Protein Intake and Dietary Sources in Adolescents Aged 14–19 Years: Insights from the Auckland, Waikato, and Bay of Plenty regions of New Zealand

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Abstract

Background

Adolescence is a critical period of growth and development, increasing the need for adequate protein intake and quality protein sources to support growth and developmental changes. However, current data on protein intake and protein sources among New Zealand (NZ) adolescents are outdated, particularly given recent shifts in dietary patterns and food environments.

Aims and objectives

This research aimed to investigate the current protein intake and sources of NZ adolescents and compare protein intake with the Nutrient Reference Values to assess adherence to dietary recommendations.

Methods

The data for this research was obtained through the Te Rourou Kai o Ngā Rangatahi: Eating Patterns of Young People in NZ study. This cross-sectional study gathered dietary data from 266 students aged between 14 to 19 years in the Auckland, Waikato, and Bay of Plenty regions of NZ using an electronic multiple pass 24-hour dietary recall, and demographic questionnaire. Dietary data were linked to a preexisting nutrient database and categorised into food groupings to determine protein intake and sources. Protein adequacy was assessed by comparing protein intakes of adolescents with the Nutrient Reference Values for Australia and NZ. Protein intake results were expressed as mean ± standard deviation (SD) for continuous values and as number (percentage) for categorical values. Contributions of each food group to protein intake were reported as both percentage ± SD and grams ± SD.

Results

Participants (n=266, 68.0% female) had mean protein intakes of 98.5 ± 66.8 g/day for males and 70.1 ± 45 g/day for females which both exceeded the Estimated Average Requirement (EAR). Males consumed significantly more protein than females ($P < 0.001$). In total, 19.5% (n=52) of adolescents did not meet the EAR for protein. The percentage of total energy (%TE) from protein was 18.3 ± 8.1% for males and 16.2 ± 5.4% for females, both within but at the lower end of the acceptable macronutrient distribution range (AMDR) of 15-25%, with males showing a significantly higher protein contribution to energy intake (P = 0.035). A high proportion of females (44.2%) and males (36.9%) were below the AMDR. For all participants, the main sources of protein included meat and meat products (17.7 ± 25.7%, 17.6 ± 35.7g/d), burgers, pizza, and Mexican dishes (13.8 ± 26.4%, 9.6 ± 20.1g/d), pasta and rice dishes (9.8 ± 22.4%, 9.7 ± 27.9g/d), and bread and bread products (7.5 ± 13.7%, 5.5 ± 11.8g/d).

Conclusions

Protein sources for NZ adolescents include both plant and animal sources, with meat being the largest contributor. Animal proteins, such as meat, will provide high-quality, complete proteins within the adolescent diet. Our findings suggest some adolescents are consuming inadequate amounts of protein to meet their dietary needs. Further research is required with two non-consecutive 24-hour recalls verifying levels of inadequacy seen within this adolescent population.

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List of abbreviations

%	Percent
% TE	Percent total energy
</>	Less than/more than
± SD	Standard deviation
24 HR	24-hour recall
AMDR	Acceptable macronutrient distribution range
AR	Average requirement
BOP	Bay of Plenty
CV	Coefficient of variation
DG	Dietary goal
EAA	Essential amino acids
EAR	Estimated average requirement
EFSA	European Food Safety Authority
EQI	Equity index
FFQ	Food frequency questionnaire
FPQ	Food propensity questionnaire
g	Grams
g/d	Grams per day
g/kg bw/d	Grams per kilogram body weight per day
g/kg/d	Grams per kilogram per day
g/kg/IBW	Grams per kilogram of ideal body weight
GH/IGF-1	Growth hormone and insulin like growth factor
IGF-1	Insulin like growth factor
KJ	Kilojoules
MP24HR	Multiple pass 24-hour recall
n	Number
NRVS	Nutrient reference values
NZ	New Zealand
PRI	Population reference intakes
RDA	Recommended daily allowance
RDI	Recommended daily intake
RNI	Reference nutrient intake
UL	Upper level of intake
UPF	Ultra processed foods
USA	United States of America
Yrs	Years

Chapter 1: Introduction

In adolescence, nutrition is important in facilitating physiological, sexual, neurological, and behavioural changes (1). Beyond the demands of regular bodily functions, the processes associated with these changes impose additional energy and nutrient requirements (2). Puberty, for example, triggers alterations in body composition, including weight, height, bone and muscle mass, expansion of blood volume, and growth in vital organs like the heart, lungs, and kidneys (1).

One essential nutrient in adolescence is protein, as it actively supports muscle and bone development, maintenance (3), and sexual maturation (4). The regulatory Insulin-like growth factor 1 (IGF-1), abundant only when adequate protein is available, stimulates bone growth (3). Sustained enhancement of IGF-1 enables adolescents to achieve peak bone mass, thereby reducing osteoporosis risk in the future (5). Insufficient protein may lead to adverse effects on bone health, such as delayed skeletal growth and reduced mass, resulting in height stunting (5). Furthermore, environmental factors like malnutrition characterised by low protein and energy intake may also diminish levels of IGF-1, potentially delaying the onset of puberty and slowing the pace of pubertal progression (6). Throughout adolescence, lean mass increases from 25% of body weight at birth to 40-45% (6). Consequently, protein is therefore indispensable for meeting the demands of existing muscle mass while also supporting the accumulation of new muscle mass during periods of rapid growth (7).

Several nutrition surveys have previously assessed protein intake and its food sources among New Zealand (NZ) adolescents (8-10). Consistently, these studies found that the average protein intake among adolescents surpassed the Estimated Average Requirement (EAR) outlined in the Nutrient Reference Values (NRVs) (8-10). Protein inadequacy of this population in the past has been minimal (8,10). Common food sources of protein for NZ adolescents previously included bread-based dishes, bread, milk, grains, pasta, and poultry (8-10).

1.1. Purpose of the study

Current data on protein intake and sources among NZ adolescents is limited as the most recent study was conducted nearly five years ago (10). A recent dietary trend has been the transition towards more plant-based diets, driven by increasing consumer awareness of environmental sustainability and health concerns (11). The Eating and Activity Guidelines for NZ adults (including 14–18-year-olds) have been updated to align with this emerging scientific evidence (12). The protein food group is now referred to as legumes, nuts, seeds, fish and other seafood, eggs, poultry, and or red meat with the fat removed (12). Portion size recommendations for legumes and eggs have increased while serving sizes of lean meats have decreased highlighting a shift in the guidelines towards promoting plant-based diets (12). However, plant-based sources do not contain as much protein as meat sources and a variety of plant-based sources of protein must be consumed to obtain all essential amino acids (11).

There is limited data on the number of adolescents following vegetarian diets in NZ. However, between 2011 and 2015, those aged 14 to 24 years showed the largest increase in vegetarianism, rising by 55% from 8.6% to 13.3% (13). Given the continuing rise of plant-based eating globally an increase in the proportion of adolescents adopting this dietary pattern could be expected (14). Therefore, it is important to investigate the protein sources consumed by adolescents as adequate protein intake which includes sources of all essential amino acids will support growth and development during adolescence and long-term overall health (6). The data obtained from this research can be used as a direct reference for informing future policy decisions and implementing targeted interventions aimed at optimising the nutritional protein status of NZ adolescents.

1.2. Aim

To describe protein intake and food sources among adolescents aged 14-19 years living in the Auckland, Waikato, and Bay of Plenty areas of NZ

1.3. Objectives

To describe the protein intake of adolescents

To compare the protein intake of adolescents with the recommended intakes for adolescents

To investigate the dietary sources of protein consumed by adolescents

1.4. Structure of thesis

This thesis contains four chapters. The first chapter discusses the purpose of the thesis and the justification for the research. Chapter two contains the literature review, which includes an extensive overview of topics related to the research, such as demographic and nutritional trends among adolescents, the importance of protein for adolescents, current protein recommendations, dietary assessment methods, protein quality and amino acids, and protein intake and food sources of protein for adolescents. Chapter three is the research study written as a manuscript. This outlines each research component including the abstract, introduction, methods, results, discussion, and conclusions. The final chapter summarises the findings of the study, its strengths, and weaknesses, and makes recommendations for further research.

1.5. Researcher contributions

Researcher	Contribution to thesis
Jessica Barrar	**MSc Nutrition and Dietetic student** Author of the thesis and assisted in data collection and analysis.
Professor Kathryn Beck	**MSc main academic supervisor** Principle investigator for the study. Conceptualisation of the study design. Acquisition of funding, ethical approval, and oversight of all parts of the study. Provided feedback on all aspects of the thesis.
Professor Cathryn Conlon	**MSc academic Co-supervisor** Developed study protocol. Provided feedback on all aspects of the thesis.

Dr Jamie de Seymour	Developed study protocol and led data collection and analysis.
Jasmin Jackson	Assisted with the development of the study protocol and access to schools.
Laurie Wharemate-Keung	Provided cultural advice and guidance for the study. Assisted with the development of study protocol and access to schools.

Chapter 2: Literature review

This chapter provides a comprehensive review of recent literature concerning the demographic and nutritional trends among adolescents in New Zealand (NZ). It examines the role of protein in adolescent physiology and explores recommendations for optimal intake. Additionally, it addresses methodologies for assessing dietary protein intake and examines the classification and quality of proteins. Lastly, it reviews the current evidence on protein intakes of adolescents, comparing these to dietary recommendations, and examines protein food sources among adolescents both locally in NZ and globally.

2.1 Search strategy

This literature review was undertaken between the dates of December 2023 and July 2024 utilising databases Google Scholar and Discover. Only papers published between 1989 to 2024 were included to ensure relevance. Keywords such as "adolescen*", "child*", "Food habits", "Nutrition", "growth", "bone health", "amino acids", "Dietary protein", "Protein*", "puberty", "immunity", "nutrient reference values", "Dietary reference intakes", "dietary assessment methods", "dietary intake", "food and nutrition guidelines", "Nutrition survey", "protein intake", "animal protein", "plant protein", "food prices", "ultra processed foods", and "New Zealand" were used with Boolean operators AND and OR to broaden search results. Citation searching was used to find further relevant papers from those already identified. Additionally, theses from academic institutions and data from official government websites were accessed as needed to gather NZ-specific research or information.

2.2 Demographic and nutritional trends among adolescents

According to the latest 2023 census data, NZ had approximately 320,637 adolescents aged 15-19 years, making up 6.4% of the population (15). From 2018 to 2023, the adolescent population increased by 6.2% for those aged 15-19 years (15). In 2023 this adolescent group had the following ethnic breakdown: 213,030 Europeans, 83,340 Māori, 43,800 Pacific peoples, 49,497 Asians, 6,237 Middle Eastern/Latin American/Africans, and 2,808 other ethnicities (15). Geographically, adolescents were more concentrated in urban areas such as Auckland, Christchurch, and Wellington compared to rural regions (15).

In recent years, the diet quality of adolescents has worsened globally, with many not adhering to nutritional recommendations (16,17). Poor dietary habits like skipping meals, replacing meals with snacks, and increased meal consumption outside the home are commonly observed among adolescents worldwide (17). Adolescents' increased exposure to food fads, restrictive diets, and disordered eating behaviours, along with peer and social media influences, further increase nutritional risk (17).

Adolescence induces major developmental changes and lays the foundations for lifelong health (16). However, adolescents tend to be overlooked from global nutrition initiatives due to the perception that this period of life is a time of good health with lower levels of disease and illness (17). To prevent nutritional problems that could have lasting effects on public health in the future, it is essential to understand what adolescents are consuming now and the impact their dietary intake has on nutrient intake (17).

2.3 Significance of protein for adolescents

2.3.1 Development of bones

Adolescence is an important time for optimising peak bone mass attainment as most of an individual’s skeletal mass is accumulated by the end of the second decade of life (5,18,19). The skeletal structure undergoes rapid transformations due to an increased height and growth velocity (20). Failure to achieve this optimisation poses an elevated risk of osteoporosis and susceptibility to fractures in the future (5,18). Genetic factors are theorised to account for 80% of the variability in bone mass, while the remaining 20% is influenced by environmental factors such as nutrition and exercise (5).

Protein is an essential nutrient for bone formation during puberty as it contributes to the structural foundation and maintenance of bone (21,22). It elevates the insulin-like growth factor-1 levels (IGF-1) circulating in the body which stimulates bone growth and enhances bone metabolism and intestinal calcium absorption (21,22). Controversy surrounds high protein intake due to the acid ash hypothesis, which suggests it may harm bone health by increasing the high acid load in the body from sulphur-containing amino acids, leading to calcium leaching from the bones and an elevated urinary calcium output (5,22,23). Recent evidence contradicts this showing that higher protein intakes >2 grams per kilogram per day (g/kg/d) can enhance calcium absorption benefiting bone health (23), especially when balanced with alkaline foods such as fruits and vegetables (21,24). In contrast, lower protein intakes <0.8 g/kg/d have been linked to the development of hypercalciuria, reduced intestinal calcium absorption, and compromised skeletal growth including decreased cortical bone formation and overall bone mass (5,22,23,25). Despite this debate which requires further research there is a consensus that moderate protein intakes ranging from 1-1.5 g/kg/d do not exert any adverse effects on bone health (24).

2.3.2 Development of muscle mass

During puberty, there is a significant accumulation of muscle mass and body weight, with over 50% of adult body weight being gained during this period (1,26). These changes exhibit sexual dimorphism, with males generally experiencing a more significant increase in muscle mass, while females tend to accumulate more fat mass (6,20,26). This complex process is regulated by hormones, including thyroid hormone and insulin (26). There is also the growth hormone/insulin-like growth factor-1 (GH/IGF-1) axis which interacts with sex steroids such as oestrogens and androgens (27). As sex steroids increase so does GH and IGF-1 levels in the body which enhances the actions of puberty and development of body composition in females and males (27). Amino acids can act as precursors for the synthesis of these hormones and are therefore responsible for exerting anabolic or catabolic effects on body composition (26,28-31). Consequently, adequate dietary protein is necessary for these hormones to function effectively. For example protein allows IGF-1 to promote muscle tissue growth by enhancing glycogen storage and facilitating the uptake of amino acids into cells, which are then used for protein synthesis (26). Maintaining a positive protein balance in adolescence is essential for building tissue for growth this means that protein synthesis must exceed degradation (6,31). Synthesis will be limited if sufficient amino acids are unavailable in the body (6,31).

2.3.3 Immune system

The human immune system comprises two defence systems: the innate and adaptive systems, both of which require amino acids for optimal functioning against threats or pathogens (32). Amino acids are crucial in producing proteins, polypeptides, and other molecules essential for biological activities within these systems, including synthesising immunoglobulins, acute-phase proteins, and cytokines (32,33). Insufficient amino acid supply within the body can adversely impact immune responses, impairing adolescent's immunity and rendering them vulnerable to opportunistic infections (32,33).

2.4 Protein recommendations

2.4.1 Nutrient reference values

Nutrient reference values (NRVs) are dietary guidelines established for NZ and Australian populations to prevent deficiency states of essential nutrients and promote optimal health (30). The NRVs most typically associated with protein intake in NZ are the estimated average requirement (EAR), recommended daily intake (RDI), and acceptable macronutrient distribution range (AMDR) (30). The RDI which is designed to identify the dietary requirements for 97-98 percent of the population is considered unsuitable for estimating protein intake in group settings (34,35). Using this could lead to overestimating the number of individuals experiencing inadequate protein intake within the group (36). In contrast, the EAR should be used for assessing group nutrient intake due to its statistical accuracy (34,36). It uses a cut-off method to determine inadequacy within a population by identifying the proportion of individuals falling below the median requirement (35,36). According to the EAR, approximately half of the population, including healthy individuals, are predicted to meet the median requirement (30,34).

Protein is the only macronutrient with an established EAR guideline (30). Alternatively, fats and carbohydrates do not have an EAR due to limited data or the greater significance of their dietary form rather than quantity (30). Instead, the AMDR is used which provides recommendations on the proportion of energy intake from each macronutrient to ensure that all essential nutrients are adequately consumed, thus promoting overall health (30). In NZ these are 20-35% total energy (TE) from fat, 45-65% TE from carbohydrates and 15-25% of TE from protein although, evidence has shown that only intakes of 10% of energy as protein are needed as a minimum for optimal physiological functioning of the body (30,34).

The upper level of intake (UL) is the maximum quantity of a nutrient an individual can safely consume without experiencing adverse outcomes (30,34). High protein intake, mainly through supplementation, can have negative health outcomes (30,34,37). However, consuming protein from foods as part of an everyday diet is unlikely to have any adverse effects (30). Due to insufficient evidence, establishing a specific UL has proven challenging for most guidelines (30,34,37). In Australia and the Netherlands, a suggested maximum target for protein intake is 25% TE (29,30). This percentage aligns with the higher end of the ADMR for protein in the diet, which is set at 25% in NZ (30).

Two common methods for determining protein requirements are the nitrogen balance technique and the factorial method (38). The nitrogen balance technique assesses the disparity between nitrogen intake sourced from dietary protein and nitrogen excretion via urine, faeces, sweat, and other bodily processes (39). The protein requirement for maintenance is defined as the dietary protein amount necessary to achieve a state where nitrogen intake equals nitrogen excretion resulting in a balanced nitrogen status (39). This requirement considers the protein needed to replace essential losses, accounting for the efficiency of dietary protein utilisation and its quality (39). The factorial method is often utilised to calculate protein needs for physiological conditions such as childhood growth, where nitrogen is crucial not only for maintenance but also for protein deposition in tissues (39). Generally, across countries there is limited experimental data to establish protein recommendations for adolescents (40). As a result, scaling methods such as interpolation and extrapolation are used, considering factors such as energy requirements, metabolic body weight, and height to estimate adolescent protein needs based on established adult data (41).

Most countries incorporate these methods into their procedures to determine protein recommendations for adolescents and children (29,30,34,37,39,42,43). However, there are slight differences in the estimated EAR values obtained, which appear to be due to the methods and numeric values they have used to derive the EAR, as seen in **Table**

1 (29,30,34,37,39,42,43). Reasons for differences in guidelines across countries include variations in the timing of guideline updates with some relying on different forms of scientific evidence or research to inform their recommendations (44). Factors such as culture, anthropometry, geography, definition of reference groups, extrapolation methods, and health status can further influence how evidence is interpreted and applied in decision-making (45). Additionally, the use of relative values in some countries (e.g., g/kg/d) (29,30,34) versus absolute values (e.g., g/d) (30,37,43) in others can impact the recommended amount of protein intake. Inconsistent measurement units create challenges for comparing protein recommendations causing confusion for health professionals and policy makers (44).

For instance, the Australia and NZ NRVs recommend an EAR of 0.76g/kg/d of protein for boys aged 14-18 years, while the Netherlands recommends 0.7g/kg/d, and the United States of America and Canada recommend 0.73g/kg/d of protein (29,30,34). The categorisation of age groups for protein recommendations also varies as seen in **Table 1** (29,30,34,37,39,42,43). The Australia and NZ NRVs group adolescents into broader categories: such as 14–18-year-olds (30). In contrast, the European Food Safety Authority (EFSA) groups adolescents individually by age such as 14-year-olds, 15-years-olds, and 16-year-olds (39).

All these variations suggest multiple inconsistencies between protein recommendations of different countries however they all have the intention of promoting optimal health for the adolescent population. It cannot be assumed that all populations of adolescents from different countries can utilise the same data and several environmental, genetic, and lifestyle factors may influence differences in protein needs (40). Therefore, variation in protein recommendations may be beneficial to suit the specific needs of each adolescent population (40).

Table 1. Protein recommendations for adolescents in developed countries.

Country	Year	Age Group	EAR/AR	RDI/RNI/RDA/PRI	AMDR/DG	UL	Methods used to derive protein requirements
NZ and Australia (30)	2006	Males 14-18yrs 19yrs Females 14-18yrs 19yrs	49g/d (0.76g/kg/d) 52g/d (0.68g/kg/d) 35g/d (0.62g/kg/d) 37g/d (0.60g/kg/d)	65g/d (0.99g/kg/d) 64g/d (0.84g/kg/d) 45g/d (0.77g/kg/d) 46g/d (0.75g/kg/d)	15-25%	25% of total energy as protein	Factorial method including estimates of the amount needed for growth and maintenance on a fat-free mass basis. A CV of 12% was used to derive the RDI
Netherlands (29)	2001	Males 14-18yrs 19yrs Females 14-18yrs 19yrs	43g/d (0.7g/kg/d) 47g/d (0.6g/kg/d) 38g/d (0.6g/kg/d) 40g/d (0.6g/kg/d)	56g/d (0.8g/kg/d) 61g/d (0.8g/kg/d) 49g/d (0.8g/kg/d) 52g/d (0.8g/kg/d)	-	25% of total energy as protein	The average protein requirement was derived from the amount of nitrogen lost via then urine, faeces, nails and sweat, plus any additional nitrogen that may be required for growth, pregnancy, and lactation
United States of America and Canada (34)	2005	Males 14-18yrs 19yrs Females 14-18yrs 19yrs	(0.73g/kg/d) (0.66g/kg/d) (0.71g/kg/d) (0.66g/kg/d)	52g/d (0.85g/kg/d) 56g/d (0.80g/kg/d) 46g/d (0.85g/kg/d) 46g/d (0.80g/kg/d)	4-18 yrs 10-30% of total calories from protein >18 yrs 10-35% of total calories from protein	Not enough evidence to set a recommendation	Adolescents aged 14-18 yrs - Nitrogen balance studies with additional requirements for growth determined by factorial method.

United Kingdom (37)	1991	Males 14yrs 15-18yrs 19yrs Females 14yrs 15-18yrs 19 yrs	 33.8g/d 46.1g/d 44.4g/d 33.1g/d 37.1g/d 36g/d	 42.1g/d 55.2g/d 55.5g/d 41.2g/d 45.4g/d 45g/d	-	Intakes should not exceed twice the RNI	Data based on nitrogen balance studies. Requirements for growth have been incorporated.
EFSA (39) Austria, Croatia, Denmark, Finland, France, Germany, Hungary, Italy, Ireland, Norway, Portugal, Sweden, and Switzerland	2017	Males 14yrs 15yrs 16yrs 17yrs 18yrs and over Females 14yrs 15yrs 16yrs 17yrs 18yrs and over	 0.72 g/kg bw/d 0.72 g/kg bw/d 0.71 g/kg bw/d 0.70 g/kg bw/d 0.66 g/kg bw/d 0.70 g/kg bw/d 0.69 g/kg bw/d 0.68 g/kg bw/d 0.67 g/kg bw/d 0.66 g/kg bw/d	 0.89 g/kg bw/d 0.88 g/kg bw/d 0.87 g/kg bw/d 0.86 g/kg bw/d 0.83 g/kg bw/d 0.87 g/kg bw/d 0.85 g/kg bw/d 0.84 g/kg bw/d 0.83 g/kg bw/d 0.83 g/kg bw/d	-	Not enough evidence to set a recommendation	Factorial method using requirements for maintenance and growth.
Japan (42,43)	2015, 2020	Males 12-14yrs 15-17yrs 18-29yrs Females	 50g/d 50g/d 50g/d	 60g/d 65g/d 65g/d	13-20% total energy as protein	Not enough evidence	Nitrogen balance method, growth requirements were added to this.

		12-14yrs 15-17yrs 18-29yrs	45g/d 45g/d 40g/d	55g/d 55g/d 50g/d			

Abbreviations: EAR (estimated average requirement), RDI (recommended daily intake), RNI (reference nutrient intake), RDA (recommended daily allowance), AMDR (acceptable macronutrient distribution range), UL (upper level of intake), AR (average requirement), PRI (population reference intakes), g/d (grams per day), g/kg/d (grams per kilogram per day), g/kg bw/d (grams per kilogram body weight per day) DG (dietary goal), yrs (years). Note, different countries/regions use different terminology to mean the same thing (e.g. RDI, RNI, RDA).

2.5 Dietary assessment methodology

Dietary assessment techniques are used to gather accurate information about the dietary habits of individuals or groups (46). In research, multiple dietary assessment methods are available, such as the 24-hour recall (24HR), food frequency questionnaire (FFQ), estimated or weighed food records, and diet history (47-49). When selecting a method, it is important to consider the population's characteristics, including the acceptability of the method based on participant abilities (48,50). Additionally, factors such as time, budget, labour, participant burden, and the method's accuracy in representing the population's nutritional status with minimal error should be carefully considered (48,51). Children aged above 10-12 years can accurately self-report their food intake without the assistance of parents (46,52). However, it is also important to note that any method used to assess adolescent populations may be prone to underreporting, particularly during this vulnerable time of life. Studies indicate this is evident in adolescents who are female or obese, possibly due to body image concerns (46,50,52,53). These adolescents tend to underestimate their intake of unhealthy foods while overreporting the consumption of healthier core foods such as fruits and vegetables (54) which could be due to a need for social approval (55). This group may also have rather unstructured eating patterns which may make applying dietary assessment methods difficult (50,56). **Table 2** compares different dietary assessment methods, outlining their general advantages and disadvantages across various populations.

2.5.1 24-hour recall

The 24HR is a structured interview designed to identify and measure all the food and drink items consumed by an individual during the previous day or 24 hours, usually with the assistance of a trained interviewer (46-48). Details of the food and drink collected in the 24HR include portion sizes, brand names, ingredients of mixed dishes, and preparation methods (57). Food models are often used to help participants accurately determine portion sizes of the foods they eat (46-48). A variation of the 24HR is the multiple pass 24-hour recall (MP24HR). This method reduces errors by prompting participants to reflect on their dietary intake multiple times through a series of three passes, starting with a broad overview of what they ate throughout the day, followed by detailed inquiries about the food and preparation methods, and concluding with a final review (46,53). To obtain an accurate assessment of dietary intake and estimate potential deficiencies using the 24HR technique within the adolescent group, it is recommended to conduct multiple 24HR on two to three non-consecutive days, to consider variability in daily intake (46,53,57). The 24HR method is considered one of the best options for adolescent populations because it is less of a burden and less time-consuming (53). However, there are some disadvantages including the ability of the participant to remember what they ate and estimate the accurate portion sizes (49,53).

Recent advancements in the 24HR method involve the use of computer-based technologies which enhance the standardisation of the recall process and potentially improve the accuracy of dietary data (49). These online tools incorporate probing questions and food photographs, improving food recognition and portion size estimation (58). They provide an integrated system for data collection, coding, entry, and intake calculations (49). Moreover, web-based tools allow researchers to gather data conveniently, regardless of location and time, particularly if internet access is available (49,58).

2.5.2 Food frequency questionnaire

An FFQ comprises a list of foods, where participants are asked about the frequency of their food intake and occasionally portion sizes consumed over various periods, including weeks, months or even a year (47,57). This approach helps capture the typical intake over an extended period, providing insights not obtained from other dietary assessment methods (47,48). However, choosing the FFQ format may pose challenges in obtaining accurate data because assuming a standard portion size for chosen foods may not accurately represent what individuals consume (47,49,57). In addition, food-based FFQs tend to underestimate the dietary intake of mixed dishes with additional elements such as oils, seasonings, and sauces (49). To enhance accuracy, it is advised to tailor the FFQ food list to match the assessed population, enabling individuals to provide more precise reports of their dietary habits (49,53,57). This has led to the development of FFQs for use in adolescent populations worldwide (59). NZ-specific versions have also been created and used in previous research, examples include the NZ Adolescent Food Frequency Questionnaire (60), the Children's Nutrition Survey FFQ (61), and the Physical Activity, Exercise, Diet and Lifestyle Study FFQ (62). However, most of these FFQs were developed more than 5 years ago and may need updating to be useful in this population (60-62). Over time the food supply changes along with trends in the selection of foods and portion sizes which can result in reduced accuracy of dietary data when older dietary assessment tools are used (63).

2.5.3 Diet history

A diet history asks a participant about their past diet retrospectively (56). A variety of different techniques can be used to obtain this information as there is no standard protocol for a diet history (56). Most commonly structured interviews are utilised however these can be combined with other methods such as an FFQ or food records for cross-checking information (56). Diet histories gather quantitative information about an individual's usual dietary intake over a specific period, such as the past month or year, to account for seasonal variations and even out short-term inconsistencies (64,65). It aims to determine typical portion sizes of the foods an individual regularly eats using household measures such as cups or teaspoons, or pictures (64). Compared with other dietary assessment methods, the diet history emphasises patterns of dietary intake rather than remembering specific instances of food consumption (64). The diet history is often used in clinical practise (56). This allows health professionals to assess the diet of their patients and formulate a diagnosis based on the information acquired to then plan an appropriate nutrition intervention and monitor and evaluate this as required (66).

2.5.4 Weighed food record and estimated food record

Food or dietary records also known as food diaries, require participants to document all foods and beverages consumed over a specified period (53). A weighed food record involves participants weighing all foods in recipes, mixed dishes, and individual food and drink items using scales (48). Conversely, an estimated food record involves participants estimating their intakes typically using household measures (48). Food records are considered a gold standard method in dietary assessment because they are believed to minimise errors by documenting food intake during consumption (47,53). Despite this, it is crucial to acknowledge that these methods place one of the highest burdens on participants, often leading to reporting errors after a few days and altered eating behaviours due to the burden of recording intake (47,53). This challenge is particularly evident among adolescents as there is significant underestimation of dietary intake (53). Factors such as fatigue, lack of motivation, and difficulty recording values when eating out contribute to this underestimation (53). Thus, food records may not be the optimal method for collecting dietary data from adolescents (53).

Photographic food records involve taking pictures of meals before and after they are eaten (67). Comparing these photographs helps determine the proportion of the meal consumed and consequently, the nutrient intake (67). This method is considered promising for assessing the dietary intake of adolescents because it does not rely on memory (68). Since adolescent's memories are not as developed as adults, they may forget how much they have eaten if food is not served and documented immediately (68). Additionally, this method minimises the burden on participants and does not alter their dietary behaviour (67).

2.6 Adjusting dietary data

Once dietary information is obtained it can be converted into nutrient data and compared to dietary recommendations for the population being assessed (48). However there is often issues found in dietary data such as under or over reporting of energy intake which needs to be adjusted before data analysis can take place (69). Intake of most nutrients is positively associated with energy intake (70). The correlation is particularly strong for macronutrients protein, carbohydrate, and fat as they are the primary contributors to overall energy intake (70). Total energy intake is a suitable primary criterion for adjusting data because it represents the only nutrient with a physiologically regulated intake that falls within a relatively narrow and predictable range (69). Common methods for adjusting energy intakes include the Goldberg method and the use of predictive equations derived from calorimetry

(69). Adjusting nutrient intakes based on total energy intake can help to correct for the effects of underreporting or overreporting (69).

Table 2. Dietary assessment methods advantages and disadvantages (53,56,64).

Dietary assessment method	Advantages	Disadvantages
24-hour recall	• Relatively low burden • Less time consuming • Relatively low in cost • Can be used on participants with a low literacy level	• Is dependent on participants memory • Answers can be influenced by social pressures • One day of intake may not be representative of dietary habits
Food frequency questionnaire	• Relatively low in cost • Can be used on participants with a low literacy level • Representation of intake over a longer time • Can be self-administered	• Is dependent on participant memory • Inaccuracies if not culturally appropriate
Diet history	• A more representative pattern of dietary intake is acquired • Does not affect the participants eating habits • Can be altered to assess different aspects of the diet e.g. whole diet or certain nutrients	• Interviews can be time consuming • The ability to recall past dietary habits may be influenced by current dietary practises • This method is hard to utilise on people who have fluctuating food patterns Requires trained interviewers
Weighed food record	• Accurate portion sizes of foods and drinks • Lack of errors due to participant memory • Can provide a more representative picture of dietary intake relative to other methods if done over multiple days	• May cause changes in dietary intake due to burden of weighing/recording • Relatively high burden • Time consuming for the researcher and the participant
Estimated food record	• Lack of errors due to participant memory • Relatively low burden compared to weighed food record • Can provide a more representative picture of dietary intake relative to other methods if done over multiple days	• Can be hard to convert household measurements to units • May cause changes in dietary intake due to burden of recording • Time consuming for the researcher and the participant

2.7 Protein intake of adolescents

2.7.1 Protein intake of New Zealand adolescents

Nutrition surveys previously conducted in NZ provide insights into the protein intake and dietary trends of adolescents (8-10). Across all studies, the average protein intake met the EAR recommendations, with males reporting higher intakes than females (8-10). However, adolescents aged 11-14 years had protein intakes that fell slightly below the recommended Acceptable Macronutrient Distribution Range (AMDR) of 15–25% of TE, while those aged 15–19 years tended to align with the lower end of this range (8-10).

The 2002 National Children's Nutrition Survey examined dietary intake among adolescents aged 11–14 years using a 24HR with a repeat 24HR recall on a subsample of participants (9). The findings showed that males in this age group consumed an average of 91 g/day of protein, contributing 14.5% of their total energy (TE) intake, while females consumed an average of 67 g/day, or 13.5% TE (9). Six years later, the 2008/09 NZ Adult Nutrition Survey assessed dietary protein intake among older adolescents aged 15–19 years with the same dietary assessment methodology (8). Protein intake was slightly higher in this survey, likely due to the participants' older age range (8). Males reported an average intake of 108–113 g/day, contributing 15.8–16% TE, while females reported 69–73 g/day, or 15.2–15.4% TE (8). The most recent data comes from the Survey of Nutrition, Dietary Assessment and Lifestyles conducted between 2019 and 2020 in Dunedin, which focused on adolescents aged 15-18 years and used two repeat 24-hour recalls (8,10). The findings indicated that protein intake in grams had remained stable since the 2008/09 survey for both sexes, with a slight increase in the AMDR value for males (8,10). Males consumed an average of 110 g/day, contributing 18.6% TE, while females consumed 73 g/day, or 15.4% TE (10).

In terms of protein inadequacy, the NZ Adult Nutrition Survey reported minimal levels of inadequacy among adolescents (8). The survey found no inadequacies (0.0%) among males and low rates among females, with 0.7% of females aged 15–18 years and 0.5% of females aged 19 years falling below the EAR (8). Similarly, the Survey of Nutrition, Dietary Assessment and Lifestyles reported negligible protein inadequacies when assessed in grams per day, with no inadequacies observed among males and only 0.4% among females (10).

However, when this study assessed protein intake in g/kg/d, females exhibited higher levels of inadequacy, ranging from 6.3% to 8.5% (10). These findings are not directly comparable to other NZ studies, as previous surveys did not evaluate protein intake using g/kg/d (8,9).

2.7.2 Protein intake of adolescents from developed countries

Table 3 presents a comprehensive overview of adolescent protein intake patterns from various developed countries across the globe, including Australia, NZ, Japan, The United States of America (USA), and several European nations. Various dietary assessment methods were used to assess adolescent intake, including 24-hour recalls, estimated, or weighed food records, photographic records of foods, and food frequency questionnaires. This diversity in methods makes direct comparisons difficult between studies. However, seven out of the thirteen studies reviewed used a form of 24-hour recall in their methodology for estimating protein intake suggesting its acceptability in assessing adolescent populations (8-10,71-74).

Most adolescent studies provided protein intake in both g/d and % TE. Across all studies that provided protein data in g/d, males consistently had higher daily protein intakes (8-10,71-79). Male intake ranged from 61.2g/d to 117.2g/d, while females ranged from 48.9g/d to 82.6g/d (8-10,71-79). This difference is expected due to the higher requirements for protein intake in males, which are attributed to their greater muscle mass (26,30). Moreover, the % TE from protein ranged from 13.5 to 18.6% TE and 13.1 to 17.8% TE in males and females, respectively (8-10,71-80). These values show that protein intake is lower in some countries than the recommended 15-25% TE from protein (30). The countries with the highest % TE from protein included Australia, Ireland, and Spain (71,73,77). In contrast, countries such as Scotland, the United Kingdom, and the USA had intakes lower than 15% (72,74-76).

Many adolescent populations tend to exceed the protein intake recommendations established by their respective countries (8-10,75,76,78,80). Most of the studies reviewed did not report inadequacies, but when inadequacies were reported, they tended to be more common in female adolescents than in male adolescents (8,10,72,74). Reasons for inadequacies in females could be underreporting of dietary intake with previous evidence suggesting that female adolescents underreport intake due to body image concerns

(50,52,53). Other factors could be the methods used to determine inadequate intakes. For example one of the highest reported inadequacy rates was in the USA where female adolescents aged 14-18 years had protein intakes 8.6% below the EAR (72). The method used to derive the inadequacy was adjusting body weights to the nearest ideal body weight for overweight/obese or underweight individuals and then comparing this to the EAR (72). However other countries such as Spain and NZ used g/d and compared this to the EAR to assess inadequacies (8,73).

Protein requirements are generally expressed as either absolute or relative amounts. Absolute intake refers to total daily protein consumed (g/d) without considering variations in weight, body composition, or activity level (30), whereas relative intake (g/kg/d) is based on an individual's body weight and typically applies to those within an acceptable weight range (e.g., Body mass index <25 kg/m^2) (81). Therefore, relative protein intake is likely a better indicator of protein adequacy as it considers body composition although in the absence of body composition data absolute protein intake can still provide useful insights (81). However, as obesity rates increase, using actual body weight can overestimate protein needs because fat mass, which does not increase protein requirements, contributes to total weight (82). To address this, ideal body weight adjustments provide more accurate estimates by accounting for individuals who are over or underweight. The higher inadequacy rates observed in the USA may reflect the use of ideal body weight adjustments, which likely provided more accurate corrections for individuals with higher body fat levels, thereby increasing the detection of inadequacies (82).

The use of different protein recommendation units represents a potential limitation when comparing inadequacy rates in adolescent populations across countries. While methodological differences exist, protein intake among adolescents generally appears adequate at the population level, with deficiency not considered a major public health concern.

Table 3. Protein intake of adolescents in developed countries.

Survey/author	Year	Country	Participants (male and female)	Dietary assessment method	Protein intake males	Protein intake females	Notes/limitations
National Children's Nutrition Survey (9)	2002	NZ	Adolescents 11-14 yrs, participants n=3275 (includes all ages in total overall study which was 5-14 yrs)	Multiple pass 24-hour recall with a repeat 24-hour recall for a sub sample of participants and qualitative FFQ	11-14 yrs- 91g/d, 14.5% TE	11-14 yrs- 67g/d, 13.5% TE	Data is 22 yrs old so may not be accurate for protein intake now Population having double the protein RNI Inadequacies not reported
NZ Adult Nutrition Survey (8)	2008/09	NZ	Adolescents 15-19 yrs, participants n=4721 (includes all ages in total overall study which was 15 yrs and over)	Multiple pass 24-hour recall with a repeat 24-hour recall for a sub sample of participants and questionnaires (dietary habits and supplement use)	15-18 yrs- 108g/d, 16% TE 19 yrs- 113g/d, 15.8% TE	15-18 yrs- 69g/d, 15.2% TE 19 yrs- 73g/d, 15.4% TE	Male inadequate protein intake 0% (15-19 yrs) Female inadequate protein intake 0.7% (15-18 yrs), 0.5% (19 yrs) Reported in g/d and compared to EAR
Survey of Nutrition, Dietary Assessment and Lifestyles (10)	2019-2020	NZ	Adolescents 15-18 yrs, participants n=401 (males and females) Adolescents 15-18yrs, participants n=145 (female)	Two non-consecutive 24-hour recalls	15-17 yrs- 110 (104-115) g/d, 18.6% TE 15-18 yrs- 109.5 (104.1,114.9), 18.6 (18.1,19.2) % TE	15-18 yrs- 73.0 (70.6,75.3) g/d, 15.4 (15.1, 15.7) % TE 15-18 yrs- 73.7 (70.1,77.3) g/d, 15.4 (14.9,16.0) % TE	Results are from three separate thesis studies which assessed protein intake of adolescents Females 15-18 yrs- 6.3-8.5% had protein intakes below the EAR Males 15-18 yrs- 0% had protein intakes below the EAR

			Adolescents 15-17 yrs, participants n=135 (male)				
National Diet and Nutrition Survey Rolling Programme (80)	2008/09-2011/2012	Scotland	Adolescents 14-19 yrs, participants n=1695 (included all age ranges of children and adults in the total overall study)	4-day food diary estimated with household measures and interview on shopping and food preparation practises	14-18 yrs- 14.5-15.2% TE 19 yrs- 17.0-17.2% TE	14-18 yrs- 14.5-15.2% TE 19 yrs- 17.0-17.2% TE	Did not provide values in grams but instead a percentage of energy which is harder to compare against other literature Protein intake exceeding RNI Inadequacies not reported
Survey of Diet Among Children in Scotland (75)	2010	Scotland	Adolescents 11-16 yrs, participants n=1674 (Included total overall study participants of children aged 3-16 years, 588 of which were 12-16 yrs)	FFQ and an interview on food purchasing behaviours.	11-14 yrs- 61.2g/d 15-16 yrs- 61.9g/d 12-16 yrs- 13.5% TE	11-14 yrs- 49.8g/d 15-16 yrs- 48.9g/d 12-16 yrs- 13.1% TE	Did not assess entire adolescent population Protein intake was higher than the RNI in all age groups Inadequacies not reported
National Nutrition and Physical Activity Survey (71)	2011/12	Australia	Adolescents 14-19 yrs, participants n=12,153 (included total overall study participants aged 2 yrs and older)	24-hour recall and a sub sample did a second 24-hour recall	14-18 yrs- 101.2g/d, 17.4% TE 19 yrs- 117.2g/d, 18.5% TE	14-18 yrs- 76.5g/d, 16.5% TE 19 yrs- 78.1g/d, 17.7% TE	Inadequacies not reported
National Diet and Nutrition Survey Rolling Programme (76)	2008/09	United Kingdom	Adolescents 11-18 yrs, participants	4-day dietary record	11-18 yrs- 77.1g/d, 14.8% TE	11-18 yrs- 58.9g/d, 14.5% TE	Meeting protein requirements above RNI Inadequacies not reported

			n=462 (Included total overall study participants aged 4-18 yrs)				
National Health and Nutrition Examination Survey (72)	2003-2004	United States of America	Adolescents 14-18 yrs, participants males n=638, females n=578)	2-day 24-hour recalls	14-18 yrs- 96.5 ± 25.5 g/d, 14.1 ± 1.8% TE 19 yrs- 109.2 ± 25.8 g/d, 15.3 ± 2.2% TE	14-18 yrs- 67.9 ± 17.3g/d, 13.5 ± 2% TE 19 yrs- 72.1 ± 18.1 g/d, 14.3 ± 2.8% TE	Data is quite old Males 14-19 yrs- <3% had a protein intake less than EAR Females 14-18 yrs- 8.6% had protein intakes less than EAR Females 19 yrs- <3% had protein intakes less than EAR Reported in g/kg/IBW and compared to EAR
National Health and Nutrition Examination Survey (74)	2001-2014	United States of America	Adolescents 14-19 yrs, participants n=57,980 (Included total overall study participants > 2yrs)	2 non-consecutive 24-hour recalls	14-18 yrs- 97.3 ± 1.5 g/d, 14.8 ± 0.1% TE 19 yrs- 106.3 ± 1.2 g/d, 15.4 ± 0.1% TE	14-18 yrs- 63.9 ± 0.8 g/d, 13.8 ± 0.1% TE 19 yrs- 70.3 ± 0.8 g/d, 14.7 ± 0.1% TE	Females 14-18 yrs- 11.48 ± 2.26% had protein intakes less than the EAR Females 19 yrs- 4.51 ± 0.66% had protein intakes below the EAR Males 14-18 yrs- 5.32 ± 1.20% had protein intakes below the EAR Males 19 yrs- 0.59 ± 0.20% had protein intakes below the EAR
National Teens Food Survey (77)	2019-2020	Ireland	Adolescents 13-18 yrs, participants n=428	Four day weighed food record	13-18 yrs- 87.2g/d, 16.7% TE	13-14 yrs- 62.2g/d, 16% TE	Inadequacy not provided
Anthropometry, Intake, and	2016	Spain	Adolescents 13-19 yrs, participants n=2285	Photo records of food and drink consumed for 3 days	13-17 yrs- 85 ± 21g/d	13-17 yrs- 70.6 ± 17.7g/d	Protein intake higher than reference intakes of Spanish populations

Energy Balance in Spain (78)			(Included total overall study participants 9-75 yrs, for those aged 13-17yrs there were at least n=200)		18-19 yrs- 81 ± 26g/d 15% TE	18-19 yrs- 69 ± 17.8g/d 15% TE	Inadequacies not reported
ENALIA (73)	2013-2014	Spain	Adolescents 14-17 yrs, participants n=1862 (Included total overall study participants aged 6mths-17yrs)	Two 24-hour dietary recalls were used. This was supplemented with an FPQ (did not include portion size)	14-17 yrs- 104.6 ± 15.6g/d, 17.7 ± 1.5% TE	14-17 yrs- 82.6 ± 13.6g/d, 17.8 ± 1.8% TE	All males 0.0% protein intake <EAR Females 14-17 yrs- 0.1% <EAR Reported in g/d and compared to EAR
National Health and Nutrition Survey (79)	1995-2019	Japan	Adolescents 14-19 yrs, participants males n=28,062, girls n=26,809 (Included all participants between 1995-2019, however participant total for 2019 which was assessed will be less)	One day semi weighed, household-based diet record	14 yrs- 74.3 ± 20.8g/d, 14.6 ± 2.4% TE 15-19 yrs- 88.7 ± 30.7g/d, 14.2 ± 2.6% TE	14 yrs- 68.1 ± 17.0 g/d, 15.1 ± 2.3% TE 15-19 yrs- 71.8 ± 21.9 g/d, 15.2 ± 3.1% TE	More recent protein intake information compared with other countries Only the most recent protein values for 2019 were included in this table

Abbreviations: ± (standard deviation), RNI (reference nutrient intake), RDI (recommended dietary intake), EAR (estimated average requirement), % TE (percent total energy), g/d (grams per day), g/kg/IBW (grams per kilogram of ideal body weight), FFQ (food frequency questionnaire), FPQ (food propensity questionnaire), yrs (years), n (number).

2.8 Protein quality

Protein can be found in various sources of food including animal, plant, and dietary supplements (83). However, the quality of the protein in these sources is assessed based on the amount of essential amino acids it provides and its digestibility and bioavailability (83).

2.9 Categorisation of amino acids

The body uses 20 amino acids to build proteins as shown in **Table 4** (31). Each protein's structure and function depend on its specific combination of amino acids (31,48,84). Amino acids are categorised as essential or non-essential based on whether the body can synthesise them from precursors or if they must be obtained from dietary sources (31,48). Generally, nine amino acids are essential (30,34,85). However, during early childhood or illness, some amino acids that are normally non-essential become conditionally essential (30). This means that they must be obtained in the diet for a specific period due to high demand, immature metabolic pathways, or insufficient synthesis (31). The conditionally essential amino acids include arginine, cysteine, glycine, tyrosine, glutamine, and proline (30,34,85). Failing to acquire essential amino acids through the diet can hinder protein synthesis, reducing the protein content in cells and impairing their ability to perform necessary functions, such as building new tissue for growth (31,48).

Table 4. Essential vs conditionally essential vs non-essential amino acids (30,34).

Essential amino acids in adulthood	**Conditionally essential amino acids in early childhood/illness**	**Non-essential amino acids**
Leucine	Tyrosine	Glutamic acid
Isoleucine	Glycine	Alanine
Valine	Cysteine	Aspartic acid
Phenylalanine	Arginine	Serine
Threonine	Glutamine	Asparagine
Methionine	Proline	
Tryptophan		
Lysine		
Histidine		

2.10 Protein sources

Animal sources of protein include meat, fish, poultry, eggs, whey, and dairy products (83,84). These are considered the highest quality proteins because they contain all essential amino acids making them complete proteins (30,83,84). Additionally, they have high digestibility, averaging 95% (86). Plant sources of protein include foods such as legumes, nuts, seeds, soy, grains, and vegetables (83,84). In contrast, these are considered incomplete because they do not contain all the essential amino acids (83). They may lack certain essential amino acids such as lysine, methionine, tryptophan, cysteine, threonine, and glycine (6,83,84). Additionally, plant proteins, have lower digestibility, ranging from 80-90% compared to animal proteins (86). Certain plant protein foods like beans and peas, can be more difficult to digest and absorb due to the anti-nutritional components they contain such as tannins, trypsin inhibitors, and lectins, (83,86). For individuals who follow a vegan or vegetarian diet and do not consume meat, combining specific plant proteins can provide complete proteins within their diets (83).

2.11 Dietary protein sources of adolescents

2.11.1 Dietary protein sources for New Zealand adolescents

The 2002 National Children's Nutrition Survey revealed the primary sources of food contributing to protein intake in adolescents aged 11-14 years. Unexpectedly, bread was the largest contributor, accounting for 13% of total protein intake (9). This food category included various types of bread and rolls, pita, focaccia, garlic bread, bagels, crumpets, and sweet buns (9). Among these, white bread was the most commonly consumed by all participants in the study, making up 79% of the bread intake (9). The frequency of bread eaten was high with 43% of participants reporting having bread 2 or more times daily (9). As white bread does not contain a high proportion of protein the high quantity of bread eaten would likely have contributed to this food group having the highest impact on protein intake

(9). Following bread, milk contributed 11% of total protein intake, poultry 9%, beef and veal 8%, and bread-based dishes, pasta, and grains each contributed 5% of protein intake (9).

This contrasts with the findings from the 2008/09 NZ Adult Nutrition Survey for adolescents aged 15-18 years, where bread-based dishes such as hotdogs, pizza, nachos, spring rolls, sandwiches, and hamburgers, commonly classified as takeaway or convenience foods were the leading protein source (8). Specifically, for males, bread-based dishes accounted for 14.1%, followed by poultry (10.5%), bread (9.9%), grains and pasta (7.3%), and beef, veal, and milk (7.2%). For females, bread-based dishes contributed 12.6%, with bread (10.8%), poultry (9.8%), and grains and pasta (9.2%) following (8). Interestingly, bread-based dish consumption increased among older adolescents (15-18 years), rising by 9.1% in males and 7.6% in females compared to the younger 11-14-year-old cohort (8). However, it is important to note that consuming these types of foods is associated with higher intake of salt, energy, and saturated fats, which could also lead to adverse health outcomes (87).

In the 2019-2020 Survey of Nutrition, Dietary Assessment and Lifestyles for 15-18-year-olds, poultry was the top source of protein for both sexes (16.4% for males and 12.5% for females) (10). For males, this was followed by grains and pasta (11.3%), milk (8.3%), and bread (8.2%) (10). For females, bread-based dishes (9.7%), bread (8.5%), and grains and pasta (8.4%) followed (10). These findings suggest a potential shift in the percentage of food source contribution to protein intake compared with the 2008/09 NZ Adult Nutrition Survey(8). For males, protein intake from bread-based dishes decreased from 14.1% in the 2008/09 NZ Adults Nutrition Survey to 7.4% in the Survey of Nutrition, Dietary Assessment, and Lifestyles, while for females, it dropped from 12.6% to 9.7% (8,10). Similarly, protein from bread decreased from 9.9% to 8.2% for males and from 10.8% to 8.5% for females (8,10). Conversely, the contribution of poultry to protein intake increased markedly, rising from 10.5% to 16.4% for males and from 9.8% to 12.5% for females (8,10). Protein intake from grains and pasta also showed an upward trend for males, increasing from 7.3% in the 2008/09 NZ Adults Nutrition Survey to 11.3% in the Survey of Nutrition, Dietary Assessment and Lifestyles (8,10).

Given the time that has elapsed since these surveys, more recent data is required to understand current protein intake and sources among adolescents. Recent evidence indicates a growing interest in plant-based protein products driven by sustainability and health concerns (14). This trend has led to an increased availability of plant-based proteins and a rise in vegetarianism worldwide (14). The global market for plant-based meat was valued at $5.6 billion in 2020 and is projected to grow to $14.9 billion by 2027 (88). In NZ there is limited data available on adolescent vegetarians however, younger consumers in NZ may be more likely to purchase and eat plant-based products as this behaviour is seen as trendy and environmentally beneficial (89). A recent study looking at female adolescents aged between 15-18 years found that out of 182 participants 15% identified as vegetarian (90). At the population level, the proportion of people following a meat free diet has more than doubled from 7% in 2017 to 15% in 2019 (91). This dietary shift could influence protein intake, as plant-based diets have been associated with lower overall protein consumption (11). Without proper planning these diets may also lead to deficiencies in certain amino acids (11).

Food prices of products such as processed, unprocessed meats, and dairy in NZ supermarkets have also risen due to factors such as COVID-19, geopolitical events, and climate change (92). For example, in 2007 a packet of 1kg beef mince was $9 while in 2021 it was $16.39 which is an 82% increase in price (93). If these products are too expensive for adolescents and their families are not purchasing them cheaper or unhealthier alternatives may be consumed (92). The prevalence of ultra-processed foods (UPFs) has also continued to rise, with estimates in 2023 indicating that 70% of packaged foods sold in NZ supermarkets were UPFs, contributing to half of the average dietary intake (94). Adolescents are therefore likely to be eating a significant proportion of UPFs. Businesses selling these types of foods also like to target children and adolescents, and unhealthy food outlets are more likely to be in highly deprived areas of NZ (95). UPFs are often low in essential nutrients including protein which could potentially effect protein intake of adolescents (96).

2.11.2 Dietary protein sources for adolescents in developed countries

Table 5 lists the food groups contributing to the protein intake of adolescents in developed countries. The primary sources of protein eaten by adolescents tend to include meat, milk and dairy, bread, grains, and cereal products (8-10,71,75-78,80,97). This indicates that adolescents' diets frequently incorporate both animal and plant-based food sources. Across countries, the percentage of sources contributing to protein intake differs although meat consistently appears to be the dominant protein source as it was identified as the major contributor in six of the ten studies reviewed (10,71,76-78,80). The way major food groups are classified also differs between countries. For example, NZ classifies its meat as separate components such as poultry, beef and veal, and pork whereas other countries such as Ireland, England, and Spain generalise this into one group called meat and meat products (9,76-78). This makes it harder to make comparisons and see individual contributions of specific foods. Most studies included protein supplements when assessing protein sources, although they did not appear to significantly contribute to overall protein intake in the adolescent population (8-10,71,75-78,80).

2.12 Why protein intake and sources differ between countries

There are several reasons why protein intake and protein sources may differ between NZ and other developed countries. Socioeconomic status and income levels play a significant role in determining what foods people can access (98). Individuals or families with smaller budgets may rely more on plant-based protein sources such as grains and cereals, which are generally more affordable and accessible (98). In contrast, those with higher incomes may consume greater amounts of animal-based protein sources like meat, dairy, and fish, which tend to be more expensive but are typically richer in protein (98). Geography, religion, and culture may also influence protein consumption (98). For example, the climate of a country can alter the production and availability of certain types of foods, thereby shaping the types of protein consumed (98). Additionally, religious beliefs and cultural practices may restrict or encourage the consumption of specific protein sources (98).

Table 5. Dietary sources of protein in adolescents living in developed countries.

Author	Year	Country	Participants (male and female)	Dietary assessment method	Protein sources from food groups (%) contribution to protein intake	Notes/limitations
National Children's Nutrition Survey (9)	2002	NZ	Adolescents 11-14 yrs, participants n=3275 (includes all ages in total overall study which was 5-14 yrs)	Multiple pass 24-hour recall with a repeat 24-hour recall for a sub sample of participants and Qualitative FFQ	Males and females- Bread (13%), milk (11%), poultry (9%), beef/veal (8%), bread-based dishes and grains/pasta (5%), potatoes, kumara, taro, sausage and processed meat, seafood, and cereal (4%)	Included dietary supplements- meal replacements
NZ Adult Nutrition Survey (8)	2008/09	NZ	Adolescents 15-19 yrs, participants n=4721 (includes all ages in total overall study which was 15 yrs and over)	Multiple pass 24-hour recall with a repeat 24-hour recall for a sub sample of participants and questionnaire	Males 15-18yrs- bread-based dishes (14.1%), poultry (10.5%), bread (9.9%), grains and pasta (7.3%), beef, veal, and milk (7.2%), and pork (4.8%) Males 19 yrs- Bread-based dishes (12.9%), bread (10%), grains and pasta (9.4%), and poultry (9.1%) Females 15-18 yrs- bread-based dishes (12.6%), bread (10.8%), poultry (9.8%), grains and pasta (9.2%), milk (6.6%), and beef/veal (6%) Females 19yrs- poultry (11.5%), grains and pasta (9.7%), bread (9.0%), milk and bread-based dishes (7.7%)	Included supplements that provided energy- meal replacements, and protein supplements (bars and powder)

Survey of Nutrition, Dietary Assessment, and Lifestyles (10)	2019-2020	NZ	Adolescents 15-18 yrs, participants n=401 (males and females) Adolescents 15-18yrs, participants n=145 (female) Adolescents 15-17 yrs, participants n=135 (male)	Two non-consecutive 24-hour recalls	Males- poultry (16.4%), grains and pasta (11.3%), milk (8.3%), bread (8.2%), bread-based dishes (7.4%), beef and veal (5.6%) Females- poultry (12.5%), bread-based dishes (9.7%), bread (8.5%), grains and pasta (8.4%), beef and veal (5.6%) Females- poultry (11.3%), bread (9.9%), grains and pasta (9.4%), bread-based dishes (8.3%), milk (5.2%)	Results are from three separate thesis studies Included supplements
National Nutrition and Physical Activity Survey (71)	2011/2012	Australia	Adolescents 10-18 yrs, participants n=12,153 (included total overall study participants aged 2 yrs and older)	24-hour recall	Males 14-18 yrs- meat, poultry, and game (31.3%), cereal-based products and dishes (26.1%), milk products and dishes (12.8%) Females 14-18 yrs- meat, poultry, game (30.5%), cereal based-products and dishes (22.6%), milk products and dishes (13.9%)	Included supplements- liquid and powdered meal replacements, protein drinks and powders, oral supplement powder and beverages.
National Diet and Nutrition Survey Rolling Programme (80)	2008/09-2011/12	Scotland	Adolescents 10-19 yrs, participants n=1695 (included all age ranges of children and adults in the total overall study)	Four-day food diary	Meat and meat products (37-39%), and cereal and cereal products (26-28%)	Included supplements
Survey of Diet Among Children in Scotland (75)	2010	Scotland	Adolescents 12-16 yrs, participants n=1674 (Included total overall study participants of children aged 3-16 years, 588 of which were 12-16 yrs)	FFQ and an interview on food purchasing behaviours	Males 12-16 yrs- milk and cream (13%), meat and meat dishes excluding processed meat (11%), bread excluding wholemeal (9%), processed meat (8%), pasta, rice, pizza, and other cereals (6%) Females 12-16 yrs- milk and cream (12%), meat and meat dishes excluding processed meat (10%), bread excluding	Included supplements

					wholemeal (8%), processed meat (7%), pasta, rice, pizza, and other cereals (6%)	
National Diet and Nutrition Survey Rolling Programme (76)	2008/09	United Kingdom	Adolescents 11-18 yrs, participants n=462 (Included total overall study participants aged 4-18 yrs)	Four-day food diary	11-18 yrs- meat/meat products (38%), cereal/cereal products (26%), milk and milk products (14%), fish and fish dishes (4%)	Included supplements
National Teens Food Survey (77)	2019-2020	Ireland	Adolescents 13-18 yrs, participants n=428	Four day weighed food record	Meat and meat products (38.6%), grains, rice, pasta, savouries (11.2%), bread and rolls (10.6%), milk and yogurt (9.3%)	Included supplements
Anthropometry, Intake, and Energy Balance in Spain (78)	2016	Spain	Adolescents 13-19 yrs, participants n=2285 (Included total overall study participants 9-75 yrs, for those aged 13-17yrs there were at least n=200)	Photo records of food consumed for three days	13-17 yrs- meat/meat products (34.6%), grains (19.1%), milk and dairy (17.9%), fish and shellfish (6.3%) 18–19 yrs meat and meat products (33.5%), grains (17.4%), milk and dairy (16.9%), fish and shellfish (10.6%)	Included supplements and meal replacements
National Health and Nutrition Examination Survey (97)	2003-2006	United States of America	Adolescents 14-18 yrs, participants n=7332 (Included total overall study participants aged 2-18yrs)	In person dietary recall interviews using multiple pass method	Milk (13.2%), poultry (12.8%), beef (11.5%), cheese (9.7%), yeast breads and rolls (6.4%), frankfurters, sausages, and luncheon meats (4.8%), pork, ham, bacon (4.2%)	Only provided food group information for 2-18 yrs which is too broad to see specifically adolescent intake of protein from food sources

						Did not include supplements

Abbreviations: % (percentage), FFQ (food frequency questionnaire), yrs (years), n (number).

2.13 Conclusion

The literature review highlights the critical importance of protein in the growth and development of adolescents. Insufficient protein intake can lead to significant consequences some of which may be irreversible. The reviewed literature showed that NZ adolescents were not at risk of protein deficiency. However, there has been a significant gap since some of these studies were undertaken, during which the food environment has changed, including increases in food prices (92), higher consumption of UPFs (87), and plant-based diets (11). This may have impacted protein consumption; therefore, the current knowledge of protein intake and food sources of this population needs to be updated. This study aims to fill this gap enabling the identification of areas for improvement and the development of targeted strategies to ensure adequacy of this nutrient in the NZ adolescent population.

Chapter 3: Research manuscript

Dietary protein Intake and Food Sources of Protein in Adolescents Living in the Auckland, Waikato and Bay of Plenty Areas of New Zealand

3.1 Abstract

Background

Adolescence is a critical period of growth and development, increasing the need for adequate protein intake and quality protein sources to support growth and developmental changes. However, current data on protein intake and protein sources among New Zealand (NZ) adolescents are outdated, particularly given recent shifts in dietary patterns and food environments.

Aims and objectives

This research aimed to investigate the current protein intake and sources of NZ adolescents and compare protein intake with the Nutrient Reference Values to assess adherence to dietary recommendations.

Methods

The data for this research was obtained through the Te Rourou Kai o Ngā Rangatahi: Eating Patterns of Young People in NZ study. This cross-sectional study gathered dietary data from 266 students aged between 14 to 19 years in the Auckland, Waikato, and Bay of Plenty (BOP) regions of NZ using an electronic multiple pass 24-hour dietary recall, and demographic questionnaire. Dietary data were linked to a preexisting nutrient database and categorised into food groupings to determine protein intake and sources. Protein adequacy was assessed by comparing protein intakes of adolescents with the Nutrient Reference Values for Australia and NZ. Protein intake results were expressed as mean ± standard deviation (SD) for continuous values and as number (percentage) for categorical values. Contributions of each food group to protein intake were reported as both percentage ± SD and grams ± SD.

Results

Participants (n=266, 68.0% female) had mean protein intakes of 98.5 ± 66.8 g/day for males and 70.1 ± 45 g/day for females which both exceeded the Estimated Average Requirement (EAR). Males consumed significantly more protein than females (P < 0.001). In total, 19.5% (n=52) of adolescents did not meet the EAR for protein. The percentage of total energy (%TE) from protein was 18.3 ± 8.1% for males and 16.2 ± 5.4% for females, both within but at the lower end of the acceptable macronutrient distribution range (AMDR) of 15-25%, with males showing a significantly higher protein contribution to energy intake (P = 0.035). A high proportion of females (44.2%) and males (36.9%) were below the AMDR. For all participants, the main sources of protein included meat and meat products (17.7 ± 25.7%, 17.6 ± 35.7g/d), burgers, pizza, and Mexican dishes (13.8 ± 26.4%, 9.6 ± 20.1g/d), pasta and rice dishes (9.8 ± 22.4%, 9.7 ± 27.9g/d), and bread and bread products (7.5 ± 13.7%, 5.5 ± 11.8g/d).

Conclusions

Protein sources for NZ adolescents include both plant and animal sources, with meat being the largest contributor. Animal proteins, such as meat, will provide high-quality, complete proteins within the adolescent diet. Our findings suggest some adolescents are consuming inadequate amounts of protein to meet their dietary needs. Further research is required with two non-consecutive 24-hour recalls verifying levels of inadequacy seen within this adolescent population.

Keywords

protein intake, protein sources, adolescents, New Zealand

3.2 Introduction

Adolescence is defined as the period between the ages of 10-19 years (1). During this time, significant advancements occur in the body's growth and development due to puberty initiation causing various physiological, sexual, neurological, and behavioural changes (1). Adequate nutrition is needed to support these processes as they impose additional nutrient requirements above those required for normal body functions (2). Protein, in particular, assists with alterations in body composition, including weight, height, bone, and muscle mass, by having elevating effects on insulin-like growth factor (IGF-1) (1). This is used by the body to enhance muscle tissue growth by stimulating glycogen storage and amino acid uptake for protein synthesis (26). It also supports the growth of connective tissue, cartilage, and bone by promoting cartilage growth and collagen formation (26).

The protein sources consumed during adolescence are also important, as essential amino acids (EAAs) such as leucine, isoleucine, and valine must be obtained through the diet (30,31). Animal proteins such as beef, chicken, and fish provide all EAAs, whereas plant foods such as grains, nuts, and seeds may lack one or more EAAs (6). Without the right proportions of amino acids, the body's ability to utilise protein effectively will be compromised (30).

The Nutrient Reference Values (NRVs) set by the Australian and NZ guidelines outline the estimated average requirement (EAR) for protein in adolescents. These recommendations, based on the factorial method, consider the protein needs for both maintenance and growth during adolescence (30). They indicate that males generally require more protein than females, and protein needs increase with age (30). Inadequate protein intake and low-quality protein sources during adolescence can lead to negative alterations in body composition, such as delayed skeletal growth, reduced muscle mass, stunting of height, and an increased risk of osteoporosis the in future (3,5,6). Malnutrition characterised by low protein and energy intake may also reduce IGF-1 levels, potentially delaying puberty onset and progression (4).

Three previous nutrition surveys have assessed protein intake and food sources among NZ adolescents (8-10). They revealed that adolescents were meeting the EAR protein requirements with minimal levels of inadequacy (8-10). For NZ adolescents, the main sources of protein were bread, milk, and poultry among those aged 11-14 years, while for those aged 15-18 years, the top contributors were bread-based dishes, bread, grains, pasta, and poultry (8,10). The evidence from these surveys is outdated, with no recent data available on the adherence of adolescents to the NRVs (8,9,30). There has been changes in the food environment since these surveys were conducted, including the rise of plant-based diets (11), ultra-processed foods (UPFs) (87), and higher food prices of animal protein sources (92).

Many vegetarian female adolescents in NZ do not meet the acceptable macronutrient distribution range (AMDR) for protein, with 73.7% falling below the recommended range, compared to 43.1% of their non-vegetarian peers (99). Children living in NZ also derive a significant proportion of their energy intake from UPFs (96). By 12 months of age, 45% of their energy comes from UPFs, increasing to 51% by five years old (96). While specific data on adolescent UPF consumption in NZ is limited, it is plausible that a substantial proportion of their diet also consists of these foods as the general food supply would be similar (96). These UPFs are generally low in nutrients like protein and therefore this could be potentially impacting on their overall protein intake (96). Regarding meat consumption, a study involving 1,061 participants, 28.8% of whom were adolescents, found that over 70% of participants reported reducing meat intake, primarily due to affordability and the desire to save money (89). Consequently, there is an urgent need for more recent data, this will help to assess whether adolescents are meeting their protein needs and identify the primary food sources of protein within their diets.

This study aims to describe protein intake and food sources among adolescents aged 14-19 years living in the Auckland, Waikato, and Bay of Plenty regions of NZ. The data obtained from this research can be used to inform future policy decisions and targeted interventions to optimise the protein intake of NZ adolescents.

3.3 Methods

3.3.1 Study design

The data for this study was obtained from the Te Rourou Kai o Ngā Rangatahi: Eating Patterns of Young People in NZ study. This cross-sectional research was conducted in the Auckland, Waikato, and BOP regions, gathering data from male and female adolescents in NZ between June and August 2024. Data collected included food sources contributing to protein intake and the total protein intake consumed by adolescents daily.

Ethical approval was granted by the Massey University Human Ethics Ohu Matatika 1, Application OM1 23/55. The NZ Heart Foundation provided funding for the study. All participants provided written informed consent electronically. Parental consent was obtained for participants under the age of 16.

3.4 Participants and recruitment process

3.4.1 School recruitment

Recruitment occurred during school terms two and three in 2024, utilising convenience sampling to select schools with students in years 7–13. A total of 251 schools in Auckland, Waikato, and the BOP that received the lunch programme were contacted by the Ministry of Education's senior advisor or nutritionist to invite them to participate in the study. Additionally, 49 schools in Auckland and 22 in Waikato and the BOP not in the programme were contacted by phone, followed by an email to provide more information and formally invite them to join the study. For schools with students under 16, parent/whānau consent form links were provided for the school to email to parents, or a printed copy was sent home if preferred. Data collection was scheduled on days and at times that suited each school.

3.4.2 Participant recruitment

Students over 16 years of age were recruited during school hours on the day of data collection. The teaching staff of recruited schools assisted by bringing students or classes to the data collection site, where researchers presented the students with information about the study. Interested students were then asked to read and accept the electronic information and consent forms. Students under 16 years old were recruited by the schools before the day, as parental consent had to be obtained. Once participants were recruited, they were allocated a unique number code that deidentified their personal information. This was used to answer the demographic questionnaire and Intake24 (an online 24-hour recall) (100).

To be eligible for inclusion in the study, participants had to be female or male adolescents aged between 14-19 years who were proficient in English.

3.5 Data collection

3.5.1 Dietary assessment

For this study, dietary information was obtained using an electronic multiple-pass 24-hour recall (MP24HR) survey called Intake24. Initially developed in the United Kingdom, Intake24 has been used in several countries to collect dietary data (100). Before its use in this study, staff at the University of Auckland and Massey University modified Intake24 to be more relevant for the NZ population (100). This process involved compiling a list of 2,621 commonly consumed NZ foods and brands, including traditional Māori, Pasifika, and Asian foods (100). New portion size images were created for items lacking appropriate visuals, including NZ-specific packaged foods, and prompts were made for food items that usually go together such as milk or sugar in tea and coffee (100). These foods were then connected to existing NZ nutrient data, and additional nutrient data, including recipes for mixed dishes, was developed as needed (100). Once the tool was modified, it was tested on a NZ population group of 37 people which included participants of a range of ages, genders, and ethnicities of which 9 were children between the ages of 11-15 (100). From the information obtained further changes were identified to ensure the tools usability in NZ populations (100).

During dietary data collection, researchers first gave a brief explanation on how to use Intake24, instructing students to record all foods and drinks consumed the previous day, from 12 am to 12 pm. Students then accessed and completed the electronic Intake24 survey on tablets or their devices. Researchers assisted students if they had questions or needed help finding something they had consumed.

The Intake24 survey utilises the MP24HR method. In the first pass, participants were asked to record the times they consumed their meals and enter the foods and drinks they had during each meal or snack (100). The second pass gathers more detailed information, asking participants to select the closest match to the items they consumed from a list, with portion sizes determined visually using standard portion sizes, guide images, as-served images, or drink scale images (100). Throughout the survey, prompts help participants recall any forgotten items such as snacks, drinks, or items typically paired with those already selected (100). In the final pass, participants are asked to review all the items they have added for each meal or snack to ensure nothing is missing before submitting their answers (100).

3.5.2 Demographic questionnaire

An online demographic questionnaire, developed specifically for the NZ context using information from the national census, was used to obtain personal information from each participant as seen in **Appendix A.** The questionnaire gathered details regarding their school, year level, sex, age, and ethnicity. If their answer was not listed, an "other" option with an answer box was provided for participants to specify.

3.6 Data handling

The demographic questionnaire asked participants to identify their ethnicity, allowing them to select multiple options if they identified with more than one. Ethnic prioritisation was applied so that each participant's main ethnicity could be reported. The ranking for prioritised reporting was as follows Māori, Pacific, Asian, other ethnicity, and NZ European (101).

Electronic dietary data obtained from students in Intake24 were linked to excel spreadsheets, which reported the protein intake in grams (g) for each food or drink item consumed throughout the day. The protein values for all items were summed to calculate each participant's total daily protein intake in grams per day (g/d). This process was repeated for energy intake, measured in kilojoules (KJ). The total protein intake in g/d for each participant was multiplied by the Atwater factor of 17KJ per gram and then divided by the total energy intake in KJ to determine the percentage of total energy (%TE) derived from protein. Ranges of energy intake were used for females (2090-14,640KJ) and males (3350-16740KJ) to assess outliers (69). Those who had intakes below these ranges were excluded and those who had intakes higher than these ranges had their 24-hour recalls including portion sizes assessed for plausibility. If the higher intakes seemed acceptable, they were included in the data analysis those that did not were excluded.

To assess adherence to dietary protein recommendations, the protein intake of participants was compared with the EAR for protein set by the Australian and NZ NRVs (30). Participants who had an intake below these targets were classified as having an inadequate intake. Additionally, the percentage of total energy from protein for each participant was compared with the acceptable macronutrient distribution range (AMDR) for protein, set at 15-25%, to determine if their intake fell within this range (30).

The food and drink items collected from Intake24 were categorised into food groupings for Intake24 as seen in **Appendix B**. The University of Auckland developed the original food groupings which were based on broad food categories that were aligned with the NZ eating and activity guidelines food group recommendations (100). Since the way foods are categorised can impact nutrient analysis, it was decided to refine certain groups for better accuracy. For example, instead of grouping all meats together, individual meat sources such as pork, beef, and poultry were separated out to provide a clearer understanding of their contributions to nutrient intake. However, for the purpose of this study alterations were made to further combine these groups for example meats such as beef, lamb, pork and poultry were combined into one grouping called meat and meat products. This categorisation helped identify the most significant protein sources among adolescents. All food groups were reported along with the percentage and grams they each contributed to protein intake in adolescents.

3.7 Statistical analysis

For the primary study objectives, a sample size of 600 participants was deemed adequate. Descriptive statistics were generated for participant characteristics and dietary intake data. The Central Limit Theorem was applied, and the mean was assumed to be normally distributed for all statistical tests with a large sample size (102). Continuous data were reported as mean and standard deviations (± SD). All categorical data were expressed as percentages. Independent t-tests were used for parametric scale data and chi-squared tests were used for categorical data. IBM SPSS Statistics version 29.0 (103) was used for all statistical analysis.

3.8 Results

3.9 School recruitment and participant demographics

A total of 698 students from 16 schools took part in the study. However, participants with incomplete data at the time of analysis (n=343), implausible energy intakes outside acceptable ranges (n=62), and participants outside age ranges (n=27) were excluded. The final analysis included 266 participants aged 14–19 years, of whom 181 were female and 84 were male, reflecting a female-to-male ratio of approximately 2:1. **Table 6** presents the demographic information of the study participants. The mean age of all participants was 16.2 ± 1.1 years. Most participants identified as Māori (30.5%) and NZ European (28.6%), followed by Pacific peoples (20.7%), other ethnicities (16.2%), and Asian (4.1%). Nearly half (49.6%) resided in areas with moderate socioeconomic deprivation, 41% in areas of high socioeconomic deprivation, and only 9.4% were from areas of low deprivation. Geographically, participants were predominantly from Auckland (45.1%).

Table 6. Demographic characteristics of participants.

Characteristics	Total	Male	Female
Total participants (n) [4 5]	266	84 (31.6)	181 (68.0)
School n (%)			
Auckland	120 (45.1)	47 (56)	72 (39.8)
Waikato	59 (22.2)	18 (21.4)	41 (22.7)
Bay of Plenty	87 (32.7)	19 (22.6)	68 (37.6)
EQI group n (%) [1]			
Low (344-428)	25 (9.4)	0 (0)	25 (13.8)
Moderate (429-494)	132 (49.6)	32 (38.1)	100 (55.2)
High (495-569)	109 (41)	52 (61.9)	56 (30.9)
Age (years) **Mean (± SD)** 14-18	16.2 ± 1.1 266 (100)	16.5 ± 0.9 84 (100)	16.0 ± 1.1 181 (100)
Ethnic group n (%)			
NZ European	76 (28.6)	14 (16.7)	62 (34.3)
Māori	81 (30.5)	28 (33.3)	52 (28.7)
Pacific [2]	55 (20.7)	27 (32.1)	28 (15.5)
Asian [3]	11 (4.1)	2 (2.4)	9 (5.0)
Other	43 (16.2)	13 (15.5)	30 (16.6)

Abbreviations: n (number), % (percentage), EQI (equity index). Continuous values are expressed as mean ± SD. Categorical values are expressed as frequency (percentage).

[1] School equity index measures the level of socioeconomic barriers that students face. The higher the EQI the more socioeconomic barriers students face (104).
[2] Pacific ethnicity includes Cook Islands Māori, Samoan, Tongan, and Niuean.
[3] Asian ethnicity includes Indian.
[4] One participant's sex was unknown but they were included in the analysis above under total population. This participant was Māori, age 17, from Auckland and from an area of high socioeconomic deprivation.
[5] One participant was 19 years and was included in the 14-18 age group.

3.10 Protein intake and protein inadequacy among New Zealand adolescents

Table 7 provides an overview of the protein intake, the percentage of total energy from protein, and the prevalence of protein inadequacy among adolescents. Adolescents had a mean ± SD daily protein intake of 79.0 ± 54.3g/day, with males consuming significantly more protein at 98.5 ± 66.8g/day compared to females at 70.1 ± 45g/day (P < 0.001). A similar pattern was observed for energy intake, with males averaging 9268.2 ± 5024.2kJ/day which was significantly higher than females, whose intake was 7403 ± 4087kJ/day (P = 0.002).

Adolescents had an average protein intake of 16.9 ± 6.4% TE, with males consuming a significantly higher percentage (18.3 ± 8.1%) compared to females (16.2 ± 5.4%) (P=0.035). The average intake for both sexes was within the AMDR of 15–25%, though at the lower end. Overall, 57.9% of participants met the AMDR for protein, while 42.1% were below this target. A higher proportion of females (44.2%) fell below the AMDR compared to males (36.9%) (P=0.263). While more males (17.9%) significantly exceeded the AMDR than females (4.4%) (P=<.001).

Regarding the EAR for protein, 80.5% of participants met the requirement, while 19.5% had inadequate intakes. The proportions of inadequacy were slightly higher in females (20.4%) compared to males (16.7%). The difference between males and females meeting the EAR was not statistically significant (P=0.468).

Table 7. Protein intake, percentage of energy from protein and inadequacies of protein among adolescents.

Nutrients	Total population 14-18 years (n=266) [3] [4]	Males 14-18 years (n=84)	Females 14-18 years (n=181)	P-value
NRV protein recommendations for adolescents (30)	AMDR- 15-25% TE	EAR- 49g/d (0.76g/kg/d)	EAR- 35g/d (0.62g/kg/d)	
Energy intake, kJ/d [1]	7988.7 ± 4473.6	9268.2 ± 5024.2	7403.0 ± 4087	.002
Protein intake, g/d [1]	79.0 ± 54.3	98.5 ± 66.8	70.1 ± 45	<.001
Protein, % TE [1]	16.9 ± 6.4	18.3 ± 8.1	16.2 ± 5.4	.035
Protein intake below AMDR n (%) [2]	112 (42.1)	31 (36.9)	80 (44.2)	.263
Protein intake above AMDR n (%) [2]	23 (8.6)	15 (17.9)	8 (4.4)	<.001
Protein intake below EAR n (%) [2]	52 (19.5)	14 (16.7)	37 (20.4)	.468

Abbreviations/notes: AMDR (acceptable macronutrient distribution range), EAR (estimated average requirement), n (number), g/d (grams per day), % TE (percent total energy), % (percentage), KJ/d (kilojoules per day). Differences between groups were tested using independent t tests and chi squared tests. Significant sex difference at $P < 0.05$.

[1]Continuous values are expressed as mean ± SD.
[2] Categorical values are expressed as frequency (percentage).
[3] One participant was 19 years and was included in the analysis of those aged 14-18 years. The EAR for 19 years is 37 g/d (0.60g/kg/d) of protein for females and 52g/d (0.68g/kg/d) for males (30).
[4] One participant's sex was unknown but they were included in the analysis above under total population.

3.11 Sources of protein among New Zealand adolescents

Table 8 highlights the food groups contributing to protein intake among adolescents. Some of the most consumed food groups were bread and bread products (n=115, 43.2%), vegetables (n=113, 42.5%), meat and meat products (n=112, 42.1%), flavour enhancers (n=102, 38.3%), milk and milk alternatives (n=80, 30.1%), and grain-based foods (n=77, 28.9%).

All food sources included in the food groupings are listed in **Appendix B.** The top source of protein for males came from meat and meat products, which contributed 21.5 ± 28.8% of total protein intake, or 25.4 ± 49.6g/day. This was followed by mixed cooked dishes (9.8 ± 21.9%, 13.3 ± 37.3g/d), pasta and rice dishes (9.7 ± 22.7%, 12.6 ± 38.6g/d), burgers, pizza, and Mexican (8.4 ± 21.7%, 5.9 ± 16.3g/d), and savoury composite foods (7.8 ± 16.9%, 6.7 ± 15.5g/d). In contrast, the top source for females was from burgers, pizza, and Mexican dishes and contributed 16.3 ± 28.1% or 11.3 ± 21.5g/day. This was followed by meat and meat products contributed 16.1 ± 24.1%, 14.1 ± 26.6g/day), pasta and rice dishes (9.9 ± 22.4%, 8.5 ± 21.3g/d), bread and bread products (8.5 ± 14.4%, 5.5 ± 9.6g/d), and savoury composite foods (5.3 ± 15.7%, 3.3 ± 9.4g/d). Bread and bread products were a higher source of protein for females (8.5 ± 14.4%, 5.5 ± 9.6g/d) compared to males (5.5 ± 11.9%, 5.6 ± 15.7g/d). Males consumed more protein from mixed cooked dishes (9.8 ± 21.9 %, 13.3 ± 37.3g/day) than females (3.4 ± 13.3%, 2.3 ± 9.1g/day). Females consumed nearly double the amount of their protein from the burgers, pizza, and Mexican food group (16.3 ± 28.1% or 11.3 ± 21.5g/day) compared with males (8.4 ± 21.7%, 5.9 ± 16.3g/d).

Plant-based sources of protein from pulse-based foods (females 0.2 ± 1.9%, males 0.2 ± 1.0%), tofu and meat alternatives (females 0.1 ± 1.2 %, males 0.0 ± 0.0%), and nuts and seeds (females 1.1 ± 3.9%, males 0.7 ± 3.1%) contributed minimally to protein intake for both females and males. Protein supplementation also had little impact on overall protein intake, with dietary supplements and sports gels and bars contributing less than 1% for both sexes.

Table 8. Food sources contributing to NZ adolescent protein intake.

Food group classifications *	Contribution to protein intake (%) in population	Contribution to protein intake (%) in males	Contribution to protein intake (%) in females	Total protein intake (g/d)	Male protein intake (g/d)	Female protein intake (g/d)	Total consumers of food group n (%)	Male consumers of food group n (%)	Female consumers of food group n (%)
Meat & meat products	17.7 ± 25.7	21.5 ± 28.8	16.1 ± 24.1	17.6 ± 35.7	25.4 ± 49.6	14.1 ± 26.6	112 (42.1)	39 (46.4)	73 (40.3)
Burgers, pizza, & Mexican	13.8 ± 26.4	8.4 ± 21.7	16.3 ± 28.1	9.6 ± 20.1	5.9 ± 16.3	11.3 ± 21.5	70 (26.3)	14 (16.7)	56 (30.9)
Pasta & rice dishes	9.8 ± 22.4	9.7 ± 22.7	9.9 ± 22.4	9.7 ± 27.9	12.6 ± 38.6	8.5 ± 21.3	60 (22.6)	20 (23.8)	40 (22.1)
Breads & bread products	7.5 ± 13.7	5.5 ± 11.9	8.5 ± 14.4	5.5 ± 11.8	5.6 ± 15.7	5.5 ± 9.6	115 (43.2)	30 (35.7)	85 (47.0)
Savoury composite foods	6.2 ± 16.3	7.8 ± 16.9	5.3 ± 15.7	4.5 ± 11.8	6.7 ± 15.5	3.3 ± 9.4	47 (17.7)	19 (22.6)	27 (14.9)
Mixed cooked dishes	5.4 ± 16.7	9.8 ± 21.9	3.4 ± 13.3	5.7 ± 22.7	13.3 ± 37.3	2.3 ± 9.1	35 (13.2)	18 (21.4)	17 (9.4)
Grain based foods	4.9 ± 11.1	5.1 ± 10.3	4.8 ± 11.5	3.5 ± 7.9	4.8 ± 9.7	2.9 ± 6.8	77 (28.9)	27 (32.1)	50 (27.6)
Milk & milk alternatives	4.7 ± 10.8	5.8 ± 9.3	4.2 ± 11.5	3.3 ± 7.6	4.6 ± 7.0	2.8 ± 7.8	80 (30.1)	33 (39.3)	47 (26.0)
Vegetables	2.9 ± 5.1	2.5 ± 5.2	3.0 ± 5.0	1.8 ± 2.9	1.5 ± 2.5	2.0 ± 3.1	113 (42.5)	34 (40.5)	79 (43.6)
Breakfast cereals	2.8 ± 7.1	3.7 ± 7.1	2.5 ± 7.0	2.0 ± 4.3	2.9 ± 5.2	1.5 ± 3.8	66 (24.8)	27 (32.1)	39 (21.5)
Chips & crisps	2.0 ± 7.1	0.9 ± 2.9	2.5 ± 8.4	0.9 ± 2.2	0.7 ± 2.0	1.1 ± 2.3	71 (26.7)	14 (16.7)	57 (31.5)
Dairy based drinks	2.0 ± 8.6	1.4 ± 8.8	2.2 ± 8.5	1.1 ± 4.0	0.5 ± 2.9	1.3 ± 4.5	26 (9.8)	3 (3.6)	23 (12.7)
Egg & egg dishes	1.9 ± 8.8	2.4 ± 8.5	1.7 ± 9.0	1.4 ± 5.1	2.2 ± 6.4	1.0 ± 4.3	23 (8.6)	10 (11.9)	13 (7.2)

Food group classifications *	Contribution to protein intake (%) in population	Contribution to protein intake (%) in males	Contribution to protein intake (%) in females	Total protein intake (g/d)	Male protein intake (g/d)	Female protein intake (g/d)	Total consumers of food group n (%)	Male consumers of food group n (%)	Female consumers of food group n (%)
Snacks and sweet biscuits	1.7 ± 4.3	1.1 ± 3.9	2.0 ± 4.4	1.2 ± 2.9	0.8 ± 3.1	1.3 ± 2.7	71 (26.7)	13 (15.5)	58 (32.0)
Cheese & cheese products	1.5 ± 4.9	0.8 ± 3.2	1.8 ± 5.5	1.0 ± 3.0	0.8 ± 3.4	1.1 ± 2.9	40 (15.0)	7 (8.3)	33 (18.2)
Bakery and dessert items	1.5 ± 4.9	1.3 ± 5.0	1.6 ± 4.9	1.0 ± 3.1	0.8 ± 2.4	1.0 ± 3.3	46 (17.3)	13 (15.5)	33 (18.2)
Savoury Asian foods	1.4 ± 8.9	0.8 ± 4.0	1.7 ± 10.4	1.0 ± 5.9	0.7 ± 3.7	1.2 ± 6.7	16 (6.0)	4 (4.8)	12 (6.6)
Fruits	1.3 ± 4.6	1.4 ± 7.4	1.2 ± 2.4	0.6 ± 1.2	0.5 ± 1.2	0.6 ± 1.2	96 (36.1)	18 (21.4)	78 (43.1)
Coffee & tea	1.2 ± 6.6	0.8 ± 4.5	1.3 ± 7.4	0.7 ± 3.2	0.5 ± 2.7	0.8 ± 3.4	27 (10.2)	5 (6.0)	22 (12.2)
Cereal and nut-based snacks	1.1 ± 5.3	1.4 ± 8.6	0.9 ± 2.8	0.5 ± 1.3	0.5 ± 1.7	0.4 ± 1.1	41 (15.4)	10 (11.9)	31 (17.1)
Nuts & seeds	1.0 ± 3.63	0.7 ± 3.1	1.1 ± 3.9	0.8 ± 3.2	0.7 ± 2.6	0.9 ± 3.4	27 (10.2)	7 (8.3)	20 (11.0)
Chocolate	0.9 ± 3.7	1.2 ± 5.1	0.8 ± 2.9	0.5 ± 2.2	0.8 ± 3.3	0.4 ± 1.4	26 (9.8)	8 (9.5)	18 (9.9)
Flavour enhancers	0.9 ± 4.1	0.8 ± 3.5	0.6 ± 2.4	0.7 ± 3.3	0.8 ± 4.7	0.50 ± 2.0	102 (38.3)	32 (38.1)	69 (38.1)
Ice cream & alternatives	0.8 ± 2.9	1.0 ± 3.0	0.8 ± 2.8	0.5 ± 1.7	0.6 ± 1.7	0.5 ± 1.7	34 (12.8)	13 (15.5)	21 (11.6)
Fish & fish products	0.8 ± 4.6	1.5 ± 6.4	0.5 ± 3.4	0.8 ± 4.9	1.9 ± 7.6	0.4 ± 2.8	12 (4.5)	7 (8.3)	5 (2.8)
Yogurts & alternatives	0.8 ± 3.9	0.2 ± 2.0	1.1 ± 4.4	0.5 ± 2.0	0.1 ± 1.0	0.7 ± 2.3	17 (6.4)	1 (1.2)	16 (8.8)
Soup	0.5 ± 4.4	0.2 ± 1.5	0.7 ± 5.2	0.2 ± 1.8	0.1 ± 0.8	0.3 ± 2.2	6 (2.3)	1 (1.2)	5 (2.8)

Food group classifications *	Contribution to protein intake (%) in population	Contribution to protein intake (%) in males	Contribution to protein intake (%) in females	Total protein intake (g/d)	Male protein intake (g/d)	Female protein intake (g/d)	Total consumers of food group n (%)	Male consumers of food group n (%)	Female consumers of food group n (%)
Other mixed dishes	0.4 ± 3.2	0.0 ± 0.0	0.7 ± 3.9	0.5 ± 3.9	0.0 ± 0.0	0.8 ± 4.7	6 (2.3)	0 (0.0)	6 (3.3)
Fruit based drinks	0.4 ± 3.0	0.2 ± 1.4	0.5 ± 3.5	0.2 ± 0.9	0.2 ± 1.0	0.2 ± 0.9	26 (9.8)	9 (10.7)	17 (9.4)
Sports gels & bars	0.4 ± 3.3	0.4 ± 2.7	0.4 ± 3.6	0.4 ± 3.0	0.4 ± 2.8	0.4 ± 3.1	5 (1.9)	2 (2.4)	3 (1.7)
Dietary supplements and meal alternatives	0.4 ± 3.4	0.8 ± 5.2	0.2 ± 2.2	0.5 ± 4.1	1.3 ± 7.1	0.1 ± 0.9	4 (1.5)	3 (3.6)	1 (0.6)
Pulse based foods	0.2 ± 1.7	0.2 ± 1.0	0.2 ± 1.9	0.1 ± 0.8	0.2 ± 1.1	0.1 ± 0.7	5 (1.9)	2 (2.4)	3 (1.7)
savoury snacks	0.2 ± 1.0	0.0 ± 0.1	0.2 ± 1.2	0.1 ± 0.6	0.0 ± 0.1	0.1 ± 0.7	10 (3.8)	1 (1.2)	9 (5.0)
Sugary foods and confectionary	0.1 ± 0.7	0.2 ± 1.2	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.2	0.1 ± 0.3	51 (19.2)	16 (19.0)	35 (19.3)
Tofu & meat alternatives	0.1 ± 1.0	0.0 ± 0.0	0.1 ± 1.2	0.0 ± 0.6	0.0 ± 0.0	0.1 ± 0.7	1 (0.4)	0 (0.0)	1 (0.6)
Sweet beverages	0.0 ± 0.2	0.1 ± 0.3	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.0	11 (4.1)	5 (6.0)	5 (2.8)
Dairy based desserts	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	5 (1.9)	2 (2.4)	3 (1.7)

Abbreviations/notes: % (percentage), g/d (grams per day), ± SD (Standard deviation). *Values are expressed as mean ± SD. One participant's sex was unknown, but they were included in the analysis above under total population

3.12 Discussion

3.13 Key findings of the results

This study aimed to assess dietary protein intake, food sources of protein, and adherence to the NRVs for protein among adolescents in NZ. Our findings indicate that males consume significantly more energy, protein, and a higher percentage of energy from protein compared to females. The mean protein intake for both sexes met the EAR and AMDR; however, inadequacy rates were high, with 16.7% of males and 20.4% of females falling below the EAR, and 36.9% of males and 44.2% of females below the AMDR. While adolescents consumed both plant and animal protein sources, meat-based sources contributed significantly more to overall protein intake among NZ adolescents.

3.14 Protein intake of adolescents

We found that the mean protein intake for both sexes was double their respective EARs, with males consuming 98.5 ± 66.8g/day and females 70.1 ± 45g/day, compared to the protein requirements of 49g/day for males and 35g/day for females (30). In terms of % TE from protein, both males (18.3 ± 8.1% TE) and females (16.2 ± 5.4% TE) met the recommended range of 15-25% (30). These results align with other NZ studies, which have also shown adolescents typically exceed EARs for protein (8-10). Notably, female protein intake has remained around 70g/day since the 2002 National Children's Nutrition Survey (8-10). While male intake of 98.5g/day is slightly lower than earlier findings of 108-113g/day, though still above EAR levels (8,10). The mean percentage of energy from protein has remained stable for males at around 18% and has increased slightly for females, from 15.4% to 16.2%, since the Survey of Nutrition, Dietary Assessment, and Lifestyles which was undertaken between 2019 to 2020 (10).

One concerning finding was that a high proportion of adolescents had protein intakes below the AMDR, with 36.9% of males and 44.2% of females falling short. This is similar to the Survey of Nutrition, Dietary Assessment, and Lifestyles which reported that 13.7% of males and 47.7% of females had intakes below the AMDR, though the percentage of males with inadequate intakes was higher in our study (10). The NZ AMDR requirements were set above 10% of energy as protein which is the minimum amount required for optimal physiological functioning of the body (30,34). It is therefore likely that not all those under the AMDR will have significant consequences although there is the risk of not meeting micronutrient requirements the lower energy intake drops (30).

In the present study most, adolescents met their respective EAR requirements (80.5%) however we observed that a high proportion of both male (16.7%) and female (20.4%) adolescents did not meet the EAR for protein intake. These findings contrast with previous studies from NZ and globally, which reported a significantly lower prevalence of protein inadequacy among adolescents (8,10,73). Our results are consistent however with prior research highlighting that females tend to have higher rates of protein inadequacy compared to males. (8,10,73). Interestingly, our findings are more comparable to studies from the USA, where similarly high rates of inadequacy have been observed (74). For instance, 11.5% of females aged 14-18 years in the USA were reported to have protein intakes below the EAR. (74). For adolescents not meeting the EAR for protein they may be at risk of growth-related issues (5,6).

Possible explanations for differences in our findings for the EAR and prevalence of low AMDR rates could include variations in the methodologies used to assess inadequacy rates, particularly the absence of repeat 24-hour recalls in our study, which could contribute to intake variability (53). Additionally, participants who did not meet the EAR and AMDR for protein tended to have energy intakes on the lower end of the established ranges for females (2090–14,640 KJ) and males (3350–16,740 KJ) in our data analysis, suggesting that underreporting could be a factor. This aligns with previous evidence indicating that adolescents, particularly those who are older, obese, or female, tend to underreport their dietary intake (50).

Another potential reason for the lower protein intakes observed in our study is the higher proportion of Māori and Pacific participants from moderately to highly socioeconomically disadvantaged areas compared to previous NZ studies (10). Socioeconomic factors such as cost, access, food insecurity and knowledge related to healthy foods likely contribute to the lower intake of protein observed compared with other NZ studies (105).

In higher socioeconomically deprived areas adolescents are more likely to have diets of a lower quality consisting of energy-dense, nutrient-poor foods as these are more commonly available (105). In our study we found that one of the largest food group contributors to adolescent protein intake was burgers, pizza, and Mexican food (13.8 ± 26.4%) which often consist of UPFs. While these foods do contain protein, UPFs are generally lower in protein density compared to whole food sources, potentially contributing to the overall lower protein intake observed (96). In contrast, previous NZ studies used a broader 'bread-based dishes' category, which included not only burgers, pizza, and Mexican foods but also items such as sandwiches, filled rolls, doner kebabs, spring rolls, wontons, and stuffing (8,10). This variation in food group classification makes direct comparisons challenging and may partially explain the differences in reported protein intakes.

3.15 Main sources of protein in the adolescent diet

Our study found that the main food sources contributing to protein intake among adolescents were meat and meat products (17.7 ± 25.7%), burgers, pizza, and Mexican dishes (13.8 ± 26.4%), pasta and rice dishes (9.8 ± 22.4%), and bread and bread products (7.5 ± 13.7%). These results align with findings from the 2008/09 NZ Adult Nutrition Survey, 2002 National Children's Nutrition Survey, and Survey of Nutrition, Dietary Assessment, and Lifestyles, which identified bread-based dishes, poultry, grains and pasta, and bread as key protein sources (8-10). However, our data suggest a decline in the contribution of milk and bread to adolescents' protein intake compared to earlier surveys (8,9). Milk, which accounted for 8.8% and 11% of protein intake in the 2008/09 and 2002 surveys, respectively, contributed only 4.7 ± 10.8% in our study, while bread decreased from 13% and 11.1% to 7.5 ± 13.7% (8,9). While our bread and bread product group were comparable to the earlier bread groups, the milk and milk products group in our study was slightly narrower than the earlier milk group, as it did not include milkshakes (8,9). This decline in milk and bread may be influenced by rising food costs, particularly for dairy products (92). Although direct comparisons are complicated by differences in food group classifications, globally, the pattern of meat, bread, grains, cereals, and dairy as major protein contributors appears to have remained consistent (71,77,78,80).

Our findings show that adolescents are primarily consuming animal-based proteins, along with plant-based sources such as bread, pasta, rice, and grains. Contrary to initial expectations, there was no significant shift toward plant-based alternatives, with low consumption of meat alternatives, legumes, beans, nuts, and seeds observed (11). As a result, adolescents are likely to meet their amino acid requirements, with meat sources offering high-quality, complete proteins (83). Several factors may explain this trend. NZ food culture is largely centred around meat consumption, with many adolescents viewing meat as 'normal' or 'necessary' therefore, adolescents and their families may continue to purchase meat products even if costs are rising (106). In comparison, plant-based eating may be perceived as expensive and put adolescents off purchasing them due to desire of saving money (106). Additionally, some adolescents may lack the skills to cook plant-based meals or have limited control over what foods are available in the household (106). Motivation can also be a barrier; despite understanding the concept of healthy eating, some adolescents may prioritise immediate food preferences over long-term health outcomes and choose less healthy options (106).

3.16 Strengths and limitations

One of the key strengths of our study was the inclusion of an ethnically and socioeconomically diverse group of participants. This diversity makes our study representative of important demographic groups. Additionally, we were among the first studies in NZ to conduct research using the advanced electronic survey tool Intake24, specifically adapted for the NZ food environment and population (100). Furthermore, we used the 24-hour multiple-pass recall method to collect dietary data which has been recognised as one of the most effective dietary assessment methods for use in adolescents (53). It is also important to consider the limitations of our study. We were unable to obtain a second 24-hour recall from a subgroup of adolescents within the study. This additional data would have enabled a more precise assessment of the usual protein intake distribution within the adolescent population, reducing the risk of overestimating the prevalence of inadequacy (107). Also, as with any dietary assessment method, there are limitations such as a participant's ability to remember what and how much they ate, and adolescent tendency to underreport due to social acceptability or motivation (46,50).

3.17 Conclusion

In this study, we demonstrated that most NZ adolescents are meeting their protein requirements, although the rates of inadequacy for both the EAR and AMDR were higher than expected. Protein food sources in adolescent diets generally include a range of both animal and plant foods. This research provides valuable updates to the field of nutrition, offering current data on protein intake and sources, building on findings from nearly five years ago (10). Future research would benefit from using two or more non-consecutive 24-hour recalls on a similar population of adolescents to verify the levels of inadequacy reported. Additionally, exploring protein intake and sources among adolescents following different dietary patterns, particularly vegetarian or vegan diets, would be a valuable area of further study.

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Chapter 4: Conclusions and recommendations

4.1 Achievement of aims and objectives

The aim of this research was to describe protein intake and food sources among adolescents aged 14-19 years living in the Auckland, Waikato, and Bay of Plenty (BOP) areas of New Zealand (NZ). Objectives included 1) To describe the protein intake of adolescents, 2) To compare the protein intake of adolescents with the recommended intakes for adolescents 3) To investigate the dietary sources of protein consumed by adolescents.

This study found that the mean intakes for protein and percentage of total energy from protein were sufficient for both sexes of adolescents when comparing these to the estimated average requirement (EAR) and acceptable macronutrient distribution range (AMDR). However, rates of inadequacy were high in this study compared to previous findings both in NZ and globally (8,10,73). Over one-third of males and nearly half of females had protein intakes below the AMDR and 16.7% of males and 20.4% of females had intakes below the EAR. We found that the primary sources of protein for adolescents were meat and meat products (17.7%), burgers, pizza, and Mexican dishes (13.8%), pasta and rice dishes (9.8%), and bread and bread products (7.5%). Most protein comes from animal-based sources consumed with plant sources such as bread, pasta, rice, and grains. Plant-based sources of protein such as legumes and soy-based meat alternatives contributed minimal amounts to protein intake suggesting that adolescents are still meeting their amino acid needs through high-quality complete animal proteins.

4.2 Research impact

This research offers the most current evidence on the protein intake of NZ adolescents, providing valuable insights until the next national nutrition survey is conducted. Findings from this study indicate high inadequacy rates which may mean that adolescents are not consuming enough protein within their diets. Therefore, the results should be disseminated to inform targeted public health interventions aimed at improving protein intake among adolescents in New Zealand who have inadequate protein consumption, for example school based food initiatives. The findings from this study could assist the government and other stakeholders in administering and evaluating NZ's school lunch programme (108). Recent changes, such as budget cuts and modified lunch options, may have a direct impact on students' nutrition (108). By including data from students participating in the programme, this study offers a baseline for future comparisons, enabling the assessment of potential shifts in protein intake and sources among adolescents because of these changes. Schools that participated in our study may also find our protein-related findings useful for implementing changes in their environments to better support students' nutritional needs.

4.3 Strengths

This study had several strengths, including the inclusion of an ethnically and socioeconomically diverse range of participants, particularly those of Māori and Pacific ethnicity, as well as adolescents facing moderate to high levels of socioeconomic barriers. These groups may require greater nutritional support, especially when compared to European adolescents or those with a high socioeconomic status. We used a multiple-pass 24-hour recall (MP24HR) as our dietary assessment method. This technique is known to improve accuracy and reduce underreporting by allowing participants to review their food and drink intake multiple times during the recall process, offering several opportunities to remember their consumption through prompts and cues (53). Lastly, our study was comprehensive because it reviewed both the quantity of protein consumed and the food sources providing protein. While understanding protein intake levels helps determine whether adolescents are meeting their nutritional needs, it is equally important to assess the quality of the protein. Adequate protein intake alone is insufficient if the diet lacks the variety necessary to provide all essential amino acids. Without high-quality protein sources, essential processes like protein synthesis could be hindered, affecting the body's ability to carry out processes such as tissue growth and repair (31,48).

4.4 Limitations

For our study, we used a single 24-hour recall with a large sample size of 266 participants, which is sufficient for accurately estimating the group mean for nutrients such as protein (109). However, we were unable to obtain a repeat 24-hour recall from a subgroup of participants, which would have allowed us to assess the distribution of usual intake. This is typically recommended when determining the proportion of a group falling below dietary recommendations (NRVs) to avoid overestimating levels of inadequacy (107). Therefore, there may be limitations in the conclusions that can be drawn from the inadequacy rates seen in our data.

There are also certain limitations when working with adolescent populations. As children age there is an evident increase in energy underreporting (50). This shift occurs as the responsibility for reporting dietary intake transitions to the adolescents themselves (50). This age group often experiences greater autonomy, leading to more irregular eating patterns and increased food consumption outside the home (50). Additionally, adolescents' higher energy requirements and potential feelings of boredom or irritation with dietary reporting can reduce their motivation to participate (50). These challenges are often compounded by heightened body image concerns during adolescence, with research showing that adolescents who are obese and those who are female are more likely to underreport their dietary intake (50). However, we utilised the electronic 24-hour recall tool Intake24, which may have been more engaging for adolescents due to its technology-based format (58). The 24-hour recall methodology is also less time-consuming and invasive than other dietary assessment methods, potentially increasing its acceptability and compliance within this age group (50).

Additionally, the food groupings we used, such as meat and meat products and bread and bread products were broad. This made it hard to interpret which specific foods within those categories contributed most to adolescent protein intake. For example, meat and meat products included chicken, pork, beef, lamb, and processed meats. However, our categorisation did not allow us to determine if one meat such as chicken or processed meats was more significant. This is important because not all meat sources have the same impact on health. For instance, processed meats, which were grouped alongside fresh meats, are associated with increased risks of diseases such as cancer (87). Similarly, bread and bread products included products like sweet breads, scrolls, rolls, bagels, and all other types bread. Bakery products such as sweet breads may be higher in overall sugar content and unhealthy fats when compared with wholegrain breads which will contain higher overall fibre content and be better for health outcomes (87). Therefore, without distinguishing between the foods in these broad categories, we cannot assess the quality of the protein intake or its potential long-term health implications.

4.5 Recommendations and suggestions for further research

The current study provided a general overview of the protein intake of NZ adolescents and highlighted potential deficiencies in their protein consumption. However, due to the absence of a second 24-hour recall for a subsample of participants, there are limitations to the conclusions that can be drawn about NZ adolescent protein deficiency. This presents several opportunities for further research.

For instance, this study did not examine the distribution of protein across the day or which protein sources were most frequently consumed for different meals, such as breakfast, lunch, or dinner. It would therefore be beneficial to explore this in the adolescent population so that it could provide more insights into possible nutritional intervention areas.

Further research could be undertaken looking at protein intake and sources of adolescents following different dietary patterns, for example, vegan and vegetarian. Adolescents who are not consuming meat or animal products could be at a higher risk of protein and essential amino acid inadequacy. Plant options tend to be incomplete and have lower overall protein content (83,86,110). So, this research could provide insight into how they are managing and implementing these diets and whether they are doing this effectively by combining plant proteins (83).

Additionally, to our knowledge there has been no research on protein intake and sources undertaken on adolescents aged 10-14 years in NZ since the 2002 Children's Nutrition Survey (9). Our study did contain some adolescents aged 14 years but of a minimal proportion. It would therefore be valuable to have more recent research on this younger age group. Given the high rates of protein inadequacy found in this study, future research with a similar population should consider using two or more non-consecutive 24-hour recalls. This would help account for day-to-day variability in dietary intake and provide a more accurate representation of protein deficiency in this population (53).

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Appendices

A) Demographic questionnaire

What is the participant ID number you were given

____

What school do you attend

____

What is your age

- ☐ 10 years
- ☐ 11 years
- ☐ 12 years
- ☐ 13 years
- ☐ 14 years
- ☐ 15 years
- ☐ 16 years
- ☐ 17 years
- ☐ 18 years
- ☐ 19 years
- ☐ 20 years

What year level are you at school

- ☐ Year 7
- ☐ Year 8
- ☐ Year 9
- ☐ Year 10
- ☐ Year 11
- ☐ Year 12

☐ Year 13

What was your sex at birth (for example, what was recorded on your original birth certificate)

☐ Male
☐ Female
☐ Prefer not to say

What is your gender

☐ Male
☐ Female
☐ Prefer not to say
☐ Other, please enter below

___

What ethnic group (s) do you belong to? (select all that apply)

☐ New Zealand European
☐ Maori
☐ Samoan
☐ Cook Islands Maori
☐ Tongan
☐ Niuean
☐ Chinese
☐ Indian
☐ Other e.g. Dutch, Japanese, Tokelauan

___

Do you take any dietary supplements regularly? (Select all that apply)

☐ No
☐ Iron
☐ Vitamin c
☐ Probiotic
☐ Magnesium

- ☐ Protein powder
- ☐ Other, please enter below

____

Did you eat the free school lunch yesterday

- ☐ Yes
- ☐ No

How much of the protein containing food did you eat? (e.g. meat, egg, chicken, fish, chickpeas, lentils)

- ☐ None
- ☐ Some
- ☐ Half
- ☐ Most
- ☐ All
- ☐ More than one portion, please list how many

____

How much of the carbohydrate-containing food did you eat? (e.g. potato, kumara, bread, rice, noodles)

- ☐ None
- ☐ Some
- ☐ Half
- ☐ Most
- ☐ All
- ☐ More than one portion, please list how many

____

What amount of vegetables did you eat? (Not including potatoes or kumara)

- ☐ None
- ☐ Some
- ☐ Half
- ☐ Most
- ☐ All
- ☐ More than one portion, please list how many

____

Was a snack provided with your lunch

- ☐ Yes
- ☐ No
- ☐ More than one snack was provided

What was snack one?

____

What amount of the snack did you eat

- ☐ None
- ☐ Some
- ☐ Half
- ☐ Most
- ☐ All
- ☐ More than one portion, please list how many

____

Did you have another snack?

- ☐ Yes
- ☐ No

B) Food groupings

Food group name	Food and drink items
Meat & meat products	Canned meat Deli meat (e.g. ham, bacon, sandwich) Meat - beef / veal Meat - chicken Meat - lamb / mutton Meat - offal Meat - pork Meat - poultry Meat - wild / game Meat - sausages Meat - schnitzel / crumb - chicken Meat - schnitzel / crumb - beef / veal / pork Meat - burger patty / mince / kebab skewer Meat - diced / strips / kebab skewer
Burgers, pizza, & Mexican	Burgers - beef / hamburger Burgers - chicken / fish Burgers - vegetarian / vegan Burgers - pork / bacon / other Pizza Pizza - homemade Tacos, nachos, burritos
Pasta & rice dishes	Pasta dishes - lasagne, cannelloni, pasta bake Pasta dishes - dairy sauce (e.g. macaroni cheese) Pasta dishes -tomato sauce (e.g. Bolognese) Pasta dishes - pesto & carbonara sauce Rice dishes (e.g. risotto, paella, fried rice)
Breads & bread products	Bread - untoasted Bread - toasted Bread - homemade (toasted & untoasted) Rolls & bagels Flat breads, wraps & pita bread English muffins and crumpets Savoury breads and rolls Sweet breads, buns and scrolls
Savoury composite foods	Kebabs, yiros, wraps & flatbreads

	Hotdog (Hot dog) Savoury pies, sausage rolls & pastries Quiche sandwiches
Mixed cooked dishes	Stir fry - meat Stir fry - chicken / poultry Stir fry - fish / seafood Stir fry - vegetarian / vegetable Curry - meat Curry - chicken / poultry Curry - fish / seafood Curry - vegetarian / vegetable Casseroles & stews - meat Casseroles & stews - chicken / poultry Casseroles & stews - fish / seafood Casseroles & stews - vegetarian / vegetable
Grain based foods	Rice Couscous, quinoa & other grains Pasta Noodles
Milk & milk alternatives	Milk - dairy (including low fat, lactose free) Milk - dairy alternatives - almond, oat, other Milk - dairy alternative - soy Flavoured milk - dairy milk (e.g. hot chocolate, prepared Milo) Flavoured milk - dairy milk alternatives (e.g. soy, almond) Flavoured milk - powders (e.g. Milo powder) Milk - goat and sheep Milk powder, evaporated milk & buttermilk
Vegetables	Avocado Asparagus Artichoke Carrot, celery & fennel Beans, peas & sprouts Beetroot, spinach & silverbeet Broccoli & cauliflower Brussel sprout, cabbages & bok choy Capsicum, eggplant & tomato Corn Cucumber, pumpkin, squash & zucchini Garlic, leek, onion & ginger Kale, lettuce & other leafy greens

	Mixed greens or vegetables Mushrooms Potato & potato dishes Potato chips, fries & wedges Kumara, cassava, taro, yams Swedes, turnips, parsnip Other vegetables Salad- potato or grain based (e.g. pasta) Salad- other
Breakfast cereals	Breakfast cereals - corn based Breakfast cereals - mixed grain Breakfast cereals - rice based Breakfast cereals - wheat based Muesli & granola Porridge & cooked oats Weet-Bix
Chips & crisps	Potato chips
Dairy based drinks	Milk shakes and thick shakes Other drinks (e.g up and go, coconut water) Smoothies
Egg & egg dishes	Raw egg Cooked eggs Omelette & scrambled eggs Egg dishes (e.g. Frittata & souffle)
Snacks and sweet biscuits	Sweet biscuits - with other fillings Sweet biscuits - with fruit, jam or cream Sweet biscuits - with chocolate Ice cream wafers & cones Crackers Crispbreads & rice/corn cakes
Cheese & cheese products	Cheese - dairy alternatives Cheese - hard (e.g. cheddar, parmesan) Cheese - medium (e.g. mozzarella, feta) Cheese - other types (e.g. goats, sheep, cheese) Cheese - processed & spreads Cheese - soft (e.g. brie, cottage cheese)
Bakery and dessert items	Banana bread & similar Cakes - cheesecake Cakes - chocolate Cakes - fruit & vegetable based (e.g. carrot)

	Cakes - other cakes (e.g. red velvet) Cakes - plain & sponge Sweet slices (e.g. brownie) Doughnuts & waffles Fruit crumble Muffins Other desserts Pancakes, pikelets & crepes Pastry (no filling) Puddings & cake style desserts Scones Sweet pie/tart/pastry - fruit (e.g. apple pie) Sweet pie/tart/pastry - other (e.g. eclair, custard)
Savoury Asian foods	Sushi Dumplings, rice paper rolls & steamed buns
Fruits	Apples Apricot, nectarine & peach Banana Cherry, plum & date Grapes, sultanas, raisins & currants Figs, kiwifruit, pomegranate & passionfruit Mandarin, orange, lemon & lime Pears Pineapple, mango & melons Strawberry, blueberry & other berries Other fruits Mixed fruits
Coffee & tea	Coffee - decaf Coffee - alternatives (e.g. turmeric latte) Coffee - instant, mixes & sachets (e.g. nescafe) Coffee - iced Teas
Cereal and nut-based snacks	Muesli or cereal style bars Other snack bars & balls (e.g. nut bars, bliss balls)
Nuts & seeds	Nuts - almond, cashew Nuts - peanut, coconut, other Nuts - mixed (e.g. trail mix) Seeds Nut spreads (e.g. peanut butter)
Chocolate	Chocolate - plain

	Chocolate - caramel Chocolate - fruit / nut Chocolate - other filling Chocolate - covered sweets / nuts / raisins
Flavour enhancers	Gravy / stock Tomato / BBQ sauces Chilli / hot sauces Mayonnaise, mustard & pesto White sauces / cheese sauces Soy, satay or teriyaki sauce Fruit sauces Seafood or Cocktail Sauce & Fish Sauce Other savoury sauces Pasta sauces Salad dressings Vinegars Pickles, chutneys & relishes Dips Savoury spreads & pates
Ice cream & alternatives	Ice cream Sorbet, gelato & frozen yoghurt Ice cream bars & sticks Icy poles & ice blocks Ice cream - dairy alternative
Fish & fish products	Fish - salmon, tuna Fish - cod, gurnard, hoki, kahawai, snapper, tarakihi Fish - sardines, anchovies, herring, mackerel Fish - battered, crumbed & fish fingers Shellfish - calamari, scallop, oyster, mussel Shellfish - prawn, crab, lobster Seafood - mixed, other (e.g. eel, caviar)
Yogurts & alternatives	Yoghurt - plain (e.g. natural Greek) Yoghurt - flavoured Drinking yoghurt (e.g. fruche, keffir) Yoghurt - dairy alternatives (e.g. soy, almond, coconut)
Soup	Soup - Vegetable based (e.g. pumpkin, tomato, minestrone) Soup - Meat or fish based (e.g. beef & vegetable, chicken, pea & ham) Soup - Asian style (e.g. ramen, hot pot, laksa)

Other mixed dishes	Other mixed dishes - meat or fish/seafood Other mixed dishes - vegetable / vegetarian Ready meal, with pasta / noodles / rice Ready meal, with vegetables
Fruit based drinks	Cordial Fruit drink Juice - mixed fruit (e.g. apple & mango) Juice - single fruit (e.g. apple)
Sports gels & bars	Protein bars Protein gels Energy gels
Dietary supplements and meal alternatives	Protein powder- ready to drink Meal replacement drink powders Meal replacement snacks & soups Other dietary supplements Supplementary & medical foods Protein powder - powder only
Pulse based foods	Baked beans Cooked legumes & pulses (excl. baked beans)
savoury snacks	Popcorn Jerky Papadum
Sugary foods and confectionary	Lollies Other confectionary (e.g. fudge, marshmallow) Sugar & honey Sweetener Syrups Jam / marmalade / paste / curd Other sweet spreads e.g. chocolate spread Toppings & sweet sauces Icing Jelly
Tofu & meat alternatives	Tofu & tempeh Protein based meat substitutes Vegetable & legume-based meat substitutes
Sweet beverages	Energy and sports drinks Soft drinks and flavoured mineral water
Dairy based desserts	Custard Cream Dairy based desserts