Nutrient Intake of New Zealand Adolescents aged 14-18 years in the Auckland, Bay of Plenty and Waikato Regions of New Zealand

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Abstract

Background

Adolescence represents a crucial stage of rapid physical, cognitive, and emotional development, during which nutrient requirements substantially increase to support optimal growth and maturation. Despite this, available data on the dietary patterns and nutritional status of New Zealand (NZ) adolescents are limited and largely outdated, hindering an accurate evaluation of nutrient adequacy and potential deficiencies within this population.

Aims and Objectives

This research aims to investigate the current nutrient status of NZ adolescents and compare their intake to their nutrient reference values and assess their adherence to dietary recommendations.

Methods

Data was obtained from *Te Rourou o Ngā Rangatahi: Eating Patterns of Young People in New Zealand*, a cross-sectional survey investigating the dietary habits of adolescents. The study included 527 secondary school students aged 14–19 years from the Auckland, Bay of Plenty, and Waikato regions. Dietary intake was collected using Intake24, a web-based multiple-pass 24-hour dietary recall tool, along with an online demographic questionnaire. Nutrient intakes were compared with the Australian and New Zealand Nutrient Reference Values (NRVs) to assess dietary adequacy.

Results

Female participants (n=370, 70.2%) demonstrated greater adherence to macronutrient recommendations than males. Mean intakes of protein, carbohydrate, and fat exceeded recommended levels, while fibre intake remained below guidelines. Mean protein intake was 76.8 ± 44.3 g for females and 105.8 ± 61.6 g for males, with 97.8% of females and 98% of males meeting the recommended percentage of energy from protein. Fibre intake averaged 19.2 ± 11.2 g for females and 20.7 ± 12.5 g for males, below the recommended 22 g and 28 g, respectively, indicating low fruit and vegetable consumption. Only 9.7% of females and 7% of males met recommendations for saturated fat intake, with the majority exceeding the upper limit.

Male participants demonstrated higher mean intakes across most micronutrients; however, several nutrients were identified as concerns. Mean calcium intake was 721.9 ± 463.6 mg/day for females and 868.3 ± 691.5 mg/day for males, with 20.3% and 31.2% meeting the Estimated Average Requirement (EAR), respectively. Iron intake averaged 9.8 ± 6.1 mg/day in females and 12.3 ± 8.0 mg/day in males, with 53.8% and 66.9% meeting the EAR. Vitamin A and vitamin E intakes were below recommendations for most participants, while magnesium and vitamin C also showed low adherence to the NRVs. Overall, both macronutrient imbalances and micronutrient inadequacies were evident among New Zealand adolescents.

Conclusion

Overall, the findings highlight significant nutritional imbalances among New Zealand adolescents, characterised by excessive macronutrient intake and inadequate consumption of key micronutrients such as calcium, iron, vitamins A and E, magnesium, and vitamin C. These results underscore the need for updated national data and targeted public health strategies to improve dietary quality and address nutrient inadequacies within this population, such as education on the importance of adequate nutrition during adolescence and to foods that fuel their bodies.

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List of Abbreviations

24HR	24-hour recall
AI	Adequate Intake
AMDR	Acceptable Macronutrient Distribution Range
ANS	Adult Nutrition Survey
CNS	Children's Nutrition Survey
DRI	Dietary Reference Intakes
EAR	Estimated Average Requirement
EER	Estimated Energy Requirement
FFQ	Food frequency questionnaire
LDL	Low-density lipoprotein
LRNI	Lower Reference Nutrient Intake
NRV	Nutrient Reference Values
NZ	New Zealand
RDI	Recommended Dietary Intakes
RNI	Reference Nutrient Intake
SDT	Suggested Dietary Target
UL	Upper Level of Intake

Chapter 1 Introduction

1.1 Background

The United Nations estimates that there are 1.3 billion adolescents worldwide (approximately 16% of the world's population), defining an adolescent as an individual between 10 and 19 years of age (1). Adolescence is a period marked by rapid physical, cognitive and psychosocial growth. How this age group thinks, feels, makes decisions and how they interact with the world around them changes during adolescence (2). During adolescence, 20% of the final adult height and 50% of adult weight is gained; and bone mass increases up to 40% (3). Therefore, adolescents need to consume an adequate intake of nutrients to ensure they meet their physical growth and maturation potential, while supporting mental and social development.

The nutrient reference values (NRV) for New Zealand (NZ) were developed in 2006 (updated in 2017) in a joint venture between the Australian National Health and Medical Research Council, Australian Government Department of Health and Ageing and the Ministry of Health of NZ (4). These reference values provide recommendations for daily intakes of essential macronutrients and micronutrients to support the body's optimal health and growth. The NRVs are intended for use by healthcare professionals to facilitate the assessment of nutrient intake among individuals and groups, and to identify over or under-consumption (4). When assessing macronutrient and micronutrient intake, we use the Estimated Average Requirement (EAR) or an Adequate Intake (AI) to determine whether a population has an inadequate intake of these nutrients.

Nutrients can be broadly grouped into macronutrients and micronutrients. Macronutrients, which comprise protein, carbohydrates and fats, are essential for providing the body with the energy required to function and perform its essential activities (5). A diet lacking in macronutrients, such as protein, can lead to adverse health consequences, including reduced muscle mass and delayed skeletal development (6). Research indicates that increased consumption of protein, particularly from animal sources, is associated with earlier onset of puberty (6). Excess intake of macronutrients may contribute to excess energy intake and over time, weight gain. Micronutrients are vitamins and minerals that are also required for the body to function, as well as to produce enzymes and hormones. Deficiencies in micronutrient intakes can cause severe health conditions (7) including anaemia, which may be the result of low iron, vitamin B12 or folate intake and scurvy, the result of a low intake of vitamin C (8). Low calcium intake during adolescence, when peak bone mass is achieved, can increase the risk of osteoporosis and low bone density later in life (9).

1.2 Significance and justification of research

Research on the dietary intake of NZ adolescents is scarce, and available research is out of date. The most recent national nutrition surveys were undertaken almost 20 years ago, with 4721 adults aged 15 years and over participating in the 2008/09 Adult Nutrition Survey (ANS 08/09) and 3275 children aged 5-14 years participating in the 2002 Children's Nutrition Survey (CNS02) (10). The ANS 08/09 identified several micronutrient intakes of concern among adolescents (15-18 years), including the lowest intake of vitamin A and potassium compared to the other age groups, a low intake of calcium and selenium in female adolescents and a low iron intake in both female and male adolescents (11). The CNS02 found that protein intake exceeded requirements in all age groups and that the protein contribution to energy was higher in males than in females. The CNS02 also showed that older children, aged 11-14 years, were at a greater risk of having an inadequate selenium intake compared with younger children. Further, the iodine status of NZ children was deemed low, which indicated mild iodine deficiency (10).

A regional study completed in Dunedin in 2020, the SuNDiAL study, investigated the dietary intakes, nutritional health status, lifestyles, motivations and attitudes towards food choices of male and female high school students (15-18 years) (12). The study reported an inadequate intake of iron in females (13) and an inadequate magnesium intake in males (14) and females (15). Calcium intake was also inadequate in males and females (16) while Vitamin B12 intake was only inadequate in females (17).

Since these studies were completed, there have been significant changes in factors that influence the dietary intake of NZ adolescents. New Zealand is currently in a cost-of-living crisis. This is evident in food insecurity. In 2022/23 it was reported that food runs out often in 21.3% of households (18). In contrast, the earlier ANS 08/09 reported that 59.1% of households were entirely or almost food secure, 33.7% were moderately food secure and 7.3% were classified as having low food security (19). The cost of food has increased dramatically over the past sixteen years, with food prices rising 9.6% in the year ending July 2023 (20), making it harder for households to provide their families with healthy and nutritious food. Additionally, from 2023 to 2024, interest on mortgage payments has increased by 31%, petrol by 9% and rental costs by 5.1% (21).

Lifestyle choices of New Zealanders have changed over time, including a decline in fruit and vegetable consumption and an increased drive for convenience foods such as takeaways and ready-to-eat meals, which are readily available and are quick and easy to prepare (22). These meals are often high in ultra-processed ingredients, saturated fat, and sugar, which are known to increase blood pressure, cholesterol, obesity rates, and the risk of type 2 diabetes (23). A recent meta-analysis found that a diet high in ultra-processed foods correlates with an increase in sugars, total and saturated fats, and a decrease in fibre, protein, magnesium, and vitamins A, C, D, E, B12, and B3 (24).

When developing dietary guidelines for adolescents, they must be based on up-to-date scientific evidence. Dietary intake data is necessary to identify macro and/or micronutrients of concern and whether adolescents are consuming a diet aligned with recommendations. This will enable the development and implementation of targeted interventions with the immediate goal of improving the health of adolescents and in the long term, reducing the risk of chronic disease (25).

1.3 Study purpose

To investigate the diet of NZ adolescents by analysing a 24-hour record of their dietary intake and comparing the intake of macronutrients and micronutrients with the nutrient reference values. It is hoped that this data will contribute to the development of future public health strategies and guidelines for NZ adolescents.

1.4 Hypothesis

More than 50% of NZ adolescents aged 10 to 18 years old do not meet the nutrient reference values for macronutrients and 13 micronutrients: vitamin A, vitamin B1, vitamin B3, vitamin B6, vitamin B12, vitamin C, vitamin E, calcium, iron, magnesium, selenium and zinc.

1.5 Aims

To determine and compare the nutrient intake of NZ adolescents with the nutrient reference values for Australia and New Zealand.

1.6 Objectives

1. To determine the macronutrient intake of NZ adolescents, including total fat, saturated fat, carbohydrate and protein, using Intake 24 (a cloud-based dietary assessment program).
2. To determine the intake of 13 selected micronutrients of NZ adolescents using Intake 24.
3. To determine the nutrient intake adequacy of NZ adolescents by comparing their macronutrient and micronutrient intake to the NRVs.

1.7 Thesis structure

Chapter 1 introduces the research topic, provides an overview of the research and outlines the aims, objectives and hypotheses. Chapter 2 reviews literature on macronutrient and micronutrient intake during adolescence, including the importance of adequate intake, the potential effects of deficient or excess intake and the findings of available research on macronutrient and micronutrient intake internationally and in NZ adolescents. Chapter 3 is a manuscript formatted in journal style, which includes a summary of the research, comprising an abstract, introduction, methods, results and discussion. Chapter 4 presents a discussion and conclusion to the research.

1.8 Researchers' contributions

Table 1: *Researchers' contributions to the study*

Researchers Name	Contribution
Carenza Barnes	**MSc Nutrition and Dietetics Student** The thesis's primary author. Conducted data analysis
Professor Kathryn Beck	**MSc main academic supervisor** Principal investigator of the study. Developed study protocol. Acquired funding and ethical approval and provided oversight on the study. Provided feedback on the thesis.
Professor Cath Conlon	**Secondary Supervisor of MSc Student** Developed study protocol. Provided feedback on thesis.
Dr Jamie de Seymour	**Secondary Supervisor of MSc Student** Developed study protocol and led data collection and data analysis.

Chapter 2: Literature review

This chapter reviews the current international and New Zealand-based literature examining the dietary intakes of children and adolescents.

2.1 Literature review strategy

Areas of interest explored in the literature review included:

1. Physiological changes during adolescence and their effects
2. Macronutrients and micronutrients of concern for adolescents
3. The effects of deficiencies with reference to previous studies looking at the nutrient intake of NZ adolescents.
4. The purpose and development of the nutrient reference values for adolescents,
5. The importance of meeting these guidelines with reference to previous studies looking at the nutrient intake of NZ adolescents.
6. Dietary assessment methods specific to adolescents and their advantages and disadvantages.

The literature review search was completed between November 2024 and 2025. Databases searched included Google Scholar, Massey University Library Discover, PubMed, and ScienceDirect. Search terms were derived from the study objectives.

Date searched: November 2024 – November 2025.
Search criteria: Macronutrient* AND adolescen* OR teen OR youth OR young people OR young person
Micronutrient* AND adolescen* OR teen OR youth OR young people OR young person
Filters: Past 5 years, past 10 years, past 15 years
Electronic databases: Google Scholar, Massey University Library Discover, PubMed, and Science Direct.

Figure 1: *Search strategy for literature review*

2.2 Adolescents in New Zealand

New Zealand Census 2023 data shows that there were 336,174 adolescents aged 10-14 years and 320,637 adolescents aged 15-19 years (26). Together, these two age groups make up 13% of the total NZ population (26). Between 2018 and 2023, the number of 10-14 year olds increased by 9.9% and the number of 15–19 year olds increased by 6.2% (26). The breakdown of ethnicities for 10–14 year olds is 224,178 (52%) who identify as European, 92,067 (21.4%) who identify as Māori, 47,784 (11.1%) who identify as Pacific people, 56,554 (13.1%) who identify as Asian, 7110 (1.6%) who identify as Middle Eastern/ Latin American/ African and 3,588 (0.8%) who identify as other ethnicity (26). For 15-19 year olds 213,030 (53.4%) identified as European, 83,340 (20.9%) identified as Māori, 43,800 identified as Pacific people, 49,497 (12.4%) identified as Asian, 6,237 (1.6%) identified as Middle Eastern/ Latin American/ African and 2,808 (0.7%) identified as other ethnicity (26).

2.2.1 Dietary intakes of adolescents

Adolescence is a transitional phase of life during which an individual moves from childhood to adulthood. This phase involves a period of rapid physical, cognitive and psychosocial development and is often considered the second stage of development (27). Adolescence is a stage of life where nutritional vulnerability can occur due to the increase in nutrient requirements and a poor diet, which has a low intake of fruit and vegetables, whole grains, lean meat and low-fat dairy and a high intake of high-sugar beverages, fats, and ready-to-eat meals (28). Globally, substandard eating patterns and inadequate nutrient consumption, often accompanied by habits such as skipping meals and replacing meals with snacks, are becoming increasingly common (28). Adolescence is considered a period of good health and the risk of severe disease is low. Consequently, less research focus is on this pivotal period of growth when the foundations of lifelong eating habits are laid, exposing adolescents to increased risk of poor health outcomes such as obesity, diabetes and cardiovascular disease (28).

During adolescence, the intake of several essential nutrients may not meet requirements, including calcium, vitamin A, B6, B12, D, E, folate, iron, zinc and selenium (28). Iron requirements increase sharply during adolescence to meet the additional needs of females related to menstruation (29). In males, iron requirements increase during adolescence to support the development of lean body mass. Inadequate iron intake during adolescence can lead to iron deficiency, resulting in compromised growth, decreased cognitive function and depressed immune function (29). As adolescent iron deficiency is common, it is recommended that adolescents increase their intake of iron and vitamin C to enhance iron absorption (30).

Peak bone mass is typically achieved near the end of adolescence and is a key determinant in reducing the risk of fractures and osteoporosis later in life. Optimising calcium and protein intake with weight-bearing exercise during the growth phase plays an important role in reaching peak bone mass (31). Adequate vitamin D intake enhances bone health. However, vitamin D also improves the efficiency of calcium absorption, making it another important nutrient during adolescence (32). Vitamin D primarily comes from exposure to sunlight, with smaller contributions from dietary sources such as fatty fish, eggs and fortified dairy products, but dietary sources alone are often insufficient to meet requirements (33).

Undernutrition is a condition characterised by a lack of proper nutrition, resulting from inadequate intake of nutritious food or insufficient food for growth and development (34). Adolescents are at risk of undernutrition due to their increased growth and development needs (34). Not meeting nutrition requirements during adolescence could lead to being underweight and malnourished (35). Being underweight can be caused by an underlying chronic disease, such as inflammatory bowel disease or impaired growth, or it could be due to inadequate intake of total energy or a specific macronutrient, such as essential fatty acids or amino acids (35). During adolescence, eating disorders such as anorexia and bulimia are at their highest rates in both males and females (36). Being underweight during adolescence can lead to having low birth weight babies or fertility issues, a compromised immune system, psychological issues and increased mortality (37).

Overnutrition is the consumption of more energy than is required, a problem affecting all ages and increasing in prevalence worldwide. Overconsumption of energy is associated with highly processed foods and high sugar intake (23). Adolescents who are overweight are more likely to experience mental health issues such as low self-esteem, depression and body image issues (38). Being overweight in adolescence can also increase the risk of cardiovascular disease, type 2 diabetes, sleep apnoea, and asthma (39).

In summary, adolescence is a pivotal developmental stage marked by rapid physical, cognitive and psychosocial changes, which substantially elevate nutritional requirements (27). However, this period is frequently characterised by suboptimal dietary practices, including insufficient intake of micronutrient-dense foods and increased consumption of energy-dense, nutrient-poor options (28). The prevalence of both undernutrition and overnutrition during adolescence poses significant concerns, with implications for immediate health outcomes and long-term disease risk (23) (34). Inadequate nutrient intake, particularly of iron, calcium, vitamin D, and essential fatty acids, can impair growth, immune function and bone health, while excess energy intake contributes to rising rates of obesity and associated comorbidities. Despite the relative under-recognition of adolescence as a period of nutritional vulnerability, it is a critical opportunity for establishing lifelong dietary behaviours (28). Targeted, evidence-based interventions during this stage are essential to optimise health trajectories and mitigate the burden of nutrition-related disorders across the lifespan.

2.3 Nutrient Reference Values

2.3.1 Development of the nutrient reference values

In 2006, the Nutrient Reference Values (NRVs) for Australia and New Zealand were established by the Australian National Health and Medical Research Council (NHMRC), in collaboration with the Australian Government Department of Health and Ageing and the New Zealand Ministry of Health. The NRVs were developed following a comprehensive review of available scientific and international evidence to determine the intake levels of essential nutrients needed to support health, prevent nutrient deficiencies and reduce the risk of chronic disease in healthy populations. The reference values serve as a key framework in clinical practice, public health nutrition and dietary assessment.

Prior to the development of the NRVs, Recommended Dietary Intakes (RDIs) were used to represent the average daily nutrient intake sufficient to meet the requirements of nearly all (97-98%) healthy individuals within a defined life stage and sex group (4). However, reliance on RDIs alone was found to be insufficient for evaluating population-level dietary adequacy, as they were often misapplied to infer the nutrient status of groups rather than individuals. In response, the NRVs introduced a tiered system of reference values that better accommodates the variability in nutrient requirements across populations (see figure 2) (4).

EAR	**Estimated Average Requirement** A daily nutrient level estimated to meet the requirements of half the healthy individuals in a particular life stage and gender group.
RDI	**Recommended Dietary Intake** The average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and gender group.
AI	**Adequate Intake (used when an RDI cannot be determined)** The average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate
EER	**Estimated Energy Requirement** The average dietary intake that is predicted to maintain energy balance in a healthy adult of defined age, gender, weight, height, and level of physical activity, consistent with good health. In children, pregnant and lactating women, the EER is taken to include the needs associated with the deposition of tissues or the secretion of milk at a rate consistent with good health
UL	**Upper Level of Intake** The highest average daily nutrient intake level is likely to pose no adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risks of adverse effects increase.

Figure 2. *Nutrient Reference Values Definitions (4)*

In order to address the issue of chronic disease, two additional sets of reference values were adopted for selected nutrients where evidence was sufficient (see Figure 3) (4).

AMDR	**Acceptable Macronutrient Distribution range:** The AMDR is an estimate of the range of intake for each macronutrient for individuals (expressed as a per cent contribution to energy), which would allow for adequate intake of all the other nutrients while maximising general health outcomes
SDT	**Suggested Dietary Target** A daily average intake from food and beverages for specific nutrients that may help in the prevention of chronic disease. The average intake may be based on the mean or median, depending on the nutrient and the availability of data.

Figure 3. *Definitions for chronic disease of selected nutrients (4)*

When establishing the NRVs, limited age-specific data restricted the ability to set adolescent-specific recommendations. Consequently, scaling methods such as interpolation and extrapolation were used, which considered energy requirements, metabolic body weight and height, thereby estimating nutrient requirements for adolescents using available data from adults (40).

The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates is set at 45–65% of total energy intake, based on evidence reviewed by the Food and Nutrition Board of the Institute of Medicine (FNB:IOM, 2002) (4). This range was determined in response to findings that carbohydrate intakes exceeding 65% of energy were associated with an increased risk of cardiovascular disease, while intakes below 45%, often accompanied by higher fat consumption, were linked to a greater risk of obesity (4). In the same report, the FNB:IOM recommended that total fat intake comprise 20–35% of total energy, a range associated with reduced risk of chronic conditions (4). The establishment of these ranges was guided by the goal of minimising the risk of chronic diseases such as coronary heart disease, obesity and type 2 diabetes, while ensuring adequate energy and nutrient intake across the population (4). The AMDR for protein is set at 15–25% of total energy intake, based on evidence indicating that a protein intake of approximately 15% of total energy is sufficient to meet the Estimated Average Requirement (EAR) for most individuals (4). Furthermore, research suggests that protein intakes should not exceed 2 g/kg/day, as higher intakes may not confer additional benefit and could place unnecessary metabolic stress on the kidneys, particularly in individuals with pre-existing renal conditions (4). For an average adult male (approximately 75 kg) and female (approximately 60 kg), this upper intake corresponds to approximately 150 g/day and 120 g/day, respectively (4). These values are equivalent to approximately 22–25% of total energy intake when calculated using median population energy intakes, thus informing the upper limit of the AMDR for protein (4).

2.4 Macronutrients

Macronutrients are essential nutrients that must be consumed in significant amounts to provide the human body with sufficient energy to sustain bodily functions. The primary macronutrients are carbohydrates, fats and protein. These are composed of organic molecules of carbon, hydrogen and oxygen (41).

2.4.1 Protein

Protein is required for growth and maintaining normal bodily processes and is the major structural component of all cells in the body, although it is primarily found in muscle (43%), blood (16%) and skin (15%) (42). Enzymes, hormones and other tissues make up the remainder of the body's protein (42). The four major proteins are collagen, haemoglobin, actin, and myosin (42). Protein works in a variety of ways within the body such as enzyme production, blood transport molecules, peptide hormone production (e.g. insulin), membrane transporters and they play an essential part in immunological function, fluid balance and energy provision (42).

Protein consists of amino acids, which are organic substances containing an amino group and an acid group (43). Amino acids can be classified as indispensable (essential) or dispensable (non-essential) (43). The body cannot synthesise essential amino acids and must obtain them through diet, while the body can synthesise non-essential amino acids in sufficient quantities (43). In certain conditions, essential amino acids are typically classified as non-essential because the body can synthesise them; however, under certain physiological conditions, such as illness, stress, or rapid growth, the body's ability to produce them endogenously becomes insufficient to meet increased metabolic demands (43). There are 20 amino acids, all of which are essential for normal cell physiology and function (43). If an essential amino acid is consumed in limited quantities, muscle tissue is broken down to release stored amino acids, which can then be utilised in biological processes (43). Is there anything you can add re protein needs during adolescence? This comment is relevant for all sections below…there may not be but just need to consider this to make relevant to adolescents.

Table 2. *Classification of amino acids*

Essential	Non-essential	Conditionally indispensable (essential)
Isoleucine	Alanine	Arginine
Lysine	Glutamic acid	Asparagine
Leucine	Aspartic acid	Cysteine
Phenylalanine		Glutamine
Tryptophan		Glycine
Methionine		Histidine
Threonine		Proline
Valine		Serine
		Tyrosine

2.4.2 Carbohydrates

Carbohydrates are the most significant source of energy and have distinct physiological properties that determine their health consequences, such as effects on blood glucose (42). Carbohydrates are classified by structure and include sugars, oligosaccharides and polysaccharides (42). The simplest carbohydrates are monosaccharides (glucose, fructose, galactose), disaccharides (sucrose, lactose, maltose) and sugar alcohols (mannitol, xylitol, and isomalt) (42). Oligosaccharides are short-chain carbohydrates and include maltodextrins and inulin (42). Polysaccharides are long-chain carbohydrates, also known as complex carbohydrates and are the most abundant carbohydrates found in food (42). The primary role of dietary carbohydrate is the provision of energy to cells, particularly the brain, which requires glucose for its metabolism (42).

2.4.3 Fats

Fats are the most concentrated source of energy for the body. Fats are needed for the absorption of fat-soluble vitamins A, D, E and K, as well as other fat-soluble biologically active compounds (42). Chemically, the majority of fats in foods are triglycerides, which are composed of a glycerol unit coupled with three fatty acids that can be the same as each other or different (42). The differences in triglycerides are primarily due to variations in fatty acid composition. Other dietary fats include phospholipids, phytosterols and cholesterol (42).

There are three major types of naturally occurring fatty acids: saturated, monounsaturated and polyunsaturated. Saturated fats are primarily found in animal-based diets, while monounsaturated and polyunsaturated fats predominate in plant-based meals (42). The primary monounsaturated fatty acid is oleic acid and the most common polyunsaturated fatty acid is linoleic acid (42). Polyunsaturated fatty acids may play an independent function in preventing coronary heart disease via various pathways (42). Trans fatty acids, a fourth type, are formed by partial hydrogenation of polyunsaturated oils during food processing and are also found naturally in ruminant animal products (42).

Excessive intake of saturated fats and trans fats has been linked to higher total and low-density lipoprotein (LDL) cholesterol levels, which increases the risk of atherosclerosis and cardiovascular disease later in life. Conversely, diets rich in monounsaturated and polyunsaturated fats are associated with better lipid profiles, reduced inflammation, and improved insulin sensitivity. These benefits are especially important during adolescence, a time of rapid growth, hormonal changes, and neurodevelopment, when sufficient intake of essential fatty acids supports brain development, cell membrane health, and overall metabolic function. However, adolescents often consume diets high in saturated and trans fats from processed and fast foods, while their intake of beneficial unsaturated fats remains low, contributing to early development of obesity, dyslipidaemia, and metabolic syndrome.

2.5 Micronutrients

Except for vitamin D, micronutrients are vitamins and minerals required by the body in small amounts and must be obtained through diet, as the body cannot synthesise them (44). Vitamins are organic molecules produced by plants or animals that can be degraded by heat, air, or acid (45). Minerals are inorganic chemicals found in soil and water that cannot be broken down (46). As the quantity of micronutrients found in food varies greatly, a diverse range of foods must be consumed to ensure that the body receives the nutrients needed to maintain optimal health, as each vitamin and mineral plays a unique purpose within the body (46).

Vitamins and minerals can be divided into four categories: water-soluble vitamins, fat-soluble vitamins, macro minerals and trace minerals. Water-soluble vitamins dissolve in water and cannot be stored in the body since they are rapidly eliminated. Water-soluble vitamins include the B complex vitamins and vitamin C (47). Fat-soluble vitamins are best absorbed when consumed with a supply of fat. Once absorbed, fat-soluble vitamins are stored in the liver and fatty tissues, where they can be later released when needed. Vitamins A, D, E and K are all fat-soluble (47).

Macro minerals are minerals that the body needs in greater quantities than trace minerals and include calcium, phosphorus, magnesium, sodium, chloride, potassium and sulphur (48). Trace minerals are required in minute amounts and include iron, manganese, copper, zinc, iodine, fluoride and selenium (48).

2.5. 1 Vitamin A

Vitamin A is a fat-soluble vitamin that promotes healthy reproduction, eyesight and immunity (42). Vitamin A comes in several forms, including retinol and retinoic acid (42). Retinol is crucial for maintaining the integrity of epithelial cells throughout the body. Retinoic acid controls the expression of genes encoding structural proteins, enzymes, extracellular matrix proteins, retinol binding proteins and receptors (42). Retinoic acid is vital for embryonic development, particularly the spinal cord and vertebrae, limbs, heart, eye and ears (42).

2.5. 2 Vitamin B1

Thiamine, also known as vitamin B1, is a water-soluble vitamin found in both plant and animal tissue, either free or phosphorylated (42). Thiamine is required for the provision of energy to issues, plays a role in glucose metabolism and has metabolic links with carbohydrate, protein and fat metabolism (42).

Vitamin B3

Niacin, also known as vitamin B3, is a water-soluble vitamin. Niacin works in both reduced and oxidised forms of the coenzyme nicotinamide adenine dinucleotide (NADH2 and NAD), which are involved in energy metabolism, as well as nicotinamide adenine dinucleotide phosphate (NADPH and NADP) (42). The coenzymes help dehydrogenase function (42). NAD is necessary for DNA repair and calcium mobilisation. It is a component of intracellular respiration that is involved in the oxidation of fuel substrates (42).

2.5. 3 Vitamin B6

Vitamin B6 is composed of six compounds: pyridoxal, pyridoxine, pyridoxamine and their 5' phosphates. It acts as a coenzyme in the metabolism of amino acids, glycogen and sphingoid bases (4).

2.5. 4 Vitamin B12

Vitamin B12 is essential for the generation of fatty acids in myelin and when combined with folate, for DNA synthesis (42). Normal blood and neurological function requires an adequate consumption of vitamin B12 and it can be stored in the liver for years (42). Vitamin B12 is primarily obtained from animal products such as poultry, dairy and red meat. Recent changes in the food environment and dietary behaviours have influenced the population's food choices (49). Increasing meat prices, along with a growing shift towards plant-based diets motivated by environmental and climate concerns, may contribute to a higher risk of vitamin B12 deficiency, particularly among adolescents (49)

B vitamins play an essential role in energy metabolism, red blood cell formation, and neurological development, making adequate intake vital during adolescence—a period characterised by rapid growth and increased metabolic demands. Deficiencies in B vitamins can result in a range of adverse health outcomes that may impair growth and cognitive development, including irritability, fatigue, dermatitis, and neurological disturbances (50). These symptoms are particularly evident in cases of vitamin B6 deficiency, as pyridoxine is essential for neurotransmitter synthesis and normal nervous system function (51).

2.5. 5 Vitamin C

Vitamin C is a reducing agent (an antioxidant). Vitamin C serves as an electron donor to eight enzymes, three of which are involved in collagen hydroxylation and aids in the absorption of iron (4). Vitamin C enhances the absorption of non-haem iron found in plant-based foods. It reduces the ferric iron to the more soluble ferrous form of iron (52).

2.5. 6 Vitamin E

Vitamin E can neutralise free radicals by transferring an electron to the free radical, making it less reactive (42). The primary function of vitamin E is to protect polyunsaturated fatty acids (PUFAs) against oxidation (42).

2.5. 7 Iron

Iron is found in a variety of proteins, including haemoglobin, myoglobin, cytochromes and enzymes involved in redox processes (4). Approximately two-thirds of the body's iron is contained as haemoglobin in circulating erythrocytes (4). Iron requirements increase during adolescence for females due to menstruation and iron deficiency is common (53)

2.5. 8 Magnesium

Magnesium plays a crucial role in maintaining bone health and is an essential component of the skeletal system. Magnesium is also a cofactor in 300 enzymes involved in aerobic and anaerobic energy production (4).

2.5. 9 Calcium

Calcium is necessary for all forms of life (42). The skeleton holds approximately 99% of the body's total calcium and requires an adequate dietary calcium intake along with vitamin D in order to enable proper growth and maintain healthy bones and teeth (42). Peak bone mass is reached in adolescence and low bone density increases the risk of bone fractures and osteoporosis in later life (42).

2.5.10 Zinc

Zinc plays a variety of roles, including stabilising DNA-binding proteins and participating in a wide range of biological processes, such as gene expression (42). Zinc aids in wound healing, immunological function, protein synthesis, DNA synthesis, and cell division by acting as a catalyst for over 200 enzyme activities known as metalloenzymes (54). Deficiency in zinc during adolescence can impair linear growth, delay sexual maturation, and weaken the immune response (55)

2.5.11 Selenium

Selenium's biological effects are mediated via selenoproteins, of which there are 25 in humans (42). These selenoproteins play a role in a wide range of bodily processes, including antioxidant defence and redox metabolism, thyroid metabolism, immune function, reproductive function and many others, with clinical implications in cancer, autoimmune thyroid disease and neurological disorders (42).

Selenium is a nutrient of concern in New Zealand due to the country’s naturally low soil selenium concentrations, which result in reduced selenium levels in locally produced foods (56). Much of New Zealand’s soil is deficient in trace minerals, such as selenium, and the country's high rainfall exacerbates this issue by causing selenium to leach from the soil (56). As a result, plants have limited capacity to uptake selenium, leading to low dietary selenium intakes among the population (56, 57). This has important implications for adolescents, as selenium plays a critical role in antioxidant defence, immune function and thyroid hormone metabolism. During adolescence, when growth, hormonal activity and metabolic demands increase, inadequate selenium intake may compromise immune competence and overall nutritional status (58). The limited selenium content in locally produced foods, combined with changing dietary patterns among adolescents, such as increased consumption of processed foods and reduced intake of animal-based products, further heightens the risk of suboptimal selenium status in this age group.

2.5.12 Potassium

The majority of cations in human cells are potassium (42). Intracellular enzymes require a potassium-rich environment (42). The Na+/K+-ATPase pump maintains a high intracellular potassium content. During nerve and muscle cell depolarisation and repolarisation, the electrical potential changes as potassium moves out of cells and sodium enters cells (42).

2.6 Previous studies of dietary intake of New Zealand Adolescents

Previous nationally representative studies of adolescent dietary intake include the Adult Nutrition Survey (ANS), conducted in 2008/09 and the Children's Nutrition Survey (CNS), conducted in 2002. Notable findings from the ANS 08/09 were that a significant proportion of adolescents aged 15-18 years had an inadequate intake of calcium (87.8% of females, 57.7% of males), vitamin A (37.5% of males and 27.4% of females) and iron (34.2% of females and 7.4% of males). Additionally, the highest prevalence of inadequate selenium across all age groups was observed in female adolescents (78.2%) (11). The 2002 children's nutrition survey also highlighted inadequate selenium intake, with children aged 11-14 years at greater risk of having inadequacy than younger children. Other findings from the CNS included a low iodine status of NZ children, indicative of mild deficiency and a protein intake that exceeded requirements in all age groups (10).

The 2019 Dunedin SuNDiAL study investigated the dietary intake of adolescents aged 15-18 years. Inadequate intake was reported for calcium (63% of males and 85% of females) (16), magnesium (61.8% of males and 58.3% of females) (14, 15), vitamin B12 (30.3% of females), (17) and iron (20.8% of females) (13). A comparison of dietary habits found that females were more likely to consume fruit and vegetables than males (59).

Together, these three studies highlight nutrients that NZ adolescents may not be consuming in adequate quantities. The CNS and ANS had large sample sizes of 3275 (10) and 4721 (11), making the findings more representative of the NZ population. However, the data collected is now outdated. The SuNDiAL study data were conducted more recently, although they are limited by a small participant number of 140 and a narrower age range of 15-18 years.

There have been other studies that looked at adolescence and their dietary habits, such as Attitudes to food differ between adolescent dieters and non-dieters from Otago, New Zealand. However, overall food intake does not show differences in food-related attitudes between adolescents who dieted and those who did not. However, there was no significance in the difference in overall food intake (60). Another study looked at physical activity, screen time and dietary behaviours in New Zealand adolescents prior to and following the onset of the COVID-19 pandemic which examined changes in lifestyle behaviours during the pandemic which focused on activity levels, screen time and general dietary patterns (61) and the third study Dietary Intake and Eating Behaviours of Obese New Zealand Children and Adolescents Enrolled in a Community-Based Intervention Programme which explored dietary intake and eating behaviours in obese youth who participated in community based programs (62). These studies looked at the dietary habits of the adolescents and not at the dietary intake, which leaves a gap in the understanding of nutrient inadequacy in the population.

2.7 Where research is now

Each year, Health NZ releases health indicators on nutrition. These indicators are divided into two categories: children aged 0-14 years and adults aged 15 and over, and only assess whether the required intake of fruit, vegetables, or both is met (63). In 2022, the Ministry of Health conducted a study that examined the dietary habits of children. The study assessed adherence to recommendations, including dietary exclusions of fruits and vegetables, consumption of meat and processed meat, frequency of takeaway and sugary drink intake, as well as weight perception and breakfast habits (64).

The New Zealand National Nutrition Survey has not been conducted in nearly two decades, and there is an urgent need for up-to-date data on nutrient intake to be collected. Research teams were commissioned in 2021 to develop tools and methods for a new national nutrition survey using Intake24. Unfortunately, another national nutrition survey has not yet been undertaken (65).

2.8 International Nutrient Recommendations

When examining international dietary recommendations, it becomes evident that a diverse range of Nutrient Reference Values (NRVs) are currently in use across many countries. Numerous factors contribute to these differences, including the frequency of updates, the type and quality of evidence used to develop the recommendations and the methodological approaches employed during their formulation (66). Additional sources of variation include cultural dietary patterns, anthropometric differences and geographical factors, all of which can influence nutrient needs and the interpretation of nutritional adequacy (67). Definitions of adolescence also vary internationally, with different age ranges used to categorise this life stage, affecting how nutrient requirements are determined and applied (67). Extrapolation methods differ between countries as well, meaning interpretation of the evidence can be different (67). Table 3 provides an overview of the different definitions from the different international nutrient guidelines.

Table 3. *International definitions of nutrient guidelines*

Country	Nutrient Reference Value	Nutrient Reference Value Definition
European Food Safety Authority	Population Reference Intake (PRI)	The intake of a nutrient that is likely to meet the needs of almost all healthy people in a population (68)
United Kingdom	Reference Nutrient Intake (RNI)	The amount of a nutrient that is enough to ensure that the needs of nearly all the group (97.5%) are being met (69).
	Lower Reference Nutrient Intake (LRNI)	The RNI is the amount of a nutrient that is enough to ensure that the needs of nearly all a group (97.5%) are being met. (69).
United States of America	Dietary Reference Intakes (DRI)	The average daily nutrient intake for the general population over time (70).

Collectively, these factors contribute to inconsistencies in NRVs across countries and present challenges when attempting to compare or harmonise dietary guidelines, particularly for adolescent populations.

An example of the broader age ranges used to describe an adolescent is found in Australia, New Zealand and the United States of America, which describe an adolescent as aged 9-13 and 14-18 years. The United Kingdom's description is 11-14 and 15-18 years.

Table 3 provides an overview of the different Nutrient Reference Values from various countries worldwide. Some examples of differences in NRVs are: Iron requirements for Australia and NZ are 6mg/day for males and females aged 9-13, and 8mg/day for males and females aged 14-18 years. In the UK, the reference intake for daily iron intake is 8.7 mg for males and females aged 11-18 and 11.4 mg for all other groups. In the United States, the dietary reference intake is 5.9 mg/day for males aged 9-13 years and 7.7 mg/day for males aged 14-18 years. For females, the dietary reference intake is 5.7 mg/day for those aged 9-13 and 7.9 mg/day for those aged 14-18 years. Regarding calcium, in Australia and NZ, the EAR is 800-1050mg/day for males and females aged 9-13 years and 1050mg/day for those aged 14-18 years. In the UK, the reference intake is 750mg/day for males aged 11-18 years and 625mg/day for females. In the United States, the dietary reference intake is 1,100 mg/day for males aged 9-18 years.

Table 4: *Comparison of nutrient reference values for Australia/New Zealand, the United Kingdom, Europe and the United States of America.*

	AUS/NZ 2006[1]				*United Kingdom*[2]			*United States of America*[3]			*EFSA*[4]		
Nutrient	**Gender**	**Age**	**EAR*/AI**	**RDI**	**Gender**	**Age**	**RNI/EAR***	**Gender**	**Age**	**DRI**	**Gender**	**Age**	**PRI**
Carbohydrates											M-F	1-17y	45-60% energy
Protein (g/d)	M	14-18y	49*	40	M	11-14y	42.1*	M	14-18y	52	M	14y	0.89g/kg
	F	14-18y	35*	45	M	15-18y	55.2*	M	14-18y	46	F	14y	0.87gkg
					F	11-14y	41.2*				M	15y	0.88g/kg
					F	15-18y	45*				F	15y	0.85g/kg
											M	16y	0.87g/kg
											F	16y	0.84g/kg
											M	17y	0.86g/kg
											F	17y	0.93g/kg
Fat (g/d)	M	14-18y	125		M	11-18y	97				M-F	4-17y	20-25% energy
	F	14-18y	85		F	11-18y	78						
Calcium (mg/d)	M	14-18y	1050*	1300	M	11-18y	1000	M	14-18y	1300	M & F	11-17y	1150
	F	14-18y	1050*	1300	F	11-18y	800	F	14-18y	1300			
Vitamin B1 (mg/d)	M	14-18y	1.0*	1.2	M	11-14y	0.9	M	14-18y	1.2	M & F	11-17y	0.1 mg/MJ
	F	14-18y	0.9*	1.1	M	15-18y	1.1	F	14-18y	1.0			
					F	11-14y	0.7						
					F	15-18y	0.8						
Vitamin B3 (mg/d)	M	14-18y	12*	16	M	11-14y	15	M	14-18y	16			
	F	14-18y	11*	14	M	15-18y	18	F	14-18y	14			
					F	11-14y	12						
					F	15-18y	14						
Vitamin A (μg/d)	M	14-18y									M-F	11-14	600
	F	14-18y									M-F	15-17	650
Iron (mg/d)	M	14-18y	8*	11	M	11-18y	11.3	M	14-18y	11	M	12-17y	11
	F	14-18y	8*	15	F	11-18y	14.8	F	14-18y	15	F	12-17y	13

Vitamin B6 (mg/d)	M	14-18y	1.1*	1.3	M	11-14y	1.2	M	14-18y	1.3	M & F	11-14y	1.4
	F	14-18y	1.0*	1.2	M	15-18y	1.5	F	14-18y	1.2	M	15-18y	1.7
					F	11-14y	1.0				F	15-18y	1.6
					F	15-18y	1.2						
Vitamin B12 (μg/d)	M	14-18y	2.0*	2.4	M	11-14y	1.2	M & F	14-18y	2.4	M & F	11-14y	3.5
	F	14-18y	2.0*	2.4	M	15-18y	1.5				M & F	15-18y	4
Vitamin E (mg/d)	M	14-18y	10		M	11-14y	8.0	M & F	14-18y	15	M	11-18y	13
	F	14-18y	8		M	15-18y	10.0				F	11-18y	11
					F	11-14y	6.8						
					F	15-18y	8.0						
Vitamin C (mg/d)	M	14-18y	28*	40	M & F	11-14y	35	M	14-18y	75	M & F	11-14y	70
	F	14-18y	28*	40	M & F	15-18y	40	F	14-18y	65	M	15-17 y	100
											F	15-18y	90
Potassium (mg/d)	M	14-18y	3600		M & F	11-14y	3100	M	14-18y	3000	M & F	11-14y	2700
	F	14-18y	2600		M & F	15-18y	3500	F	14-18y	2300	M & F	15-18y	3500
Selenium (μg/d)	M	14-18y	60*	70	M	11-14y	45	M & F	14-18y	55	M & F	11-14y	55
	F	14-18y	50*	60	M	15-18y	70				M & F	15-18y	70
					F	11-14y	45						
					F	15-18y	60						
Magnesium (mg/d)	M	14-18y	340*	410	M & F	11-14y	280	M	14-18y	410	M	10-17y	300
	F	14-18y	300*	360	M & F	15-18y	300	F	14-18y	360	F	10-17y	250
Zinc (mg/d)	M	14-18y	11*	13	M	11-14y	9.0	M	14-18y	11	M & F	11-14y	8.9
	F	14-18y	6*	7	M	15-18y	9.5	F	14-18y	9	M	15-17y	11.8
					F	11-14y	9.0				F	15-17y	9.9
					F	15-18y	7.0						

[1] Nutrient Reference Values Australia and New Zealand [2] United Kingdom [3] United States nutrient recommendations [4] Europe dietary reference values

Abbreviations:

AI	Adequate Intake
DRI	Dietary Reference Intake
EAR	Estimated Average Requirement
PRI	Population Reference Intake
RNI	Reference Nutrient Intake

2.9 International studies.

Comparing nutrition studies internationally is challenging due to differing study protocols, differing adolescent age definitions, differences in NRVs and different dietary assessment methods used (71).

Across New Zealand (NZ) and international adolescent nutrition studies, several consistent themes emerge. A recurring finding is the widespread inadequacy of key micronutrients, particularly iron, calcium, magnesium and selenium, with female adolescents consistently showing a higher prevalence of nutrient inadequacy compared to males (10, 13-17, 55-62). For instance, both the NZ Children's Nutrition Survey (2002) and the Adult Nutrition Survey (2008) reported suboptimal intakes of iron, calcium and selenium, particularly among females (10, 56). These findings were mirrored in the Sundial studies, which targeted NZ adolescents aged 15-18 years, where the mean intakes of iron, calcium, magnesium and vitamin B12 were below the Estimated Average Requirement (EAR) in a large proportion of participants (13-17). Comparable results were also reported in recent international studies, including those from Australia, the UK, Ireland, Canada and Scotland, where adolescents exhibited similar nutrient inadequacies – particularly for iron and calcium, with females again being the most affected group (55, 57-61)

Methodologically, most studies relied on 24-hour dietary recalls, providing comparable data across regions, although this approach is subject to recall bias and may not capture usual intake. Studies using multi-day food records, such as the National Teens' Food Survey (2019-2020), offered more reliable habitual intake estimates but at higher participant burden (58, 60). Across countries, macronutrient distributions were remarkably consistent with protein contributing approximately 15-17% of energy, 30-32% fat and 48-50% carbohydrates.

The NZ data is now over 15 years old, highlighting a significant research gap in current adolescent nutrient data, whereas other countries have conducted more recent national surveys. Selenium is a nutrient of concern that is unique to NZ, due to low soil selenium levels reducing the selenium content of locally produced foods, a pattern not observed in other countries until the Scottish 2023 nutrition survey. Overall, the evidence indicates that while adolescent diets across developed countries show broadly similar macronutrient profiles, persistent micronutrient inadequacies, especially among females, remain a concern.

Table 5 provides a summary of the literature available from various countries, including the USA, Australia, New Zealand, Ireland, Scotland and Canada, which utilised 24-hour recalls or food frequency questionnaires as their dietary assessment method.

2.10 Summary of literature

Table 5: *New Zealand and International studies examining the micronutrient intakes of children*

Study Country, Author and year	Study Population	Nutrient analysis method	Nutrients analysed	Primary outcomes	Limitations / Notes
New Zealand					
NZ Children's Nutrition Survey 2002 (10)	N=3275 5-14 years	24-hour recall	Energy, fats, protein, fibre Selenium, potassium, B vitamins, Calcium, vitamin A, vitamin E, folate, phosphorus, magnesium, iron, zinc, potassium, manganese, and copper	Excess protein intake 88g for males, 66g for females aged 11-14 years Median intake of iron: 14.1mg for males and 9.9mg for females aged 11-14 years. Low intake for females. Median intake of selenium: 44µg for males and 34.9µg for females aged 11-14 years. Low intake of selenium	Data > 20 years old
NZ Adult Nutrition Survey 2008 (72)	N= 4721 15-<70 years	24-hour recall	Energy, protein, fats, fibre, sugars Vitamin A, vitamin C, vitamin E, B vitamins, calcium, iron, zinc, potassium, selenium	Median intake of vitamin A: 732µg for males and 599µg for females aged 15-18 years. Inadequate vitamin A intake in males (37.5%) and females (27.4%) Median intake of calcium: 980mg for males and 682mg for females aged 15-18 years. Inadequate calcium intake in females (87.8%) and males (57.7%) Median intake of iron: 13.5mg for males and 9.1mg for females aged 1518 years. Inadequate iron intake in females (34.2%) and males (7.4%) Median intake of selenium: 64.0µg for males and 38.7µg for females aged 15-18 years. Inadequate selenium intake of selenium in females (78.2%).	Data > 15 years old
Sundial					

Hall, N (17)	N=132 15–18-year females	24hr recall	Vitamin B12	Median intake of vitamin B12: 2.5μg for females aged 15-18 years. Inadequate intake - 30.3% females.	Small sample size
Henderson, C (16)	N= 243 females, 102 males 15-18 years	24hr recall	Calcium	Median intake of calcium: 935mg for males and 711mg for females aged 15-18 years. Inadequate intake - 63% males, 83% females	
Menzies, B (13)	N=145 15–18-year females	24hr recall	Iron	Mean intake of iron: 11.8mg for females aged 15-18 years. Inadequate intake - 20.8%	
Mollo, M (15)	N=132 15–18-year females	24hr recall	Magnesium	Median intake of magnesium: 280mg for females aged 15-18 years. Inadequate intake - 58.3% below EAR	
Foote, I (14)	N=135 15–18-year males	24hr recall	Magnesium	Median intake of magnesium: 318.3mg for males ages 15-18 years. Intake below EAR - 61.8%	
International					
Australian Health Survey 2011 (73)	N=12153 2->71 years	24hr recall	Fat, energy, carbohydrates, protein Calcium, vitamin B12, sodium, iodine, iron, thiamine	Energy contribution 9-13 years – protein 16.1%, fat 31.4%, carbohydrates 49.8% 14-18 years – protein 17%, fat 31.8% carbohydrates 48.5% Mean intake of calcium: Males – 900mg, females 806mg aged 9-13 Males – 925mg, females 741mg aged 14-18 years. Low calcium intake. Mean intake of iron: Males 11.6mg and females 9.1mg aged 9-13 years. Males 12.5mg and females 9.2mg aged 14-18 years. Low iron intake.	
National Diet and Nutrition Survey	N=1000 1.5->71 years	4-day diet record	Fat, energy, protein, carbohydrates, fibre	Mean intake of protein: Males 70.2g, females 57.7g aged 11-18 years.	

2019-2023 (UK) (74)			Calcium, iron, vitamin A, vitamin B12, vitamin D	Mean intake of fat: Males 68.3g and females 56.4g aged 11-18 years Mean intake of carbohydrate: Males 230g and females 204g aged 11-18 years. Mean intake of thiamine: Males 1.6mg and females 1.3mg aged 11-18 years. Mean intake of niacin: Males 36mg and females 28mg aged 11-18 years. Mean intake of vitamin B6: Males 1.8mg and females 1.4mg aged 11-18 years. Mean intake of iron: Males 9.9mg and females 8.3mg aged 11-18 years. Mean intake of calcium: Males 842mg and females 677mg aged 11-18 years.	
What We Eat In America, NHANES 2017-2018 (75).	N=531 males 514 females 12-19 years	1-day diet recall	Fats, proteins, energy, carbohydrates Calcium, iron, vitamin A, and magnesium	Mean intake of energy: Males 2275kcal and females 1768 kcal aged 12-19 years. Mean intake of fat: Males 90.2g and females 71.9g aged 12-19 years. Mean intake of calcium: Males 1079mg and females 813mg aged 12-19 years Mean intake of magnesium: Males 275mg and females 219mg aged 12-19 years. Mean intake of iron:	

				Males 15.5mg and females 12.2mg aged 12-19 years.	
National Teen Food Survey 2019-2020 (Ireland) (76)	N=216 females, 212 males aged 13-18 years 216 females aged 13-18 years	Four-day weighed food record	Fats, protein, carbohydrates, fibre Calcium, iron, magnesium, potassium, and vitamin E	Mean intake of carbohydrate: Males 264g and females 196g, aged 13-18 years. Mean intake of protein: Males 87.2g and females 62.2g aged 13-18 years. Mean intake of fibre Males 18.9g and females 15.0g aged 13-18 years. Mean intake of calcium: Males 965mg and females 666mg aged 13-18 years. Mean intake of iron: Males 12.7mg and females 9.4mg aged 13-18 years. Mean intake of magnesium: Males 268mg and females 205mg aged 13-18 years.	
Canadian Community Health Survey (2015) (77)	1802 males 1792 females	24 hr recall	Carbohydrates, fats and fibre, and protein Calcium, iron and potassium	Mean intake of calcium: Males 1058mg and females 882mg aged 9-13 years Males 1078mg and females 902mg aged 14-18 years. Mean intake of iron: Males 13.8mg and females 11.9mg aged 9-13 years. Males 16.1mg and females 11.3mg aged 14-18 years. Mean intake of potassium: Males 2552mg and females 2248mg aged 9-13 years. Males 3043mg and females 2300mg aged 14-18 years.	

Dietary Intake in Scotland's CHildren (DISH) 2023 (78)	11-15year olds 319 female 261 male	24 hr recall (Intake24)	Carbohydrates, energy, protein, fats, protein Iron, calcium, magnesium, potassium, selenium, zinc	Mean intake of carbohydrates: Males 256g and females 216g aged 11-15 years. Mean intake of energy: Males 1907kcal and females 1596 kcal aged 11-15 years. Mean intake of protein Males 76g and females 59g aged 11-15 years. Mean intake of iron: Males 10.9mg and females 8.8mg (43% below LRNI) aged 11-15 years. Mean intake of calcium: Males 921mg and females 755mg aged 11-15 years Mean intake of magnesium: Males 242mg (21% below LRNI) and females 201mg (40% below LRNI) aged 11-15 years. Mean intake of potassium: Males 2568mg (12% below LRNI) and females 2147mg (21% below LRNI) aged 11-15 years. Mean intake of selenium: Males 43µg (13% below LRNI) and females 33µg (33% below LRNI) Mean intake of zinc: Males 8.3mg (13% below LRNI) and females 6.5mg 33% below LRNI)	Did not assess the entire adolescent population
Survey of Diet Among Children in Scotland (2010) (79)	n=1674 (Included total overall study participants of children aged 3-16 years, 588 of	FFQ	Energy, protein, fats, carbohydrates Iron, calcium, magnesium, potassium	Mean intake of protein: Males 55.2g and females 45g aged 12-16 years. Mean intakes of iron: 9.2mg for males and 7.4mg for females aged 12-16 years.	Included supplements, Data was collected in 2010

	which were 12-16 years)				Did not assess the entire adolescent population Inadequacies were not reported

Abbreviations:

LRNI Lower Reference Nutrient Intake

RNI Reference Nutrient Intake

EAR Estimated Average Requirements

2.11 Dietary assessments for adolescents

Accurate dietary assessment is crucial for evaluating the relationship between diet and population health, as well as for informing public health initiatives. There are four traditional methods, which include 24-hour recalls, food frequency questionnaires, food records and diet histories (80). The choice of method depends on the study's objectives, design, sample size and available resources. Adolescents aged 10 years and older can generally report their dietary intake themselves with parental consent. However, all methods are prone to reporting biases (80). Underreporting is especially common among adolescent females, those with obesity and individuals concerned about body image (80). Overreporting may occur due to social desirability, leading to exaggerated accounts of healthy foods such as fruit and vegetables (80).

2.11.1 24-hour recalls

The 24-hour dietary recall (24HR) is a widely used method for assessing dietary intake, collecting detailed information on all foods and beverages consumed in the previous 24 hours (81). To account for day-to-day variation, multiple recalls on non-consecutive, randomly selected days are recommended. Traditionally conducted via face-to-face or telephone interviews, self-administered digital formats are increasingly common (82).

A key strength of the 24HR is the use of trained interviewers who employ structured probes to enhance data accuracy, including prompts on meal timing, portion sizes, preparation methods and added ingredients (83). This method also accommodates individuals with low literacy or cognitive impairments (82)). Conducting recalls soon after consumption reduces recall bias.

Technological advancements have enhanced 24-hour accuracy through web and mobile platforms, incorporating visual aids and automated prompts (84). However, these tools require validation for cultural and population-specific applicability. Limitations include the need for intensive interviewer training, high resource demands and susceptibility to recall bias and underreporting (82).

Despite these challenges, adolescents generally respond well to the 24HR method due to its simplicity, reduced literacy requirements and shorter completion time, supporting its use in adolescent dietary assessment (85).

2.11.2 Food frequency questionnaire

Food Frequency Questionnaires (FFQs) are widely used to estimate usual dietary intake over extended periods, capturing habitual patterns rather than short-term consumption (82). Food Frequency Questionnaires vary in format, qualitative (frequency only), semi-quantitative (standard portion sizes) and quantitative (detailed portion estimates calibrated against food records) (82). Food Frequency Questionnaires (FFQs) are affordable, easy to administer and ideal for large-scale epidemiological research. They enable the ranking of dietary intake and help identify associations between diet and health outcomes.(82), (86). They can be culturally adapted to suit specific populations.

However, FFQs have limitations, including inaccuracies in portion size estimation, food misclassification and reliance on participant literacy and memory (82). These challenges are particularly relevant in adolescent populations, where recall ability may be inconsistent. FFQs are less suitable when precise nutrient quantification is required or in clinical settings (82). Despite this, they remain valuable for assessing general dietary patterns in large, diverse populations.

2.11.3 The food record

Food records (also referred to as food diaries) involve the prospective documentation of all foods, beverages and dietary supplements consumed over a defined period, typically three to seven days. Food records can be weighed or estimated, where participants are instructed to measure intake at the time of consumption, providing more accurate portion and nutrient estimations compared to retrospective methods (82).

Although considered one of the most precise dietary assessment tools, especially in controlled environments, food records present several limitations. These include high participant burden, the need for training in accurate recording and adequate literacy and numeracy skills. Furthermore, reactivity bias may occur, wherein participants alter their eating behaviours due to the awareness of being monitored (82).

Despite these challenges, food records remain valuable in research requiring detailed dietary data, such as validation studies or nutrient-specific analyses (82). However, their application in large-scale studies or among populations with limited literacy, including adolescents, may be restricted (82).

2.11.4 Diet history

A diet history is a dietary assessment method where an individual's usual intake and eating habits are assessed over an extended period of time eg a week (82). Diet histories are conducted via structured interviews or using questionnaires that probe participants on meal patterns, portion sizes, food preparation and frequency of food items (82). In an adolescent population, diet histories can be valuable in assessing long-term dietary patterns where persistent nutrient inadequacies or dietary behaviours over a period of time may not be provided by a 24-hour recall (82). A limiting factor is the participants' ability to recall what they consumed makes this method vulnerable to recall bias, underreporting and underestimation of portion sizes (82). One way of overcoming the expense of intensive interviewer training is getting participants to complete the food recalls themselves. This would require participants to have a level of literacy, numeracy and require them to understand how to complete the dairies (82).

2.11.5 Intake 24

Intake24 is an open-source, self-administered, computerised 24-hour dietary recall tool developed in the United Kingdom (UK) to collect detailed dietary intake data without interviewer involvement (87). Validated in a sample of 180 individuals aged 11–24 years, the system demonstrated strong agreement with interviewer-led recalls, underestimating energy intake by only 1% and indicating high accuracy for a self-completed method (87).

Since 2019, Intake24 has been employed in the UK National Diet and Nutrition Survey Rolling Programme from Year 12 onwards, supporting its utility in population-level dietary monitoring (87). Recognising its potential for broader application, New Zealand researchers adapted the tool to reflect local dietary patterns. In collaboration with Auckland University and Massey University, the system was modified to include a culturally relevant food database of 2,621 items, incorporating traditional Māori, Pasifika and Asian foods, as well as commonly consumed branded products (88).

To improve precision, the adaptation also introduced new portion size images for locally specific foods and packaging and integrated New Zealand-specific nutrient composition data, including recipes for common mixed dishes (88). A pilot study involving 37 participants of diverse backgrounds evaluated the system's usability. Feedback from this study informed further refinements, demonstrating that the New Zealand version of Intake24 is a culturally appropriate and efficient dietary assessment tool, particularly suitable for adolescents and multi-ethnic populations (88).

2.12 Summary of Literature Review

This literature review underscores the critical importance of adolescence as a unique and vulnerable stage in the human life cycle. Characterised by rapid physical, psychological, and social development, adolescence presents both opportunities and challenges for establishing lifelong health behaviours.

The reviewed evidence reveals that despite increased nutritional requirements during this period, many adolescents fail to meet recommended nutrient intakes. This nutritional inadequacy, whether due to undernutrition or overnutrition, can lead to serious and lasting health consequences, including obesity, type 2 diabetes, and micronutrient deficiencies. Furthermore, the review highlights a concerning gap in up-to-date, high-quality research focused on adolescent nutrition, indicating a pressing need for more contemporary studies to inform policy and intervention strategies. Addressing these gaps is essential to support the health and development of future generations.

Chapter 3 Manuscript

3.1 Abstract

Background

Adolescence is a critical period of rapid growth and development, during which nutrient requirements increase significantly to support physiological, cognitive and emotional maturation. However, current data on the dietary habits and nutritional status of New Zealand (NZ) adolescents remain outdated and insufficient, limiting the ability to assess nutrient adequacy within this population accurately.

Aims and Objectives

This research aims to investigate the current nutrient status of NZ adolescents and compare their intake to their nutrient reference values and assess their adherence to dietary recommendations.

Methods:

Data was collected from the Te Rourou o Ngā Rangatahi: Eating Patterns of Young People in New Zealand, a cross-sectional survey examining adolescent dietary habits. The sample comprised 527 secondary students aged 14-19 years from Auckland, Bay of Plenty and Waikato regions. Dietary information was collected using Intake24, a web-based multiple-pass 24-hour dietary recall assessment tool, along with an online demographic questionnaire. Nutrient intakes were assessed against the Australian and New Zealand Nutrient Reference Values (NRVs) to determine adequacy.

Results

Female participants (n=370, 70.2%) showed greater adherence to macronutrient intake than males. Mean protein, carbohydrate and fat intake all exceeded recommended intakes, with fibre being well below the recommendations. Mean protein intake was 76.8 ± 44.3g for females and 105.8 ±61.6g for males. The energy intake was met by 97.8% of females and 98% of males. Macronutrients of concern were fibre intake of 19.2 ±11.2g for females and 20.7 ±12.5g for males, well below the 22g for females and 28g for males, suggesting a low intake of fruits and vegetables. Energy coming from saturated fat was met by only 9.7% of females and 7% of male participants, with the remaining participants well above the recommendations

Male participants demonstrated higher mean nutrient intakes across most micronutrients. Calcium, iron, vitamin A and vitamin E were micronutrients of concern. Mean calcium intake was 721.9 ± 463.6 mg/day for females and 868.3 ± 691.5 mg/day for males, with only 20.3% and 31.2% meeting the EAR, respectively. Iron intake averaged 9.8 ± 6.1 mg/day in females and 12.3 ± 8.0 mg/day in males, with 53.8% and 66.9% of the participants meeting the recommendations, respectively. Vitamin A and vitamin E intakes were below the EAR for the majority of participants, while magnesium and vitamin C also showed low adherence.

Conclusion

The findings from this study indicate a high prevalence of nutrient inadequacy among New Zealand adolescents. These results highlight the urgent need for a nationally representative nutrition survey to provide updated data on nutrient intake and adequacy within this population. Given that adolescence is a formative stage for establishing lifelong dietary habits, addressing these nutritional gaps is critical for long-term health outcomes. Future research should incorporate at least two non-consecutive 24-hour dietary recalls to more accurately verify nutrient inadequacies observed in this study.

3.2 Introduction

Adolescence is defined as the period between 10 and 19 years, with the United Nations reporting 1.3 billion adolescents globally, making up 16% of the world population (1). During adolescence, the human body transitions from childhood to adulthood, a period marked by rapid physical, cognitive, and psychosocial growth, which is termed puberty (27). During puberty, 20% of the final adult height and 50% of the adult weight is gained; and bone mass increases up to 40% (3). Adequate nutrition during this period is critical to meet the increased growth demand. Protein, calcium, and iron requirements increase due to gains in lean body mass, bone deposition and the beginning of menses for females. Not meeting the requirements for these nutrients can result in various deficiencies, such as anaemia and an increased risk of osteoporosis and low bone density later in life (9)

In 2006, the Australian and New Zealand (NZ) Nutrient Reference Values (NRVs) were published, which outline the nutrient requirements of healthy people across the lifecycle (4). These guidelines are aligned with international nutrient reference standards used in other developed countries. The requirements for most macronutrients and micronutrients are greater for males with the exception of iron, which in females over 14 years increases to support the beginning of menses (4). Males have a higher rate of lean body mass, higher energy requirements and bone mass during puberty than adolescent females, which necessitates higher nutrient requirements (29).

The Sundial study undertaken in 2020 is the most recent study investigating nutrient intake in New Zealand adolescents (aged 15-18 years), showed that calcium intake was below the estimated average requirements (EAR) for 63% of males and 85% of females (16). A considerable proportion of females had nutrient intakes below the EAR with approximately 60% for magnesium, 30% for vitamin B12, and 20% for iron [7–10]. Saturated fat intake was above requirements in 96% of adolescent males (89) and 83% of females (90). The National Children's Nutrition Survey undertaken in 2002 showed that adolescents (aged 11-14 years) had a low intake of selenium (44µg for males and 34.9µg for females). An excess intake of protein (88g for males and 66g for females) was observed. In contrast, adolescent females had a low intake of iron, at 20.8% which was as the Sundial study (13). Calcium intake was also reported to be below the EAR for 28.7% of males and 29.6% of females aged 11-14 years (10). The 2008/09 Adult Nutrition Survey found that adolescents (aged 15-18 years) had the lowest intake of vitamin A across all ages. Intakes below the EAR were observed for zinc (37.5% of males and 27.4% of females), calcium (57.7% of males and 87.8% of females), selenium (40.4% of males and 78.2% of females), and iron (34.2% of females) (11).

Since these studies were completed, there have been changes in the food environment, such as the cost of food increasing by 9.6% (91) and an increase in food insecurity (18). There has been an increase in the consumption of convenience foods such as takeaways and ready-to-eat meals (22). These meals are often high in ultra-processed ingredients, saturated fat, and sugar, which are known to increase blood pressure, cholesterol, obesity rates, and the risk of type 2 diabetes (23). In contrast, there has also been an increase in the consumption of plant-based diets due to ethical, environmental, and health concerns, and the affordability of animal-based food products (92).

Apart from the Sundial study, there is limited recent evidence regarding the dietary intake of NZ adolescents. Understanding the dietary intake of adolescents aged 14-19 years will enable researchers and policymakers to develop and implement targeted interventions that improve the health of adolescents and reduce the long-term risk of chronic disease. This study aims to determine and compare the nutrient intakes of New Zealand adolescents aged 14 to 18 years in the Auckland, Waikato, and Bay of Plenty regions with the NRVs for Australia and NZ.

3.3 Methodology

3.3.1 Study design

Data was collected as part of the Te Rourou o Nga Rangatahi: Eating Patterns of Young People in New Zealand study. Using a cross-sectional design, data was collected from adolescent participants between June and August 2024 in the Auckland, Waikato and Bay of Plenty regions.

Ethical approval was granted by Massey University Human Ethics Ohu Matatika 1, Application OM1 23/55. The New Zealand Heart Foundation provided study funding. All participants provided informed consent electronically prior to data collection. For those under 16 years of age, schools were supplied with parent/whānau information sheets and consent forms for students under 16 and links were provided to distribute to parents. These could be emailed to parents, or printed copies were supplied if preferred. Data collection was scheduled at the school’s convenience.

3.4 Participants and recruitment

3.4.1 School recruitment

School recruitment was carried out using a convenience sampling approach. Schools with students from years 7 to 13 were approached during terms two and three of 2024 and invited to take part in the study. During these terms, a senior advisor or a nutritionist from the Ministry of Education contacted a total of 256 schools in the Auckland, Waikato, and Bay of Plenty regions participating in the school lunch programme, inviting them to become involved. Additionally, 49 schools in Auckland and 22 in the Waikato and Bay of Plenty, which were not part of the lunch programme, were also contacted by phone, followed up with an email containing more details and a formal invitation to participate.

3.4.2 Participant recruitment

The study's inclusion criteria included being aged 9 to 19 years and being proficient in English. Recruitment of students aged 16 years and older, along with data collection, took place on the same day, typically in the school hall. Students who were interested in participating were presented with an electronic information sheet and consent form to review and were allowed to ask questions before consenting to participate. Students aged under 16 were recruited by the schools prior to data collection, as parental/whanau consent was required.

Participants were allocated a unique code to de-identify their personal information. This unique code was entered when answering the demographic questionnaire and when completing Intake24 (an online 24-hour recall).

3.5 Data Collection

3.5.1 Dietary assessment

Dietary assessment was completed using an electronic multiple-pass 24-hour recall (MP24HR) programme called Intake24. Intake24 was initially developed in the United Kingdom and has been used in various countries to collect dietary data in nutrition studies (87). Intake24 was adapted to improve the suitability for the NZ population research (88). These improvements included compiling a list of 2621 foods and brands that are commonly consumed by the NZ population, such as traditional Māori, Pasifika, and Asian foods (88); and creating new portion size images where items were lacking existing visuals, including NZ foods, brands and packaged foods (88). Foods were compiled using the food list from the Australian 2023 Nutrition and Physical Activity Survey, supplemented with an additional 2,618 foods from the New Zealand Food Composition Database, and familial recipes were matched to other food composition databases (88). Upon completion of the Intake24 modification, a convenience sample of 37 individuals, representing various ages, ethnicities, and genders, was collected. The purpose of this sample was to determine if participants could use the programme to record their dietary intake and to allow for further improvements where required (88). Participants reported that Intake24 was generally easy to use; however, several usability issues were identified, including challenges with the instructional video, search functionality, and portion size estimation. These issues were addressed by revising food categories and adjusting portion size options to improve accuracy and user experience [19].

Within the current study and prior to data collection, researchers provided a concise overview of the study and instructions for documenting the previous day's dietary intake from 12am to 12pm using Intake24, including examples of how to identify and enter the contents of a sandwich or lunch. Researchers were also available to assist participants with any questions or to help them locate specific foods.

Intake24 includes prompts throughout to help participants remember all foods and drinks they consumed during the dietary intake period. It starts by asking participants to record the time they had each meal. Then, participants are prompted to add the foods and drinks they ate, which are matched against a predefined food list. If they can’t find their foods, they are directed to a food list within Intake24 where they can search using the available categories in Intake24. Participants see an image of various portions and select the portion size they consumed. Intake24 also reminds participants to recall any forgotten items, such as snacks, drinks, or items usually paired with meals they have chosen. Once finished, participants are asked to review their meal entries to ensure they have recorded their entire 24-hour intake before submitting.

3.5.2 Demographic questionnaire

An online demographic survey was developed as part of this study using national census variables. The information gathered included details about the participants' age, sex, ethnicity, school, and year of education. If the answer was not listed, an alternative “other” option was available with an open-text box to allow the answer to be specified. The demographic survey was translated into Māori for Kura (Māori immersion school).

3.6 Data Handling

The demographic questionnaire allowed participants to identify with multiple ethnicities. Where more than one ethnicity was selected, ethnicity prioritisation was used based on Statistics NZ ranking. The rankings were Māori, Pacific Peoples, Asian, other ethnicity, and NZ European (93)

Dietary intake data obtained from Intake24 were exported to Microsoft Excel for processing and analysis. The mean daily intake of each nutrient was calculated for all participants. Adherence to nutrient recommendations was assessed in accordance with the Estimated Average Requirement (EAR) values outlined in the Australian and New Zealand Nutrient Reference Values. Nutrient intakes were expressed in grams per day for each participant. Data were examined for implausible energy intakes, and participants with reported energy intakes below 2092 kJ/day or above 20920 kJ/day were excluded from the analysis.

3.7 Statistical analysis

For the wider study objectives, a sample size of 631 was adequate. Descriptive statistics were generated for participant characteristics and dietary intake data. The Central Limit Theorem was applied, and the data was assumed to be normally distributed for the statistical tests. Continuous data was reported as mean and standard deviation, with categorical data expressed as percentages. Independent t-tests were used for parametric data and chi-squared tests were used for categorical data. IBM SPSS Statistics version 30 was used for all statistical analyses.

3.8 Results

3.8.1 School recruitment and participant demographics

A total of 631 adolescents from 16 schools participated in the study. Participants with incomplete data (n=67) were excluded for missing age. Additionally, participants aged 9–13 years (n=37) were excluded because of insufficient sample size within this age group. The final analysis included 527 participants (Table 4) aged 14-18 years. Of the participants, (n=370, 70.2% were female) and (n=157, 29.8%) were male. The mean (SD) age of all the participants was 16.3 (±1.1) years. Most participants identified as Māori (32.0%) or NZ European (31.8%), followed by Pacific Peoples (20.3%), Asian (13.4%), Middle Eastern, Latin American, and African (MELAA) (1.3%), other (0.1%), and not stated (0.9%). Geographically, most respondents were from Auckland (36.9%), the Bay of Plenty (36.6%), and Waikato (21.4%), with 5.1% not stating their location.

Table 1: Demographic characteristics of participants

Characteristics	Total	Male	Female	p-value
Participants, n (%)[1]	527 (100)	157 (29.8)	370 (70.2)	<0.001
School region, n (%)[1]				0.008
Waikato	113 (21.4)	36 (22.9)	77 (20.8)	
Bay of Plenty	193 (36.6)	41 (26.1)	152 (41.1)	
Auckland	195 (36.9)	68 (43.3)	126 (34.1)	
Not stated	27 (5.1)	12 (7.6)	15 (4.1)	
Equity index group, n (%) [1]				<0.001
Low	101 (19.1)	11 (7.0)	90 (24.3)	
High	400 (75.8)	134 (85.4)	265 (71.6)	
Not stated	27 (5.1)	12 (7.6)	15 (4.1)	

Age years (SD)[2] 14 and over	16.3 (1.1)	16.6 (0.9)	16.1 (1.1)	<0.001
Ethnic Group, n (%)[1]				<0.001
NZ European	168 (31.8)	33 (21.0)	135 (36.5)	
Māori	169 (32.0)	53 (33.8)	115 (31.1)	
Pacific Peoples	107 (20.3)	48 (30.6)	59 (15.9)	
Asian	71 (13.4)	20 (12.7)	51 (13.8)	
MELAA	7 (1.3)	2 (1.3)	5 (1.4)	
Other	1 (0.1)		1 (0.3)	
Not stated	5 (0.9)	1 (0.6)	4 (1.1)	

Abbreviations: MELAA = Middle Eastern, Latin American and African,

[1] Chi Squared test [2] Independent t test

3.8.2 Adherence to Nutrient Reference Values

Macronutrients

Table 2 provides an overview of the macronutrient intake of participants, the recommended intakes for adolescents based on sex, the number and percentage of participants meeting these recommendations and the percentage of participants meeting the macronutrient total energy recommendations.

The results revealed distinct dietary patterns among New Zealand adolescents, with notable differences between male and female participants. Males reported higher mean energy intakes (9862.7 kJ/day) compared with females (8176.8 kJ/day), reflecting greater energy requirements due to larger body size and higher activity levels typically observed in males. Carbohydrates contributed within the recommended range of total energy intake (45–65%) for most participants; however, a higher proportion of females (71.1%) met this recommendation compared with males (55.4%), suggesting that male participants may have relatively higher energy intakes coming from protein and fat.

Fibre intake was suboptimal across both sexes, with mean intakes of 19.2 g/day for females and 20.7 g/day for males and only one-third of females and one-quarter of males achieved the recommended levels. This indicates insufficient consumption of fibre-rich foods such as fruits, vegetables and whole grains, which are essential for maintaining gastrointestinal health and preventing long-term chronic disease risk.

Protein intake was substantially higher than the recommendations, with nearly all participants exceeding the AMDR of 15–25% of total energy intake. This pattern suggests that adolescents in this sample consumed diets high in protein-rich foods, possibly from meat, dairy, or other protein products such as protein powders or protein bars. Although such intakes exceed recommendations, they are unlikely to pose health risks in healthy adolescents and instead reflect adequate or excessive energy intake from protein sources.

Fat intake showed recommendations were met, with around half of participants meeting the AMDR of 20–35% of energy. However, very few adolescents (females 9.7%, males 7.0%) achieved the guideline of less than 10% of total energy from saturated fat, indicating a high intake of energy-dense, processed, or fast foods.

Overall, these results demonstrate that while adolescents generally consumed sufficient energy and protein, dietary quality remains a concern due to inadequate fibre intake and excessive saturated fat consumption.

Table 2: Macronutrient intake of participants, macronutrient recommendations and number of participants meeting the recommendations.

Nutrient	Mean Intake (SD)		Recommended intakes		N (%) meeting the recommendations	
	Female	Male	Female	Male	Female	Male
Energy						
Total (kJ/day)	8176.8 (4005.4)	9862.7 (4576.3)				
Carbohydrate						
Total (g/day)	231.1 (121.4)	270.3 (149.5)				
% total energy intake			45-65[1]	45-65[1]	263 (71.1)	87 (55.4)
Fibre (g/day)	19.2 (11.2)	20.7 (12.5)	22[2]	28[2]	123 (33.2)	39 (24.8)
Protein						
Total (g/day)	76.8 (44.3)	105.8 (61.6)	45[3]	65[3]	281 (75.9)	105 (66.9)
% total energy intake			15-25[1]	15-25[1]	362 (97.8)	154 (98.0)
Fat						
Total (g/day)	75.6 (45.4)	89.6 (51.7)				
% total energy intake			20-35[1]	20-35[1]	193 (52.2)	73 (46.5)
Saturated fat (g/day)	29.8 (20.1)	35.1 (22.5)				
(n= saturated fat % total energy intake)			<10%	<10%	36 (9.7)	11 (7.0)

[1] NRVS: Acceptable Macronutrient Range, [2] Fibre from AI in NRVs, [3] NRVs: Protein Recommended intakes

Micronutrients

Table 3 presents the participants' micronutrient intake and the proportion of participants whose intake met the EAR. Appendix A shows the Recommended Daily Intakes (RDI) and the percentage of participants meeting the RDI.

Overall, the micronutrient intakes of New Zealand adolescents varied considerably by nutrient and sex, with males generally reporting higher mean intakes than females. Despite this, a large proportion of both sexes did not meet the Estimated Average Requirements (EARs) for several key micronutrients.

Iron intake averaged 9.8 mg/day for females and 12.3 mg/day for males, with just over half of females (53.8%) and two-thirds of males (66.9%) meeting the EAR, indicating that iron remains a nutrient of concern, particularly for adolescent girls due to increased physiological requirements. Calcium intake was notably low, with mean intakes of 721.9 mg/day for females and 868.3 mg/day for males; only 20.3% of females and 31.2% of males achieved the recommended 1050 mg/day, highlighting calcium as one of the most inadequate nutrients across both sexes.

For magnesium, only around one-third of females (34.3%) and two-fifths of males (41.4%) met recommendations, suggesting suboptimal intake of whole grains, nuts, and vegetables, which are key magnesium sources. Selenium intake showed wide variability, with less than half of females (43.0%) and just over half of males (52.2%) meeting the EAR.

Overall, participants' B-vitamin intake met recommendations more consistently than other micronutrients. Thiamine requirements were met by over half of participants (58.4% of females and 62.4% of males), while vitamin B6 and B12 adequacy rates were high, with 79.2% and 64.9% of females and 82.8% and 80.9% of males meeting recommendations. Vitamin B3 intake was the most adequate of all micronutrients, with over 85% of both sexes meeting the EAR.

Intakes of potassium, zinc, and vitamin C were suboptimal, with fewer than half of participants meeting recommendations, suggesting low consumption of fruits, vegetables, and other micronutrient-rich foods. Vitamin A adequacy was also low, achieved by only 38.9% of females and 42.7% of males, while vitamin E intake was insufficient in over half of both sexes.

Collectively, these findings indicate that while intakes of some B-vitamins and protein-related nutrients such as vitamin B3 and vitamin B6 were adequate, calcium, magnesium, iron (particularly for females), potassium, vitamin A, vitamin E and fibre remain key nutrients of concern in this adolescent population. These results reflect an overall pattern of energy-sufficient but micronutrient-poor dietary intake among New Zealand adolescents.

Table 3: Micronutrient intake, micronutrient intake recommendations, and percentage meeting the EAR

Nutrient	**Mean Intake (SD)**		**EAR/AI**		**N (%) Meeting the EAR**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
Iron (mg/day)	9.8 (6.1)	12.3 (8.0)	8	8	199 (53.8)	105 (66.9)
Calcium (mg/day	721.9 (463.6)	868.3 (691.5)	1050	1050	75 (20.3)	49 (31.2)
Magnesium (mg/day)	270.3 (146.3)	311.0 (163.1)	300	340	127 (34.3)	65 (41.4)
Selenium (µg/day)	189.3 (1042.3)	635.6 (4223.3)	50	60	159 (43.0)	82 (52.2)
Thiamine (mg/day)	1.4 (1.2)	1.8 (1.8)	0.9	1.0	216 (58.4)	98 (62.4)
Potassium (mg/day)	2536.3 (1419.5)	2979.8 (1799.3)	2600	3600	144 (38.9)	47 (29.9)
Zinc (mg/day)	8.8 (5.2)	12.1 (7.4)	6	11	240 (64.9)	76 (48.4)
Vitamin B12 (µg/day)	3.8 (3.3)	6.4 (6.3)	2.0	2.0	240 (64.9)	127 (80.9)
Vitamin C (mg/day	103.2 (169.8)	119.5 (262.8)	28	28	147 (39.7)	63 (40.1)
Vitamin A (µg/day)	507.8 (477.2)	617.7 (650.36)	485	630	144 (38.9)	674 (42.7)
Vitamin B3 (mg/day)	31.65 (20.0)	48.18 (35.9)	11	12	324 (87.6)	148 (94.3)
Vitamin E (mg/day)	8.8 (6.2)	9.8 (6.9)	8	10	162 (43.8)	62 (39.5)
Vitamin B6 (mg/day)	2.6 (2.6)	4.0 (4.7)	1.0	1.1	293 (79.2)	130 (82.8)

Abbreviations: EAR= Estimated Average Requirement, AI= Adequate Intake

3.9 Discussion

3.9.1 Key findings of results

This study aimed to assess the nutrient intake of NZ adolescents and compare them with the nutrient reference values for Australia and New Zealand. Adherence to macronutrient recommendations was higher among female participants, with over 70% meeting the recommended carbohydrate and protein intakes, compared with 55–67% of male participants. In contrast, fibre intake was substantially below recommended levels for both sexes, with only 33% of females and 24.8% of males meeting the dietary guidelines. This finding suggests insufficient consumption of fruits, vegetables, grains and other fibre-rich foods within the study population.

Overall, a greater proportion of male participants met the micronutrient recommendations compared with females. Among micronutrients, calcium and potassium exhibited the lowest nutrient adherence, with only 20.3% of females and 31.2% of males achieving adequate calcium intake. This is especially concerning given calcium's essential role in skeletal development, with peak bone mass typically reached by the end of adolescence. Conversely, B vitamin intake demonstrated the highest adherence, with over 80% of participants in both sexes meeting the recommendations, likely reflecting the contribution of food fortification, particularly in breakfast cereals.

3.9.2 Dietary intake of adolescents

Protein, fat and carbohydrate intakes were consistent with previous studies, such as the NZ Adult Nutrition Survey (11), where mean intakes exceeded the recommended intakes. International studies showed similar intakes exceeding the recommendations, as seen in the 2015 Canadian Community Health Survey (77), 2017-2018 What We Eat in America study (94) and the 2019 Ireland study (76).

The NZ Acceptable Macro Distribution Range (AMDR) requirements are set above the required 10% of energy coming from protein for optimal physiological functioning of the human body [5]. Recommended protein intakes of 15–25% of total energy was achieved by 179 (48.4%) females and 81 (51.6%) males. Among female participants, 8 (2.2%) consumed less than the minimum recommendation of 15%, 15 (4.1%) were within the recommended range and 347 (93.8%) exceeded 25% of total energy from protein. Similarly, among males, 3 (1.9%) were below 15%, 4 (2.5%) were within the recommended range and 150 (95.5%) exceeded 25% of energy from protein. The consistently high protein contribution across sexes indicates that adolescents are easily meeting protein requirements, likely due to sufficient overall energy intake.

Excessive carbohydrate consumption in NZ and globally is primarily driven by dietary patterns and cultural foods. High refined carbohydrate consumption, including white bread, sugary drinks and snacks, contributes to the high energy intake. Foods such as taro and rice are energy-dense but nutrient-poor foods and are often cheaper at supermarkets. Marketing also targets adolescents, influencing dietary choices and promoting frequent consumption.

Energy from total fat was met by 370 (95.1%) of females and 153 (97.4%) of males. Among female participants, 18 (4.9%) were below the minimum of 20% energy intake, 44 (11.9%) were within the recommended 20-35%, and 308 (83.2%) exceeded the maximum 35% energy intake. Among male participants, 4 (2.5%) were below the minimum of 20%, 11 (7.0%) were within the recommended 20-35%, and 142 (90.4%) exceeded the maximum 35% energy intake.

Mean saturated/ trans-fat intakes were similar to the results seen in the 2008 NZ Adult Nutrition Survey and in the 2017-2018 What We Eat in America (94).

Energy from saturated/ trans-fat was met by 36 (9.7%), with 334 (90.3%) over the recommendations of under 10% for female participants. Of male participants, only 11 (7.0%) were correctly consuming the recommendations of under 10% with 146 (93%) being over.

Saturated fat intake during adolescence is a concern as excessive consumption is linked to elevated cholesterol levels and an increased risk of heart disease, stroke and obesity later in life (95).

Mean fibre intakes were below the adequate intake recommendations. Similar results were seen in previous studies, such as the NZ Adult Nutrition Survey (11) and the 2002 NZ Children's Survey (10). It is concerning that approximately only one-third of females and one-quarter of males met the recommended fibre intake. These results align with international studies, such as the 2015 Canadian study (77), the 2019 Ireland study (76) and the 2017-2018 What We Eat in America in adolescents (94)

The results may suggest that NZ adolescents have a low intake of fruits and vegetables. The Children's Dietary Habits support this study from the 2019/20 New Zealand Health Survey, which showed only 40.4% of 10–14-year-olds met the 5 servings of fruit and vegetable intake (64).

Calcium, magnesium and potassium intakes were consistent with previous NZ studies, such as the 2020 Sundial studies (16), (14) and NZ Adult Nutrition Survey (11), where intakes were below the EAR. International studies reported similar results with low intakes of these essential nutrients, but also a high percentage of nutrient inadequacy. These can be seen in the 2015 Canadian Community Health Survey (77), 2017-2018 What We Eat In America (94) and the 2019 Ireland study (76).

Particularly of concern was calcium, where the number of adolescents meeting the requirements was significantly low at 20.3% of females and 31.2% of males. Similar results were seen in the 2020 Sundial studies. This could be a result of the push to a more plant-based diet, where foods are not calcium-fortified (92). Low calcium intake in adolescents is a concern, as research shows that calcium plays a protective role in chronic inflammatory diseases and in autoimmune conditions (96). Peak bone mass is reached towards the end of adolescence and a low calcium intake during this period also increases the risk of osteoporosis and fractures later in life (96).

The low intake of magnesium observed in this population is concerning, with only 34.3% of females and 41.4% of males meeting the Estimated Average Requirement (EAR). Magnesium plays a critical role in numerous physiological processes, including energy metabolism, muscle and nerve function, and the maintenance of bone health. Insufficient intake during adolescence, a period of rapid growth and increased nutritional needs, may therefore have implications for long-term health. One possible contributing factor to these low intakes is the limited consumption of magnesium-rich foods, such as whole grains, nuts, seeds, legumes, and green leafy vegetables [28]. Dietary patterns that favour refined and processed foods over whole, minimally processed options can exacerbate this issue. For example, the refining process of staple grains such as rice and wheat removes much of their natural magnesium content, reducing the overall dietary supply of this essential mineral [28].

When examining the adolescents who met the requirements for potassium, only 38.9% of females and 29.9% of males achieved the EAR. Low potassium intake in this age group is often associated with an intake that is low in fruit and vegetables which are primary sources of potassium (28). Irregular meal patterns, a common behaviour during adolescence due to lifestyle factors such as school schedules, school activities and snacking habits can exacerbate low potassium intake (28). Insufficient potassium intake may have long lasting implications such as poor blood pressure, muscle function and may lead to long term cardiovascular disease (28).

Mean intakes for iron and zinc were above the EAR, which was consistent with the Sundial studies (13) and the 2008 NZ Adult Nutrition Survey (11). This is consistent with international studies such as the 2015 Canadian study (77), the What We Eat in America and the 2019 Ireland study (76). The international studies reported that the highest rate of nutrient inadequacies is the iron intake of adolescent girls aged 14-18 years.

A low iron intake increases the risk of developing anaemia with its associated effects, including compromised growth, decreased cognitive function and depressed immune function (29). The results of this study showed that 53.8% of females and 66.9% of males met the EAR for iron. These results showed a decrease compared to the 2020 Sundial studies, which had 79.2% (13). This is of concern as iron requirements increase significantly in females during adolescence with the onset of menses and in males with the increase in lean body mass.

One contributing factor to the low intakes observed in New Zealand and internationally is the decline in consumption of red meat and other haem iron sources, which are highly bioavailable forms of iron (92). At the same time, there has been an increased reliance on plant-based foods that primarily provide non-haem iron, which has lower absorption efficiency (92). This shift in dietary patterns contributes to suboptimal iron status among adolescents, particularly females.

Zinc intake among the adolescents in this study shows a notable disparity between sexes, with 64.9% of females meeting the (EAR) compared with only 48.4% of males. Zinc is an essential trace mineral that plays a key role in growth, immune function, wound healing, and reproductive development processes that are particularly critical during adolescence. The lower proportion of males meeting the EAR may be partly explained by their higher zinc requirements during this period of rapid growth. Dietary factors also contribute to inadequate zinc intake. Adolescents may consume fewer zinc-rich foods such as seafood, nuts, seeds, and legumes, either due to dietary preferences, cost, or adherence to plant-based diets, which are generally lower in bioavailable zinc. Additionally, the high consumption of processed foods, which are typically low in zinc, may further reduce overall intake. Plant-based sources of zinc contain phytates, compounds that inhibit zinc absorption, meaning that even if adolescents consume legumes or whole grains, the bioavailability of zinc may still be limited.

Vitamin A and Vitamin E intakes were above the EAR for females and just below the EAR in males. These findings were consistent with the 2008 NZ Adult Nutrition Survey and are consistent with international studies, 2017-2018 What We Eat in America survey (94) and the 2019 Ireland Teens study (76).

Adherence to the recommended intake of vitamin A was low among participants, with only 38.9% of females and 42.7% of males meeting the recommendations. Low adherence to recommendations may reflect adolescent dietary patterns with low consumption of beta carotene-based vitamin A, which is found in fruit and vegetables such as dark leafy vegetables and carrots and retinol-based vitamin A sources, which are animal-based, such as oily fish and cheese. Adequate vitamin A intake is essential for bone development, immune function and reproductive maturation that occurs during adolescence. Consequences of a poor intake leads to an increase in susceptibility to infections and delayed growth.

Vitamin E adherence was low, with 43.8% of females and 39.5% of males meeting the recommendations. Vitamin E is a fat-soluble antioxidant that plays a critical role in supporting cell membrane integrity, immune function and protection against oxidative stress associated with rapid growth and increased metabolic activity. Vitamin E acts as a major chain breaking antioxidant that prevents lipid peroxidation in cell membranes. Low adherence reflects a low intake of vitamin E rich foods such as nuts, seeds, vegetable oils and green leafy vegetables. A low intake of healthy fats can impair the absorption of vitamin E. Insufficient vitamin E intake may lead to a reduced immune system, neuromuscular problems and an increase in oxidative damage

B Vitamins

Mean intakes of vitamins B3, B6, and B12 were substantially above the Estimated Average Requirement (EAR), consistent with findings from the 2008 New Zealand Adult Nutrition Survey (11). The Sundial study also reported a slight increase in vitamin B12 intake among females (17). Compared with international data from 2017-2018, What We Eat in America (94) and the 2019 Irish study (76), intakes of vitamins B6 and B12 were comparable, while vitamin B3 intake in this cohort was approximately double that observed in the American study (94).

Overall, adherence to dietary recommendations was high, with over 80% of participants meeting the EAR for these nutrients. One reason for the high rates of nutrient adequacy could be the food fortification of B vitamins in cereals in New Zealand.

Selenium

Mean selenium intake was more than double the EAR. The findings were also significantly higher than the results seen in the 2008 NZ Adult Nutrition Survey (11). A possible reason for this could be that participants of our study were from the North Island, specifically Auckland, Waikato and Bay of Plenty, where selenium intake is higher due to the routine use of imported wheat from Australia, which has a higher concentration of selenium. In the South Island of New Zealand, bread is made from locally grown wheat, which has been proven to have reduced selenium content (97). Another consideration is the geographical location of the participants, e.g. in Auckland, there is a greater intake of fish and poultry, which are high in selenium, as seen in Pacific Peoples (97).

Limited international data on selenium intake is available due to the higher selenium content in the soil and consequently, inadequate dietary intake of selenium is less of a concern.

Overall, the study demonstrated a high prevalence of nutrient deficiencies within the adolescent population. Although some adolescents met the EAR requirements, the proportion achieving adequacy remained below 50% for several key nutrients critical to adolescent growth and development, including iron and calcium. Calcium had one of the lowest intakes in relation to recommendations, with only 20.3% of females and 31.2% of males meeting the EAR requirements. Vitamin B6 and vitamin B3 had the highest adherence to the nutrient recommendations, where 87.6% of females and 94.3% of males met the recommendations for vitamin B3 and 79.2% of females and 82.3% of males met the vitamin B6 recommendations.

When compared with international studies, the nutrient intake of New Zealand adolescents was generally similar to or higher than that reported in other countries. However, intakes for most micronutrients remained well below recommended levels. When compared to international studies, the continuation of high nutrient inadequacies shown in this study was also prevalent, which was further confirmed in a global analysis of nutrient inadequacy in 2024, which reported that 67% of the world's population had insufficient intakes of vitamin E, 66% for calcium, 65% for iron, and 53% for vitamin C [31]. The study also found that women were more likely to have inadequate intakes of vitamin B12, iron, and selenium, while men showed higher inadequacies in magnesium, vitamin B6, zinc, vitamin C, vitamin A, thiamine, and vitamin B3 (98). These nutrient shortfalls may begin during adolescence, a period often characterised by increased consumption of convenience and ultra-processed foods, meal skipping, and meal replacements with snack foods that are typically low in magnesium and other essential micronutrients [31].

When compared with international studies, it is important to look at the year the research was conducted, the differences in nutrient recommendations between the countries and NZ and the dietary assessment methods used in the studies.

When looking at the results of studies, it is important to investigate the socio-economic factors of households. Over the last five years, there have been events such as the COVID-19 pandemic and the increased cost of living. There has been an increase in food and energy prices, which has put added financial pressure on households to provide nutritious food. All of these factors could have contributed to a poorer quality of the adolescent's diet and lack of food security leading to an intake that is below overall energy requirements.

Strengths and Limitations

One of the study's strengths is that the participants came from a range of ethnicities. Secondly, the 24-hour multiple pass method was the dietary assessment method used, which is one of the most effective dietary methods for adolescents (85). Similarly, the use of Intake24 in this study was one of the first studies in NZ that used this advanced technology, which had been adapted to the NZ population (88) and the use of technology-based data collection may have been more engaging for the participants (99).

The study's limitations included the inability to obtain a second 24-hour recall from a subgroup of adolescents. An additional 24-hour recall would have enabled a more accurate assessment of the dietary intake of NZ adolescents. Another study limitation is the participants' ability to accurately recall what they consumed over the 24 hours. Adolescents tend to misreport their food intake, which is often influenced by factors such as a lack of motivation and the desire to appear socially desirable (100).

Other comparable studies have used different dietary assessments such as the 2019 Ireland study. The study used a 4-day weighed food record, whereas this study used Intake24 to record the intake. The 4-day weighted food record may have been more accurate in recording portion sizes. However, it places the burden on participants to accurately weigh their food, meaning participants need to have adequate literacy and numeracy skills. In contrast, Intake24 uses pictures of various food items, allowing participants to indicate the portion they believe they consumed (82).

Another limitation of this study was the unequal ratio of female and male participants, with 370 females compared to 157 males. This imbalance may have influenced the overall results and reduced the generalisabilty of the findings to the wider adolescent population. The higher proportion of females could have skewed the mean nutrient intakes and the proportion meeting dietary recommendations, particularly for nutrients that differ by sex, such as iron and calcium. Consequently, the results may more accurately reflect female dietary patterns and nutrient adequacy than those of males, limiting the ability to draw balanced comparisons or apply the findings to both genders equally (100)

3.10 Conclusion

The study provides valuable and updated insights into the dietary intake and nutrient inadequacy of New Zealand adolescents. The findings reveal that macronutrient intake, particularly protein and fat, generally exceeded recommendations, while several micronutrients, most notably calcium, magnesium, vitamin A and vitamin E remained below the EAR for the majority of participants. These results highlight persistent nutrient inadequacies consistent with both previous national and international trends, suggesting that adolescent diets continue to be high-energy-dense, nutrient-poor with insufficient intake of fruits, vegetables and dairy products.

The study also highlights the need for targeted public health strategies and nutrition education, such as school based nutrition programs to learn about the key nutrients, fortification of food with iron and calcium and improving access to healthy foods such as GST-free fruit and vegetables. Additionally, a sugar tax on fizzy drinks, which will help to address the shortfalls and to promote healthier dietary behaviours during adolescents

Chapter 4: Discussion

Conclusion and Recommendations

4.1 Achievement of aims and objectives

The study aimed to determine and compare the nutrient intake of NZ adolescents with the nutrient reference values for Australia and New Zealand. The objectives of the study were

1) to determine the macronutrient intake of NZ adolescents, including total fat, saturated fat, carbohydrate, protein and fibre intake using Intake24.

2) to determine the intake of 13 selected micronutrients of NZ adolescents using Intake24.

3) to determine the nutrient intake adequacy of NZ adolescent by comparing their macronutrient and micronutrient intake to the NRVs.

Female participants demonstrated greater adherence to the recommended macronutrient distribution, with over 70% meeting the carbohydrate and protein guidelines compared to 55–67% of males. Despite this, fibre intake remained notably inadequate across both genders, with only 33% of females and 24.8% of males meeting the recommended levels. This finding reflects a generally low intake of fruits, vegetables, and other fibre-rich foods among adolescents, which may be influenced by dietary preferences, limited access to fresh produce, and the increasing consumption of convenience foods.

Fat intake also raised concerns, as only 52.2% of females and 46.5% of males met the recommended levels, while the remaining participants consumed amounts exceeding the guidelines. High intakes of total fat, particularly saturated and trans fats, were evident, with only 9.7% of females and 7.0% of males meeting the guideline of less than 10% of total energy from these fats. These results suggest a dietary pattern characterised by excessive consumption of energy-dense, processed foods and a possible reliance on takeaway or packaged options, which are commonly high in saturated and trans fats. Such patterns are concerning, given the association between high saturated fat intake and increased risk of obesity and cardiovascular disease later in life.

Overall, a greater proportion of male participants met the micronutrient recommendations compared with females. Nutrients of concern included calcium, vitamin A, vitamin C, vitamin E, potassium and magnesium, with intakes substantially below recommended levels, as fewer than 50% of participants met the respective guidelines. Iron, another critical nutrient during adolescence due to its role in growth and red blood cell production, was also insufficient for many participants, with only 53.8% of females and 66.9% of males meeting the recommendations. Calcium demonstrated the lowest adherence, with just 20.3% of females and 31.2% of males achieving adequate intake. In contrast, B vitamins, particularly vitamin B3 and vitamin B6, showed the highest compliance, with 87.6% of females and 94.3% of males meeting the vitamin B3 requirements, likely reflecting the benefits of food fortification and the frequent consumption of fortified products such as breakfast cereals and breads.

The hypothesis that more than 50% of New Zealand adolescents would not meet the NRVs for macronutrients and micronutrients was not supported. Overall, more than 50% of adolescents met the nutrient recommendations for most macronutrients and micronutrients. However, certain nutrients such as calcium, vitamin C and magnesium remained well below recommended levels for a substantial proportion of adolescents.

Interpretation and reasoning:

The hypothesis was not supported as fewer than half of the adolescents failed to meet the NRV's for most nutrients. The findings suggest that while some nutrient inadequacies remain, overall dietary intake among New Zealand adolescents may be closer to recommendations than expected.

Persistent inadequacies in nutrients such as calcium, vitamin C and magnesium highlight areas of concern, particularly given their importance for bone health, immune function and energy metabolism during adolescence. These results indicate that specific deficiencies still require public health attention.

4.2 Research impact

This research provides valuable insights into the nutrient intake of adolescents in Auckland, Bay of Plenty, and Waikato. The study found a high rate of nutrient inadequacy among NZ adolescents in key nutrients vital at this stage of life. The findings indicate it is possible that the NZ adolescents' diet lacks variety and quality and is insufficient in the main food groups. This may lead to low fruit and vegetable consumption, meal skipping, and excessive intake of ultra-processed foods, which are common in this population.

The findings could be used to inform policy changes, such as targeted initiatives to increase the nutrient intake of NZ adolescents. Ideas include school-based initiatives to improve students' knowledge and behaviours around healthy eating and healthier choices. Initiatives such as healthier school lunches, ensuring that adolescents are eating healthy and nutritious lunches. The introduction of a sugar-sweetened beverage tax to stop adolescents from consuming sugar-loaded drinks and improve front-of-pack labelling, where consumers are more informed of what foods are healthy and nutritious and which ones are not. Restricting the marketing of unhealthy foods to adolescents in and around schools so that adolescents are not influenced to consume these. Strengthening nutrition education in schools, teaching adolescents as well as young people cooking and food literacy skills early. Supporting community-based nutrition programs that develop families' knowledge and education around nutrition and balanced meals.

4.3 Strengths

The study has several strengths, including a diverse range of adolescent ethnicities who participated, particularly Māori and Pacific Peoples. The study used the 24-hour recall as a dietary assessment method, which helps reduce underreporting (100). It also utilised the Intake24 program, allowing students to review their entries and see photos of their portion sizes before submitting. This study was one of the first to use Intake24 in a nutritional study in NZ.

4.4 Limitations

One limitation of the study was not being able to repeat a second 24-hour recall, which would have allowed us to assess the usual nutrient distribution and prevent bias. Therefore, some conclusions from the findings may not be able to be drawn from our results.

A further limitation is that when working with adolescents, there is an increased likelihood that adolescents to underreport their energy intake (100). During adolescence, this age group is taking more responsibility for their dietary intake, which can lead to irregular eating patterns and an increase in intake (100). Adolescents are more concerned about their body image, with people who are obese and female tending to underreport (100).

4.5 Recommendations for further research

The research provides an overview of the nutrient intake of adolescents living in the Auckland, Waikato and Bay of Plenty regions, highlighting the extent of nutrient inadequacies among them.

Research in this age group would be beneficial, given the high rates of deficiency that were found in this population in this study, as well as the significant gaps in the current evidence base. The most recent comprehensive investigation into the nutritional status of NZ adolescents was the NZ Children's survey conducted in 2003. Since then, there have been a limited number of smaller-scale studies undertaken, such as the Sundial studies, which had limited participants. This restricts the generalisation of the findings to the adolescent population as a whole. An urgent Nutrition Survey is essential to provide up-to-date data on the nutritional status of NZ adolescents.

The lack of a second 24-hour diet recall limits what conclusions can be drawn from the research and would provide an area for further study. Any further research in this population should consider the dietary assessment method. If using a 24-hour recall, ensure that a second 24-hour recall is also collected. Future research could explore the barriers to healthy eating among adolescents to better understand the social, environmental and behavioural factors influencing dietary choices. Interventions could focus on nutrition education targeting key nutrients of concern, such as iron and calcium and highlight the long-term health implications of inadequate intake. Further studies should also consider the inclusion of biochemical measures to assess nutrient status, particularly for nutrients not captured through dietary recall, such as vitamin D. This would provide a more comprehensive understanding of adolescent nutritional health.

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Appendix A: Table of participants meeting the RDI

Nutrient	Mean Intake (SD) Female	Male	Recommended Daily Intake Female	Male	N (%) Meeting the RDI Female	Male
Iron (mg/day)	9.8 (6.1)	12.3 (8.0)	15	11	66 (17.8)	73 (46.5)
Calcium (mg/day	721.9 (463.6)	868.3 (691.5)	1300	1300	49 (13.2)	29 (18.5)
Magnesium (mg/day)	270.3 (146.3)	311.0 (163.1)	360	410	82 (22.2)	43 (27.4)
Selenium (µg/day)	189.3 (1042.3)	635.6 (4223.3)	60	70	119 (32.2)	69 (43.9)
Thiamine (mg/day)	1.4 (1.2)	1.8 (1.8)	1.1	1.2	152 (41.1)	82 (52.2)
Potassium (mg/day)	2536.3 (1419.5)	2979.8 (1799.3)				
Zinc (mg/day)	8.8 (5.2)	12.1 (7.4)	7	13	208 (56.2)	57 (36.3)
Vitamin B12 (µg/day)	3.8 (3.3)	6.4 (6.3)	2.4	2.4	211 (57.0)	119 (75.8)
Vitamin C (mg/day	103.2 (169.8)	119.5 (262.8)	40	40	175 (47.3)	74 (47.1)
Vitamin A (µg/day)	507.8 (477.2)	617.7 (650.36)	700	900	80 (21.6)	32 (20.41)
Vitamin B3 (mg/day)	31.65 (20.0)	48.18 (35.9)	14	16	299 (80.8)	137 (87.3)
Vitamin E (mg/day)	8.8 (6.2)	9.8 (6.9)				
Vitamin B6 (mg/day)	2.6 (2.6)	4.0 (4.7)	1.2	1.3	265 (71.6)	120 (76.4)