children in school? (Provided with the Ministry of Education)

1-2 ☐

2-4 ☐

4-6 ☐

6-8 ☐

More than 9 ☐

6. Do you sell deep-fried foods?

Yes ☐

No ☐

6.1 What kind of deep-fried food do you sell? Select all that apply

rolls, patties, cutlets, samosa ☐

fried potatoes, manioc ☐

murrukku ☐

Processed short eats mixed with salt -bytes ☐

popcorn ☐

Other (Please specify): …….

6.2 Which type of oil do you use for deep frying?

Coconut oil ☐

Vegetable oil ☐

Palm oil ☐

Sunflower oil ☐

Other (please specify): ……

7. What type of drinks do you sell? (Select all that apply)

Mineral water bottles ☐

Coffee ☐

Black coffee ☐

Ice coffee ☐

Instant coffee mix ☐

Malted drinks (Milo, Nestamolt) ☐

Plain tea ☐

Plain tea with sugar ☐

Ice tea ☐

Natural fruit juices (orange, wood apple, papaw etc.) ☐

Fruit nectar, RTS ☐

Leaf cunjee (Gotu kola, hathawariya, welpenala etc.) ☐

Herbal drink (iramusu, belimal, ranawara etc) ☐

Carbonated drinks ☐

Energy drinks ☐

Alcoholic drinks ☐

Other (please specify): ……..

8. Do you sell dairy products?

Yes ☐

No ☐

8.1 Please select the dairy products available

Condensed Milk ☐
Fresh milk ☐
Flavoured milk ☐
Pasteurised milk ☐
Milk tea ☐
Set Yogurt ☐
Probiotic yogurt ☐
Drinking yogurt ☐
Jelly yoghurt ☐
Fruit yogurt ☐
Curd ☐
Chees ☐
butter ☐
Other (please specify):

9. Do you sell confectionery (e.g. sweets or lollies)?

Yes ☐
No ☐

9.1 Please select the available confectionary items

Chocolate and compound chocolate ☐
Dough -nuts, Eclairs ☐
Biscuits (cream, chocolate, etc) ☐
Cake (chocolate, icing, cupcake) ☐
Sweets, chewing gum, toffees, Lollipops, jelly, boondi, kisses, jujubes, Bombay mottai, bulto ☐
packets of ice, ice palam ☐
Other (please specify): ……

10. Do you sell packaged snack foods?

Yes ☐
No ☐

10.1 Please select the available snacks items

Salted groundnuts, gram, cashew nuts ☐
Pickles in packed form ☐
Soup cubes and instant soup mixtures ☐
Processed instant noodles ☐
Packed pieces of fresh fruits ☐
Dried fruits, e.g. dates and grapes ☐
Other (please specify): ……

11. When selecting vegetables to prepare the meal which kind of factors do you consider?

Freshness of vegetable ☐
Colour of the vegetable ☐
Cost associated with the vegetable ☐
Appearance of the vegetable ☐
Taste of the vegetable ☐
Shelf-life of the product ☐
Other (specify): …….

12. When you selecting the food items to the canteen, do you consider traffic light system introduced for the food items?

Yes ☐
No ☐

13. Are you aware of the healthy guidelines issued by the Ministry of Health and Ministry of Education with regards to school children's diet?

Yes ☐

No ☐

14. Other things to note about the school menu

_____

_____

_____

_____

_____

3.13. Appendix - Data Collection Sheet – Food policy and practice

Food Policies and Practices – School Administrators

Healthy Food Environment in Schools

This survey aims to examine Sri Lankan students' access to healthy food in school settings.

The topics covered in this survey include your school's food environment - especially policy and practices to do with food and drinks.

This questionnaire should be completed by a member of the food committee or person relevant to the food arrangement in a school.

This survey should take approximately 10 minutes to complete.

Your answers in this survey will be anonymous. It is important you answer questions as accurately as you can. Any data published from this survey will not identify you or your school by name.

Thank you for taking part in this survey.

1. Name of school:

   _____

2. Where your school is located (Educational zone):

   _____

3. Number of students currently enrolled:

   _____

4. Type of school

National Schools (type 1AB and/or type C) ☐

Type 1AB (Science A/L only or with non-science A/L) ☐

Type 1C (Non-Science A/L/ schools only) ☐

Type 2 (year 1 to 11 schools) ☐

Type 3 (year 1-8 and year 1 to 5 schools) ☐

5. What is your job title?

Principal/Deputy Principal (head of the committee) ☐

Teacher in charge of School Health Promotion ☐

A representative teacher ☐

PHI of the area ☐

A member of the School Health Club ☐

A member of the Environmental Brigade ☐

A member of the Past Pupils Association ☐

A member of the School Development Society ☐

Head Prefect or another Prefect ☐

A member of the School Consumer Society ☐

Other (please specify): ……..

6. Does your school have a canteen within the premises?

Yes ☐

No ☐

Don't Know ☐

7. **Which programme(s) is your school involved in? (Select all that apply)**

The Government programme to provide meals to the schoolchildren ☐

"Food for Education Programme" jointly implemented by the Ministry of National Policies and Economic Affairs and World Food Programme ☐

Programme to provide a glass of fresh milk/ milk packets as an additional nutritional supplement ☐

There is no nutritional feeding program conducted at the moment ☐

Other (please specify): _____

8. **Does your school have its own food program or any other arrangement by the school's Old Pupil Association (alumni)?**

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

If your school has a school canteen or follows the feeding programme, please answer the following question

9. Does your school have a school food committee? (For example, a formal policy set by the circular 35/2015 or 10/2017)

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

10. Does your school food committee meet every month stipulated as policy?

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

11. **Are you aware that the food committee is required to provide a monthly report about the school food environment to the Zonal Education?**

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

12. Are you aware that the Zonal Education Director sends the follow-up report back to the food committee of that particular school?

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

13. Is there a mechanism to address the feedback received from the Zonal Director of Education?

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

14. If the functions of the school food committee are not to a satisfactory level what are some suggestions to overcome any issues?

……

……

……

15. If your school has a canteen and/feeding program, but does not have a school food committee

Would you like to have a food committee in your school?

Yes ☐

No ☐

16. **Who do you think is likely to promote the healthy food and drink behaviour in school? (*Select all that apply)***

School development committee/ Board of Trustees ☐

School food committee ☐

Students ☐

Teachers ☐

School administration ☐

School canteen owners ☐

Outside food providers ☐

Initiation should come from the Ministry of Education ☐

Initiation should come from the Ministry of Health ☐

17. **How is information about the school healthy food and drink behavior communicated with staff, students and others?** ***(Select all that apply)***

School newsletter ☐

Staff meetings ☐

Student Assemblies ☐

Information seminars/Workshops ☐

Email to staff, students and others/ direct communication via letters and phone ☐

School website ☐

Other (please specify): ……

18. Is there a mechanism to provide drinking water for all students within school?

Yes ☐

No ☐

No but would like to ☐

Don't know ☐

19. **Are you aware the Ministry of Health and the Ministry of Education provide guidance about developing a healthy food and drink policy in Sri Lankan schools? (*select all that apply)***

Yes, on the Ministry of Health website or material provided by them ☐

Yes, on the Ministry of Education website or material provided by them ☐

Yes, from the school library ☐

Yes, from another source (please specify): ……

No, I am not aware of any guidelines ☐

20. Have you accessed any resources available for developing a healthy food and drink policy in Sri Lankan schools?

Yes, from materials provided by the Ministry of Health (including Medical Officer of Health, Public Health Inspector) ☐

Yes, from the materials provided by the Ministry of Education ☐

Yes, from the school library ☐

Yes, from another sources (please specify): …….

No, I couldn't find any ☐

21. How strongly do you agree with the following statement?

There are sufficient numbers of water filters/other drinking facilities at your school for students

Strongly disagree ☐

Disagree ☐

Neither agree nor disagree ☐

Agree ☐

Strongly agree ☐

22. Does your school enable access to food and drinks to students for activities including excursions, camps, sports days and other school functions?

Yes ☐

No ☐

No but would like to (Please explain) ☐

Don't know ☐

23. Does your school promote healthy eating during school hours?

Yes ☐

No ☐

No but would like to (Please explain) ☐

Don't know ☐

24. If yes, which kind of activities promote healthy eating and drinking behaviours during school hours?

1.……

2. ……..

3. ……..

25. **Do any food and beverage companies support your school sport meetings or other special function initiatives? (For example: Nestle Fonterra Elephant house sponsors)**

Yes (Please list some companies involved with the event) ☐

……

……

……

No ☐

Don't Know ☐

26. Are any of the following barriers faced by your school when implementing a healthy

food and drink environment? ***(Select up to three)***

Resistance from teachers ☐

Insufficient cooperation from parents ☐

Loss of profits from sale of less healthy foods and beverages ☐

Convenience and ease of preparation of processed and ready-to-eat foods and beverages compared to healthier options ☐

Lack of choice in options provided by school canteen/ feeding programmes ☐

Healthy eating is not a priority ☐

Lack of preparation and storage facilities ☐

Other (please specify): ……..

No barriers ☐

27. Are there any other comments you would like to make about your school's food policies or practices?

_____

_____

_____

_____

End of the survey - thank you!

_____

3.14. Appendix - Characteristics of Schools in Rathnapura District

Characteristics of the schools in *Rathnapura* District

The Sabaragamuwa Province is one of the nine provinces of Sri Lanka, the first-level administrative division of the country, and it contains two districts: Ratnapura and Kegalle. Rathnapura District has 598 schools with 223,143 student population.

Table 1: Characteristics of the schools in *Rathnapura* District

Class Range	Count of Schools	Percentage of Schools	Sum of Total Students	Percentage of Total Students	Average of Total Students
1-13SC*	10	1.67%	23321	10.45%	2332
6-13SC	43	7.19%	53746	24.09%	1250
1-13A/C**	72	12.04%	48539	21.75%	674
6-13A/C**	21	3.51%	6296	2.82%	300
1-11	228	38.13%	53474	23.96%	235
1-5	187	31.27%	34329	15.38%	184
1-7	4	0.67%	403	0.18%	101
1-9	28	4.68%	2674	1.20%	95
1-8	5	0.84%	361	0.16%	72
Grand Total	598	100.00%	223143	100.00%	373.15

*SC class range – schools having an advanced level in Arts, Commerce and Science streams

**A/C class range – schools having an advanced level in Arts and Commerce streams, but no Science stream

3.15. Appendix - Characteristics of the study population

Characteristics of the study population

All schools in the *Ratnapura* district, having classes ranging from grade 1 to 8 and an average total of students of more than 500 in a school were selected. 82 schools were considered as a study population representing 13.71% of the total population and 71860 students were the study population and it is representing 32.2% of the total student population in Rathnapura District, Sri Lanka.

Table 2: Characteristics of the study population

	Number of School	Percentage of the school	Number of students	Percentage of students
1-13SC	10	12.2	23321	32.45
1-13A/C	72	87.8	48539	67.55
Total	82	100	71860	100.0

Appendix – 4
Study documents
New Zealand Study

4.1. Appendix - Ethics approval Letter from Massey University, New Zealand

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

7/12/2023

Dear: Harshani Perera

Re: Ethics Application - OM1 23/46 - Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring Application

Thank you for the above application that was considered by the Massey University Human Ethics Committee:

Ohu Matatika 1 at their meeting held on **Tuesday, 10 October 2023**

On behalf of the Committee I am pleased to advise you that the ethics of your application are approved.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely



Professor Tracy Riley,
Acting Chair, Research Ethics Chair's Committee

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand T 06 951 6841; 06 95106840
E humanethics@massey.ac.nz; animalethics@massey.ac.nz; gtc@massey.ac.nz

4.2. Appendix - Permission Request Letter



Investigator
School of Sports, Exercise and Nutrition,
College of Health
Massey University
New Zealand

25.09.2023

Principal
……. School
Auckland

Dear Sir/Madam,

Re: Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring

Requesting permission to collect data on the dietary intake of school children

We are a team of evaluators from Massey University with expertise in nutrition and physical activity. We are conducting a study with reference to the feasibility, validity and reliability of a modified method to measure the dietary intake of school children. We are writing in the hope that your school whanau may be interested in participating.

The study involves the trial of a revised interviewer-supported 24-hour dietary recall method, validated against (parental) weighed food records and a light device to measure fruit and vegetable intake. Additionally, the height and weight of the children will be recorded. Most of the research will be conducted at home, with only a morning 24-hour dietary recall interview conducted in an appropriate meeting room at the school or another venue that accommodates the parent-child schedule. The interviewers are PhD and Master's student dietitians who are well-experienced in conducting dietary assessments in children and are trained to create a comfortable and supportive environment to encourage accurate reporting.

At the end of the study, findings and possible recommendations will be shared with the participating schools (hui and written), published in journals, and sent to the Ministries of Health and Education to contribute to the information database for possible policy or methods for future research to enhance healthy, active learning in school-aged children.

Therefore, we would be most grateful if we could meet with you to provide further information and discuss the study.

Thank you.

Yours sincerely,

4.3. Appendix - Research Advertisement

Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ) Study

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Invitation to Parents and Children

WHAT IS THIS STUDY ABOUT?

Diet contributes to children's growth and development, educational performance and attainment, health and well-being. We are testing the feasibility and validity of a modified 24-hour dietary recall tool to understand the current food group and nutrient intake in New Zealand schoolchildren better.



WHO CAN JOIN?

Schoolchildren aged 9-13 years old and their parents/caregivers.

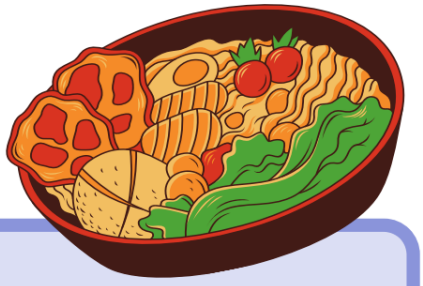


Scan me to sign up!

https://forms.gle/1rqrPbq3WykFJfiq8

WHAT WILL YOU HAVE TO DO?

Parents: Weigh or itemize food consumed by your child on 2 separate days (10-20 min)
Children: Recall their diet in the past 24 hours (10-20 min), place finger on the spectroscopy based device to measure carotenoids (e.g. Vitamin A) in the body, and have body weight and height measured (15 min).



INTERESTED?

Scan the QR code above or reach out to us through email or phone number and we will get in touch with you soon!

contact us by email: shalika.harshani@gmail.com or

Tel: [redacted]

This project has been reviewed and approved by the Massey University Human Ethics Ohu Matatika 1, Application OMI 23/46. If you have any concerns about the conduct of this research, please contact the Chairperson, Massey University Human Ethics Ohu Matatika 1, email humanethics1@massey.ac.nz.

4.4. Appendix – Information Sheet

Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring

PARTICIPANT INFORMATION SHEET

Researcher Introduction

We are researchers from Massey University with expertise in nutrition and physical activity.

Background and Invitation to Participate in a Research Study

A healthy, balanced diet contributes to children's growth and development, educational performance and attainment, and long-term health and well-being. However, obesity rates continue to increase and remain a problem in New Zealand. The last national nutrition survey in New Zealand school-aged children was done in 2002, meaning new, up-to-date data is required to provide objective evidence to inform dietary changes and nutrition policy. This study tests modifications and refinements to an existing tool for assessing what a child has eaten over the past 24 hours to identify the foods consumed accurately. Having the correct information about what was eaten means researchers can determine what nutrients an individual has consumed. The tool (interviewer-led 24-hour multiple pass recall) is used by a trained interviewer who will sit down with a child and prompt them to remember what they ate in the last 24 hours in as much detail as possible. To learn more about vegetables and fruits consumed, we will measure the colour of the fat pad of the fingertip. Vegetables and fruit contain colours, and some of these, called carotenoids, the body uses to make vitamin A. The colour of the fingertip is related to carotenoid levels and is measured by gently pushing the fingertip onto a light. We'll use this data to evaluate the accuracy of the modified 24-hour recall for measuring fruit and vegetable intake.

The results from this study will be used to decide whether the improved 24-hour dietary recall tool for collecting information about what has been eaten by NZ schoolchildren does a good job of correctly estimating what was eaten. If the tool is found to be successful, it will be used in future studies designed to improve children's food and nutrition choices.

We would like to invite you as a parent or caregiver and your child to take part in this assessment.

Participant recruitment

We are collecting dietary data from schoolchildren aged 9 to 13 from selected schools sampled across the Auckland region. Dietary recall can be challenging for some students, and research

shows parental assistance enhances reliability. Therefore, as their parents/guardians, we ask you to help your child complete the dietary interviews.

Project Procedures and Participant Involvement

- Parents and students will receive a letter of invitation to participate, followed by either an in-person or phone/video meeting. The data collection will proceed with a familiarisation interview and instructions session, followed on subsequent days by face-to-face data collection interviews. There will also be follow-up phone calls for support and scheduling. One face-to-face data collection will be conducted twice, with different interviewers. The date, time and venue will be arranged to suit parents and students.
- Clear instructions will be provided to the parent. The diet assessment day will be randomly allocated as suitable for the parent-child pair.
- The meeting location will also suit the preferences of the parents and students.

During the interview

Three trained post-graduate researchers will undertake the 24-hour multiple-pass recall for food intake. Each interview session will take approximately 20 to 30 minutes.

- In the first pass, the researcher will record a quick list of all food and drink consumed that the parent can remember.
- In the e second pass, the researcher will go through each food item on the quick list to compile details such as the time, place, description of the food, brand, and amount. Also, if you are happy to photograph food items, it could help remind your child what they eat over 24 hours. Measurement aids (such as a photographic Food Atlas, household measuring cups and spoons) will be used to determine portions.
- In The third pass, the researcher will seek any missing details from the parents and recipes will be recorded where relevant.

Skin Carotene Content Measuring – Veggie Meter

- We will ask you to provide information including your child's age, gender, ethnicity and a few questions about specific foods your child eats or does not eat. We will measure your child's body weight and height using a stadiometer and digital scales, respectively.
- Three measures of your child's skin colour will be recorded, and we will tell you if the score is low, medium or high. Each measure takes 10 seconds, and the finger is removed for 5 seconds before placing it over the light again.
- In the following photos, you can see the set-up of the Veggie meter and how we will take the reading of your child. It runs on batteries and doesn't require plugging directly into a wall socket.

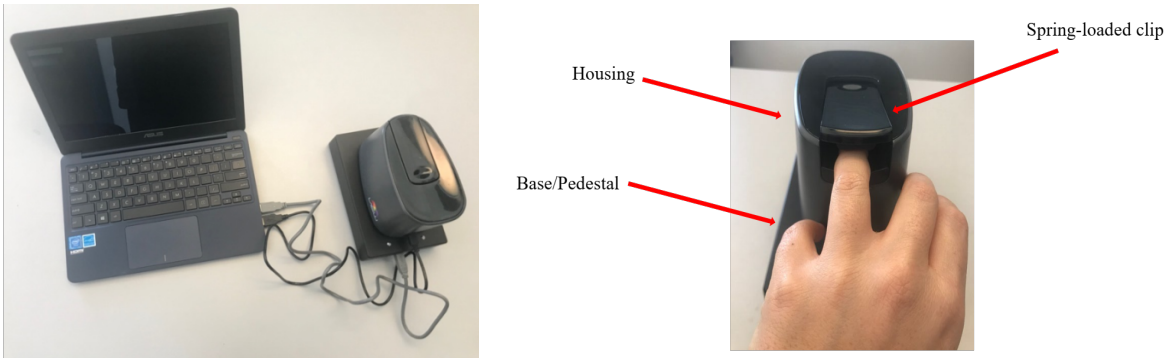


Figure 1: Veggie Meter

- There are no known risks of using a veggie meter, and some children might feel the discomfort of the slight pressure when the finger is placed over the light as the cover is spring loaded- like a peg.
- It will take 15 minutes to complete all the measurements.

Weighed Food Record

- We will ask you to weigh all your child's food for 24 hours. We will provide written n and video instruction and give in-person tuition for how you can do it.
- All food weighing scales, measuring tools, and a hard copy of the recording booklet will be provided.
- You will be asked to record each food item your child consumes, including the description of the food, its brand, the weight served and any leftovers. You will be asked to provide recipe details for composite foods such as a fruit pie or meat casserole.
- It will be much appreciated if you can take photographs of meals using cell phones, cameras, or tablets.
- School-day food consumption will be evaluated from item identification, weighing, and a photograph of the lunch box content before and after school.
- It will take about 30 minutes to complete a one-day weighed food record.

Benefits

Results from this research will add to an evidence base for dietary intake of New Zealand schoolchildren. You will receive a copy of your child's veggie meter result immediately, or you could take a photo of the computer screen with your cell phone.

Each parent-child pair will receive NZ$200 reimbursement (as a gift voucher) at the end of the data collection period as koha and recognition for their contribution to the study. In addition, the school will receive an NZ$200 gift voucher (koha) for their participation.

Data analysis

We would like to assess dietary intake during two weekdays (school days) and one weekend. In addition, we take each student's Veggie meter reading, weight and height. We will use a unique identifier to connect the responses for each student. However, consistent with the confidentiality and non-identity of a participant, we will not provide personal data to your child's school, the Ministry of Education or any other external party who will receive the dataset or results. All data will be deidentified, and a unique study code will connect the participant.

Participant's Rights

You or your child are under no obligation to accept this invitation. Your child's participation or non-participation will not influence their standing in the school. If you give consent for your child to participate, they have the right to:

- Decline to answer any particular question.
- Withdraw from the evaluation at any time, even after you have signed a consent form (if you or your child choose to withdraw, you cannot withdraw his/her data from the analysis after the data collection has been completed.).
- Ask any questions about the evaluation at any time during the participation.
- Provide information on the understanding that your child's name will not be used in any publications.
- Be given access to a summary of the project findings when it is concluded.

Good Practice and Cultural Safety for Massey University Research

- We acknowledge the concept of respecting the participant`s inherent dignity and acting in a caring manner towards them by way of:
- Taking full responsibility for performing the data collection in a safe and ethical manner
- Providing the participants with all of the critical information regarding the study in a clear way so that they can make informed decisions
- An awareness of the cultural significance and sensitivity to culturally safe implementation of the project
- Respect for the privacy and confidentiality of participants
- Researchers have passed Police vetting.

Confidentiality

All data collected will be used solely for research purposes. Findings will be presented at conferences and submitted for publication in journals. A summary infographic will be provided to the participating schools and available to participants upon request. All personal information will be kept confidential by assigning numbers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with confidentiality and will be stored in a secure location for ten years at the School of Sport, Exercise and Nutrition, College of Health, Massey University, Albany Campus. After this time, an appropriate staff member from the School of Sport, Exercise and Nutrition will dispose of it.

Project Contacts

If you have any questions regarding this evaluation, please do not hesitate to contact either of the following for assistance:

Name	Title	email Address	Contact Number
T.S.Harshani Perera School of Sport, Exercise and Nutrition, Massey University	Investigator (PhD Candidate)	harshani.perera.1@uni.massey.ac.nz	(02)[redacted]
Varshika Patel	Research assistant	V.V.Patel@massey.ac.nz	(02)[redacted]
Sarah McArley	Research assistant	S.M.McArley@massey.ac.nz	(02)[redacted]
Prof David Rowlands School of Sport, Exercise and Nutrition, College of Heath, Massey University	Supervisor Professor of Nutrition, Metabolism and Exercise	D.S.Rowlands@massey.ac.nz	(09)9793295
Prof Aj Ali School of Sport, Exercise and Nutrition, College of Heath, Massey University	Co-Supervisor Professor of Sport and Exercise	A.Ali@massey.ac.nz	(09)2136414
Prof Carol Wham School of Sport, Exercise and Nutrition, College of Heath, Massey University	Co-Supervisor Professor of Public Health Nutrition	C.A.Wham@massey.ac.nz	(09)2136644

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Ohu Matatika 1, Application OM1 23/46. If you have any concerns about the conduct of this research, please contact the Chairperson, Massey University Human Ethics Ohu Matatika 1, email humanethics1@massey.ac.nz

Thank you for taking part in this research.

4.5. Appendix – Consent Form



Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring
CONSENT FORM

This consent form will be held for a minimum of Ten (10) years.

I have read the Information Sheet and have had the details of the evaluation explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw my child from the evaluation and to decline to answer any particular questions (if I/they choose to withdraw I/we cannot withdraw his/her data from the analysis after the data collection has been completed).

I agree for my child to provide information to the researcher on the understanding that his/her name will not be used without my permission (the information will be used only for this project and publications arising from this study).

I agree for my child to participate in the 24 hours dietary recall under the conditions set out in the 24-h dietary recall Information Sheet.

I agree to give my child's dietary information during the 24 hours dietary recall interview under the conditions set out in the 24-h dietary recall Information Sheet.

I agree to allow researchers to measure the carotene level of my child's finger under the conditions set out in the Veggie meter Information Sheet.

I agree to keep weighed records of my child's meals within 24 hours on behalf of my child under the conditions set out in the weighed record Sheet.

I agree to take photographs of my child's meal under the conditions set out in the 24-h dietary recall Information Sheet.

Parents Name: …… Signature: ……

Child Full Name: …….

School: …… Room number: ……

Phone Number: …… Date: ……

4.6. Appendix – Data Collection Sheet – 24 hours Multiple Pass Dietary Recall



Assessment of the Dietary Intake of New Zealand Schoolchildren Aged 9 to 13 Years in the Auckland Region, New Zealand

DIETARY ASSESSMENT: 24 HOUR MULTIPLE PASS RECALL

Sample Person ID ..... Interviewer ID: ……

Recall Number: 1 or 2

Day of Recall Day: Mon / Tue / Wed / Thu / Fri / Sat / Sun

Date of interview: …….. Time Started: ……. (am/pm)
Time Completed: ……..(am/pm)

Date of intake: …… Interview conducted at: ……..

1. **Was the amount of food that you had yesterday about what you usually have, less than usual or more than usual?**

Usual amount.....
Less than usual.....
More than usual.....
Don't know.....
Refused to answer.....
Not asked.....

2. **What is the main reason the amount you ate yesterday was <u>less than usual</u>?**

1 Sickness
2 Going a journey
3 At a party or celebration, on a special day
4 On a fun trip away or school holiday
5 Too busy
6 Not Hungry
7 Other reason: …….

3. What is the main reason the amount you ate yesterday was more than usual?

1 Going a journey
2 At a party or celebration, on a special day
3 On away from home or school holiday
4 Very hungry
5 Other reason: …….

4. Was the amount of drink that you had yesterday about what you usually have, less than usual or more than usual?

Usual amount.....
Less than usual.....
More than usual.....
Don't know.....
Refused to answer.....
Not asked.....

5. Did you or school child has difficulty with this interview?

Yes..... (Go to Question 6)
No..... (Go to Question 7)
Not asked.....

6. What was the reason for this difficulty?

Did not understand the questions.....
Poor memory of food.....
Did not know about preparation method....
Sick.....
Difficulty with eyesight or vision problems
Hearing impairment.....
Language barrier.....
Other (specify).....
Not applicable.....
Item not completed.....

7. Overall, how well do you think the record reflects what the student ate and drank over this 24 hour period?

Good.....
Moderate.....
Poor.....
Item not completed.....

8. Please add any additional comments below:

Quick List	Time (24 hour)	Description of food or drink (as much detail as possible)	Homemade / retail (H.R.NA) If H: Prompt for recipes	Cooking method Oven – O Fried – F Grilled – G Boiled – B Steamed – S Not Applic. - NA	Brand	Amount served Preface with W: Weight P: Photo H: Household	Leftover Preface with W: Weight P: Photo H: Household	To be completed by nutritionist	
								Food Group	Weight

RECIPE 1:
Name of home-made dish:_____

Ingredients	Amount
Cooking method	

Occasion: 1) Breakfast 2) Brunch 3) Lunch 4) Evening tea 5) Dinner 6) Late night meal

Remind them about anything else eaten yesterday, that hasn't already been mentioned.

Thank you for your Cooperation!

Time ended: ……..

Interviewer Observation

A. Did you or the respondent have difficulty with this intake interview? No Yes

B. What was the reason for this difficulty?

4.7. Appendix – Data Collection Sheet – Weighted Food Record



Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring

2 Day Weighed Food Record

Thank you very much for taking part in the EDANZ Study. We are extremely grateful for your time, effort and commitment!

All information in this diary will be treated with the strictest confidence. No one outside the study will have access to this.

What to do?

- Record all that your child eats and drinks on the following dates.

_____

_____

If possible, record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.

- Include all meals, snacks, and drinks, even tap water.
- Include anything you have added to your child's foods, such as sauces, gravies, spreads, dressings, etc.
- Write down any information that might indicate the volume or weight of the food to identify the portion size eaten.
- Use a new line for each food and drink. You can use more than one line for food or drink. See the examples given.
- Include any supplements (brand name, type, the number taken, etc.)
- Use as many pages of the booklet as you need.

Describing Food and Drink

- Provide as much detail as possible about the type of food that your child has eaten. For example, **brand names and varieties/types** of food.

General description	**Food record description**
Breakfast example – cereal, milk, sugar	50g Sanitarium Natural Muesli 275ml Pam's whole milk 5g Chelsea white sugar
Coffee	3g Gregg's instant coffee 200ml cup of water 10ml Meadow fresh light green milk
Pasta	100g San Remo whole grain pasta spirals (boiled)
Pie	Big Ben Classic Mince and Cheese Pie (170g)

- Give details of all the **cooking methods** used. For example, fried, grilled, baked, poached, boiled…

General description	Food record description
2 eggs	2 size 7 eggs fried in 10ml canola oil 2 size 6 eggs (soft boiled)
Fish	100g salmon (no skin) poached in 175ml of water for 10 minutes

- When using foods that are cooked (eg. pasta, rice, meat, vegetables, etc), please record the **cooked portion** of food.

General description	Food record description
Rice	175g cooked Jasmine rice (cooked on stove top)
Meat	90g lean T-bone steak (fat and bone removed)
Vegetables	200g cooked mixed vegetables (Wattie's peas, corn, carrots)

- Please specify the **actual amount of food eaten by your child** (eg. for leftovers, foods where there is waste)

General description	Food record description
Apple	1 x 120g Granny Smith Apple (peeled, core not eaten – core equated to ¼ of the apple)
Fried chicken drumstick	100g chicken drumstick (100g includes skin and bone); fried in 3 Tbsp Fern leaf semi-soft butter

- **Record recipes** of home-prepared dishes where possible and the proportion of the dish your child ate. There are blank pages for you to add recipes or additional information.

Recording the amounts of food you eat

It is important to record the quantity of each food and drink consumed.

- By weight marked on the packages – eg. a 425g tin of baked beans, a 32g cereal bar, 600ml Coke

- Weighing the food – this is an ideal way to get an accurate idea of the quantity of food eaten, in particular for foods such as meat, fruits, vegetables and cheese.

General description	Food record description
Cheese	22g

- If your child goes out for meals, describe the food eaten in as much detail as possible.

- ***Please allow your child to eat as normally as possible - don't adjust what your child would normally eat just because you are keeping a food record, and be honest! Your child's food record will be identified with a child identifier rather than a child's name.***

Example day

Time and place food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed (units, measures, weight)**
Example7:55am At home	Kellogg's Corn flakes	30 g
" "	Anchor Blue Top milk	150ml
" "	Chelsea white sugar	10g
" "	Orange juice (Citrus Tree with added calcium – nutrition label attached)	275 ml
10.00am At school	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00 pm At school	Home-made pizza (recipe attached)	100g - 1 slice, 10g tomato paste, 10g olives, 20g rashers bacon (fat removed), 5g chopped spring onion, 15g mozzarella cheese)
1.00 pm At school	Water	500ml plain tap water
3.00 pm on car	Biscuits	20g x 6 x chocolate-covered Girl Guide biscuits (standard size)
6.00pm At home	Lasagne	50g cooked mince, 100g cooked Budget lasagne-shaped pasta, 50g Wattie's creamy mushroom and herb pasta sauce, 100g mixed vegetables (Pam's carrots, peas and corn), 20g grated Edam cheese
6.30 pm At home	Banana cake with chocolate icing (homemade, recipe attached)	120g of a cake and 20g chocolate icing
" "	Tip Top Cookies and Cream ice cream	250g
7.30 pm At home	Coffee	3g Gregg's instant coffee 300ml cup of water 10ml Meadow fresh blue top milk powder 10g sugar

Date_____ DAY 1

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ DAY 1 continued

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Recipes (Day 1)

Date_____ DAY 2

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ DAY 2 continued

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Recipes (Day 2)

Date_____ (spare pages)

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ (spare pages)

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

4.8. Appendix – Data Collection Sheet – Veggie meter



Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring

Questionnaire for Veggie Meter Foods

(The researcher will fill this out when the Veggie meter reading is taken.)

Date: ……

01. Age: ……..

02. Height: …….cm

03. Weight: ……kg

04. Gender: ……..

05. Ethnicity: ……

Choose the best answer by placing a circle around it according to the child's answer.

06 Are there any **foods that you do not** eat? Yes No Don't Know

If yes, what are they?

07 Do you eat **liver** (including liver pate)? Yes No Don't Know

If yes, how often every day / most days / every week / every month / once a year

08 Do you eat **eggs**? Yes No Don't Know

If yes how often every day / most days / every week / every month / once a year

09 Do you take any **vitamin supplements**? Yes No

If yes, name the supplement

If yes how often

Vegetables and fruits

A serving is a handful. It can be fresh, frozen or canned. Do not count fries or hot chips as a vegetable.

10 How many servings of **vegetables** do you eat **in one day?**

0 1 2 3 4 5 6 7 7+ Don't Know

11 How many servings of **fruit** do you eat **in one day?**

0 1 2 3 4 5 6 7 7+ Don't Know

Which vegetables?

12 How many servings of **carrot or pumpkin** or do you eat **in one week**?
0 1 2 3 4 5 6 7 7+ Don't Know

13 How many servings of **dark green leafy vegetables (silver beet, spinach)** do you eat **in one week?**
0 1 2 3 4 5 6 7 7+ Don't Know

14 How many servings of tomatoes **(fresh, canned, concentrated)** do you eat **in one week?**
0 1 2 3 4 5 6 7 7+ Don't Know