Determining the Relative Validity and Reproducibility of a Food Frequency Questionnaire to Assess Food Group Intake in High Performing Athletes

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Abstract

Background: *Optimal nutrition is essential for high performing athletes in order to train effectively, optimise recovery and improve their performance. Given the differences in dietary requirements and practices that exist between athletes and the general population, dietary assessment tools designed specifically for athletes are required. Food frequency questionnaires (FFQs) are commonly used to assess habitual dietary intake as they are inexpensive, quick and easy to administer. Currently there are no athlete-specific, up-to-date, valid and reproducible FFQs to assess food group intake of athletes. This study aims to determine the relative validity and reproducibility of an athlete-specific FFQ against an estimated four day food record (4DFR) to assess food group intake in high performing athletes.*

Methods: *Data from 66 athletes (24 males, 42 females) representing their main sport at regional level or higher and aged 16 years and over, was collected as part of a validation study in 2016. Athletes completed the athlete-specific FFQ at baseline (FFQ1) and four weeks later (FFQ2) to assess reproducibility. An estimated 4DFR was completed between these assessments to determine the relative validity of the FFQ1. Foods appearing in the 4DFR were classified into the same 129 food groups as the FFQ, and then further classified into 28 food groups in gram amounts. Agreement between the two methods for intake of food group and core food group intake was assessed using Wilcoxon signed rank tests, Spearmans correlation coefficients, cross classification with tertiles, the weighted kappa statistic and Bland-Altman analysis.*

Results: *The FFQ overestimated intake for 17 of 28 food groups compared with the 4DFR (p<0.05). Correlations ranged from 0.11 (processed foods) to 0.78 (tea, coffee & hot chocolate), with a mean of 0.41. Correct classification of food groups into the same tertile ranged from 35.4% (starchy vegetables) to 55.5% (fats & oils). Misclassification into the opposite tertile ranged from 4.6% (legumes) to 15.4% (starchy vegetables; sauces & condiments). The weighted kappa demonstrated fair to moderate agreement (k=0.21-0.60) for food groups. Bland-Altman plots suggested that for most of food groups, the difference between FFQ1 and the 4DFR increased as the amount of each food group consumed increased. Intake from FFQ1 was significantly higher than from FFQ2 for 13 of 28 food* *groups. All effect sizes were small (r=0.1). Reproducibility correlations ranged from 0.49 (potato chips; fats & oils) to 1.00 (tea, coffee & hot chocolate), with a mean of 0.65. For the 23 food groups classified into tertile, 20 had >50% of participants correctly classified, <10% grossly misclassified, and 20 demonstrated moderate to good agreement (k=0.61-0.80). The exceptions were dairy; fats & oils; and processed foods & drinks which presented fair agreement (k=0.21-0.40).*

Conclusions: *The FFQ showed reasonable validity and good reproducibility for assessing food group intake in high performance athletes in New Zealand. The FFQ could be used in future research as a convenient, cost-effective and simple way to obtain athletes' food group intake, and identify those who could benefit from interventions to improve their nutritional adequacy and potentially their athletic performance.*

Keywords: *athlete; dietary assessment; questionnaire; validation; reproducibility*

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Dedication

I would like to dedicate this thesis to my Oma, Julia Vonk. Sadly you passed away during the completion of this thesis, but I know you will be watching on from heaven proud of my achievements. You had the most beautiful soul and were always so supportive and encouraging of everything I did in life. You are dearly missed and will always hold a place in my heart.

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Abbreviations List

FFQ	Food frequency questionnaire
FFQ1	Food frequency questionnaire appointment one
FFQ2	Food frequency questionnaire appointment two
FR	Food record
4DFR	Four day food record
24-hr	Twenty-four hour
DLW	Doubly labelled water
NZ	New Zealand
NZWFFQ	New Zealand Women's food frequency questionnaire
MUHNRC	Massey University Human Nutrition Research Centre
MUHEC	Massey University Human Ethics Committee
ISAK	International Society for Advancement of Kinanthropometry
SPSS	Statistical package for the social sciences
RDI	Recommended daily intake
LOA	limits of agreement
SD	standard deviation
CI	confidence interval
r	correlation coefficient
df	degrees of freedom
t	test statistic
i.e.	in other words
k	weighted kappa statistic
p	p-value
n	number
e.g.	example

BW	body weight
EI	energy intake
PAL	physical activity level
BMR	basal metabolic rate
MJ	Mega-joule
M	male
F	female
CHO	carbohydrate
BCAAs	branched chain amino acids
ATP	adenosine tri-phosphate
FUQ	Food use questionnaire
RAM	Rapid assessment method
REAP	Rapid eating assessment method
DATA	Digital analysis tool for athletes
VSSR	Virtual Self-Service Restaurant
US	United States
UK	United Kingdom
>	greater than
<	less than
≤	less than or equal to

Chapter 1: Introduction

Diet has been increasingly recognised as a key component of athletes' success in sport. Athletes, particularly high performance athletes, partake in rigorous training practices which creates greater energy expenditure and increases stress placed on the body resulting in quicker depletions of micronutrient stores (Jeukendrup & Gleeson, 2018). As a result athletes typically have significantly higher nutritional requirements than that of the general population and thus require a dietary intake plentiful in energy and nutrients from a variety of foods and all core food groups to support health, prevent deficiencies and illnesses, and enable development of functional and metabolic adaptations for optimal athletic performance (Jeukendrup & Gleeson, 2018). Due to immense pressure placed on athletes, internally and externally, to perform, athletes can become particularly susceptible to nutrition faddism, dieting and other unhealthful practices such as drugs, alcohol and the inappropriate use of supplements. Having low energy availability compromises key constituents involved in improving athletic performance such as protein synthesis and muscle glycogen storage. It can also severely implicate the functioning of the cardiovascular, gastrointestinal and immunological systems, having detrimental effects on health (Godois, Coelho-Ravagnani, Raizel, & Verly-Junior, 2018; Maughan, 2009). These additional requirements for athletes highlight the importance of assessing their dietary intake to not only provide effective nutritional strategies which help promote training adaptations and achievement of sporting goals, but also ensures identification of unhealthful behaviours or nutritional inadequacies related to health status and athletic performance.

It is recommended athletes follow general population food and nutrition guidelines for baseline nutrition to support overall health (Ministry of Health, 2015). These guidelines advise eating a variety of foods from the core food groups; vegetables and fruit, grains and cereals, milk and milk products, and lean proteins, and choosing drinks and snacks low in fat, sugar and salt (Ministry of Health, 2015). An internationally accepted athlete-specific food pyramid has been developed and validated by nutritionists and dietitians as an extension on the basic food pyramid to incorporate athletes' surplus needs. It provides additional servings required from each food group based on different training volumes and body masses (Mahan &

Raymond, 2016; United States Olympic Committee, 2010). Sport nutrition guidelines outline more specific nutrient recommendations (e.g. energy, carbohydrate, and protein) for athletes which are calculated using body weight and encompass their specific training regime (Thomas, Erdman, & Burke, 2016).

In order for sports dietitians and nutritionists to evaluate an athlete's dietary intake and provide them with effective nutrition strategies and recommendations, they need to have access to accurate and reliable dietary assessment methods. Use of prospective methods of dietary assessment such as duplicate portion and weighed or estimated food records are deemed the most accurate for use as they monitor current food consumption with day to day recording (Magkos & Yannakoulia, 2003). However, they are expensive and time consuming to complete which often results in poor compliance and alterations made to dietary intake recorded for convenience (Magkos & Yannakoulia, 2003). These methods may be particularly problematic in athletes who often lack the time and energy required to accurately complete them due to their busy and rigorous training schedules (Black, 2001). Retrospective methods such as 24-hr diet recalls, food frequency questionnaires (FFQs) and diet histories provide better descriptions of habitual food and beverage consumption, are relatively inexpensive and have minimal subject burden. Although they are reliant on the athlete's memory, honesty and ability to recall food intake, they may be better suited for use in the athlete population as less time is required to complete them and they can be easily scheduled to fit in and around the athlete's daily activities (Black, 2001).

Of the retrospective methods, and particularly when investigating dietary intake of large population groups, FFQs are the most frequently used as they can be self-administered, are the least time consuming for both the participants and the research team, and can be developed to be population-specific (Magkos & Yannakoulia, 2003; Pedišić, Vranešić Bender, & Mišigoj Duraković, 2008). For athletes this would include consideration of larger portion sizes and sports foods and drinks. FFQs also enable capturing of dietary intake over longer periods of time and thus are able to provide better descriptions of overall and 'usual' intake compared to food records. It is important that FFQs are current or updated and country specific due to differences and changes in common food choices, food composition, climate and food availability (Pedišić et al., 2008; Willett et al., 1985).

FFQs and all methods of dietary assessment have inherent limitations, however, there are also a number of challenges associated with assessing athletes' intakes compared to the general population. These include; larger energy intakes and portion sizes, use of supplements and ergogenic aids, higher intakes of fluid, variations in training programs, competition versus training phases, and differing behaviourisms (e.g. methods of weight-control practices to meet weight categories), seasonality changes (e.g. pre versus post season) and physiological requirements associated with different sports (e.g. strength and power versus endurance sport) (Baker, Heaton, Stein, Nuccio, & Jeukendrup, 2014; Magkos & Yannakoulia, 2003). Additionally, under-reporting of energy/macronutrient intake due to weight-restrictive sports, difficulty remembering numerous snacks consumed, and/or over-reporting of foods and supplements perceived to be beneficial is also common among athletes (Baker et al., 2014; Braakhuis, Hopkins, Lowe, & Rush, 2011; Briggs, Rumbold, Cockburn, Russell, & Stevenson, 2015). These limitations make precise descriptions and analysis of dietary intake difficult and highlight the importance of ensuring dietary assessment tools are well designed, population specific, up-to-date and thoroughly tested for validity and reproducibility (Heaney, O'Connor, Gifford, & Naughton, 2010).

Testing for validity and reproducibility of a dietary assessment tool in a population of interest prior to use is imperative. Despite the clear need for valid and reproducible dietary assessment tools for use in athletes, there is a severe lack of the applicability of such methods in the literature (Capling et al., 2017). Currently, only eleven have been developed and validated world-wide (Baker et al., 2014; Braakhuis et al., 2011; Briggs et al., 2015; Fogelholm & Lahti-Koski, 1991; Kurka, Buman, & Ainsworth, 2014; Nogueira & Da Costa, 2004; Rumbold, Gibson, Stevenson, & Dodd-Reynolds, 2011; Scoffier, Gernigon, Billi, & d'Arripe-Longueville, 2013; Sunami et al., 2016; Ward et al., 2004; Wardenaar et al., 2015). Of those, several are no longer suitable for use as their validation was undertaken over 10 years ago (Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Ward et al., 2004), many have only investigated one nutrient or component of dietary intake (Braakhuis et al., 2011; Briggs et al., 2015; Scoffier et al., 2013; Wardenaar et al., 2015), and the remainder have been validated for use overseas in countries such as Japan, the United Kingdom (UK) and the United States (US) (Kurka et al., 2014; Rumbold et al., 2011; Sunami et al., 2016) which is not directly translatable for use in New Zealand (NZ). Only four of these dietary assessment tools have been FFQs

(Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Sunami et al., 2016), and only two of these studies additionally tested for reproducibility (Braakhuis et al., 2011; Ward et al., 2004). Both of which only investigated one nutrient/component of the diet, and their re-administration periods were shorter than recommended, introducing possible errors of memory bias (Cade et al, 2002). Thus, there is a need for an up-to-date, validated and reproducible athlete-specific dietary assessment tool to assess dietary intake, specifically food group intake, in high performing athletes living in New Zealand.

1.1 Purpose of the study

Currently, there are no valid and reliable dietary assessment tools available for use in New Zealand to assess food group intake of athletes. Therefore, the purpose of this study is to determine the relative validity and reproducibility of an FFQ for assessing food group intake in high performing athletes in New Zealand. Such a tool would be useful for sports dietitians and nutritionists to identify athletes who would benefit from additional dietary advice. It may additionally be useful for future research studies exploring associations between dietary intake and athletic performance.

1.2 Aims, objectives & hypothesis

To determine the relative validity and reproducibility of a FFQ designed to assess intake of food groups in high performing athletes.

Objectives

- To validate the FFQ for food group intake against a consecutive four day estimated food record.
- To assess the reproducibility of the FFQ for food group intake by having athletes complete the FFQ on two separate occasions, four weeks apart.

Hypothesis

The FFQ will be a valid and reliable tool for assessing food group intake in high performing athletes.

1.3 Structure of the thesis

This thesis is comprised of four chapters. Chapter one introduces concepts of the research and highlights the purpose of the study. Chapter two is a review of the literature covering the importance of athletes' dietary intake for performance, dietary assessment methods, challenges with assessing athletes' dietary intake, considerations when assessing validity and reproducibility of FFQs, and a review of currently available dietary assessment tools exploring dietary intake in athletes. Chapter three is a research manuscript which includes a complete presentation of the research study conducted which includes an abstract, introduction, methodological procedures, results, discussion, and conclusion of findings. Chapter four concludes the thesis by providing a summary of the research findings, as well as a reflection of the strengths and limitations of the study, and recommendations for future research.

1.4 Researcher contributions

Table 1.1 *Researcher contributions to this study*

Researcher	Contribution to thesis
Dayna Stockley	**MSc Nutrition & Dietetic Student** Main researcher responsible for data entry and analysis of the 4DFR and FFQ, statistical analysis, interpretation of the results, author of thesis.
Dr Kathryn Beck	**MSc Main Academic Supervisor** Developed study protocol and adapted the FFQ. Supervision of the progression of the research through to completion, thesis revision and approval.
Dr Cath Conlon	**MSc Academic Co-supervisor** Developed study protocol, assisted with academic supervision and thesis revision.
Dr Helen O'Connor	Developed study protocol and assisted with food groupings.
Dr Pamela von Hurst	Developed study protocol.
Dr Rozanne Kruger	Developed original NZWFFQ.

Chapter 2: Literature Review

2.1 Introduction to the literature review

Assessing high performing athletes' dietary intakes is essential to ensure they are maintaining a well-balanced and energy adequate diet that supports their health, reduces their risk of illness and injury, and optimises their athletic performance. This literature review explores aspects related to the dietary assessment of athletes, specific dietary requirements for athletes, exploration of the various dietary assessment methods and challenges when assessing athletes' dietary intake, with particular focus on the use of FFQs. Current dietary assessment tools available for athletes are reviewed.

Relevant literature was gathered through use of the following online databases: PubMed, Web of Science and Google Scholar. The search was undertaken in reverse chronological order using the key search terms: dietary assessment, athletes, validity, reproducibility, food frequency questionnaire, NZ. These search terms were also used in combination with the two functions 'AND' and 'OR'. Journal articles matching the search criteria, within the publication period of 1984 to 2018 were reviewed along with relevant cited articles.

2.2 Dietary intake and performance

An athlete is defined as a person who is training in sports for several hours in all or most days of the week, with aims to improve their performance and participate in sporting competitions (Araújo & Scharhag, 2016). Adequate nutrition is essential for athletes to train effectively, optimise recovery, reduce risk of illness and injuries, and improve their athletic performance (Jeukendrup & Gleeson, 2018; Thomas et al., 2016). Athletes typically partake in a significantly greater amount of physical activity than the general adult (Mahan & Raymond, 2016). Physical activity not only expends energy, but also places considerable stress on the body which depletes stores of vitamins and minerals and increases nutrient requirements (Burke & Deakin, 2015). Thus it is particularly important that an athlete's diet contains a wide variety of foods from all core foods groups in sufficient quantities to provide enough energy and optimal levels of macro- and micronutrients to support exercise training and performance (Jeukendrup & Gleeson, 2018).

In high performing/elite athletes especially, consuming enough food at regular intervals can be challenging due to a lack of time (busy training schedules in addition to work/study commitments), difficulties consuming the sheer volume of food required to meet their needs, feeling too tired after training to prepare food, poor accessibility to food when travelling abroad for competition, and minimal knowledge or poor food preparation and cooking skills (Burke & Deakin, 2015; Maughan, 2009). Furthermore, research suggests that many athletes obtain nutrition information from unreliable sources including coaches, fellow athletes, advertisements and the internet rather than accredited and educated professionals such as sport dietitians (Bourke, Baker, & Braakhuis, 2018; Morente-Sánchez & Zabala, 2013). As a result, many athletes fall prey to nutrition faddism such as 'diets' and use of 'special sport supplements', and often make dietary choices that are not conducive to health or optimal performance. Although sports foods (e.g. sports bars) can provide a compact and convenient way to consume carbohydrates and protein when wholefoods may not be easily accessible, they should not be included in the 'everyday' diet and do not compensate for poor food choices (Buell et al., 2013). Supplements are typically expensive, contain a limited range of nutrients and can be harmful to health and performance if taken in excessive amounts over a prolonged period of time (Buell et al., 2013; Maughan, Greenhaff, & Hespel, 2011; Maughan, 2009). In addition, they may contain prohibited substances according to the World Anti-Doping Agency (WADA), which could result in athletes being disqualified from competition.

Athletes are often under immense pressure and have high expectations placed upon them to perform optimally, not only by themselves but also by their coaches, family members and the wider community (Buell et al., 2013). This pressure is further heightened for athletes involved with aesthetic and performance based sports where having a smaller weight is perceived as advantageous (e.g. long distance running, gymnastics). As a result, it is common for athletes to use unhealthful substances such as drugs (e.g. steroids) and partake in methods such as restrictive eating, binging and purging, or over-exercising beyond the requirements for good health, in attempts to improve performance and meet certain expectations (e.g. weight requirements) (Morente-Sánchez & Zabala, 2013). These behaviours typically result in inadequate energy intake which can lead to a host of serious health and performance implications including unwanted loss of muscle mass, menstrual dysfunction and hormonal disturbances, sub-optimal bone density, increased risk of fatigue, injury and illness, impaired adaptions and prolonged recovery (Spronk, Heaney, Prvan, & O'Connor, 2015).

These factors highlight the importance of assessing the nutritional adequacy of athletes' diets to identify potential problems and/or risk behaviours, prevent deficiencies and provide them with effective nutritional strategies to achieve their sporting and performance goals in a healthy way. It further highlights the need of ensuring athletes are provided with correct and relevant dietary information so they can carry out, and understand the importance of consuming a healthy, balanced diet that provides optimal amounts of energy and nutrients.

2.3 Athlete dietary requirements

According to the position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine, athletes are recommended to eat a well-balanced diet encompassing all macronutrients (carbohydrate, protein, fat) and all core food groups, in line with national food and nutrition guidelines for the general population to support long term maintenance of health (Rodriguez, DiMarco & Langley, 2009; Thomas et al., 2016). However, as these guidelines are designed for the general, moderately active, population, they can be difficult to apply practically for high performing athletes (Heaney et al., 2010; Mettler, Mannhart, & Colombani, 2009). Various visual models have been developed to demonstrate to athletes the importance of consuming a range of food groups. For example, in Switzerland an extension on the general population's food pyramid was developed for athletes to highlight their different energy and macronutrient needs in a user-friendly way (Mettler et al., 2009). In the United States of America, the Athletes Plate Model was developed as a guide to help athletes modify their servings and portions from each food group based on their training regime (Mahan & Raymond, 2016; United States Olympic Committee, 2010).

Although the general dietary principles for athletes are similar, energy and nutrient requirements can vary considerably between sports, and also individuals (Spronk et al., 2015). More individualised macro- and micronutrient composition modifications should be made depending on the age, gender, height, weight and body composition goals, type of sport, training frequency, intensity and duration, environmental conditions (such as heat and altitude) and lifestyle/culture of the athlete (Mahan & Raymond, 2016). Strategic amounts and timing of meals or snacks around training sessions may help to optimise energy availability, promote adaptations to training, and enhance recovery.

Carbohydrates

Carbohydrates (CHO) are the most essential nutrient for athletes as they are the body's main source of fuel for exercise (Jeukendrup & Gleeson, 2018). The body has a limited capacity to store CHO (approximately enough for 60-90 minutes of high intensity exercise) meaning CHO-rich foods need to be consumed regularly to replace these stores and support continued/repeated exercise training (Burke & Deakin, 2015).

CHO requirements vary depending on training load (duration, frequency and intensity of exercise) and thus CHO intake should directly reflect daily exercise levels (Burke & Deakin, 2015; Thomas et al., 2016). Daily CHO recommendations (g/kg body weight [BW]) for athletes range from; 3-5 for low intensity exercise volumes (i.e. <1 hour), 5-7 for moderate exercise volumes (i.e. 1-2 hours), 7-10 for high intensity exercise volumes (2-6 hours), and 8-12 for extreme endurance events (i.e. 6 hours+) (Burke & Deakin, 2015).

Timing of CHO intake can be manipulated to promote high CHO availability for a specific exercise session by consuming CHO before or during the session, or during the recovery period from the previous session. For simultaneous training sessions within eight hours of each other, consumption of CHO should occur as soon as possible after the first training to maximise effective recovery (Burke & Deakin, 2015; Thomas et al., 2016). During longer recovery periods (>8 hours) the timing of CHO-rich meals and snacks can occur whenever is most convenient for the athlete throughout the day as long as total energy needs are met (Rodriguez et al., 2009; Thomas et al., 2016). During these periods it is beneficial to choose nutrient-rich CHO foods such as wholegrain breads and cereals, fruits, vegetables and dairy products as they provide more sustained energy and additional nutrients to assist with recovery. Refined CHO foods such as honey, fruit juice, and sports gels are only necessary during long endurance events to provide a quick CHO source to the body or for athletes who have high energy requirements (Burke & Deakin, 2015).

Protein

Protein is a key nutrient for athletes as it supports the building and repair of muscles, metabolic adaptations, oxygen transport, muscle contractions, and the preservation of lean muscle mass (Jeukendrup & Gleeson, 2018). Total daily protein recommendations for endurance and strength-trained athletes range from 1.2 to 2.0 (g/kg BW) (Heaney et al., 2010; Thomas et al., 2016; Tipton & Wolfe, 2004). These recommended protein intakes can generally be met through diet alone without the use of additional supplements (e.g. protein powders). Maximal muscle protein synthesis post-exercise increases in a dose-dependent manner from zero to 20g, with no further benefits seen from ingesting >20g protein, as a "muscle full effect" occurs whereby any additional protein is oxidised and results in urea production (Morton, McGlory, & Phillips, 2015). From this, more recent guidelines have arisen recommending athletes consume moderate amounts (0.3g/kg BW) of high-quality/complete protein after key exercise sessions and every three to five hours, over multiple meals throughout the day, for optimal exercise training benefits (Thomas et al., 2016). High-quality/complete protein sources include beef, lamb, pork, chicken, fish, eggs and dairy products.

Fat

Fat is another necessary dietary component for athletes as it provides energy, essential fatty acids and facilitates the absorption of fat soluble vitamins (A, D, E & K). Daily recommendations for both the general population and athletes range from 20-35% of total energy intake with <10% from saturated fat (Thomas et al., 2016). It is recommended these percentages be individualised based on training load and body composition goals. Consumption of ≤20% of energy from fat is not recommended for athletes as it reduces dietary variety and the intake of fat soluble vitamins and essential fatty acids (Burke & Deakin, 2015). Conversely, high fat diets are also not recommended for athletes. This is as they displace CHO intake thus down regulating CHO metabolism, even when stored CHO (glycogen) is available, which diminishes rates of fat oxidation and impairs high intensity exercise performance (Rodriguez et al., 2009; Thomas et al., 2016). Examples of healthy/unsaturated fats include avocado, nuts and seeds, oily fish (e.g. salmon, tuna) and vegetable oils (e.g. olive oil) (Ministry of Health, 2015).

Vitamins, minerals and antioxidants

Vitamins, minerals and antioxidants play an important role in energy production, immune function and other key physiological processes required for general health. Exercise imposes stress on many metabolic pathways which overtime can lead to biochemical adaptations that increase the turnover and loss of many vitamins and minerals in the body (Burke & Deakin, 2015; Rodriguez et al., 2009). Greater intakes of micronutrients may be required to cover increased needs for building, repair and maintenance of lean body mass in athletes. The most common vitamins and minerals of concern in athletes' diets are calcium, vitamin D, B vitamins, iron, zinc, magnesium, and antioxidants such as vitamins C and E, beta carotene, and selenium (Thomas et al., 2016). Many of these, particularly water soluble vitamins (e.g. vitamin C and B vitamins) need to be consumed daily in order to maintain optimal levels (Jeukendrup & Gleeson, 2018). Deficiencies of micronutrients in athletes can result in significant impairments in training and sporting performance. Athletes at greatest risk are those who restrict energy intake, follow severe weight loss practices, eliminate foods or food groups, have minimal dietary variety, or are ill and/or recovering from injury. Athletes can meet their micronutrient requirements from a varied and energy-adequate diet, without additional supplementation required. When a well-balanced, energy-adequate diet is consumed, vitamin and mineral supplementation does not offer any additional benefits to performance (Maughan, 2009).

Fluid

Being well hydrated is an important component of optimal health and exercise performance. Dehydration (water deficit in excess of 2-3% body mass) can significantly impair exercise performance and increase feelings of fatigue (Jeukendrup & Gleeson, 2018). Other consequences of inadequate hydration include; cardiovascular strain, altered metabolic and central nervous system function, increased stored CHO utilisation and increased risk of heat stroke (Meyer, Szygula, & Wilk, 2016). Thus athletes should ensure they have adequate fluid intake before, during, and after exercise to prevent dehydration.

Recommendations for athletes to maintain hydration are as follows: Pre exercise, athletes should consume 5-10 ml/kg BW fluid two to four hours prior to starting exercise activity. During exercise, fluids should be consumed to replace sweat losses and prevent a >2% body fluid deficit. Although sweat losses vary considerably (from 0.3 to 2.4 L/hr) and many factors may limit the availability and opportunity to consume fluid during exercise, consumption of 0.4 to 0.8 L/hr fluid is generally recommended. Post exercise, fluid consumption should exceed the volume of fluid lost during exercise (i.e. consumption of 1.25-1.5 L fluid for every one kg BW lost) (Thomas et al., 2016).

Complete restoration of fluid balance after exercise is an important part of the recovery process for athletes, and becomes even more important in hot, humid conditions. Rehydration during and after exercise requires not only replacement of volume losses, but also replacement of electrolyte losses in sweat. Sodium should be ingested in conjunction with fluid (at approximately 0.5 to 0.7 g/L) when long bouts of exercise (either lasting more than two hours in duration, or resulting in sweat outputs >1.2 L/hr) are completed to prevent hyponatremia and minimise the risk of muscle cramps (Mahan & Raymond, 2016; Maughan, 2009).

In order to optimize performance, athletes must know how to consume a healthy, balanced diet and combine this with specific sports nutrition strategies relevant to their training and competition situation. Studies by Spronk et al. (2015), Heaney et al. (2010) and Nogueira and Da Costa (2004) on the nutritional adequacy of athletes dietary intake showed that a substantial proportion of athletes, across different sports and countries, fail to meet even basic dietary recommendations. This suggests that assessment of diet adequacy in athletes should move beyond the nutrient guideline values towards focusing more on dietary/food variety.

2.4 Dietary assessment methods

In order to determine the dietary intake of high performing athletes and provide them with effective nutrition strategies, sports dietitians and nutritionists need to have access to accurate and reliable dietary assessment methods. There are a number of methods; prospective and retrospective, available to assess dietary intake. Their procedures, advantages and disadvantages are displayed in Table 2.1.

Prospective methods

Prospective methods such as duplicate portion and food records (weighed or estimated) involve recording food and fluid intake as it is consumed.

Duplicate Portion

Duplicate portion involves chemically analysing duplicate samples of food and fluid consumed for their energy and nutrient content. Participants are required to weigh and record food and fluid as it is consumed and then measure out the exact same portion of food and fluid again to hand in to researchers for analysis. It is a very accurate method but is rarely used due to high participant burden and the expensive and time consuming nature of the analysis (Magkos & Yannakoulia, 2003).

Food Records

Food records are collected over a specified time period, typically between three to seven consecutive days (Gibson, 2005). They require participants to weigh or estimate all foods and fluids at the time of consumption and provide a detailed description including the type of food, brand name, and portion size and preparation method.

Weighed food records require the participant to weigh and record all food and fluids at the time of consumption using dietary scales. Currently, this method is considered to be the 'gold standard' for assessing dietary intake as it provides the most accurate and precise descriptions of portion sizes and does not rely on memory (Gibson, 2005). However, the amount of time required to accurately complete the record and weigh all foods and fluids can be rather difficult and inconvenient. This may be particularly difficult for athletes who typically have irregular training and eating schedules, numerous eating occasions in order to meet their higher energy and nutritional requirements, and are often having to eat while on the move (e.g. in the car) (Magkos & Yannakoulia, 2003). Three days is usually the minimum number of days required for keeping a reliable food record, and in athletes a three to seven day monitoring period is believed to provide an accurate estimation of habitual energy and macronutrient consumption (Heaney et al., 2010). Within this monitoring period, days involving different training demands, weekdays as well as a weekend day should be included as these components can affect dietary intake significantly (Magkos & Yannakoulia, 2003).

Estimated food records are more commonly used to assess dietary intake in athletes as the recording process is simpler than with weighed food records. They still require recording of all food and fluid at the time of consumption, however the amount consumed is estimated. Estimates can be made using household measures such as cups and spoons and supplemented by measurements with a ruler, or by comparing the quantity to an object (e.g. a coin). Photographs or digital images can also be used to estimate weight and amount of meals and plate waste by comparing to a food portion size guide that includes reference pictures of pre-weighed portions (Nelson, Atkinson, & Meyer, 1997). In recent years phone applications have been developed that function as food records. They use built in cameras, integrated image analysis and a nutrient database to capture and analyse dietary intake (Zhu et al., 2010). A systematic review by Gemming, Utter, and Mhurchu (2015) assessing use of image-assisted dietary assessment methodology found improved self-reported accuracy and reduced systematic errors. However, the use of images and image analysis alone to assess dietary intake is problematic if images of foods eaten are not captured, or are of poor quality, and thus this method is not currently recommended.

Food records, even the more simplified estimated food records, require participants to be motivated, conscientious, numerate and literate (Gibson, 2005). Participants may alter their usual eating pattern for convenience to simplify the recording process or to impress the researcher. Reported intakes may also decrease due to fatigue if the recording period required is longer than four consecutive days (Gibson, 2005). Food records are typically only used to assess the intake of individuals, not populations as they are the most expensive method of dietary assessment due to the time taken to code and analyse the food (Gibson, 2005).

Retrospective methods

Retrospective methods such as diet recalls, FFQs and diet histories involve the recall and collection of previously consumed foods and fluids.

Diet Recall

Diet recalls (e.g. 24-hr recall) involve an interviewer obtaining information on all foods and fluids consumed during a defined period (e.g. the past 24 hours or the previous day). Recalls may be self-administered, or administered by an interviewer face to face or over the telephone. A structured and standardised interview process assists in retrieving as much information as possible from participants and helps to eliminate errors in data collection (Gibson, 2005). This method involves a systematic repetition of open-ended questions asking participants to describe quantities in household measures. It is typically a three stage process that involves firstly, collating a list of all foods and fluids consumed, secondly gathering further detailed descriptions of each item including brands, cooking methods used and portion sizes consumed. Lastly, a review is completed to ensure all foods and fluids have been accurately recorded (Gibson, 2005).

A major advantage of a 24-hr recall is that it involves minimal participant burden and has good compliance. It only lasts for 15-30 minutes so can be scheduled around trainings and other daily activities, or conducted over the telephone for convenience. Participants are typically more willing to answer questions and provide information to an interviewer compared to completing other dietary assessment methods that are more demanding (Bingham, 1987). They are also relatively inexpensive and suitable for use with illiterate participants.

This method, however, relies on participant honesty, memory, motivation and their ability to accurately recall portion sizes. It also requires a trained interviewer and can be time consuming for the researchers. Additionally, the interview process may result in athletes omitting or adding foods to present a more desirable diet (Bingham, 1987). Diet recalls may not be representative of the athlete’s usual intake due to daily variation in exercise load and dietary intake. Ideally multiple recalls should be performed on days that reflect changes in the athlete’s lifestyle (e.g. training days, competition days and rest days) (Magkos & Yannakoulia, 2003; Thompson & Subar, 2013). If the sample collected is representative of different days of the week, it can be a useful method for assessing average intakes of large populations.

Food Frequency Questionnaires

Food frequency questionnaires are used to assess how frequently food items (typically presented as a list) are consumed over a given period (e.g. over the last three months). Some FFQs also enquire about portion sizes of each food consumed or provide a list of standard portions sizes to choose from (Bingham, 1987; Gibson, 2005; Willett et al., 1985). The FFQ is provided in a survey format that is often self-administered and usually takes between 15-30 minutes to complete. More recent computerised versions enable a quicker, more convenient application that ensures complete data collection and eliminates the need for additional data entry (Cade, Thompson, Burley, & Warm, 2002). The FFQ list is usually developed using a large number of food records or recalls to determine the most common food items for the population studied. It can additionally be modified to include supplementary items that may be valuable to gather data on depending on the specific population group (e.g. in athletes, including questions about sports food and supplement intake). FFQ data can be used to categorise participants into low, medium and high intakes of specific foods, food components and nutrients. These categories can be compared with health outcomes (e.g. iron deficiency).

The FFQ method minimises errors that arises from day-to-day variability and thus can more accurately determine habitual dietary intake within a group. It is considered the most suitable method for assessing large populations as it is relatively inexpensive, often has the highest response rate from participants as it is quick to complete and less burdensome than other dietary assessment methods (Black, 2001).

The accuracy of the FFQ is often lower than other dietary assessment methods, as it is dependent on the ability of participants to accurately describe their diet in regards to frequency of consumption and portion size measurements (Gibson, 2005). Participants may over and under-estimate total intake of food items or groups when asked to report frequency of consumption, particularly when a long list of foods is provided. However errors due to misreporting can be minimised by including summary/cross-check questions that ask participants for daily or weekly consumption of different foods and food groups (Cade et al., 2002).

Diet History

Diet histories ascertain an individual's 'usual' intake by firstly gathering descriptive detail and quantifiable information about foods consumed during a typical day. This is usually performed by a trained interviewer and tends to include questions about meal patterns and commonly consumed foods (Gibson, 2005). The second component is a cross-check and consists of a FFQ where further details are obtained about usual intake over the past three to 12 months to clarify the information given in the first component. The cross-check may also explore the preparation of meals and cooking techniques (Thompson & Subar, 2013). The interviewer may also investigate other aspects surrounding dietary intake such as social and behavioural influences of food choice, knowledge, beliefs and attitudes towards food, and where they get their nutrition information from. Diet histories are rarely used as assessment tools in sports nutrition research, but are commonly used by sports dietitians in practice. Although diet histories provide a comprehensive assessment of usual intake and can delve into influences surrounding food choices, they are time consuming, have a high participant burden, are dependent on a skilled interviewer, and rely largely on participant honesty, memory and literacy (Gibson, 2005).

Each dietary assessment method has different strengths and limitations. It is important to carefully consider these with relation to the population group of interest when selecting a dietary assessment method to use.

Table 2.1 *Dietary assessment methods: procedures, advantages and disadvantages*

Dietary Assessment Method	Procedure	Advantages	Disadvantages
Prospective			
Duplicate Portion	All food and fluid consumed is collected in duplicate samples and chemically analysed for energy and nutrient content	• Most accurate method • Does not require food databases	• Usual intake may be altered due to high participant burden • Chemical analysis of food is expensive and time consuming
Weighed food record	All food and fluid consumed is weighed on a scale; recorded at time of consumption. Plate waste and uneaten items (e.g. apple core) are also weighed and recorded. Recording is usually completed over a 3-7 day period and should include a weekend day	• Gold standard method • High accuracy due to weighing amounts and no reliance on memory • Provides quantifiable dietary intake • Potential to enhance behaviour change or weight control through self-monitoring and awareness	• High participant and researcher burden • Participant training required • Usual intake may be altered for convenience whilst weighing • Participant compliance decreases as period of recording increases • Time consuming, particularly for athletes who often have several eating occasions to meet higher energy requirements • Less portable, particularly for athletes who often eat on the move
Estimated food record	Portion sizes of all food and fluid consumed is estimated using household measures (e.g. cups, tablespoon or photographs); recorded at time of consumption. Recording is usually completed over 3-7 days and should include a weekend day	• Acceptable accuracy as not reliant on memory • Increased compliance when compared to weighed food record	• Participant compliance decreases as period of recording increases • Usual intake may be altered for convenience • Time consuming, particularly for athletes who often have lots of eating occasions due to their high energy requirements
Retrospective			
Diet recall	Participants are asked to describe and quantify all food and fluid consumed over the past 24 hours	• Minimal participant burden • Relatively fast to complete • Can be conducted over the phone	• Dependent on participant's memory and ability to estimate quantity of food • Requires a trained/experienced interviewer

Dietary Assessment Method	Procedure	Advantages	Disadvantages
		• Interviewer can prompt participants memory • Appropriate for use across populations	• May not be representative of usual intake unless multiple recalls are conducted
Food Frequency Questionnaire (FFQ)	Participants describe their frequency of consumption of specific foods and fluids on a predetermined list. Time period for consumption can range from daily to yearly	• Low comparative participant burden • Can be self-administered • Relatively inexpensive • Eating behaviour is not affected • Assesses usual dietary intake • Provides quantitative information • Large populations can be studied	• Dependent on participants memory and ability to quantify portion sizes • Participant burden increases as the food list length increases • Can be cognitively difficult for participants • Each questionnaire is population specific and requires validation in population of interest • Researcher burden for quality control of data entering/cleaning of data
Diet history	Participant describes all food and fluid consumed on a typical day and also completes a FFQ	• Uses a variety of methods to obtain dietary intake data • Captures day-to-day and seasonal variation • Eating behaviour is not affected • Can obtain information on factors influencing dietary intake • Provides quantitative and qualitative information	• Relies heavily on participant's memory • Can be cognitively difficult for participants • Relatively time consuming • Requires a trained/experienced interviewer • Expensive to conduct and analyse

2.5 Selecting a dietary assessment method to be used in research

Selection of the most appropriate method of dietary assessment is difficult and dependent on a number of factors including; the study objective, dietary outcomes of interest, required level of precision, the specific participant group (e.g. athletes versus non-athletes) and available resources. More accurate methods tend to be associated with higher costs and burden on participants (Gibson, 2005).

There are very few dietary assessment tools validated for use in the athlete population. Weighed food diaries (typically three to seven days) are the accepted gold standard method for dietary assessment of the general population and this is also suggested to be the case for athletes (Heaney et al., 2010). However, as micronutrients of concern in athletes include iron and calcium, the food record ideally needs to be completed over at least an 11 day period to enable accurate capture of these micronutrients (Black, 2001; Heaney et al., 2010). This would be extremely difficult to do in athletes and would likely result in poor compliance due to their often demanding schedules with vigorous training regimes and numerous eating occasions.

Food frequency questionnaires are considered to be the most appropriate method of dietary assessment when investigating dietary intake of large populations as they are relatively cost effective and less time consuming (Black, 2001). They enable measurement of intake to be assessed over longer periods of time so can provide more accurate estimates of 'usual' or habitual intake compared to short duration assessment methods, which can be affected by day-to-day variations of intake (Gibson, 2005). They can also be customised and made population-specific to comprise of only questions most relevant to athletes (Magkos & Yannakoulia, 2003). Additionally, with the development of electronic versions, they can now be self-administered online whenever it is most convenient for the athlete. This also ensures complete data capturing of the athletes dietary intake as they are unable to skip an area/section (even by accident) until it is completed (Cade et al., 2002). Additionally, according to Willet (2013), the inclusion of interactive and engaging components such as an electronic version, enhances participant motivation and encourages continued participation.

Studies have previously shown FFQs to have a high acceptability of completion by athletes, however validated FFQ methodology in athlete populations is largely non-existent (Capling et al., 2017; Heaney et al., 2010). Despite a rather substantial body of published work in the area of dietary intake in athletes, relatively little discussion has occurred surrounding the issues of dietary assessment and analysis in this population. Thus there is a need for more precision in assessment and analysis of athletes' dietary intakes.

2.6 Dietary assessment challenges in athletes

There are a number of challenges associated with assessing the dietary intake of athletes compared to the general population. These include; under and over-reporting, additional serves of food groups and snacks to meet their higher energy requirements, additional fluid intake to maintain adequate hydration, supplement use and ergogenic aids to enhance performance, differences in behaviours associated with particular sports (e.g. weight-control practices to meet weight categories), differing physiological requirements (e.g. strength and power versus endurance sports), whether athletes are in competition phase or training phase (or a combination of both) and seasonality of sports (Baker et al., 2014; Magkos & Yannakoulia, 2003). These challenges are reviewed in the following sections.

Under- and over-reporting

All dietary assessment methods are subject to under- and over-reporting (or misreporting) of energy and/or nutrient intake, whether that be intentional or unintentional. This can be due to inaccuracies in portion size estimates, errors in description of foods, or alterations of usual intake during the period of monitoring for convenience or conformity to social pressures and desirabilities (e.g. not reporting foods or meals that are less desirable, such as 'fatty foods' or sweets, in order to present a more favourable, and healthier diet) (Black, 2001). In athletes, it is particularly common for under-reporting to occur in those competing in weight-category sports, or due to difficulties remembering the often high frequency of snacks consumed (Morente-Sánchez & Zabala, 2013). Alternatively, over-reporting of food items and/or supplements perceived to be beneficial is also common (Baker et al., 2014; Braakhuis et al., 2011; Briggs et al., 2015).

Use of the doubly labelled water (DLW) technique has allowed for validation of self-reported energy intake and results show misreporting in athletes to account for 10-45% of their total energy expenditure, regardless of the dietary assessment method used or the type of athlete involved (Black, 2001; Capling et al., 2017). When food intake was recorded by, or with assistance from trained staff or dietitians, the energy intake recorded closely matched the DLW determined energy expenditure.

Errors from misreporting can be quantified by monitoring body mass and/or composition changes, and identified by comparison of reported energy intake (EI) with expected energy requirements (basal metabolic rate [BMR] and physical activity level [PAL]) using the EI:BMR ratio and Goldberg cut-off values (Tooze, Krebs-Smith, Troiano, & Subar, 2012). A Goldberg cut-off value of 0.9 (lower 95% confidence limit) for EI:BMR is indicative of under-reporting. Several studies have used this method to quantify under-reporting in athletes and have shown the greatest prevalence of under-reporting to occur in female endurance athletes (Schoeller, 1995), female gymnasts (Jonnalagadda, Benardot, & Dill, 2000) and cyclists (Westerterp, Saris, Van Es, & Ten Hoor, 1986). Further, it has been shown that under-reporting in athlete's increases as energy expenditure increases, likely due to the increased burden and difficulty associated with estimating and remembering the larger amounts of food consumed (Capling et al., 2017; Schoeller, 1995).

Larger portion sizes

Due to the considerable amounts of exercise training athletes perform, they often consume larger quantities of food to meet their higher energy requirements (Mahan & Raymond, 2016). It is recommended athletes consume an additional portion of CHO and fat each day for each additional hour of exercise completed (Mettler et al., 2009; Nogueira & Da Costa, 2004). Thus standard portion sizes, recommended by general guidelines and presented as options on FFQs, are usually not applicable nor appropriate for use in this population. Considerations should therefore be made to account for these larger portion sizes when assessing the dietary intake of athletes.

Higher frequency of snacks

To meet their higher energy requirements athletes often use snack foods. Studies have reported snacking occasions of athletes to amount to as many as six times a day in addition to the consumption of three main meals (Erdman, Tunnicliffe, Lun, & Reimer, 2013; Nogueira & Da Costa, 2004). Use of snack foods should be considered when assessing an athlete's dietary intake as they can contribute to between 17-37% of total energy intake and are often under-reported in this population due to their high frequency of occurrence each day (Erdman et al., 2013; Ziegler, Jonnalagadda, Nelson, Lawrence, & Baciak, 2002).

Sports food, supplement and ergogenic aid use

The use of sports foods, nutritional supplements and ergogenic aids is widespread in all sports. Many athletes, whether recreational, elite or professional, use some form of dietary supplement in attempts to meet increased nutritional needs, improve athletic performance and recovery, or to assist with weight loss (Buell et al., 2013; Maughan et al., 2011). Athletes are generally able to meet their increased requirements, without the use of supplements, through a well-balanced and energy-adequate diet (Jeukendrup & Gleeson, 2018). Despite minimal evidence on the efficacy and safety of many supplements and ergogenic aids, studies show a high prevalence of use in athletes (46-59%) and particularly in high performing/elite athletes (64-88%) compared to the general population (35-40%) (Buell et al., 2013; Maughan et al., 2011). The types and reasons for use are varied and differ considerably between genders. Women athletes often consume sports foods and supplements to improve their health, overcome an inadequate diet (e.g. multi-vitamin tablets or bars) or to assist in reductions of weight and excess body fat (e.g. fat burners). Whereas men often consume sport foods and supplements to improve their performance in regards to speed, agility, strength and power (e.g. creatinine and pre-workout drinks), or to build lean body mass (e.g. protein shakes and protein bars) (Maughan et al., 2011). It is important to consider the use of supplements among athletes when undertaking dietary assessments, as supplements are usually consumed outside of meal times and may not be considered as food by the athletes, thus are prone to misreporting (Magkos & Yannakoulia, 2003). Probing for this information and being familiar with a range of supplements and ergogenic aids targeted at athletes is also important to not only provide them with correct science-based advice, but also to ensure they are not taking any substances that may be prohibited in sport (Jeukendrup & Gleeson, 2018).

Eating behaviours and habits associated with different sports

Athletes have different regimes and requirements to comply with depending on their sport and thus have to apply different behaviours and eating habits to achieve these requirements (e.g. changing eating habits to achieve a certain physique or complete different training regimes/modes).

Different sports and training modes require use of different energy systems by the body and thus result in athletes having differing energy and nutrient requirements. For example, training and competing for endurance sports (e.g. long distance running and rowing), predominantly involves working at a high capacity with a low power output which utilises the aerobic-oxidative energy system. This system uses oxygen to convert nutrients (CHO, fats and protein) into adenosine tri-phosphate (ATP) which provides energy for muscle contraction during exercise (Jeukendrup & Gleeson, 2018). For these athletes, it is advantageous to have higher intakes of CHO-rich foods to supplement endogenous stores (Thomas et al., 2016).

Furthermore, eating habits and types of foods consumed by athletes are also likely to be different depending on the physique required for the sport they are involved in. Athletes involved in sports such as sumo wrestling and weight lifting often have high energy diets that involve numerous snacking occasions and the consumption of energy-dense food items to encourage gains in body mass and enable greater power generation (Erdman et al., 2013; Nogueira & Da Costa, 2004). However, sports that impose specific weight limits for competition (e.g. boxing, wrestling) or require a low body weight (e.g. gymnasts, dancers) are likely to involve low energy diets with little to no snacks. Unhealthy slimming techniques may also be employed such as excluding food groups (e.g. dairy, grains and cereals) from the diet, consuming stimulants (e.g. coffee, green tea) and meal replacements (e.g. diet drinks), using pills and supplements (e.g. fat burners and laxatives) or binging and/or purging practices (Morente-Sánchez & Zabala, 2013).

The type of eating behaviours, habits and nutrition beliefs of athletes can result from the influence of coaches, social environmental factors (such as seeing pictures of other people's physiques on Instagram and Facebook) and team-mates. Alcohol intake is strongly linked with modern sport culture and is typically associated with post-competition socialising and team sports (Burke & Deakin, 2015). Athletes who partake in unhealthy behaviours such as consuming alcohol, regularly, are at risk of numerous health problems and consequently disadvantage their performance. It is, therefore, important to be aware of, and consider the different requirements, cultures, and behaviourisms (such as weight-control practices) associated with different sports when assessing an athletes dietary intake due to the considerable variation in daily food consumption they may introduce (Magkos & Yannakoulia, 2003).

Training regimes and seasonality of sports

In addition to seasonal changes in eating patterns and food intake, athletes also undergo changes in food consumption as a result of different periods and training regimes associated with their sport such as off-season, pre-and-post season training, phases/stages of training (e.g. light and hard sessions/stages) and pre-and-post competition regimes (Magkos & Yannakoulia, 2003). Athletes are also likely to have different nutritional requirements (e.g. vitamin D) and food intakes depending on the climate or physical environment required for their sport (e.g. performing at high altitudes, or always indoors), and whether their sport is primarily undertaken during summer or winter (Mahan & Raymond, 2016). Their dietary intake may or may not be considerably different depending on the various demands and periodicity of the sport concerned, and these circumstances should be taken into consideration when interpreting an athlete's dietary intake.

Fluid intake

Water and fluid consumption is often neglected in dietary assessments as it can be especially difficult to quantify. Beverages consumed outside of meal times, such as sports drinks (e.g. Powerade) are particularly prone to under-reporting compared to those consumed with meals (Magkos & Yannakoulia, 2003). Adequate fluid intake is essential for athletes due to their excess fluid losses as a result of increased sweating. However, many athletes do not consume enough fluids to maintain euhydration. Research shows dehydration of as little as 2% body weight is detrimental to performance and increases cardiovascular and thermoregulatory strain leading to increased fatigue and perception of effort, impaired mental concentration, muscular strength and endurance, decreased motivation and total work capacity/performance (Casa et al., 2010; Logan-Sprenger, Palmer, & Spriet, 2011). Therefore, it is important to assess and probe about fluid consumption when conducting a dietary assessment in athletes. Fluid intake can additionally be assessed by measuring hydration status through use of practical indices such as body weight changes (pre-and-post training) or analysing urine colour (using the 'Pee Chart' or a refractometer to determine the urine specific gravity) (Meyer et al., 2016).

Summary of dietary assessment in athletes

Dietary assessment in the athletic population is complex. These challenges highlight the importance of having a dietary assessment tool that is appropriately designed, tested, up-to-date and as specific to the athletic population as possible to ensure the most accurate description of their dietary intake is provided. It is also important that researchers are aware of, and understand these challenges to help minimise error and ensure data is interpreted correctly and appropriately.

2.7 Dietary assessment methods designed to assess dietary intake in athletes

Validated and reliable dietary assessment tools for use in athletes are severely lacking in the literature. Only eleven been developed and validated globally (Table 2.2). These include four FFQs (Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Sunami et al., 2016), two self-administered checklists (Kurka et al., 2014; Ward et al., 2004), the use of a combination of dietary methods such as diet recalls with food records (Briggs et al., 2015; Rumbold et al., 2011) or with FFQs (Wardenaar et al., 2015), and various online assessment tools (Baker et al., 2014; Scoffier et al., 2013). The majority of the studies used food records (Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Scoffier et al., 2013; Ward et al., 2004), or diet recalls (Baker et al., 2014; Kurka et al., 2014; Nogueira & Da Costa, 2004; Sunami et al., 2016) as their reference method, while only a few that used other techniques such as direct observations (Briggs et al., 2015; Rumbold et al., 2011) or urinary nitrogen excretions (Wardenaar et al., 2015). Sample size used ranged from 12 (Briggs et al., 2015) to 156 (Sunami et al., 2016), however the majority only analysed samples of athletes from a few selected sports. Studies have validated dietary assessment tools for intakes of energy (Briggs et al., 2015; Rumbold et al., 2011; Scoffier et al., 2013), macronutrients (e.g. protein) (Wardenaar et al., 2015), or micronutrients (e.g. calcium)/antioxidants (Braakhuis et al., 2011; Ward et al., 2004), while some assessed a combination of energy, macronutrients and micronutrients (Baker et al., 2014; Nogueira & Da Costa, 2004). Only two have assessed food group intake (Fogelholm & Lahti-Koski, 1991; Sunami et al., 2016). Furthermore, only three dietary assessment tools have been tested for reproducibility (Braakhuis et al., 2011; Pedišić et al., 2008; Ward et al., 2004) (Table 2.3).

There is a need for an up-to-date, thoroughly tested valid and reliable dietary assessment methods, specifically FFQs, to assess food group intakes of athletes. The validation of an athlete-specific FFQ will provide sports dietitians and other health professionals with a useful, cost-effective and efficient way to analyse dietary intake of athletes and identify those who could benefit from supplementary dietary advice. It could additionally be useful for future studies exploring associations between dietary intake and sporting performance.

Table 2.2 *International dietary assessment validation studies in athletes*

Reference (author, year, country)	Population characteristics	Assessment Tool	Reference Tool	Validated for	Main Statistical Findings	Authors Conclusions
Sunami et al. (2016), Japan	156 (92 M, 64 F) tertiary level athletes (aNR) from mixed sports	FFQ (138 food items) assessing intake over 1 month	3 day non-consecutive 24-h DR	19 food groups and 35 nutrients (e.g. energy, fibre, calcium)	FFQ underestimated energy intake by ~10% (M & F). Correlation coefficients 19 food groups – 0.32 (M), 0.34 (F) 35 nutrients - 0.30 (M), 0.32 (F) Cross classification in extreme miss-categorization - 3% to 5% (both food groups & nutrients).	The FFQ demonstrated comparable validity for assessing habitual dietary intake in young tertiary level athletes, especially for calcium, vitamin C, vegetables, fruits, and milk and dairy products.
Ward et al. (2004), USA	76 F tertiary level athletes (17-21 yr) from mixed sports	RAM - self-administered calcium checklist	6 day FR	Calcium intake	The RAM overestimated calcium intake for fruits/vegetables and sugars/fats, and underestimated intake for meat/legumes. Agreement for classification was 0.42.	RAM briefly & accurately estimates calcium intake in F collegiate athletes compared to FR.
Braakhuis, et al. (2011), NZ	113 (56 M, 57 F) national level rowers (17-36 yr)	FFQ assessing intake over 1 month (70 food items)	7-day FR and biomarker (FRAP)	Total antioxidant intake and food group antioxidant intake	Correlations were small to moderate for antioxidant intake between the FFQ and FR (r=0.38) and FFQ and biomarker (r=0.28). Correlations were highest for cereals (r = 0.55) and tea and coffee (r=0.51), and moderate for fruit (p=0.34) and vegetables (r=0.31).	The FFQ was considered valid for estimating antioxidant intake in athletes and less labour intensive than a 7-day FR.
Scoffier et al. (2013), France	22 (9 M, 13 F) adolescent athletes from weight-control sports and 20 (8 M, 12 F) adolescent athletes from other sports	VSSR	1-day FR	Energy intake	No significant differences between VSSR and FR for energy intake in adolescent athletes of weight sports (p<0.11) or other sports (p=0.56).	The VSSR is a valid assessment of energy intake that can be used to promote education nutrition programs for sedentary and athletic populations.

Reference (author, year, country)	Population characteristics	Assessment Tool	Reference Tool	Validated for	Main Statistical Findings	Authors Conclusions
Briggs et al. (2015), UK	12 M academy level soccer players (13-14 yr)	Combined self-reported weighed FR and a 24-hr DR	Researcher OBS	Energy intake	Combined method under-reported energy intake by 88 kcal per day compared to OBS.	The combined self-reported method was deemed a valid alternative to the gold standard; OBS technique for adolescent soccer players, providing appropriate adjustments are made for under-reporting.
Wardenaar et al. (2015), Holland	47 (31 M, 16 F) elite, Olympic level disabled and non-disabled athletes (18-35 yr) from cycling, athletics, archery, skating	Combined web-based 24-hr DR (3 day, non-consecutive)	24-hr urinary nitrogen excretions	Protein intake	The combined method significantly underestimated mean protein intake by 25.5% compared to 24-hr nitrogen excretion (r=0.65). Under-reporting was greater in athletes with higher protein intakes.	Combined 24-hr DR and questionnaire underestimated protein intake more than that reported for the non-athlete population.
Fogelholm & Lahti-Koski, (1991), Finland	84 M recreational athletes (20-28 yr) from mixed endurance sports	FUQ (122 items)	7-day FR (7DR)	Food groups, and macro- and micronutrients (e.g. CHO, protein, calcium, iron)	The FUQ overestimated nutrient intake compared to the 7DR at group level. Correlations below 0.24 were reported for vegetable oils, milk, pork, beef and poultry. Correct classification of nutrients into tertiles ranged from 37 to 54%.	The FUQ had comparable validity to the 7DR for portion sizes at the group level.
Baker et al. (2014), UK	56 (41 M, 15 F) competitive, tertiary level athletes (14-20 yr) from mixed sports	DATA iPad administered	Registered Dietitian OBS and 24-hr DR interview	Energy, CHO, protein, total fat, water, sodium, calcium and iron intake	Significant difference were found between DATA and OBS for energy, CHO, Protein, fat, water, sodium, iron, calcium (ICC 0.78-0.91). No differences between DATA and interviews for energy, CHO, Protein or fat.	DATA presented good relative validity for group-level comparisons in athletes, but minimal validity for individual-level, especially in athletes with higher energy and nutrient intakes. DATA may be a useful athlete-specific alternative to conventional 24-h dietary recall methods at the group-level.

Reference (author, year, country)	Population characteristics	Assessment Tool	Reference Tool	Validated for	Main Statistical Findings	Authors Conclusions
Kurka et al. (2014), USA	391 (228 M, 163 F) collegiate NCAA Division 1 athletes (aNR)	REAP (27 questions)	Healthy Eating Index and FFQ	Dietary intake patterns	Eating behaviour pattern scores (mean ± SE) were higher for dessert in non-aesthetic versus aesthetic sport M athletes (2.16 ± 0.07 vs. 1.93 ± 0.11). Higher scores were reported for dessert (2.11 ± 0.11 vs. 1.88 ± 0.08), meat (1.95 ± 0.10 vs. 1.72 ± 0.07), high-fat food (1.70 ± 0.08 vs. 1.46 ± 0.06), and dairy (1.70 ± 0.11 vs. 1.43 ± 0.07) in aesthetic versus non-aesthetic F athletes.	The REAP demonstrated construct validity when measuring dietary patterns in collegiate athletes.
Rumbold et al. (2011), UK	13 F adolescent netball players (14-16 yr)	Combined weighed FR and 24-hr DR	Researcher observed method	Energy intake	Mean differences between observed and participant reported energy intake was 0.46 MJ d^{-1} (change in mean of 4.2%) - slight bias towards over-reporting. Good agreement at group level - confidence interval for bias (0.00 to 0.92 MJ d^{-1}.)	Combined self-reported, weighed FR and 24-hr DR was found to be an accurate method for quantifying energy intake in F adolescent netball players.
Nogueira & Da Costa (2004), Brazil	38 triathletes (18-54 yr)	FFQ assessing intake over 3 months	24-hr DR	Energy, protein, CHO, lipids, vitamins B1, B2, B3 and B6, calcium, magnesium, phosphorus	FFQ overestimated vitamin B2, phosphorus, and magnesium (43%, 37%, and 39%, respectively) compared to the 24-hr DR. No statistical differences reported for for energy, protein, CHO, lipids, calcium or vitamins B1, B3 and B6.	The FFQ adapted for the Brazilian population was considered valid for estimating energy, protein, CHO, lipids, calcium and vitamins B1, B3 and B6.

M – males; F – females; FR – Food Record; FFQ – Food Frequency Questionnaire; DR – Diet Recall; RAM – Rapid Assessment Method; REAP – Rapid Eating Assessment for Patients; VSSR – Virtual Self-Service Restaurant; FUQ – Food Use Questionnaire; DATA – Digital Dietary Analysis Tool for Athletes; OBS – observation; NZ – New Zealand; UK – United Kingdom; USA – United States of America; FRAP – ferric-reducing ability of plasma; MJ – megajoule; CHO – Carbohydrate; aNR – age not reported; yr – year; hr – hour; d - day

Table 2.3 *International dietary assessment reproducibility studies in athletes*

Reference (author, year, country)	Population characteristics	Assessment Tool	Time frame	Reproducibility of	Main Statistical Finding	Authors Conclusions
Braakhuis et al. (2011), NZ	20 national level rowers (17-36 yr)	FFQ	1 week	Total antioxidant, and food group antioxidant intake	Repeat administration 1 week later showed high reproducibility (r=0.83).	The FFQ demonstrated high reproducibility for antioxidant intake after 1 week and deemed trustworthy for estimating antioxidant intake.
Ward et al. (2004), USA	35 F tertiary level athletes (17-21 yr) from mixed sports (basketball, cross-country, field hockey, soccer and volley ball)	RAM - self-administered calcium checklist	2 weeks	Calcium intake	Mean calcium intake on the second administration of the RAM was lower than the first. Agreement between the 2 administrations was moderate (r=0.58).	The RAM reliably and accurately estimated calcium intake in F collegiate athletes after 2 weeks.
Pedisic et al. (2008), Croatia	83 athletes/physically active university students (7-10.5 hr physical exercise/week)	Questionnaire consisting of 104 questions divided into FFQ (74 questions) and general questionnaire	4 weeks	Dietary habits and macro- and micronutrient intakes	Mean reproducibility of macro- and micronutrient intake was high for M (r=0.83) and F (r=0.86).	The FFQ demonstrated acceptable reproducibility of dietary habits in Croatian athletes and other physically active individuals.

M – Males; F – Females; FFQ – Food Frequency Questionnaire; RAM – Rapid Assessment Method; NZ – New Zealand; USA – United States of America; yr – year; hr – hour

2.8 Design and development of food frequency questionnaires

The FFQ is provided in a survey format, where a list and description of food and beverage items are presented. Participants are required to select how often (times per day, week or month) they consume each food and beverage.

There are several aspects that need to be considered when designing an FFQ, these include: questionnaire length and number of food items; provision of portion size; time period assessed and the selection of frequencies used.

Questionnaire length and number of food items

The length of the food list within an FFQ should be chosen based on the objectives of the study. A single-nutrient FFQ design is used when measuring intake of specific foods or nutrients and tends to be shorter (40-60 food items), whereas a multi-nutrient or food group FFQ designed to assess total intake tends to be longer (>100 food items) to enable capturing of more detail (Thompson & Subar, 2013). It has been reported that the inclusion of more than 100 food items within an FFQ can result in over-estimation of daily nutrient intake, although conversely having less than 100 items limits the ability of accurately measuring variations in day-to-day intake, which is a particular issue in athletes (Bountziouka et al., 2012; Thompson & Subar, 2013). Researchers have not yet determined the optimal number of food items that should be listed in an FFQ, however when assessing intake in athletes, it has been shown they become fatigued when answering FFQs containing more than 150 items (Thompson & Subar, 2013; Willett, 1994).

It is important that the food list is current and developed for the purpose of the study and the specific target population, as food preferences, dietary patterns and intake differ not only between individuals, but also over time (Cade et al., 2002; Cade, Burley, Warm, Thompson, & Margetts, 2004; Willett et al., 1985). In regards to athletes, this refers to the inclusion of larger portion sizes and supplements and ergogenic aids (Pedišić et al., 2008). Open-ended summary questions may also be included in the FFQ to ensure the participant's total diet is captured and enable the identification of any foods consumed that are not listed in the FFQ. Additionally, FFQs need to be country specific due to the differences in common food choice, food composition, climate and availability (Pedišić et al., 2008; Willett et al., 1985).

Portion size

Previously developed FFQs have all differed in the way portion sizes have been described. A review by Cade et al. (2002) of studies that have developed FFQs showed 42% specified portion sizes within the FFQ, 36% had participants specify portion sizes themselves, and 22% had no recording of portion sizes. It has been shown that use of tools that allow participants to report their own portion sizes, such as food portion guides, improves reporting accuracy (Gemming et al., 2015; Margetts & Nelson, 1997). Portion sizes of foods commonly defined in units (e.g. slice of bread, piece of fruit) are more easily reported than poured liquids or amorphous foods (e.g. spinach, pasta). The within-individual variability in portion sizes of foods is much greater than between-individual variability, thus using constant predefined portion sizes provides increased accuracy (Thompson & Subar, 2013).

Time period assessed and selection of frequencies

Frequency has been found to be a greater contributor than portion size to the variance and intake of most foods (Thompson & Subar, 2013). The time period asked of usual intake depends on the research being conducted but tends to vary between the past week and one year. It has been shown that even when participants are asked about their intake over the past year, the season the FFQ is administered within appears to influence the reporting over the entire year (Thompson & Subar, 2013). It is recommended questionnaires include closed, multiple-choice frequency questions as open ended questions often result in lower completion rates, errors in recording, and the provision of incomplete or uninterpretable answers (Cade et al., 2004). Multiple choice questions offered on FFQs tend to provide five to ten frequency options, usually ranging from never to six plus times per day (Cade et al., 2004; Margetts & Nelson, 1997).

Although FFQs allow for easy usage and data analysis, if they are not designed and applied appropriately, they are unable to provide useful and/or required information (Pedišić et al., 2008). Thus, it is important that FFQs are assessed for their validity and reproducibility in the population of interest prior to use.

2.9 Considerations when assessing the validity of food frequency questionnaires

Validity refers to the extent to which a test method (i.e. the FFQ) is able to measure what it is intended to measure (Gibson, 2005; Lombard, Steyn, Charlton, & Senekal, 2015). There are several forms of validity identified in the literature, however the majority of dietary assessment methods validated for use in athletes have assessed relative validity which involves comparison of a dietary assessment tool with a more accurate independent reference method (i.e. a food record) (Baker et al., 2014; Fallaize et al., 2014; Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Scoffier et al., 2013; Sunami et al., 2016; Ward et al., 2004). Others have assessed absolute (or construct) validity (Braakhuis et al., 2011; Kurka et al., 2014), which is the highest standard of validity and involves the assessment of actual food intake during the study and again either before or after to compare. Determining absolute validity is difficult, time consuming, often impractical, and generally limited to studies that have small sample sizes or cover a short period of time (Gibson, 2005; Masson et al., 2003). Due to these limitations, the assessment of relative validity to assess dietary intake is most often performed (Gibson, 2005). There are several factors which can affect the validation process, these include; the study population, sample size, recording days required, reference methods and analysis of the data.

Study population

Validation of the FFQ needs to be undertaken in a sample which represents the population it has been intended for use in. Several factors such as ethnicity, sex, age, health status and literacy can influence how participants answer questions and thus how the results of the study are depicted. For example it has been shown that participants who are obese are more likely to alter their reported dietary intake when completing dietary assessments than participants who are not obese (Block & Hartman, 1989). Although athletes are not typically obese individuals, they are a group which is likely to alter reported intake in efforts to present a healthier diet (Burke & Deakin, 2015; Maughan, 2009).

Sample size

The sample size required is dependent on factors involved with the analysis of validity and reproducibility such as the precision required, the daily food variation of participants, and the number of recorded days required for the reference method (Willett et al., 1985). For validation studies, a minimum of 50 participants from each population group is recommended to detect meaningful differences (Cade et al., 2002; Cade et al., 2004). Sport science research tends to contain relatively small sample sizes as athletes perceive research studies to be time consuming and disruptive to training and competition regimes, thus recruitment can be difficult (Capling et al., 2017).

Reference method and recording days required

There is no dietary assessment method that enables usual dietary intake to be measured with absolute accuracy (Cade et al., 2004). When selecting the reference method, it is crucial that error sources are independent of those found with a FFQ. Common errors that arise from FFQs include food consumption recall, estimation of portion size and incomplete food lists. The most suitable comparative method with the least correlated errors with the FFQ is the weighed food record (Margetts & Nelson, 1997). According to Cade et al. (2002) food records are the most commonly used reference method in validation studies. However, only half of the food records used were weighed. Second was the 24-hr food recall, however diet recalls depend on estimation of portion size and memory which is similar to FFQs (Cade et al., 2002; Margetts & Nelson, 1997). Further, it is suggested the reference method be administered following the test method, as if completed first it can draw attention to details of the participant's diet which may result in alterations made to 'usual' dietary intake (Cade et al., 2002).

The intra- to inter-participant variation influences how many days are required for estimation of usual intake. Studies suggest that in majority of situations, the ideal number of collection days is four (Heaney et al., 2010; Willett et al., 1985). Due to the high respondent burden, collecting more than five days can result in less participants completing the study and higher potential for dietary intake to be altered for convenience, which may be particularly problematic in athletes.

Analysis of dietary data

Regardless of the dietary assessment method used for the study, all dietary data needs to be analysed to enable investigation of specific aspects of the diet related to the objective and purpose of the study. Data can be assessed for validity at the nutrient, food, food group or dietary pattern level. Food composition databases are typically used to analyse nutrient intakes and it is important that the same food composition database is used for the analysis of both dietary assessment methods to match errors and decrease their effect on the validity (Gibson, 2005). Selecting an appropriate database includes consideration of the following: using the national database to ensure it encompasses all relevant population-specific foods and nutrients, using the latest version as new foods are frequently introduced and composition of foods and preparation/cooking methods are constantly changing, and ensuring the database is complete as accuracy is reduced if a large proportion of foods need to be substituted because they are not available on the database (Greenfield & Southgate, 2003; Margetts & Nelson, 1997).

The comparison between the two methods for validity can be undertaken using a range of statistical methods including; t-tests and effect size for agreement, correlation coefficients, cross-classification for quantifying agreement and the weighted kappa statistic and Bland-Altman analysis for determining the difference between methods (Gibson, 2005; Lombard et al., 2015). There is no single 'gold standard' method of statistical analysis for determining validation and thus it is recommended dietary validation studies use a combination of these statistical methods (Gibson, 2005; Willett et al., 1985). These methods are discussed in section 2.11.

2.10 Considerations when assessing the reproducibility of food frequency questionnaires

Testing the precision/reproducibility of a dietary assessment tool refers to the tool's ability to produce the same estimate of dietary intake on two separate occasions (ideally four to eight weeks apart to avoid participant recollection and the second measurement being influenced by the first (Block and Hartman, 1989) under the same circumstances (Black, 2001; Gibson, 2005)). This can be measured using a test-retest design by calculating the level of agreement using t-tests on the mean and effect size, correlation coefficients (including intra-class correlation coefficients), the percentage of misclassification, weighted kappa statistic and Bland-Altman's level of agreement (Bland & Altman, 1986; Gibson, 2005) (see section 2.11). It is important to test for reproducibility as it can help identify problems in the tool's design and instructions to participants, identify poor quality control (e.g. coding or typing errors) and increase the power of the tool to detect effects (Gibson, 2005).

Studies involving population group's with regular routines and repetitive dietary intakes (e.g. the elderly) tend to have increased reproducibility than groups with considerable variation in day-to-day activities and intake such as athletes (Block & Hartman, 1989). Thus the same dietary assessment method may produce different reproducibility results in different population groups.

2.11 Statistical analysis of validity and reproducibility

There are a range of statistical methods that can be used to assess the validity and reproducibility of an FFQ compared to a reference method. However, there is a lack of consensus on the most appropriate statistical methods. It is suggested that a combination of statistical tests be used to allow different facets of validity and reproducibility to be investigated and to produce the most accurate results (Lombard et al., 2015). The statistical methods most frequently used in validation and reproducibility studies are listed below.

Correlation coefficient

Correlation coefficients (Pearson's or Spearman) are the most commonly used statistical test in dietary assessment validation studies (Lombard et al., 2015). They measure the strength and direction of the association between the two different methods (test and reference) at the individual level (Hopkins, Marshall, Batterham, & Hanin, 2009; Lombard et al., 2015). When the data is normally distributed, Pearson's correlations can be used, and when the data cannot be normalised by log transformation, Spearman's rank correlations can be used. Correlation co-efficient values range from -1 (perfect negative correlation) to 1 (perfect positive correlation) with a co-efficient of zero equalling/expressing no linear relationship between the two methods (Hopkins et al., 2009). Although correlations can depict association between two methods, they cannot determine the level of agreement, and there can be poor agreement even when there is high correlation (Bland & Altman, 1986). It has been shown that even when the test method is consistently higher or lower than the reference method (i.e. due to bias), high correlation can still occur. Similarly, when there is high between-subject variation or a small sample size there will be a higher correlation than when there is lower between-subject variation or a larger sample size (Cade et al., 2002). Further, it is argued that a positive correlation will always exist between two dietary assessment methods that are measuring the same thing (e.g. food group or nutrient intake). Thus the use of correlations, solely, to assess validity of dietary assessment methods would be inappropriate. However when used in conjunction with other methods they are considered to be useful, particularly as they enable comparison across validation studies (Bland & Altman, 1986; Hopkins et al., 2009; Lombard et al., 2015).

Wilcoxon signed rank test

Wilcoxon's signed rank test can assess relative validity at the group level by comparing the percentage difference between the means of the reference and test method (Lombard et al., 2015). For normally distributed data paired t-tests should be used, however when data is non-normally distributed Wilcoxon's signed rank test is more appropriate (Gibson, 2005). These tests are useful to determine absolute intakes and differences between participants, however they are not able to determine the quality of the test method at an individual level or the ability of the test method to describe the distribution of intakes (Bland & Altman, 1986).

Cross classification and weighted kappa statistic

Cross classification analysis classifies participants into categories (e.g. tertiles, quartiles or quintiles), depending on the sample size and based on their dietary intakes (Lombard et al., 2015). Participants with the same category classification by the two methods are considered 'correctly classified', and those with opposite categories are considered 'grossly misclassified' (Gibson, 2005). These values are given as a percentage. Cross classification indicates how well the assessment method is able to rank participants and thus reflects agreement at the individual level (Lombard et al., 2015). However, the percentage agreement also includes agreement by chance. To eliminate this, the weighted kappa statistic is used as it ranks data into categories or groups dependent on weight, and excludes agreement occurring by chance (Lombard et al., 2015). It is suggested that weighted kappa be used for ordinal variables, as with larger differences/higher category numbers the potential for disagreement increases which can result in an underestimation of the agreement (Gibson, 2005). Unfortunately, comparisons with other studies are limited as category numbers and weightings will differ.

Bland-Altman analysis

Bland-Altman analysis evaluates the level of agreement between two methods at the group level. The difference between the measurements is plotted against the mean of the two measurements for each participant to display the level of disagreement and identify the presence, direction and extend of bias, and any outliers (Lombard et al., 2015). Level of agreement are calculated as the mean difference ± 1.96 standard deviations (SD) with their corresponding 95% confidence interval (CI). It has been suggested that with increased dietary intake, a greater difference may be observed between the two methods, than from participants with smaller energy intakes (Cade et al., 2002). 2002). The use of Bland and Altman plots are considered the best way to visually see the agreement between two methods (Bland & Altman, 1986; Cade et al., 2004), however only three studies have used them in assessment of the validity of dietary assessment methods designed for use in athletes (Baker et al., 2014; Briggs et al., 2015; Rumbold et al., 2011).

2.12 Summary

This literature review discussed the importance of nutrition for athletes and of assessing the nutritional adequacy of athlete's dietary intakes. It discussed strengths and limitations of dietary assessment methodology and particular challenges associated with accurately assessing dietary intake of the athlete population. Aspects to consider include: larger energy intakes and portion sizes; increased frequency of snacking; use of supplements and ergogenic aids; additional fluid intake; different eating behaviours associated with different sports (e.g. weight-control practices); and greater potential of under- and over-reporting to present a more favourable diet. It highlights the importance of ensuring dietary methodology for use in this population is athlete-specific, up-to-date, valid and reproducible. The current review of the literature identified a lack of studies (n = 11), world-wide, that have assessed the validity of dietary assessment methods for use in athletes, with only two of these that additionally tested for reproducibility. All studies included dietary assessment methods that were either out dated, validated for use in other countries outside of NZ, or that only analysed one component of athlete's dietary intake (e.g. calcium intake) rather than considering their dietary intake as a whole. There is a need for an up-to-date FFQ to be developed and evaluated for its ability to assess food group intake in high performing athletes living in NZ.

Chapter 3: Research Manuscript: Determining the relative validity and reproducibility of a food frequency questionnaire to assess intake of food groups in high performing athletes

3.1 Abstract

Background: Optimal nutrition is essential for athletes to achieve their full athletic potential. Food frequency questionnaires (FFQs) are commonly used in the general population to assess habitual dietary intake as they are inexpensive, quick and easy to administer. Currently there are no athlete-specific, up-to-date, valid and reliable FFQs available to assess food intake of athletes. This study aimed to determine the relative validity and reproducibility of an athlete-specific FFQ to assess food group intake in high performing athletes.

Methods: Athletes (n=66) 16-35 years, from a range of sports competing at regional level or above completed the FFQ at baseline (FFQ1) and four weeks later (FFQ2) to assess reproducibility. An estimated four day food record (4DFR) was completed between these assessments to determine the validity of FFQ1. Foods in the 4DFR were classified into the same food groups as the FFQ using gram amounts. Agreement between dietary assessment tools was assessed using Wilcoxon signed rank tests, correlation coefficients, cross classification, the weighted kappa statistic and Bland-Altman analysis.

Results: The FFQ overestimated intake for 17 of 28 food groups compared with the 4DFR ($p<0.05$). Correlations ranged from 0.11 (processed foods) to 0.78 (tea, coffee & hot chocolate), with a mean of 0.41. Correct classification of food groups into the same tertile ranged from 35.4% (starchy vegetables) to 55.5% (fats & oils). Misclassification into the opposite tertile ranged from 4.6% (legumes) to 15.4% (starchy vegetables; sauces & condiments). The weighted kappa demonstrated fair to moderate (*k* =0.21-0.60) agreement for the majority of food groups. Bland-Altman plots suggested that for the majority of food groups, the difference between FFQ1 and the 4DFR increased as the mean intake of each food group increased. Intake from FFQ1 was significantly higher than from FFQ2 for 13 food groups. Reproducibility correlations ranged from 0.49 (potato chips; fats & oils) to 1.00 (tea, coffee & hot chocolate), with a mean of 0.65. When classified into tertiles, the majority (20 of 23 assessed) of food groups had >50% of participants correctly classified, <10% grossly misclassified, and demonstrated moderate to good agreement (k=0.61-0.8). The exceptions were dairy; fats & oils; and processed foods & drinks which presented fair agreement (k=0.21-0.40).

Conclusions: The FFQ showed reasonable relative validity and good reproducibility for assessing intake of food groups in high performance athletes. The FFQ could be used in future research as a convenient and cost-effective way to obtain athletes' food group intake, and to identify athletes who might benefit from interventions to improve their dietary intake.

Keywords: athlete; dietary assessment; questionnaire; validation; reproducibility

3.2 Introduction

Diet has been increasingly recognised as a key component of athletes' success in sport (Thomas et al., 2016). Sports dietitians and nutritionists therefore need to have access to accurate and reliable dietary assessment tools in order to provide athletes with effective nutrition strategies. There are however a number of challenges and factors that need to be considered when assessing dietary intake in athletes compared with the general population. These include; the use of sports foods and supplements to enhance performance, increased fluid intakes to replace sweat loss during exercise, additional serves of food groups and snacks to meet higher energy requirements, whether athletes are in the competition or training phase (or a combination of both), and seasonality of sports (Baker et al., 2014; Magkos & Yannakoulia, 2003).

Traditional, prospective methods of dietary assessment such as duplicate portion and weighed or estimated food records are the preferred methods of dietary assessment for both athletes and the general population. However they are labour intensive which may result in poor compliance and alterations to the athlete's usual dietary intake for convenience around their busy training schedules (Magkos & Yannakoulia, 2003). Retrospective techniques such as diet recalls, diet histories and FFQs rely on honesty, memory and an ability to recall food intakes, however they have very minimal participant burden and thus may be more suitable for athletes as they can easily be scheduled to fit around their daily activities (Black, 2001).

Food frequency questionnaires, require participants to select how often they consume foods and beverages from a list provided over a specified time period. They are useful for assessing dietary intake as they are convenient, inexpensive, and the least time consuming for both the athletes and the research team. They can be adapted for use in specific population groups such as athletes and also provide better approximates of 'usual' or habitual intake when compared to food records (Cade et al., 2004; Willett et al., 1985). Whether an FFQ is newly developed or a current FFQ is modified, it is important that they are assessed for validity and reproducibility in the population of interest prior to use.

Validated and reliable dietary assessment tools for use in athletes are severely lacking in the literature. Only eleven have been developed and validated world-wide (Baker et al., 2014; Braakhuis et al., 2011; Briggs et al., 2015; Fogelholm & Lahti-Koski, 1991; Kurka et al., 2014;

Nogueira & Da Costa, 2004; Rumbold et al., 2011; Scoffier et al., 2013; Sunami et al., 2016; Ward et al., 2004; Wardenaar et al., 2015). Of those, a few are no longer suitable for use as their validation was undertaken over 10 years ago (Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Ward et al., 2004), several have only investigated one nutrient or component of dietary intake (Braakhuis et al., 2011; Briggs et al., 2015; Scoffier et al., 2013; Wardenaar et al., 2015), and the remainder have been validated for use overseas in countries such as Japan, the UK and the US (Baker et al., 2014; Kurka et al., 2014; Rumbold et al., 2011; Sunami et al., 2016) which is not directly translatable for use in New Zealand (NZ). Furthermore, only two of these studies additionally tested for reproducibility (Braakhuis et al., 2011; Ward et al., 2004). Thus, to our knowledge, there are no athlete-specific, up-to-date, validated and reliable dietary assessment methods to assess food group intake of athletes in NZ. Therefore, this study aims to determine the relative validity and reproducibility of an athlete-specific FFQ against an estimated four day food record (4DFR) to assess food group intake in NZ high performing athletes.

3.3 Study Methodology

Study design and participants

High performing athletes (defined as representing their main sport at regional level or higher), aged 16 years and above from any sports participated in this cross sectional, validation study. Athletes were recruited using a convenience sampling method through media outlets (social media, newspapers), flyers, posters, emails and phone calls to sporting institutes and organisations, sports teams and academies, secondary schools and sports professionals including dietitians, nutritionists and physiotherapists. Recruitment of participants was completed between December 2015 and September 2016.

Ethical approval was granted by the Massey University Human Ethics Committee (MUHEC), Northern, Application 15/37; and all participants provided written informed consent.

Development of the food frequency questionnaire

The FFQ was designed to assess usual food group intakes of athletes over the previous month. Nine categories ranging from 'never' through to 'four plus times per day' were used to assess the frequency of intake that best represented food groups consumed over the past month.

The FFQ was adapted from the New Zealand Women's FFQ (NZWFFQ) previously used at the MUHNRC to assess the dietary intake of young women (Beck, Houston, McNaughton, & Kruger, 2018).

This FFQ was adapted as follows:

1) A larger range of portion sizes were provided to cover the broader range of portions consumed by athletes.

2) The food list was reduced to exclude food items that were consumed minimally in the first validation study (Beck et al., 2018).

3) Supplementary questions asking about food types were removed to reduce the complexity.

4) 'Sports foods' were added to the FFQ, including; sports drinks (e.g. Powerade), oral rehydration solutions/electrolyte replacements, sports bars, sports gels, sports confectionary, liquid meal supplements (e.g. Sustagen sport), and protein powders.

The final FFQ included 129 food groups (see Appendix A). Foods were grouped according to their composition (e.g. whole grain bread versus white bread) and nutrient content (e.g. red meat versus white meat). Examples were provided in each section of grouped foods to help with accurate answering. For example, with 'pork mixed dishes' the example of 'casserole, stir-fries was provided to help prompt participants. The final question of the FFQ was open ended to allow participants to add any food consumed as well as portion size and frequency of consumption which were not included in the FFQ.

The FFQ was administered online using Survey Monkey (Survey Monkey INC, 2016), an online survey development programme. This ensured complete data capture, as participants could not progress through the FFQ until all questions had been completed on the current page. The FFQ took approximately 25 minutes to complete.

Study procedures

This study was conducted in three phases: 1) administration of the FFQ (FFQ1), 2) completion of an estimated four day food record (4DFR), and 3) re-administration of the FFQ (FFQ2).

Phase one was completed at the Massey University Human Nutrition Research Centre (MUHNRC) and took approximately one hour. Standard order of procedures (SOPs) were developed and followed to ensure the same techniques (e.g. to measure height) were used in order of administration (Appendix B). Anthropometric measurements were taken which included height (portable stadiometer: Seca, model #213) and weight (Wedderburn). Measurements were recorded in duplicate using the International Society for the Advancement of Kinanthropometry (ISAK) protocol (Olds et al., 2006) and a third was completed if the measurement error was greater than 1%. Participants completed a short online questionnaire related to demographics, sport, training regime and supplement use (including type, brand, dose, and frequency). Participants then completed the online FFQ (FFQ1). A research assistant provided standardised instructions and two example questions prior to the athlete completing the FFQ and was present during the completion of FFQ1 to answer any questions that arose.

Phase two was completed at participants' homes and involved completion of an estimated 4DFR (see Appendix C). The 4DFR was used as the reference method to assess the relative validity of the FFQ. Athletes were allocated four consecutive days to complete their food record, which included one hard training day, one rest day and one weekend day to ensure variations in the diet were accounted for. These days were allocated based on the athlete's usual weekly training regime.

Participants were given instructions on how to keep an estimated 4DFR by trained researchers (including watching a video developed by nutritionists and dietitians at MUHNRC). Participants were asked to record all food, fluids and supplements consumed at the time of consumption. Details of consumption included; time, location, brand-names, type (e.g. full fat or trim milk), quantities (e.g. in household measures such as one cup of cereal) and cooking methods (e.g. baked or microwaved). Participants were also instructed to record homemade recipes and provide researchers with packaging of products if possible to aid in accurate data entry for food composition analysis. Additionally, participants were provided with a food portion size booklet (Nelson et al., 1997) to assist with quantification of food amounts consumed. All food diaries were returned to the MUHNRC by post and followed up by phone call or email from a research assistant to ensure accuracy of dietary data collected. Across all participants, all seven days of the week were covered.

Phase three (completion of FFQ2) was completed either at home or at the MUHNRC, four weeks after completion of phase one. In addition, participants were asked if they had made any changes to their routine (i.e. dietary intake, training or supplement use) since the initial assessment.

Data handling

Food groups

The 129 food groups presented within the FFQ were condensed and combined to form 28 food groups for analysis. These food groups were further combined to form seven core food groups. The condensed groups were formed to include food groups of particular interest in athletes such as red meat, starchy vegetables and non-starchy vegetables, and were based on food groupings from the Ministry of Health (2011). Food groupings were discussed and decided by three members of the research team. The amended food group list can be found in Appendix D.

Food frequency questionnaire analysis

Data from both FFQs (FFQ1 and FFQ2) was exported from SurveyMonkey onto an excel spread sheet and checked for quality control.

Responses (timeframe and number of portions) were converted into daily amounts so comparisons of food group intake could be made with the 4DFR. Conversion of responses into daily amounts were as follows: yearly was divided by 365; monthly was divided by 28; weekly was divided by seven and daily remained the same. The midpoint of each frequency of intake response was used. For example, a frequency of intake of one to three times per month was regarded as two times per month. This equated to 0.07 times/day (2/28). For foods consumed daily, these amounts were multiplied by the frequency of consumption per day to give the total gram amount per day. The table of frequency conversion factors is shown in Appendix E.

Portions (described in metric or unit measurements) were converted to gram amounts using FoodWorks 9 (FoodWorks 9 Professional, 2016). FoodWorks uses the New Zealand Food Composition Database and FOODfiles (NZ Food Composition Database 2017). Extreme outliers of implausible consumption amounts (e.g. 20,000 L water per day) were removed from data analysis.

The same process was completed for both FFQ data.

Four day food record

Any missing portion sizes from the 4DFR were followed up with participants. For any mixed dishes and homemade recipes, individual ingredients from the dish and recipe were assigned to the appropriate FFQ food category. For example, couscous salad was broken down into couscous, vegetables, nuts and oils and inputted into these separate categories. For any food items that did not match a food category within the FFQ, they were categorised into the 'other' category and excluded from the analysis. Examples include flour and cocoa powder. Additional food item columns were also created for foods that did not align with any column/grouping listed in the FFQ but that were consumed/listed by multiple participants. Examples include soup, sushi and herbs and spices.

To enable comparison with the FFQ, all food items on the 4DFR were manually entered into an excel spreadsheet and categorised into one of 129 food groups in the FFQ. The New Zealand FoodWorks 9 database was used to convert portion sizes reported into gram amounts (FoodWorks 9 Professional, 2016) (see Appendix F for the full list of conversions). The Australian database was additionally used to ensure accurate analysis of some sport supplements (e.g. Musclepharm protein powder) and less common food items such as chia seeds, vermicelli, and frooze balls. All total gram amounts for each food item were divided by four to provide the average gram amount per day.

Many assumptions were made during data entry for any unclear reporting or for food items that were not identified in the FoodWorks databases. The full list of assumptions made can be found in Appendix G.

Statistical analysis

All statistical analyses were conducted using SPSS 23.0 for windows (IBM Corp, 2015). Normality of distribution was evaluated using normality plots and the Kolmogorov-Smirnov tests. The population was described using mean ± standard deviations (SD) for normally distributed data; median (25^{th} or 75^{th} percentile) for non-normally distributed data; or frequency summary statistics for categorical data.

Relative Validity

To assess relative validity of the FFQ, food group intakes from the FFQ were compared with corresponding 4DFR data using a range of statistical methods. These included; Wilcoxon signed rank test and effect size, Spearman's correlation coefficients (for non-normally distributed data), cross classification with tertiles, weighted kappa statistics and Bland-Altman analyses. A p-value (two-tailed) of <0.05 was considered statistically significant.

Wilcoxon signed rank tests were used to measure agreement between the FFQ and 4DFR at the group level (Lombard et al., 2015). The effect size was calculated as an objective measure of the importance of an effect using the formula: r = √ t2 / t2 + df where t is the test statistic, and df is the degrees of freedom. Determination of effect size was based on recommendations from Cohen (1988) and Field (2009); small effect when r=0.1, medium effect when r=0.3, and a large effect with r=0.5.

Spearman's correlation coefficients were used to determine the strength and direction of association for each food group between the FFQ and 4DFR. The relationship between the assessment tools for each food group was described as: almost perfect 0.9 - 1; very high 0.7 - 0.9; high 0.5 - 0.7; moderate 0.3 - 0.5; low 0.1 – 0.3 and insubstantial 0 – 0.1 (Cohen, 1988; Hopkins et al., 2009).

Cross classification was used to divide the absolute intake of each food group into tertiles for both the FFQ and 4DFR. Correct classification into the same tertile should occur for >50% of participants, and gross misclassification into the opposite tertile should occur for <10% (Masson et al., 2003). Levels of agreement for cross classification were further investigated using the kappa (*k*) statistic. The formula used to determine the k statistic is: *k* = Pr(a) - Pr(e) / 1 – Pr(e) where Pr(a) is the relative observed agreement between the FFQ and 4DFR, and Pr(e) is hypothetical probability of chance agreement. If the two assessment tools completely agree then *k*=1, and if there is no agreement, other than that expected by chance, then *k*=0. Agreement levels for *k* statistic are; very good agreement >0.80, good agreement 0.61 - 0.80, moderate agreement 0.41 - 0.60, fair agreement 0.21 - 0.40, and poor agreement <0.20 (Masson et al., 2003).

The strength of the agreement between the FFQ and 4DFR, and the presence, direction and extent of bias at the group level were determined using Bland-Altman analyses. The limits of agreement (LOA) were used to assess relative bias (mean difference) and random error (1.96 SD of the difference). (Bland & Altman, 1986). The agreement was further assessed using linear regression analysis to determine the distribution of differences and detect proportional bias. The significance level was assumed at p<0.05.

Reproducibility

To assess reproducibility of the FFQ, the same statistical methods for determining relative validity were used. All tests were two-tailed with the significance level of the p-value set at <0.05.

3.4 Results

3.4.1 Participant Characteristics

A total of 122 high performing athletes expressed interest in participating in this study, and of those 99 took part. Between appointment one (FFQ1) and the completion of the study, twenty eight athletes withdrew (mainly due to time constraints including training/sporting commitments). An additional five participants with unreliable data (e.g. 3032g bread/day equivalent to 95 slices) were excluded prior to analysis. This left a sample size of 66 athletes (24 males, 42 females). Of these participants, one did not return their food diary and one did not complete the FFQ2 four weeks later, leaving 65 participants for validation of the FFQ and 65 participants for reproducibility testing.

The characteristics of the athlete population are presented in Table 3.1. The majority of participants were New Zealand European (81.8%) and female (63.6%), with a mean age of 21 ± 4 years. The athletes were involved in more than 30 different sports, with team sports reflecting the main sport played by most (36.4%). Athletes were training a mean of 12.3 ± 5.1 hours per week.

Table 3.1 *Athlete characteristics (n=66)*

Characteristics [a]	Male (n= 24)	Female (n= 42)	Total (n= 66)
Age (years)	22 ± 5	21 ± 4	21 ± 4
Height (m)	1.8 ± 0.1	1.6 ± 0.1	1.7 ± 0.1
Weight (kg)	81 ± 10	62 ± 9	69 ± 13
Body Mass Index (kg/m^2)	24.8 ± 3.1	22.7 ± 2.7	23.5 ± 3
Exercise Frequency (hours/week)	12.3 ± 4.8	12.3 ± 5.3	12.3 ± 5.1

Ethnicity [b]			
European/New Zealander	21 (31.8)	33 (50)	54 (81.8)
Māori	2 (3)	3 (4.6)	5 (7.6)
Pacific Island	0 (0)	1 (1.5)	1 (1.5)
Asian	1 (1.5)	4 (6.1)	5 (7.6)
Middle Eastern/African	0 (0)	1 (1.5)	1 (1.5)
Main Sport [b]			
Athletics	2 (3)	1 (1.5)	3 (4.5)
Aesthetic sports (e.g. figure skating, gymnastics)	1 (1.5)	5 (7.6)	6 (9.1)
Combat sports (e.g. boxing, karate, judo, mixed martial arts)	1 (1.5)	2 (3)	3 (4.5)
Endurance sports (e.g. cycling, running, swimming, triathlon)	3 (4.5)	7 (10.6)	10 (15.2)
Power sports (e.g. powerlifting, weight lifting)	2 (3)	4 (6)	6 (9.1)
Precision sports (e.g. archery, golf, shooting)	1 (1.5)	2 (3)	3 (4.5)
Racquet sports (e.g. badminton, squash, tennis)	2 (3)	1 (1.5)	3 (4.5)
Team sports (e.g. cricket, hockey, soccer/football)	9 (13.6)	15 (22.7)	24 (36.4)
Water sports (e.g. kayaking, rowing, sailing, water polo)	3 (4.5)	5 (7.6)	8 (12.1)
Highest Representation Level [b]			
Regional – competitive/representative	3 (4.5)	7 (10.6)	10 (15.2)
National	6 (9.1)	12 (18.2)	18 (27.3)
International – age group	7 (10.6)	11 (16.7)	18 (27.3)
International – open	8 (12.1)	12 (18.2)	20 (30.3)
Additional Characteristics [b]			
Carded athlete *	3 (4.5)	8 (12.1)	11 (16.7)
Taken supplements in the last 4 weeks (1st appointment)	22 (33.3)	31 (47)	53 (80.3)
Carrying an injury (1st appointment)	5 (7.6)	17 (25.8)	22 (33.3)

Current illness or chronic condition (1st appointment)	1 (1.5)	4 (6.1)	5 (7.6)
Current allergies or intolerances	1 (1.5)	6 (9.1)	7 (10.6)
Vegetarian or vegan	0 (0)	3 (4.5)	3 (4.5)

[a] Data are presented as mean ± standard deviation.

[b] Data are presented as number (percentage).

*Carded athletes are those who receive performance support (e.g. injury and illness prevention and rehabilitation, strength and conditioning nutrition, athlete life advice, performance and technique analysis, physiology, psychology, and performance planning) from High Performance Sport New Zealand.

3.4.2 Validity of the FFQ

Food group intakes

Daily food group consumption from the FFQ1 was compared with the 4DFR (Table 3.2). The full list of food group constituents are presented in Appendix D. Median food group intakes in grams were higher for the FFQ data in comparison with the 4DFR for the majority of food groups. Significant differences were observed for: dairy; discretionary dairy; cereals; starchy foods; red meat; poultry; fish & seafood; legumes; starchy vegetables; non-starchy vegetables; fruit; tea, coffee & hot chocolate; alcohol; muesli bars; potato chips; sports drinks; and sports foods/supplements ($p<0.05$). The majority produced a medium effect size ($r=0.3$) with discretionary dairy; starchy foods; poultry; tea, coffee & hot chocolate; alcohol; and muesli bars producing a small effect size ($r=0.1$). Validity correlations for all food groups between the FFQ1 and 4DFR ranged from 0.11 (processed meats) to 0.78 (tea, coffee & hot chocolate), mean 0.41. Most correlations were significant ($p<0.05$), with the exception of processed meats; fish & seafood; sauces & condiments; potato chips; and takeaway foods (Table 3.2).

Table 3.2 *Comparison of daily food group intakes in grams from FFQ1 and 4DFR (n=65)*

Food Group (g)	FFQ1 median (25^{th}, 75^{th} percentile)	Food Record median (25^{th}, 75^{th} percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Dairy (milk, cheese & yoghurt)	376.8 (212.8, 685.8)	219.5 (105.5, 402.7)	0.00*	-0.42	0.44	<0.01
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	66.4 (22.6, 204.5)	39.8 (0.0, 138.8)	0.00*	-0.28	0.51	<0.01
Bread (e.g. wholegrain, white, bagels, scones, crackers)	85.7 (46.8, 123.6)	89.3 (51.9, 124.9)	0.99		0.45	<0.01
Breakfast Cereals (wholegrain & sweetened)	49.9 (17.9, 113.5)	26.8 (0.0, 57.7)	0.00*	-0.38	0.48	<0.01
Starchy Foods (rice, pasta, canned spaghetti, couscous)	93.0 (53.4, 145.4)	62.5 (18.1, 127.8)	0.01*	-0.24	0.32	0.01
Red Meat	94.5 (36.0, 143.0)	50.0 (12.1, 94.6)	0.00*	-0.30	0.33	0.01
Processed Meats (e.g. ham, bacon, sausages)	11.0 (2.4, 19.8)	15.5 (0.0, 32.0)	0.17		0.11	0.39
Poultry	67.2 (39.8, 122.4)	49.9 [a] (25.0, 79.3)	0.02*	-0.21	0.34	0.01
Fish & Seafood	39.2 (8.9, 85.1)	0.0 (0.0, 41.8)	0.00*	-0.30	0.21	0.09
Eggs	36.7 [a] (14.3, 53.0)	38.3 (12.8, 57.8)	0.74		0.59	<0.01
Legumes (beans, hummus, tofu, nuts & seeds)	37.1 (15.5, 94.9)	23.8 (12.5, 58.9)	0.00*	-0.30	0.62	<0.01
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	171.7 (79.5, 312.8)	50.0 (0.0, 104.2)	0.00*	-0.49	0.32	0.01

Food Group (g)	FFQ1 median (25th, 75th percentile)	Food Record median (25th, 75th percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	266.9 (163.7, 489.6)	150.6 (69.6, 278.9)	0.00*	-0.46	0.46	<0.01
Fruit (whole & dried)	282.9 (150.6, 399.6)	166.5 (113.3, 297.7)	0.00*	-0.45	0.50	<0.01
Fruit Juice	18.0 (0.0, 92.7)	0.0 (0.0, 13.3)	0.12		0.28	0.03
Water	1505.2 (1000.0, 2053.5)	1650.0 (1081.3, 2152.5)	0.63		0.48	<0.01
Tea, Coffee & Hot Chocolate	200.9 (64.5, 534.3)	150.0 [a] (0.0, 355.9)	0.00*	-0.28	0.78	<0.01
Soft Drinks, Energy Drinks & Low Calorie Drinks (e.g. cordials)	17.9 (0.0, 58.7)	0.0 (0.0, 0.0)	0.78		0.52	<0.01
Alcohol	20.5 (0.0, 51.5)	0.0 (0.0, 0.0)	0.00*	-0.26	0.31	0.01
Sauces & Condiments	18.4 (10.0, 38.8)	13.7 (3.2, 39.7)	0.91		0.24	0.06
Cakes, Puddings & Biscuits	17.6 (5.9, 42.6)	15.0 (0.0, 31.7)	0.06		0.50	<0.01
Chocolate, Lollies, Sugar & Sweets	9.2 (4.3, 21.2)	6.3 (0.6, 18.4)	0.19		0.35	0.01
Muesli Bars	14.4 (0.0, 28.4)	0.0 (0.0, 20.0)	0.00*	-0.32	0.52	<0.01
Potato Chips	2.9 (0.0, 6.7)	0.0 (0.0, 0.0)	0.04*	-0.18	0.24	0.06
Fats & Oils	14.3 (7.2, 32.5)	11.5 (6.3, 32.7)	0.92		0.43	0.00

Food Group (g)	FFQ1 median (25^{th}, 75^{th} percentile)	Food Record median (25^{th}, 75^{th} percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation- significance
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curries)	67.9 (26.8, 115.7)	42.0 (0.0, 123.8)	0.54		0.23	0.07
Sports Drinks (e.g. Powerade, Gastrolyte)	53.6 (0.0, 99.7)	0.0 (0.0, 0.0)	0.00*	-0.39	0.29	0.02
Sports Foods/Supplements (e.g. sports bars, protein powders)	3.5 (0.0, 25.0)	0.0 (0.0, 15.0)	0.01*	-0.25	0.70	<0.01

*p<0.05, significant difference

[a]Data includes 64 participants – extreme values due to the removal of extreme outliers

Note: mean results table reported in Supplementary Results (Appendix H, Table 10)

Core food group intakes

Median core food group intakes were higher for the FFQ data in comparison with the 4DFR for all food groups. Significant differences in the amount consumed was observed for milk & milk products; grains; meat & proteins; and fruit & vegetables ($p<0.05$). A large effect size ($r=0.5$) was found for fruit & vegetables, whilst the remainder had small ($r=0.1$) to medium ($r=0.3$) effect sizes. Validity correlations for daily amount for all food groups between the FFQ1 and 4DFR ranged from 0.22 (processed foods & drinks) to 0.56 (fruit & vegetables), mean 0.41. All correlations were significant, with the exception of processed foods & drinks (Table 3.3).

Table 3.3 *Comparison of daily core food group intakes in grams from the FFQ1 and 4DFR (n=65)*

Core Food Group (g)	FFQ median (25th, 75th percentile)	Food Record median (25th, 75th percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Milk & Milk Products	491.7 (295.3, 891.5)	333.7 (138.7, 509.7)	0.00*	-0.45	0.55	<0.01
Grains (bread, breakfast cereals & starchy foods)	248.3 (175.2, 379.1)	214.0 (119.9, 264.3)	0.00*	-0.26	0.39	<0.01
Meat & Proteins	363.4 [a] (244.5, 434.5)	244.1 [a] (159.4, 353.1)	0.00*	-0.40	0.38	<0.01
Fruit & Vegetables	755.6 (502.1, 1153.2)	391.9 (276.1, 645.8)	0.00*	-0.57	0.56	<0.01
Fats, Oils, Sauces & Condiments	38.0 (20.4, 73.3)	36.2 (15.6, 77.9)	0.64		0.28	0.02
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	135.1 (77.6, 218.1)	96.9 (34.4, 213.9)	0.23		0.22	0.08
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	1931.8 (1363.2, 2531.9)	1875.3 (1311.6, 2335.6)	0.62		0.45	<0.01

*p<0.05, significant difference

[a]Data includes 64 participants due to the removal of extreme outliers

Note: mean results table reported in Supplementary Results (Appendix H, Table 11)

Cross classifications and weighted kappa statistics for food groups and core food groups

The percentage of correctly classified participants, using tertiles for food groups ranged from 35.4% (starchy vegetables) to 55.5% (fats & oils) between the FFQ1 and 4DFR, mean 47.3%, (Table 3.4). Gross misclassification between FFQ1 and the 4DFR ranged from 4.6% (legumes) to 15.4% (starchy vegetables; sauces & condiments). In conjunction with the cross-classification analysis, the weighted kappa statistic was calculated to assess the agreement for each food item between FFQ1 and 4DFR. The majority of food groups had a fair to moderate agreement (*k*=0.21-0.60), with starchy foods; starchy vegetables; poultry; and takeaway foods presenting poor agreement (*k*=<0.20) (Table 3.4).

Table 3.4 *Cross classification and weighted kappa for daily food group consumption between FFQ1 and 4DFR (n= 65)*

	Cross classification		**Weighted kappa statistic**
Food Group	**Correctly classified into same tertiles (%)**	**Grossly misclassified (%)**	
Dairy (milk, cheese & yoghurt)	47.7	12.4	0.28
Bread (e.g. wholegrain, white, bagels, scones, crackers)	53.8	12.4	0.35
Breakfast Cereals (wholegrain & sweetened)	44.6	6.2	0.32
Starchy Foods (rice, pasta, canned spaghetti, couscous)	39.9	13.8	0.18
Poultry	40.0	10.8	0.20
Legumes	52.3	4.6	0.42
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	35.4	15.4	0.11

Food Group	Cross classification		Weighted kappa statistic
	Correctly classified into same tertiles (%)	Grossly misclassified (%)	
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	52.2	10.8	0.35
Fruit (whole & dried)	55.4	13.9	0.35
Sauces & Condiments	50.8	15.4	0.28
Fats & Oils	55.5	10.8	0.37
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curries)	40.0	13.9	0.17

*Cross classification into tertiles could not be calculated for the following food groups as >33.3% of participants did not consume any food from these food groups or multiples of the same values were reported and even cuts in the data could not be made: Discretionary Dairy; Red Meat; Processed Meat; Fish & Seafood; Eggs; Fruit Juice; Water; Tea, Coffee & Hot Chocolate; Soft Drinks; Energy Drinks & Low Calorie Drinks; Alcohol; Cake, Puddings & Biscuits; Chocolate, Lollies, Sugar & Sweets; Muesli Bars; Potato Chips; Sports Drinks; and Sports Foods/Supplements.

The percentage of correctly classified participants, using tertiles for core food groups ranged from 32.3% (processed foods & drinks) to 55.3% (fruit & vegetables) between the FFQ1 and 4DFR, mean 44.8% (Table 3.5). Gross misclassification between FFQ1 and the 4DFR ranged from 7.7% (fruit & vegetables) to 18.5% (processed foods & drinks). The majority of core food groups had fair to moderate agreement (*k*=0.21-0.60), with processed foods & drinks; and fats, oils, sauces & condiments presenting poor agreement (*k*=<0.20) (Table 3.5).

Table 3.5 *Cross classification and weighted kappa for daily core food group amount consumed between FFQ1 and 4DFR (n= 65)*

	Cross classification		Weighted kappa statistic
Core Food Group	**Correctly classified into same tertiles (%)**	**Grossly misclassified (%)**	
Milk & Milk Products	52.2	10.8	0.35
Grains (bread, breakfast cereals & starchy foods)	46.2	10.8	0.28
Meat & Proteins	44.6	12.4	0.25
Fruit & Vegetables	55.3	7.7	0.42
Fats, Oils, Sauces & Condiments	35.3	15.4	0.11
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	32.3	18.5	0.04
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	53.9	12.3	0.34

Bland-Altman Analysis

Bland-Altman plots were constructed to assess the strength of agreement between dietary intake data from the FFQ1 and 4DFR. Examples of Bland-Altman plots for starchy foods; poultry; fats, oils, sauces & condiments; and processed foods & drinks are shown in Figure 3.1. Visual inspection of the Bland-Altman plots suggests that for most food groups, the scatter of the difference between the FFQ1 and 4DFR increases as the mean intake of each food group and core food group increases (Appendix H1). Proportional bias towards over-reporting was observed for poultry; alcohol; and sports supplements, and a bias towards under-reporting was observed for bread; processed meats; fruit juice; soft drinks, energy drinks & low calorie drinks; sauces and condiments; and takeaway foods ($p<0.05$). Overall, a good level of agreement was reported for the majority of food groups between the FFQ and

4DFR. The mean difference indicates that, on average, the FFQ shows a tendency towards under-reporting food group intake as mean food intake increases (Appendix H, Tables 6 & 7).

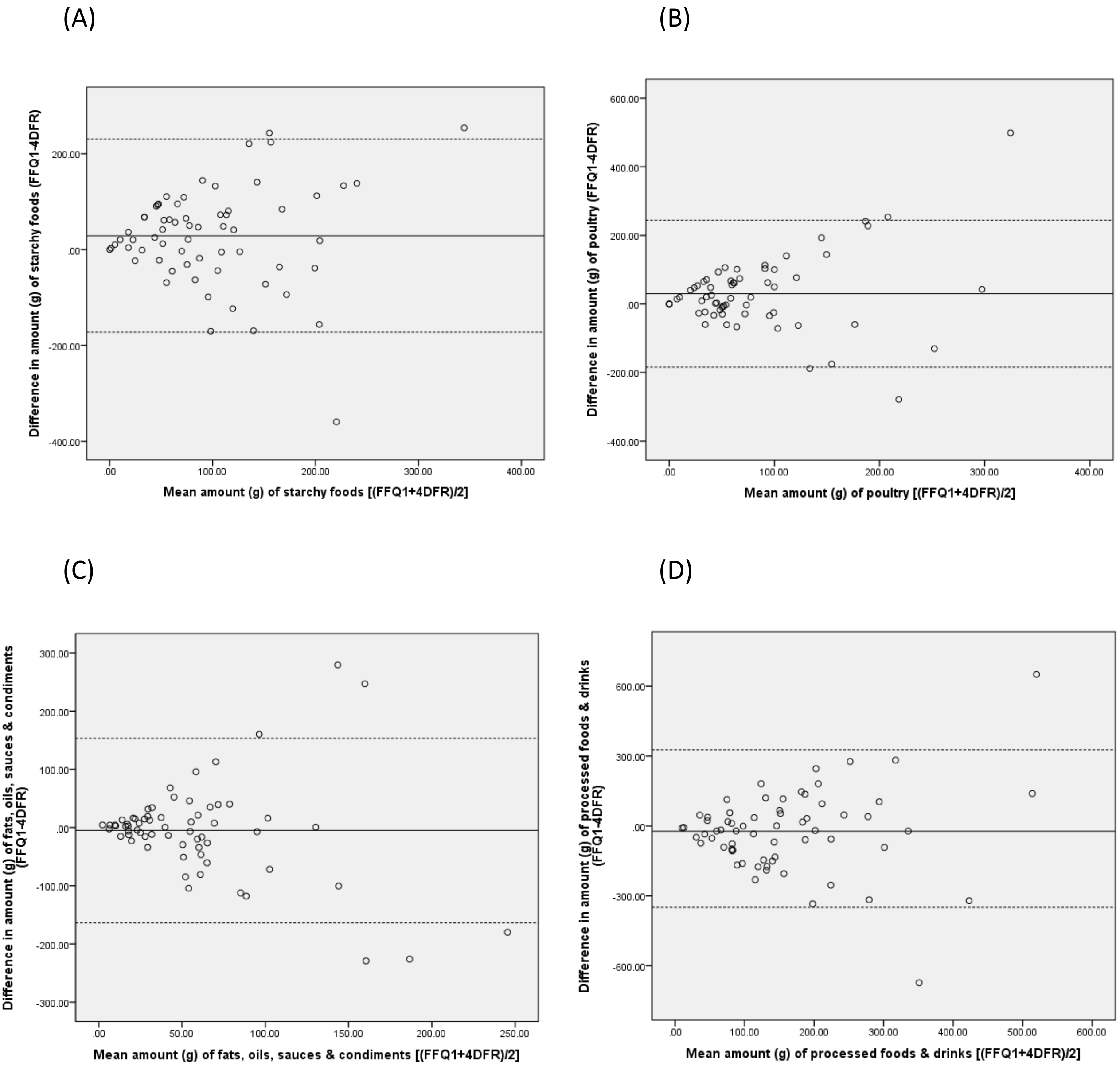


Figure 3.1 *Bland-Altman plots of agreement for daily intake of (A) starchy foods (B) poultry (C) fats, oils, sauces & condiments and (D) processed foods & drinks between the FFQ1 and 4DFR. The solid line represents the mean difference between the two dietary assessment methods, and the dashed lines represent the limits of agreement (LOA = mean difference ± 1.96 standard deviations).*

3.4.3 Reproducibility of the FFQ

Food group intakes

Daily food group intake was compared between the first and second administration of the FFQ (Table 3.6). Median food group intakes were higher for the FFQ1 data in comparison with the FFQ2 for the majority of food groups. Significant differences in the amount consumed was observed for the following: discretionary dairy; bread; starchy foods; poultry; starchy vegetables; non-starchy vegetables; fruit juice; sauces & condiments; fats & oils; sports drinks; and sports foods/supplements ($p<0.05$). All effect sizes were small ($r=0.1$). Reproducibility correlations between FFQ1 and FFQ2 ranged from 0.49 (potato chips; fats & oils) to 1.00 (tea, coffee & hot chocolate), mean 0.65. All correlations were significant (Table 3.6).

Table 3.6 *Comparison of daily food group intakes in grams from the FFQ1 and FFQ2 (n = 65)*

Food Group (g)	FFQ1 median (25^{th}, 75^{th} percentile)	FFQ2 median (25^{th}, 75^{th} percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Dairy (milk, cheese & yoghurt)	365.4 (212.8, 648.6)	325.7 (154.6, 636.3)	0.43		0.59	<0.01
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	66.4 (22.6, 195.1)	43.5 [a] (16.8, 211.3)	0.02*	-0.20	0.70	<0.01
Bread (e.g. wholegrain, white, bagels, scones, crackers)	85.7 (46.8, 123.6)	69.1 (33.5, 110.3)	0.01*	-0.22	0.66	<0.01
Breakfast Cereals (wholegrain & sweetened)	51.1 (17.9, 113.5)	53.4 [a] (18.0, 100.0)	0.75		0.64	<0.01
Starchy Foods (rice, pasta, canned spaghetti, couscous)	93.0 (53.4, 148.2)	79.1 (33.4, 124.8)	0.02*	-0.21	0.57	<0.01

Food Group (g)	FFQ1 median (25th, 75th percentile)	FFQ2 median (25th, 75th percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Red Meat	94.5 (36.0, 143.0)	72.0 (36.6, 142.0)	0.19		0.50	<0.01
Processed Meats (e.g. ham, bacon, sausages)	11.0 (2.4, 19.8)	6.2 (2.4, 14.2)	0.14		0.57	<0.01
Poultry	66.8 [a] (39.8, 122.4)	58.7 (22.3, 111.3)	0.03*	-0.19	0.73	<0.01
Fish & Seafood	39.2 (10.4, 85.1)	31.7 (9.6, 69.4)	0.12		0.72	<0.01
Eggs	36.2 (12.5, 53.0)	36.2 (10.7, 43.9)	0.78		0.72	<0.01
Legumes	37.1 (17.1, 94.9)	28.4 (14.1, 79.5)	0.06		0.63	<0.01
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	174.7 (79.5, 312.8)	143.5 (66.4, 261.6)	0.04*	-0.18	0.56	<0.01
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	273.8 (163.7, 489.6)	246.8 (158.8, 447.7)	0.02*	-0.21	0.66	<0.01
Fruit (whole & dried)	275.3 (150.6, 399.6)	270.5 (173.3, 358.2)	0.12		0.72	<0.01
Fruit Juice	18.0 (0.0, 92.7)	5.2 (0.0, 36.1)	0.00*	-0.25	0.75	<0.01
Water	1505.2 (1000.0, 2053.5)	1500.0 (781.3, 2000.0)	0.26		0.63	<0.01
Tea, Coffee & Hot Chocolate	199.8 (72.6, 522.9)	199.8 (72.6, 522.9)	1.00		1.00	-
Soft Drinks, Energy Drinks & Low Calorie Drinks	17.9 (0.0, 58.7)	10.2 (0.0, 44.5)	0.64		0.75	<0.01

Food Group (g)	FFQ1 median (25th, 75th percentile)	FFQ2 median (25th, 75th percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Alcohol	20.5 (0.0, 49.9)	22.4 (0.0, 58.71)	0.40		0.67	<0.01
Sauces & Condiments	18.2 (10.0, 38.8)	11.9 (4.5, 38.9)	0.01*	-0.24	0.64	<0.01
Cakes, Puddings & Biscuits	17.6 (5.9, 44.0)	12.9 (5.2, 28.5)	0.19		0.67	<0.01
Chocolate, Lollies, Sugar and Sweets	9.2 (4.3, 20.4)	9.2 (3.9, 17.1)	0.98		0.77	<0.01
Muesli Bars	14.4 (0.0, 28.4)	5.6 (0.0, 28.4)	0.16		0.60	<0.01
Potato Chips	1.9 (0.0, 6.7)	1.9 (0.0, 6.7)	0.61		0.49	<0.01
Fats & Oils	14.3 (7.2, 32.5)	10.8 (3.6, 21.7)	0.01*	-0.24	0.49	<0.01
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curries)	67.9 (26.8, 113.2)	49.3 (20.6, 100.9)	0.36		0.55	<0.01
Sport Drinks (e.g. Powerade, Gastrolyte)	53.6 (0.0, 99.7)	15.3 (0.0, 71.5)	0.02*	-0.20	0.69	<0.01
Sports Foods/Supplements (e.g. sports bars, protein powders)	1.8 (0.0, 25.0)	0.5 (0.0, 9.7)	0.01*	-0.28	0.72	<0.01

*p<0.05, significant difference

[a]Data includes 64 participants due to the removal of extreme outliers

Note: mean results table reported in Supplementary Results (Appendix H, Table 12)

Core food group intakes

Median core food group intakes were higher for the FFQ1 data in comparison with the FFQ2 for all core food groups. Significant differences in the amount consumed was observed for grains; meat & proteins; fruit & vegetables; and fats, oils, sauces & condiments ($p<0.05$). All effect sizes were small ($r = 0.1$). Reproducibility correlations for daily amount for all core food groups between the FFQ1 and FFQ2 ranged from 0.51 (processed foods & drinks) to 0.72 (grains; fruit & vegetables), mean 0.63. All correlations were significant (Table 3.7).

Table 3.7 *Comparison of daily core food group intakes in grams from the FFQ1 and FFQ2 (n=65)*

Core Food Group (g)	FFQ1 median (25^{th}, 75^{th} percentile)	FFQ2 median (25^{th}, 75^{th} percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Milk & Milk Products	483.7 (295.3, 858.1)	453.2 [a] (256.4, 717.8)	0.15		0.63	<0.01
Grains (bread, breakfast cereals & starchy foods)	248.3 (175.2, 379.1)	222.9 (146.3, 327.3)	0.01*	-0.24	0.72	<0.01
Meat & Proteins	358.8 [a] (244.5, 433.5)	280.2 (192.9, 448.8)	0.01*	-0.23	0.59	<0.01
Fruit & Vegetables	760.5 (502.1, 1153.2)	727.7 (456.8, 973.0)	0.01*	-0.24	0.72	<0.01
Fats, Oils, Sauces & Condiments	38.1 (20.1, 73.3)	26.7 (10.3, 57.5)	0.00*	-0.28	0.68	<0.01
Processed foods (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	135.1 (77.6, 218.1)	108.8 (64.5, 210.4)	0.24		0.51	<0.01

Core Food Group (g)	FFQ1 median (25th, 75th percentile)	FFQ2 median (25th, 75th percentile)	Wilcoxon (p-value)	Effect size (r)	Spearman's correlation coefficient (r)	Spearman's correlation-significance
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	1955.2 (1363.2, 2502.5)	1782.8 (1195.1, 2677.2)	0.38		0.61	<0.01

*p<0.05, significant difference

[a]Data includes 64 participants due to the removal of extreme outliers

Note: mean results table reported in Supplementary Results (Appendix H, Table 13)

Cross classifications and weighted kappa statistics for foods groups and core food groups

Using tertiles, all food groups had >50% of participants correctly classified and <10% grossly misclassified, with the exception of dairy and fats & oils. The percentage of correctly classified participants ranged from 44.6% (fats & oils) to 99.9% (tea, coffee & hot chocolate) between the FFQ1 and FFQ2, with an average of 60.6% (Table 3.8). Gross misclassification between FFQ1 and FFQ2 ranged from 0% (tea, coffee & hot chocolate) to 12.3% (starchy vegetables). The majority of food groups presented moderate to good agreement (k=0.41-0.8), whilst dairy; starchy vegetables; and fats & oils presented fair agreement (k=0.21–0.40). Tea, coffee & hot chocolate presented complete agreement (k=1) (Table 3.8).

Table 3.8 *Cross classification and weighted kappa for daily food group consumption between FFQ1 and FFQ2 (n= 65)*

	Cross classification		Weighted kappa statistic
Food Group	**Correctly classified into same tertiles (%)**	**Grossly misclassified (%)**	
Dairy (milk, cheese & yoghurt)	48.5	7.7	0.35
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	63	6.2	0.52
Bread (e.g. wholegrain, white, bagels, scones)	60.1	6.1	0.49
Breakfast Cereals (wholegrain & sweetened)	60	6.2	0.49
Starchy Foods (rice, pasta, canned spaghetti, couscous)	60	9.2	0.45
Poultry	58.5	1.5	0.51
Legumes	52.4	4.6	0.42
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	56.9	12.3	0.38
Non Starchy Vegetables	56.9	6.2	0.45
Fruit (whole & dried)	67.7	4.6	0.59
Tea, Coffee & Hot Chocolate	99.9	0.0	1
Sauces & Condiments	58.4	4.6	0.49
Cakes, Puddings & Biscuits	64.6	4.6	0.54
Chocolate, Lollies, Sugar & Sweets	64.7	1.5	0.58
Fats & Oils	44.6	6.1	0.29
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curries)	53.8	6.1	0.42

*****Cross classification into tertiles could not be completed for the following food groups as >33.3% of participants did not consume any food from these food groups or multiples of the same values were reported and even cuts in the data could not be made: Red Meat; Processed Meat; Fish & Seafood; Eggs; Fruit Juice; Water; Soft Drinks; Energy Drinks & Low Calorie Drinks; Alcohol; Muesli Bars; Potato Chips; Sports Drinks; and Sports Foods/Supplements.

All core food groups had >50% of participants correctly classified and <10% grossly misclassified, using tertiles, with the exception of processed foods & drinks. The percentage of correctly classified participants for core food groups ranged from 49.3% (processed foods & drinks) to 67.7% (beverages) between the FFQ1 and FFQ2, with an average of 59.4% (Table 3.9). Gross misclassification between FFQ1 and the FFQ2 ranged from 0% (fats & oils) to 10.8% (processed foods & drinks). Processed foods and drinks was the only core food group to present fair agreement (*k*=0.21-0.40), the majority presented moderate to good agreement (*k*=0.61-0.8) (Table 3.9).

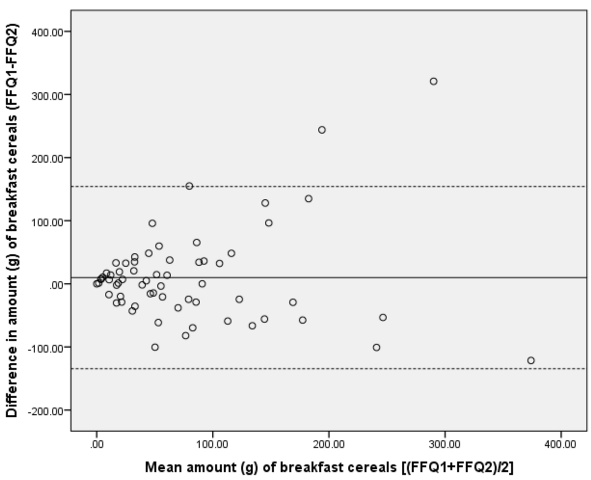
Table 3.9 *Cross classification and weighted kappa for daily core food group amount consumed between FFQ1 and FFQ2 (n= 65)*

	Cross classification		**Weighted kappa statistic**
Core Food Group	**Correctly classified into same tertiles (%)**	**Grossly misclassified (%)**	
Milk & Milk Products	60	6.2	0.49
Grains (bread, breakfast cereals & starchy foods)	64.6	4.6	0.55
Meat & Proteins	55.4	7.7	0.42
Fruit & Vegetables	58.5	1.5	0.52
Fats, Oils, Sauces & Condiments	60	0.0	0.55
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	49.3	10.8	0.32
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	67.7	7.7	0.55

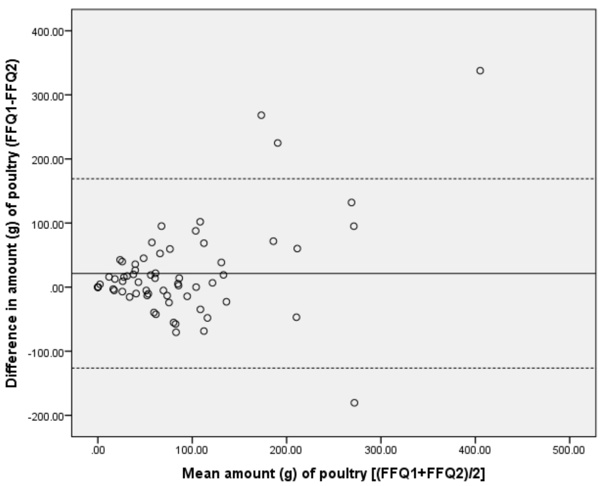
Bland-Altman Analysis

Examples of Bland-Altman plots for breakfast cereals; poultry; takeaway foods; fats, oils, sauces & condiments are shown in Figure 3.2. Overall, a good level of agreement was reported for the majority of food groups and core food groups between the FFQ1 and FFQ2. Visual inspection of the Bland-Altman plots suggests that for most food groups the scatter of the difference between the FFQ1 and FFQ2 increases as the mean intake of each food group and core food group increases (Appendix H2). Proportional bias towards over-reporting was observed for poultry; starchy vegetables; and potato chips, and a bias towards under-reporting was observed for processed meats; soft drinks, energy drinks & low calorie drinks; alcohol; sauces & condiments; and chocolate, lollies sugar & sweets ($p<0.05$). The mean difference indicates that, on average, the FFQ1 shows a tendency towards over-reporting food group intake compared to the FFQ2 as mean food intake increases (Appendix H, Tables 8 & 9).

(A)



(B)



(C) (D)

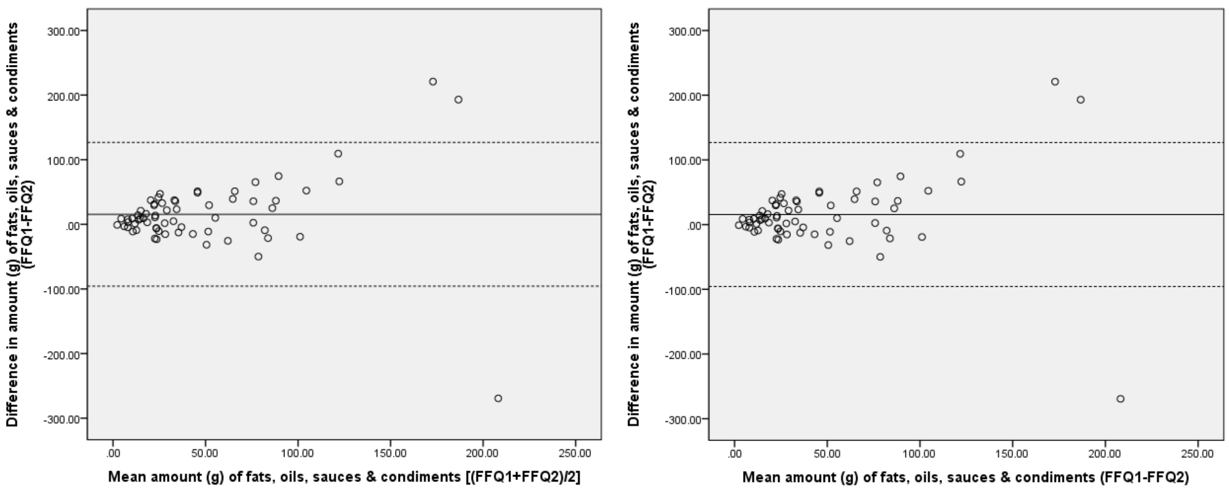


Figure 3.2 *Bland-Altman plots of the agreement between daily intakes for (A) breakfast cereals (B) poultry (C) takeaway foods and (D) fats, oils, sauces & condiments between the FFQ1 and FFQ2. The solid line represents the mean difference between the two dietary assessment methods, and the dashed lines representing the limits of agreement (LOA = mean difference ± 1.96 standard deviations).*

3.5 Discussion

The FFQ was compared to a 4DFR to assess relative validity of food group intake in high performing athletes. Reproducibility was assessed by having participants complete the FFQ on two occasions approximately four weeks apart. The FFQ demonstrated reasonable relative validity and good reproducibility for daily gram amounts of food group intakes. This suggests that the FFQ is a useful tool to assess food group intake in New Zealand high performing athletes.

3.5.1 Validity for food groups

In general, the FFQ tended to over-estimate intake for majority of food groups and thus core food groups compared to the 4DFR. This finding has been repeatedly shown in validation studies comparing FFQs with food records (Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Ward et al., 2004). Significant differences in daily amounts consumed were reported for 17 of 28 food groups ($p<0.05$), the majority being of small effect size. The food groups consumed in larger quantities each day (e.g. fruit & vegetables; milk & milk products; and meat & proteins) had the greatest differences between the FFQ1 and 4DFR, with lower consumed food groups and core food groups (e.g. fats, oils, sauces & condiments; cakes, puddings & biscuits; and processed foods) showing good comparability. Previous studies have also identified decreases in the accuracy of reporting as the amount and frequency of consumption of food increases, which is problematic with athletes who typically have high energy intakes (Baker et al., 2014; Black, 2001; Capling et al., 2017).

Over-reporting of foods deemed to be 'healthy' such as fruit & vegetables, meat & proteins and milk & milk products is well-documented in the literature (Black, 2001; Braakhuis et al., 2011; Feskanich et al., 1993; Jonnalagadda et al., 2000). Athletes are particularly prone to misreporting in efforts to present a more favourable diet thought to benefit their athletic performance or weight goals (Black, 2001). This is even more prevalent in female athletes (Black, 2001; Schoeller, 1995; Westerterp et al., 1986), who made up the majority of participants in this study. Snacks in-between meals considerably contribute to unintentional under-reporting. Athletes consume as many as six snacks per day which is much higher than that of the general population, which consequently results in greater chances to misreport (Erdman et al., 2013; Nogueira & Da Costa, 2004). We tried to minimise misreporting by reviewing athletes completed food records and clarifying missing or incomplete foods, as any errors in reporting (under and over) can considerably affect the validity.

Previous validation studies have also found that fruit and vegetable intake is more likely to be over-reported in an FFQ than any other food group (Feskanich et al., 1993; Mullen, Krantzler, Grivetti, Schutz, & Meiselman, 1984). Although it is possible to overstate the consumption of 'healthy' foods in a food diary, it is easier to exaggerate consumption of 'healthy foods' in a FFQ. It has also been shown that the longer the list of food items, the greater the over-estimation (Krebs-Smith, Heimendinger, Subar, Patterson, & Pivonka, 1995). Of all food groups within the FFQ, the fruit and vegetable food groups presented the longest lists of food items. The difference and over-estimation of fruit and vegetable intake between the FFQ1 and 4DFR became significantly greater when these groups were combined to present total core food group intake. Other studies have recommended adjusting for fruit and vegetable intake to improve the quality of the validation results (Feskanich et al., 1993; Mullen et al., 1984; Watson et al., 2015). However, any adjustments made to the fruit and vegetable groups would not have had an effect on the other food groups in this study and thus was not deemed necessary to complete. Adjustment for fruit and vegetable intake should be considered for future research in this area if nutrients are to be analysed.

Furthermore, listing food items within food groups singularly rather than several food items within one category may lead to overestimation of intakes (Cade et al., 2002). This is also likely to occur for foods that can be eaten both alone and in mixed dishes (e.g. vegetables, meats and proteins) due to double counting/reporting. The food group's poultry and red meat contained a 'mixed dish' category within the FFQ which may have contributed to the overestimation of these two groups by the FFQ compared to the 4DFR. It may be worth reconsidering the use of the 'mixed dish' category or providing clearer instruction in regards to the use of this within the FFQ before implementation.

Moderate validity correlations were observed for daily amounts of food groups and core food groups consumed between the FFQ and 4DFR (r=0.41; 0.43, respectively). Correlations were highest for tea, coffee & hot chocolate; and fruit & vegetables, and lowest for processed foods; and fats & oils. Only two validation studies conducted in athletes have assessed food group intake (Fogelholm & Lahti-Koski, 1991; Sunami et al., 2016) making comparisons between studies difficult. Fogelholm and Lahti-Koski (1991) similarly reported an overall moderate association between the FFQ and food record for food group intakes, with a low correlation also reported for vegetable oils and fats (r=<0.24) and a high correlation reported for coffee (r=>0.75). Sunami et al. (2016) reported median correlations of 0.33 for males and 0.34 for females. Direct comparisons should be interpreted with care as median correlations were reported separately for males and females.

Discrepancies and difficulties with categorisation of food intake into the appropriate sections of the FFQ, for athletes as well as for researchers inputting data from the 4DFR, could have contributed to the moderate validity correlations. For certain foods, there was some overlap where the food item could have been placed into more than just one food group in the FFQ. For example, fish (e.g. fish fingers or mussel fritters) could have been allocated to the fish section as well as the takeaway section (under 'deep fried fish'). Further, the definition of takeaway foods was not clearly defined within the FFQ and thus whilst researchers considered all food items purchased from restaurants and fast food outlets (including Subway and sushi) to be classified into the takeaways food group, athletes may not have.

Difficulties with portion size estimates have been noted by other studies as a cause for lower validity correlations between questionnaires and food records (Cade et al., 2004; Pedišić et al., 2008; Salvini et al., 1989). While food portion size booklets (Nelson et al., 1997) were given to participants to improve the accuracy of measurements reported, food quantification is still difficult to complete for even the most literate individuals. Additionally, athletes may have found it technically challenging to report both the portion size measurement and the frequency of consumption in the FFQ, which could have further resulted in reporting errors. The addition of food portion photographs within the FFQ could help improve accuracy of dietary reporting (Fallaize et al., 2014; Simpson, Gemming, Baker, & Braakhuis, 2017). It was apparent that participants struggled with correct use the "four plus times per day" column with the majority of participants who used this column having to be excluded from the analysis for having some extreme values beyond possible consumption limits (e.g. 3032g/95 slices of bread per day). Clearer instructions should be given in regards to this column if this FFQ is to be used in future.

The use of correlation coefficients can be misleading as they measure the relation between two methods rather than the agreement between them (Bland & Altman, 1986). It has been shown that even when the test method is consistently higher than the reference method, high correlations can still occur as both methods are measuring food group intake (Cade et al., 2002). The Bland-Altman method is considered a better measure of how well two dietary assessment methods compare (Bland & Altman, 1999). The scatter of difference in the amount consumed between the FFQ1 and 4DFR appeared to increase as the amount consumed of each food group increased, indicating overall systemic bias. This observed divergence further indicates a decrease in reporting accuracy for individuals with higher intakes. However, this should be confirmed with a larger sample. Interestingly, the FFQ showed proportional bias towards under-reporting of food groups deemed 'unhealthy' such as soft drinks and takeaway foods. Few validation studies in athletes have used Bland-Altman statistics. The majority that have (Briggs et al., 2015; Rumbold et al., 2011), analysed energy intake which is not comparable to the present study. A study by Baker et al. (2014) found acceptable agreement between an online dietary assessment tool for athletes (DATA) and a

24-hr recall for nutrient intake in athletes, and similarly reported larger differences between the two methods as mean intake increased.

Food frequency questionnaires are usually used to rank participants based on high, medium and low intakes rather than for assessing absolute intake. Cross classification was therefore used to rank participants according to food group intake. When amount consumed for food groups from the FFQ and 4DFR were classified into tertiles, 35.4% (starchy vegetables) to 55.5% (fats & oils) of participants were correctly classified into the same category, and 4.6% (legumes) to 15.4% (starchy vegetables; sauces & condiments) were grossly misclassified into opposite tertiles. For core food groups, participants correctly classified ranged from 32.3% (processed foods & drinks) to 55.3% (fruit & vegetables), and those grossly misclassified ranged from 7.7% (fruit & vegetables) to 18.5% (processed foods & drinks). Some degree of misclassification by this dietary assessment method is inevitable and poor agreement is often attributed to small sample sizes (Masson et al., 2003; Wong, Parnell, Black, & Skidmore, 2012). Limited studies have reported cross classification of intakes in athletes. Other studies that have compared a FFQ against a food record and assessed food group intake in adults using cross classification into tertiles, reported correct classification ranges from 37.9% (vegetables) to 70.7% (cereals) in Japanese middle aged adults (Maruyama et al., 2015), and 32.0% (potato & grains) to 76.0% (alcoholic beverages) in healthy individuals aged 15-90 years (De Keyzer et al., 2012). These results are similar to the present study, including the lower classifications reported for starchy foods/vegetables.

The weighted kappa statistic was used in conjunction with the cross classification analysis to assess the agreement between the FFQ1 and 4DFR, and overcome the effect of chance (Masson et al., 2003). Relative validity was fair to moderate (k=0.21-0.60) for the majority of food groups and core food groups, which is considered to be an acceptable outcome (Lombard et al., 2015) and comparable to similar studies such as De Keyzer et al. (2012). No studies assessing the validity of dietary assessment tools in athletes have used cross-classification or the weighted kappa statistic.

3.5.2 Reproducibility for food groups

Overall the FFQ demonstrated good reproducibility, when repeated four weeks later, for assessing food group and core food group intake. Daily consumption of food groups and thus core food were over-estimated in the FFQ1 compared to the FFQ2 for 11 of 28 food groups ($p<0.05$). However, all effect sizes were small ($r=0.1$). This pattern of lower reported intakes in the second administration of the FFQ has been observed in numerous other reproducibility studies (Fallaize et al., 2014; Goulet, Nadeau, Lapointe, Lamarche, & Lemieux, 2004; Pedišić et al., 2008; Wong et al., 2012). It is proposed to result from reduced motivation and questionnaire fatigue on the second occasion (Wheeler, Rutishauser, Conn, & O'Dea, 1994; Wong et al., 2012).

Reproducibility correlations for the daily amount for all food groups between the FFQ1 and FFQ2 ranged from moderate to perfect ($r=0.49–1.00$), and for core food groups ranged from high to very high ($r=0.51–0.72$). These results are similar to a study by Pedišić et al. (2008) which assessed the reproducibility of a comprehensive FFQ for nutrient intake in athletes four weeks later and reported correlations ranging from 0.51 to 0.95 in males, and 0.30 to 0.78 in females. The other two studies that assessed reproducibility of dietary assessment methods in athletes reported moderate to high total correlations of 0.83 (Braakhuis et al., 2011) and 0.58 (Ward et al., 2004), respectively for antioxidant and calcium intake. However, none of the studies assessed food group intake, and Pedišić et al. (2008) analysed nutrient data correlations separately for males and females which does not allow for direct comparison. The investigation of reproducibility correlations between genders could be worth exploring in future research associated with the FFQ as gender appears to have an effect on reproducibility correlation coefficients (Pedišić et al., 2008). Furthermore, a review by Cade et al. (2002) described a correlation coefficient range between two administrations of FFQs to be acceptable when between 0.5 and 0.74, which suggests the FFQ has acceptable to good reproducibility.

The high reproducibility correlations shown in this study between the first and second administration may be attributed to the relatively short time period between repeat tests (four weeks). Re-test periods one month apart or less tend to produce higher correlations than those six months to one year apart (Cade et al., 2002; Wheeler et al., 1994). The dietary intake of athletes is consistently changing due to periodicity of training and pre- and post-competition phases (Magkos & Yannakoulia, 2003). Therefore, it would likely be inappropriate to use a time period longer than four weeks between tests when analysing athlete's as those changes in dietary intake may result in the questionnaire being mistaken for poor accuracy over time. It is also important not to re-administer the questionnaire too soon after the first administration as well as participants may remember their previous responses and replicate them rather than report their dietary intake accurately (Cade et al., 2002). The use of a large FFQ containing 129 food groups, such as in this study, would also make it rather unlikely for participants to remember their previous responses.

Cross classification, using tertiles, of daily food group intakes between the FFQ1 and FFQ2 found that majority of food groups (20 of 23 analysed) and core food groups (1 of 7 analysed) had more than 50% of participants correctly classified into the same category and less than 10% grossly misclassified into opposite categories, which is in line with cross classification recommendations (Masson et al., 2003). Currently, no studies in athletes have completed cross classification analyses of repeated measures. Compared to previous studies in the general population, cross classification values for food groups in NZ adolescents ranged from 46% to 88% (Wong et al., 2012) using tertiles, and 46% to 86% in UK adults >18 years olds (Fallaize et al., 2014), using quartiles. These results are similar to the present study, however as Fallaize et al. (2014) used quartiles, direct comparisons cannot be made. Increasing the number of segments used for cross classification (i.e. using quartiles instead of tertiles) also reduces the proportion of participants misclassified and correctly classified (Willett, 2012).

A good level of agreement was found for the majority of food groups and core food groups between the FFQ1 and FFQ2 from linear regression and analysis of the Bland-Altman plots. The scatter of difference between the two methods was shown to increase as food intake increases, with the FFQ1 demonstrating a tendency towards over-reporting food group intake compared to the FFQ2 as volume of food intake increased. No other studies assessing the reproducibility of dietary assessment tools undertaken in athletes have used Bland-Altman plots.

3.5.3 Strengths and Limitations

This study has a number of strengths. The FFQ was assessed for both validity and reproducibility which has only been completed by a few studies in the athletic population previously (Braakhuis et al., 2011; Ward et al., 2004). A range of statistical assessment methods were used to improve the quality of the assessment of validity and reproducibility (Block & Hartman, 1989).

A further strength of the study was the use of a 4-day food record reference method. Although no dietary assessment methods are able to measure dietary intake with absolute accuracy, the food record has the least correlated errors with the FFQ (Margetts & Nelson, 1997), is the most commonly used reference method for FFQ validation, and has been used by several other validation studies completed in athletes (Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Scoffier et al., 2013; Ward et al., 2004). The food record was required to be completed over four consecutive days, including three week days and one weekend day, and to encompass a range of different training intensities (at least one rest day, and one hard training day). These aspects were all additional strengths as; consecutive day recording provides a truer representation of food intake (Willett, 2012), four days of recording is regarded as the 'ideal' time period to capture accurate estimations of dietary intake (Heaney et al., 2010; Willett et al., 1985), and knowledge of training regimes enables correlations to be made between training intensity and dietary intake.

A limitation associated with use of food records is the high participant burden which can result in misreporting, particularly for athletes who have numerous eating occasions. Follow up emails and phone calls were conducted to help minimise this and improve accuracy. It may have been valuable to use biomarkers alongside food records to estimate dietary intake independently of the participants reported intake (Cade et al., 2002). However, this method is expensive, invasive and nutrient specific (e.g. 24-hour urinary nitrogen for protein) and as this study did not assess food group intake at a nutrient level, the use of biomarkers were not deemed necessary. Future research could aim to assess the validity and reliability of the FFQ at the nutrient level.

Another strength of the present study was the administration of the FFQ twice, before and after the food record, as recommended by Willett (2012) and Cade et al. (2002). This prevents attention drawn to the diet from completing the food record first to implicate answers on the FFQ1, and reduces disadvantages associated with solely administering the FFQ either before or after the food record (Cade et al., 2002). The validity and/or reproducibility of the FFQ may have been affected if the athletes changed their diet during the study between administration of the FFQ1, 4DFR and FFQ2 due to injury/illness, variations in training routines or competition demands. Errors in reporting due to this could be reduced by averaging the results of both FFQs (Naska, Lagiou, & Lagiou, 2017). This would provide a more accurate estimate of food group intake, particularly as the FFQ1 tended to overestimate intake compared with the 4DFR and FFQ2 in the present study. Research has also shown improvements in accuracy of dietary intake estimates when a combination of dietary assessment methods are used, such as FFQs and 24-hr recalls (Capling et al., 2017; Naska et al., 2017). However, the use of two methods is more costly to conduct and requires higher researcher and participant compliance, which may be particularly problematic in studies conducted in the athlete population (Rumbold et al., 2011). Combining results of both FFQs is worth considering for future research as it may reduce errors associated with over-estimation of food group intake by the FFQ1.

Participants may have experienced confusion with some of the food groupings (e.g. which category to put soups and sushi in). Clarification with examples of some food groupings (e.g. international foods including sushi) or the inclusion of additional food groupings (i.e. adding in a category for herbs and spices and soup) may be a way to enhance the FFQ. Another limitation to this study was the relatively small sample size of 66 participants due to the busy nature of athletes and the removal of some participants from the study due to incompletion of both phases and implausible reported values. However, this sample size is consistent with other similar validation studies undertaken in athletes who have had participant numbers ranging from 12 (Briggs et al., 2015) to 156 (Sunami et al., 2016). It also encompassed a large variety of high performing athletes from over 30 sporting disciplines and thus was able to capture a wide range of dietary intakes. The participants of this study were volunteers and therefore were more likely to be motivated, possibly increasing the apparent validity and reproducibility of the FFQ. This study did not include a representative sample of all ethnicities in the NZ population, and would require further investigation in Māori and Pacific population groups.

3.6 Conclusions

Compared with a 4DFR, the FFQ showed reasonable relative validity and good reproducibility for assessing food group intake in high performing athletes. This self-administered online FFQ would be a valid tool to use in future research to assess food group intake in athletes, where the use of food records is not feasible or appropriate. It could also be used to identify athletes who would benefit from further dietary advice. The FFQ could be enhanced with the addition of food photographs, the removal and/or simplification of some food groups, and the provision of clearer instructions in regards to the reporting of mixed dishes and frequencies of consumption. Future research should aim at validating this FFQ in a larger study population, and validating this FFQ at an energy and nutrient level.

3.7 Acknowledgements

We gratefully acknowledge the contribution of all 66 participants who took part in this study, and Michelle Eickstaedt and Rachel Blair for collecting the data.

3.8 Author Contributions

Dayna Stockley was the main author of the thesis, assisted with data entry and analysis of the 4DFR and FFQ, completed the statistical analysis and editing of the manuscript. Dr Kathryn Beck supervised the progression of the research through to completion and assisted with development of the study protocol and adaptation of the FFQ. Dr Cath Conlon assisted with development of the study protocol and editing of all chapters. Dr Helen O'Connor and Dr Pamela von Hurst also assisted with development of the study protocol, and Dr Rozanne Kruger developed the original NZFFQ.

3.9 Conflicts of Interest

The authors declare no conflicts of interest.

Chapter 4: Conclusions and Recommendations

4.1 Introduction

This thesis investigated the validity and reproducibility of a food frequency questionnaire (FFQ) designed to assess food group intake in high performing athletes. This chapter will discuss the main results of this study including their significance, strengths and limitations, future research recommendations, and final conclusions.

4.2 Summary of findings

Accurate, efficient and reliable dietary assessment tools are needed to evaluate the dietary intake of high performing athletes. Assessing dietary intake of athletes enables identification of those at risk of sub-optimal dietary intake who would benefit from additional dietary advice to improve their health and sporting performance. A comprehensive review of the literature highlighted a lack of athlete-specific valid and reproducible dietary assessment methods available to assess the dietary intake of athletes. In this research, a self-administered online food frequency questionnaire (FFQ) adapted from the New Zealand (NZ) Women's FFQ to be athlete-specific was assessed for validity against an estimated four day food record (4DFR), and reproducibility by re-administering the FFQ four weeks later, to assess food group intake.

When compared to an estimated 4DFR, the findings show that the FFQ has reasonable relative validity and good reproducibility when assessing for food group intake in high performing athletes. Similar to results of previous studies, the FFQ over-estimated food group intake compared to the food record (Braakhuis et al., 2011; Fogelholm & Lahti-Koski, 1991; Nogueira & Da Costa, 2004; Ward et al., 2004). Food groups consumed in large quantities, such as fruits and vegetables presented the greatest differences, whilst food groups consumed in lower quantities such as fats, oils, sauces and condiments presented good agreement. Previous validation studies have also reported this finding estimating it is predominately due to the ease of over- and under-reporting of foods deemed 'healthy' and 'unhealthy' in a questionnaire compared with a food record (Braakhius et al., 2011; Black, 2001). However, limitations of FFQs such as difficulties with question comprehension and portion size estimates may have further contributed to these results. These results indicate that although the FFQ is reasonably accurate, it is not suitable for the assessment of absolute food group intake.

In regards to reproducibility, the FFQ demonstrated high reproducibility correlations, with the majority of food groups presenting good agreement. These results are likely to be attributed to the use of a four week re-administration period which is deemed short enough to prevent errors related to changes in dietary intake over time, and long enough to reduce errors of memory implicating the results (Cade et al., 2002; Wheeler, Rutishauser, Conn & O'Dea, 1994). Slightly lower reported intakes were observed in the second administration compared to the first, which has also been reported by other reproducibility studies thought to occur due to reduced motivation and questionnaire fatigue on the second occasion (Wong et al., 2008; Wheeler, Rutishauser, Conn & O'Dea, 1994). Only three studies have assessed the reproducibility of dietary assessment tools in athletes (Braakhuis et al., 2011; Pedišić et al., 2008; Ward et al., 2004) which made it difficult to make comparisons with other literature.

In summary, this study demonstrates that a convenient, self-administered athlete-specific FFQ can estimate food group intake reliably and reasonably accurately in high performing athletes. The FFQ provides a useful and cost-effective way to identify athletes who could benefit from interventions to improve their nutritional adequacy and sporting performance. It may be used in research involving large groups of athletes to rank participants according to their intake of various food groups.

4.3 Strengths and Limitations

There are a number of challenges associated with validation of dietary assessment in athlete population groups. These include the study population, study design and analysis, and reference method accuracy. Their potential effects on the results of this study are discussed in this section.

Study participants

All athletes recruited in this study were volunteers. As a result, they are likely to be more motivated individuals with an interest in nutrition and health, thus the sample studied may not be representative of all athletes. However, the study sample contained a range of different high performing athletes from over 30 sporting disciplines and thus was able to capture a wide variety of dietary intakes. Although, results may not be valuable to studies only interested in athletes of one specific sport. Errors in reporting associated with different eating behaviours and habits of different sports may be reduced if only one specific sport is analysed.

The majority of athletes in this study were female (63.6%) and of NZ European decent (81.8%). This meant that Māori (7.6%) and Pacific (1.5%) population groups were under-represented. Future research should investigate whether these results can be replicated in Māori and Pacific population groups, which make up 14.9 and 7.4% of the NZ population, respectively (Statistics New Zealand, 2014).

Sample size

A possible weakness of this study was the relatively small sample size recruited of 66 participants due to drop out, incompletion of both phases, and exclusion upon cleaning of the data. Although this sample size is greater than the minimum of 50 participants required for validation studies to achieve reputable results, smaller sample sizes have reduced capability to truly represent the population of interest and this can deflate validity correlations (Cade et al., 2002; Willet, 1998). However, the sample size recruited in the present study is comparable to, and greater than several previous dietary assessment tool validation studies conducted in the athlete population (Baker et al., 2014; Briggs et al., 2015; Nogueira & Da Costa, 2004; Rumbold et al., 2011; Wardenaar et al., 2015).

Food frequency questionnaire related challenges

Although all dietary assessment methods are prone to errors of misreporting, inaccuracies in dietary intakes reported may have also occurred due to participant boredom, confusion or misinterpretation of components within the FFQ. The FFQ required participants to record amounts and frequencies of foods consumed which can be difficult to complete accurately. In addition, participants may have misunderstood or misinterpreted questions differently to what was intended, thus unintentionally providing incorrect answers. For example, some participants may not have known the difference between sports drinks, energy drinks and sports water so may have inaccurately reported their consumption of all of these drinks as a result. Several studies have shown fewer errors in reporting when multiple images of portion sizes are provided (Contento, 2010; Gemming et al., 2015; Longnecker et al., 1993; Subar et al., 1995; Willett, 2012). The addition of food photographs within the FFQ to better assist with estimation of portion size could improve accuracy. Lastly, any errors associated with boredom during completion of questionnaires such as ticking the same frequency box for every food item, was checked for and excluded during the cross checking process. This process also picked up any participants who severely under- or over-reported dietary intakes, and these participants were excluded from the analysis.

Choice of reference method

All dietary assessment methods are hampered by errors of precision. It is therefore important that dietary assessment and reference methods used in validation studies are as independent as possible. Food records have the least correlated errors with FFQs as they are prospective, thus not reliant on memory, and contain an open-ended format for providing information on dietary intake (Willet, 1998; Margetts & Nelson, 2010).

It is argued that weighed food records are the most appropriate reference method as they are technically more accurate than estimated food records. However, it is well known that weighing every food item significantly increases participant burden and typically results in altered and therefore inaccurate reporting of dietary intake for convenience (Magkos & Yannakoulia, 2003). When comparing weighed and estimated food records, studies have shown estimated food records to have acceptable accuracy, and more importantly, considerably better compliance from participants (Black, 2001; Magkos & Yannakoulia, 2003). Several other validation studies completed in the athletic population have also used estimated food records as their choice of reference method as weighed food records are deemed not as appropriate or feasible for use in athletes due to their busy schedules and frequent on-the-go snacking occasions (Black, 2001).

Recording days and sequence of administration

A strength of this study was the number of days dietary intake was recorded. Participants were required to complete the food record for a duration of four days, consecutively over three week days and one weekend day. Research suggests this to be the recommended and 'ideal' duration of time to complete food records to obtain accurate estimations of habitual food and macronutrient consumption (Heaney et al., 2010; Willet et al., 1985). An additional strength of this study was that collection days included different training intensities (a rest day and the athletes hardest training day), which are known to affect and influence dietary intake. Completing food records over consecutive days is also suggested to be advantageous as it enables capturing of a greater diversity and a truer representation of food intake than if completed non-consecutively where participants could select their more favourable days of the week to record (Willet, 1998). It is acknowledged that misreporting may still occur due to multiple-day recording that potentially discourages accurate completion (Willet, 1998). The food record was administered following completion of the FFQ to prevent alterations being made to answers on the FFQ based on awareness of food intake from completing the food record (Cade et al., 2002). The disadvantage of this approach is the FFQ assessed a different period of time compared with that of the 4DFR. Results of both FFQs could have been averaged to provide a more accurate estimation of food group intake (Naska et al., 2017). This could be worth considering for future research involving the FFQ.

Dietary assessment and analysis of food groups

Not all food items reported in the 4DFR had an appropriate food group to be classified into on the FFQ (e.g. soups, sushi, herbs and spices). Assigning individual food items from the 4DFR to corresponding food groups from the FFQ was difficult at times, and like with many other studies that investigate dietary intake, a number of assumptions needed to be made (see Appendix G). Clarification with examples of some food groupings (e.g. international foods including sushi) or the separation of some food groups (i.e. adding in a category for herbs and spices, soup and sushi) may be a way to further enhance the FFQ and reduce inaccuracies. However, the trade-off between adding items for improvement of validity, and having a longer questionnaire that could affect participation rate should be considered. For the food groups that presented with low validity, such as fruits and vegetables, the removal or combination of food items could enhance accuracy as less options would likely reduce overestimation of intake. Additional analysis of energy and nutrient intakes would provide more in depth estimates of dietary intake in the athlete population.

Reproducibility

A further strength of this study was that reproducibility of the FFQ was assessed by having athletes complete it on two separate occasions four weeks apart. Only two validation studies of dietary assessment tools designed for use in the athlete population have additionally tested for reproducibility alongside validity. They both used re-test periods of one to two weeks apart and reported moderate to high reproducibility (Braakhius et al., 2011; Ward et al., 2004). It is recommended to have a re-test period of four to eight weeks apart, as re-administrations with shorter time intervals can be affected by memory where participants may remember and replicate their answers from the previous FFQ rather than accurately reporting their current dietary intake (Cade et al., 2002; Block & Hartman, 1989). This is unlikely to be an issue in the present study as the FFQ contained a list of 129 food groups which would be difficult to remember after a period of four weeks. Use of longer re-test periods in the athlete population would also be problematic as athletes dietary intakes change frequently to match changes with their training regimes and competition schedules.

Statistical Analysis

A strength of the study was the comprehensive statistical analysis completed using a range of methods; Wilcoxon signed rank test, correlation coefficients, cross classification, weighted kappa statistics and Bland-Altman plots. Due to the lack of agreement on the most suitable way to present results obtained from validation studies, it is recommended that more than one statistical method be used (Cade et al., 2002). No other studies assessing the validity and/or reproducibility of FFQs for use in the athlete population have completed such a robust analysis.

4.5 Research recommendations for further development and future research

Recommendations that could be made to further improve the FFQ for future use in New Zealand:

- Clarification of food groupings within the FFQ by providing examples (e.g. international foods including sushi), creating additional categories (e.g. for soups, and herbs, spices and salt) and/or separating groups (e.g. separating international foods into curry-type dishes and sushi)
- Reconsider the use of the 'mixed dish' category or provide clearer instructions in regards to the use of this category within the FFQ
- The addition of photographs representing portion sizes within the online FFQ

- Extensive education and instructions regarding the purpose and protocols of documenting dietary intakes may assist with compliance and enhance the accuracy and validity of self-reported information (e.g. clear instructions of how to use the four plus times per day frequency column)

- Investigate the validity of a shortened version of the FFQ with removal of some categories within food groups that were over-reported as well as combining food groups (e.g. some vegetables) to offer less choice and avoid confusion

Recommendations for future research:

- Assess the validity of the FFQ in different population groups such as Māori and Pacific and separately for males and females

- Adapt the FFQ for use in athlete populations overseas by altering food items included to be population specific

- Assess validity and reproducibility in individual sports (e.g. long distance running) or particular groups of sports (e.g. weight-category or team sports)

- Assess validity and reproducibility of the FFQ at a nutrient level

- Use the FFQ in large population groups to investigate associations with health and athletic performance

4.6 Conclusion

To our knowledge this is the first dietary assessment tool in New Zealand that has been tested for validity and reproducibility to assess food group intake in high performing athletes. A comprehensive literature review was conducted on dietary assessment tool use in athletes. A key finding was that there is a lack of tools available for use in athletes that are valid and reproducible. Of those that have been developed, none have conducted in New Zealand and assessed athlete's overall food group intake. This gap formed the objective of the present study, which was to investigate the validity and reproducibility of a FFQ specifically designed to assess food group intake in high performing athletes.

The FFQ demonstrated reasonable validity when compared to an estimated four day food record, and good reproducibility when re-administer four weeks later, for food group intake. The FFQ is therefore a reasonably valid and reproducible tool that can provide a useful and efficient way to assess dietary intake in high performing athletes in New Zealand and identify those who may benefit from additional dietary intervention. It could additionally be used in future studies to explore associations between dietary intake and athletic performance.

Appendices

Appendx A: Food frequency questionnaire

Athlete Food Frequency Questionnaire

Please make sure when filling out this questionnaire that you:
- Tell us what **YOU** usually eat (not someone else in your household!).
- Fill in the form **YOURSELF**.
- Are as accurate as possible, but don't spend too much time on each food.
- Answer **EVERY** question.

Please answer by **ticking the box** which best describes **how often you ate or drank** a particular **food or drink** in the **past month**.

For example:

In the past month I have eaten this food….												
Please fill in one category for each food or drink	**Quantity**	**Increase or decrease quantity to required amount**	**Never**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**	**Day Week Month Year Never**
Sugar	**0.5 teaspoons** **1 teaspoon** **2 teaspoons** **3 teaspoons** **4 teaspoons** **5 teaspoons** **6 teaspoons**	**2 teaspoons**										**X -5x**

If every day you have 3 cups of coffee with 2 tsp sugar, one bowl of cereal with 2 tsp sugar and 2tsp sugar on pancakes at dinner every day, you would choose 2 tsp '4 Plus times per day – 5x'.

In the past month I have eaten this food….												
Please fill in one category for each food or drink	**Quantity**	**Increase or decrease quantity to required amount**	**Never**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**	**Day Week Month Year Never**
Flavoured milk (e.g. milkshake, smoothies, iced coffee, Primo, Nesquik)	0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres	**3 cups / glasses**					**X**					

If you drink 3 glasses of flavoured milk per day on three days of the week, you would select 3 glasses of milk under quantity, and 2-3x week under frequency.

Note that if you select NEVER, you do not need to select a quantity.

How often in the past 3 months have you eaten these foods?

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Dairy									
Flavoured milk (e.g. milkshake, smoothies, iced coffee, Primo, Nesquik)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Standard OR regular milk alternatives as a drink (e.g. hot drinks made with mainly milk (e.g. Latte), milk in protein shakes, milk added to breakfast cereals)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Low fat OR reduced fat milk (e.g. lite, trim, super trim) as a drink (e.g. hot drinks made with mainly milk (e.g. Latte), milk in protein shakes, milk added to breakfast cereals)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Standard OR regular milk added to hot drinks made with water (e.g. coffee, tea)	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Low fat OR reduced fat milk (e.g. lite, trim, super trim) added to hot drinks made with water (e.g. coffee, tea)	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Cream, sour cream or cream cheese	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Ice cream	0 or NEVER ½ cup 1 cup								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Custard, dairy food or milk puddings (e.g. instant)	0 or NEVER 1 pottle or ½ cup 2 pottles or 1 cup 3 pottles or 1.5 cups 4 pottles or 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Yoghurt, plain or flavoured (including fromage frais)	0 or NEVER 1 pottle or ½ cup 2 pottles or 1 cup 3 pottles or 1.5 cups 4 pottles or 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Cheese (e.g. tasty, mild, gouda, edam, mozzarella, feta, camembert, brie, blue or other specialty cheese)	0 or NEVER 1/16 cup 1/8 cup ¼ cup ½ cup ¾ cup 1 cup 1 ¼ cups 1 ½ cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	1 ¾ cups 2 cups 2 ½ cups 3 cups 3 ½ cups 4 cups								
Cottage or ricotta cheese	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								
Breads									
Plain white bread or roll (includes high fibre white bread, paraoa parai (fry bread), rewena bread, doughboys or Māori bread	0 or NEVER 1 sandwich slice 1 toast slice 1 roll 2 sandwich slices 2 toast slices 2 rolls 3 sandwich slices 3 toast slices 3 rolls 4 sandwich slices 4 toast slices 4 rolls 5 sandwich slices 5 toast slices 5 rolls								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	6 sandwich slices 6 toast slices 6 rolls 7 sandwich slices 7 toast slices 7 rolls 8 sandwich slices 8 toast slices 8 rolls								
Wholemeal or wheat meal bread or whole gain roll	0 or NEVER 1 sandwich slice 1 toast slice 1 roll 2 sandwich slices 2 toast slices 2 rolls 3 sandwich slices 3 toast slices 3 rolls 4 sandwich slices 4 toast slices 4 rolls 5 sandwich slices 5 toast slices 5 rolls 6 sandwich slices 6 toast slices 6 rolls 7 sandwich slices 7 toast slices 7 rolls 8 sandwich slices 8 toast slices								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	8 rolls								
Fruit bread, fruit bun or iced bun	0 or NEVER 1 sandwich slice 1 toast slice 1 bun 2 sandwich slices 2 toast slices 2 buns 3 sandwich slices 3 toast slices 3 buns 4 sandwich slices 4 toast slices 4 buns 5 sandwich slices 5 toast slices 5 buns 6 sandwich slices 6 toast slices 6 buns 7 sandwich slices 7 toast slices 7 buns 8 sandwich slices 8 toast slices 8 buns								
Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	0 or NEVER 0.5 medium 1 medium 2 medium 3 medium 4 medium 5 medium								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	6 medium 7 medium 8 medium								
Crumpet or English muffins	0 or NEVER 1 crumpet or whole muffin split 2 crumpets or whole muffin splits 3 crumpets or whole muffin splits 4 crumpets or whole muffin splits 5 crumpets or whole muffin splits 6 crumpets or whole muffin splits 7 crumpets or whole muffin splits 8 crumpets or whole muffin splits								
Waffle or pancakes, scone, croissant, pikelet	0 or NEVER 1 medium waffle, pancake, scone or croissant or 2 small pikelets 2 medium waffle, pancake, scone or croissant or 4 small pikelets or 3 medium waffle, pancake, scone or croissant or 6 small pikelets 4 medium waffle, pancake, scone or croissant or 8 small pikelets 5 medium waffle, pancake, scone or croissant or 10 small pikelets 6 medium waffle, pancake, scone or croissant or 12 small pikelets 7 medium waffle, pancake, scone or croissant or 14 small pikelets 8 medium waffle, pancake, scone or croissant or 16 small pikelets								
Bran, savoury or fruit muffin	0 or NEVER 0.5 medium 1 medium 2 medium								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	3 medium 4 medium 5 medium 6 medium 7 medium 8 medium								
Crackers or crisp bread	0 or NEVER 1 cracker 2 crackers 3 crackers 4 crackers 5 crackers 6 crackers 7 crackers 8 crackers 9 crackers 10 crackers								
Breakfast cereals									
Porridge, rolled oats, oat bran, oat meal	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Muesli (all varieties), bran or bran based cereals (e.g. All Bran, Bran Flakes, Sultana Bran, Sultana Bran Extra)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups								

Please fill in one category for each food or drink	**Quantity – athlete can increase or decrease to desired amount**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**
	3 cups 3.5 cups 4 cups								
Weetbix (all varieties)	0 or NEVER 1 weetbix 2 weetbix 3 weetbix 4 weetbix 5 weetbix 6 weetbix 7 weetbix 8 weetbix 9 weetbix 10 weetbix 11 weetbix 12 weetbix								
Cornflakes or rice bubbles	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Light and fruity cereals (e.g. Special K, Light and Tasty)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	4 cups								
Sweetened cereals (e.g. Nutrigrain, Fruit Loops, Honey Puffs, Frosties, Milo cereal, Coco Pops)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Breakfast drinks (e.g. Up and Go)	0 or NEVER 1 carton or 250ml 2 cartons or 500ml 3 cartons or 500ml 4 cartons or 500ml								
Starchy foods									
Rice, white or brown/wild	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Pasta, white (e.g. spaghetti, vermicelli, instant pasta) or wholemeal or noodles (e.g. instant, hokkien, udon)	0 or NEVER ½ cup or packet 1 cup or packet 1.5 cups or packets 2 cups or packets 2.5 cups or packets 3 cups or packets 3.5 cups or packets								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	4 cups or packets								
Canned spaghetti (e.g. Watties)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Couscous / polenta	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Meat									
Canned corned beef	0 or NEVER 1 slice 2 slices 3 slices 4 slices 5 slices 6 slices 7 slices 8 slices								
Beef, veal, vension, game - roast, chop, steak, schnitzel, corned beef or beef mince dishes (e.g.	0 or NEVER 1 slice or patty or ½ cup or palm size 2 slices or patties or 1 cup or 2x palm sizes								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
rissoles, meatloaf, hamburger pattie)	3 slices or patties or 1.5 cups or 3x palm sizes 4 slices or patties or 2 cups or 4 x palm sizes 5 slices or patties or 2.5 cups or 5x palm sizes 6 slices or patties or 3 cups or 6x palm sizes 7 slices or patties or 3.5 cups or 7x palm sizes 8 slices or patties or 4 cups or 8x palm sizes								
Beef, lamb, hogget, mutton, pork or veal mixed dishes (e.g. casserole, stews, stir-fry)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Sausage, frankfurter or saveloy	0 or NEVER 1 sausage/ frankfurter or 2 saveloys 2 sausages/frankfurters or 4 saveloys 3 sausages/frankfurters or 6 saveloys 4 sausages/frankfurters or 8 saveloys 5 sausages/frankfurters or 10 saveloys 6 sausages/frankfurters or 12 saveloys 7 sausages/frankfurters or 14 saveloys								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	8 sausages/frankfurters or 16 saveloys								
Ham or bacon	0 or NEVER 2 rashers bacon or 1 medium slice ham 4 rashers bacon or 2 medium slice ham 6 rashers bacon or 3 medium slice ham 8 rashers bacon or 4 medium slice ham 10 rashers bacon or 5 medium slice ham 12 rashers bacon or 6 medium slice ham 14 rashers bacon or 7 medium slice ham 16 rashers bacon or 8 medium slice ham								
Salami, chorizo, luncheon meats or brawn	0 or NEVER 1 slice or cube 2 slices or cubes 3 slices or cubes 4 slices or cubes 5 slices or cubes 6 slices or cubes 7 slices or cubes 8 slices or cubes								
Offal (e.g. liver, kidneys) or pate	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Chicken									
Chicken or poultry (includes turkey, duck, mutton bird, quail)	0 or NEVER 1 wing or drumstick, or ½ breast 2 wings or drumsticks or 1 breasts 4 wings or drumsticks or 2 breasts 6 wings or drumsticks or 3 breasts 8 wings or drumsticks or 4 breasts Palm size or ½ cup 2x palm size or 1 cup 3x palm size or 1.5 cups 4x palm size or 2 cups 5x palm size or 2.5 cups 6x palm size or 3 cups 7x palm size or 3.5 cups 8x palm size or 4 cups								
Chicken mixed dishes (e.g. casserole, stir-fry)	0 or NEVER Palm size or ½ cup 2x palm size or 1 cup 3x palm size or 1.5 cups 4x palm size or 2 cups 5x palm size or 2.5 cups 6x palm size or 3 cups 7x palm size or 3.5 cups 8x palm size or 4 cups								
Crumbed chicken (e.g. nuggets, patties, pieces)	0 or NEVER 1 piece or 2 nuggets 2 pieces or 4 nuggets 3 pieces or 6 nuggets								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	4 pieces or 8 nuggets								
Fish and seafood									
Salmon, tuna, mackerel, sardines, anchovies, herring (includes canned)	0 or NEVER 1 small can or 1 medium can 2 small cans or 2 medium cans 3 small cans or 3 medium cans 4 small cans or 4 medium cans Palm size or ½ cup 2x palm size or 1 cup 3x palm size or 1.5 cups 4x palm size or 2 cups 5x palm size or 2.5 cups 6x palm size or 3 cups 7x palm size or 3.5 cups 8x palm size or 4 cups								
Fresh fish (snapper, tarakihi, hoki, cod, flounder, gurnard, kahawai, trevally, lemon fish, shark, trout, whitebait)	0 or NEVER Palm size or ½ cup 2x palm size or 1 cup 3x palm size or 1.5 cups 4x palm size or 2 cups 5x palm size or 2.5 cups 6x palm size or 3 cups 7x palm size or 3.5 cups 8x palm size or 4 cups								
Frozen crumbed fish patties /cakes / fingers/ nuggets/ portions	0 or NEVER 1 patty or cake, 2 nuggets or fingers 2 patties or cakes, 4 nuggets or fingers 3 patties or cakes, 6 nuggets or fingers 4 patties or cakes, 8 nuggets or fingers								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	5 patties or cakes, 10 nuggets or fingers 6 patties or cakes, 12 nuggets or fingers 7 patties or cakes, 14 nuggets or fingers 8 patties or cakes, 16 nuggets or fingers								
Shrimp, prawn, lobster, crayfish, crab, surimi, squid, octopus, calamari, cuttlefish, scallops, mussels, oysters, paua, clams, pipi, cockle	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Eggs									
Whole eggs (e.g. hard-boiled, poached, fried, mashed), scrambled omelette or mixed egg dish (e.g. quiche, frittata, other baked egg)	0 or NEVER 1 egg or slice 2 eggs or slices 3 eggs or slices 4 eggs or slices 5 eggs or slices 6 eggs or slices 7 eggs or slices 8 eggs or slices								
Legumes									
Dahl or canned beans (e.g. baked beans, chickpeas, lentils), tofu or soybeans	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	2.5 cups 3 cups 3.5 cups 4 cups								
Hummus	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Tofu	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Vegetables									
Potato - boiled, mashed, baked or roasted	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Pumpkin - boiled, roasted or mashed	0 or NEVER ½ cup 1 cup 1.5 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Kumara - boiled, roasted or mashed	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Mixed frozen vegetables	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Green or runner beans	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Silver beet, spinach, kale, other green leafy vegetables (e.g. Whitloof, watercress, taro leaves, puha)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	2.5 cups 3 cups 3.5 cups 4 cups								
Carrots	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Sweet corn	0 or NEVER 1 medium cob or ½ cup 2 medium cobs or 1 cup 3 medium cobs or 1.5 cups 4 medium cobs or 2 cups								
Mushrooms	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Tomatoes	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Taro, cassava or breadfruit, or green bananas (e.g. plantain)	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Turnips, swedes, parsnip yams, or beetroot	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Onions, celery, leeks	0 or NEVER ¼ cup ½ cup 1 cup								
Cauliflower, Broccoli, broccoflower, brussel sprouts, cabbage, red cabbage	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus or cucumber	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Capsicum (or peppers)	0 or NEVER ½ medium or 1/2 cup 1 medium or 1 cup 1 ½ medium or 1.5 cups 2 medium or 2 cups								
Avocado	0 or NEVER								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	¼ avocado ½ avocado 1 avocado 1 ½ avocado 2 avocadoes								
Lettuce greens (e.g. mesculin, cos, iceberg)	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Fruit									
Apple	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Pear or nashi pear	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Bananas	0 or NEVER 1 medium or ½ cup 2 medium or 1 cup 3 medium or 2 cups 4 medium or 4 cups								
Citrus fruit e.g. orange, mandarin, tangelo, grapefruit, lemon	0 or NEVER 1 medium or 2 small 2 medium or 1 cup								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	3 medium or 2 cups 4 medium or 4 cups								
Stone fruit – e.g. peach, nectarine, plum or apricot	0 or NEVER 1 medium or ½ cup or 2 small 2 medium or 1 cup or 4 small 3 medium or 2 cups or 6 small 4 medium or 4 cups or 8 small								
Tropical fruit – e.g. mango, paw-paw, persimmons, pineapple, water melon, rock melon	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Grapes	0 or NEVER ½ cup (8-10 grapes) 1 cup 2 cups 3 cups 4 cups								
Strawberries and other berries (e.g. blueberries) or cherries	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Kiwifruit (all varieties)	0 or NEVER 1 medium or 2 small								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	2 medium or 4 small 3 medium or 6 small 4 medium or 8 small								
Feijoas, tamarillos, rhubarb	0 or NEVER 1 medium or ½ cup or 2 small 2 medium or 1 cup or 4 small 3 medium or 2 cups or 6 small 4 medium or 4 cups or 8 small								
Dried fruit (e.g. Sultanas, raisins, currants apricots, prunes, dates)	0 or NEVER 1 small box 2 small boxes 3 small boxes 4 small boxes								
Drinks									
Fruit juice (e.g. Just Juice, Fresh-up, Charlie's or Rio Gold)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Low-calorie / diet fruit drinks, cordial or powdered drinks	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L								

Please fill in one category for each food or drink	**Quantity – athlete can increase or decrease to desired amount**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**
	8 cups/glasses or 2 Litres								
Fruit drink (e.g. Choice, Rio Splice etc.), cordial or Powdered drinks (e.g. Thriftee, Raro, Vita-fresh etc.)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Vegetable juice e.g. tomato juice, V8 juice	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Sugar-free/low calorie /diet soft/fizzy/carbonated or energy drinks (e.g. diet sprite, sugar-free V)	0 or NEVER 1 cup/glass or 1 can or 250ml 2 cups or 2/3 bottle or 500ml 3 cups or 1 bottle or 750ml 4 cups or 1 1/3 bottle or 1L 5 cups or 1 2/3 bottles or 1250ml or 1.5L 6 cups or 2 bottles								
Soft/fizzy/carbonated drinks (e.g. coke, lemonade etc.)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Energy drinks (e.g. V, Monster, Red Bull)	0 or NEVER 1 small can 2 small cans 3 small cans 4 small cans 5 small cans 6 small cans 7 small cans 8 small cans 9 small cans 10 small cans								
Coconut water	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Flavoured water (e.g. sports water, Mizone, H2Go flavoured)	0 or NEVER 1 cup/glass or 1/3 bottle or 250ml 2 cups or 2/3 bottle or 500ml 3 cups or 1 bottle or 750ml 4 cups or 1 1/3 bottle or 1L								

Please fill in one category for each food or drink	**Quantity – athlete can increase or decrease to desired amount**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**
	5 cups or 1 2/3 bottles or 1250ml or 1.5L 6 cups or 2 bottles								
Water (including unflavoured mineral water, soda water, tap water)	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Coffee instant or brewed with or without milk (e.g. Nescafe, express), or specialty coffees (e.g. flat white, cappuccino, lattes)	0 or NEVER 0.5 cups or 125ml 1 cup or 250ml 2 cups or 500ml 3 cups or 750ml 4 cups or 1 Litre 5 cups or 1.25L 6 cups or 1.5L 7 cups or 1.75L 8 cups or 2 Litres								
Hot chocolate drinks (e.g. milo, drinking chocolate, hot chocolate, Koko)	0 or NEVER 0.5 cups or 125ml 1 cup or 250ml 2 cups or 500ml 3 cups or 750ml 4 cups or 1 Litre 5 cups or 1.25L 6 cups or 1.5L 7 cups or 1.75L 8 cups or 2 Litres								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Tea (e.g. English breakfast tea, Earl Grey)	0 or NEVER 0.5 cups or 125ml 1 cup or 250ml 2 cups or 500ml 3 cups or 750ml 4 cups or 1 Litre 5 cups or 1.25L 6 cups or 1.5L 7 cups or 1.75L 8 cups or 2 Litres								
Herbal tea or Green tea	0 or NEVER 0.5 cups or 125ml 1 cup or 250ml 2 cups or 500ml 3 cups or 750ml 4 cups or 1 Litre 5 cups or 1.25L 6 cups or 1.5L 7 cups or 1.75L 8 cups or 2 Litres								
Beer or cider including low alcohol	0 or NEVER 1 glass or can or bottle 2 glasses or cans or bottles 3 glasses or cans or bottles 4 glasses or cans or bottles 5 glasses or cans or bottles 6 glasses or cans or bottles 7 glasses or cans or bottles 8 glasses or cans or bottles 9 glasses or cans or bottles 10 glasses or cans or bottles 11 glasses or cans or bottles 12 glasses or cans or bottles								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	13 glasses or cans or bottles 14 glasses or cans or bottles 15 glasses or cans or bottles 16 glasses or cans or bottles 17 glasses or cans or bottles 18 glasses or cans or bottles 19 glasses or cans or bottles 20 glasses or cans or bottles								
Wine (red, white, champagne / sparkling wine / wine cooler), sherry or port	0 or NEVER 1 small glass 2 small glasses 3 small glasses 4 small glasses 5 small glasses 6 small glasses 7 small glasses 8 small glasses 9 small glasses 10 small glasses								
Spirits, liqueurs	0 or NEVER 1 shot or 30ml 2 shots or 60ml 3 shots or 90ml 4 shots or 120ml 5 shots 6 shots 7 shots 8 shots 9 shots 10 shots 11 shots 12 shots 13 shots								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	14 shots 15 shots 16 shots 17 shots 18 shots 19 shots 20 shots								
RTD (e.g. KGB, Vodka Cruiser, Woodstock bourbon)	0 or NEVER 1 bottle or can 2 bottles or cans 3 bottles or cans 4 bottles or cans 5 bottles or cans 6 bottles or cans 7 bottles or cans 8 bottles or cans 9 bottles or cans 10 bottles or cans 11 bottles or cans 12 bottles or cans 13 bottles or cans 14 bottles or cans 15 bottles or cans 16 bottles or cans 17 bottles or cans 18 bottles or cans 19 bottles or cans 20 bottles or cans								
Dressings and sauces									
Mayonnaise or creamy dressings (e.g. aioli, tartae sauce, white sauce/cheese sauce/ béarnaise)	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
including low fat/calorie dressing	3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Salad dressing (e.g. French, Italian)	0 or NEVER ¼ cup ½ cup 1 cup								
Tomato sauce/ BBQ sauce/ sweet chilli/ mustard / chutney or relish	0 or NEVER 0.5 Tablespoons 1 Tablespoon 2 Tablespoons 3 Tablespoons 4 Tablespoons 5 Tablespoons 6 Tablespoons 7 Tablespoons 8 Tablespoons								
Gravy homemade or instant	0 or NEVER ¼ cup ½ cup 1 cup								
Coconut milk (including lite)	0 or NEVER ¼ cup ½ cup 1 cup 1 ½ cups 2 cups								
Cakes, biscuits and puddings									

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Cakes, loaves, sweet muffins	0 or NEVER 1 piece or 1 slice or 1 muffin 2 pieces or 2 slices or 2 muffins 3 pieces or 3 slices or 3 muffins 4 pieces or 4 slices or 4 muffins 5 pieces or 5 slices or 5 muffins 5 pieces or 5 slices or 5 muffins 6 pieces or 6 slices or 6 muffins 6 pieces or 6 slices or 6 muffins 7 pieces or 7 slices or 7 muffins 7 pieces or 7 slices or 7 muffins 8 pieces or 8 slices or 8 muffins								
Sweet pies or pastries, tarts, doughnuts	0 or NEVER 1 medium 2 medium 3 medium 4 medium 5 medium 6 medium 7 medium 8 medium								
Other puddings or desserts (not including milk-based puddings) e.g. cheesecake, pavlova	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Plain biscuits/ cookies (e.g. Round wine, ginger nut)	0 or NEVER 1 biscuit 2 biscuits								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	3 biscuits 4 biscuits 5 biscuits 6 biscuits 7 biscuits 8 biscuits 9 biscuits 10 biscuits								
Fancy biscuits (e.g. chocolate, cream)	0 or NEVER 1 biscuit 2 biscuits 3 biscuits 4 biscuits 5 biscuits 6 biscuits 7 biscuits 8 biscuits 9 biscuits 10 biscuits								
Miscellaneous foods									
Ice blocks or jelly	0 or NEVER 1 ice block or ½ cup 2 ice blocks or 1 cup 3 ice blocks or 3 cups 4 ice blocks or 4 cups								
Sugar added to food/drinks	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	7 teaspoons 8 teaspoons								
Jam, honey, marmalade or syrup	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								
Vegemite or marmite	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								
Peanut butter or other nut spreads	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Nuts - peanuts, almonds, cashew, pistachio, macadamia, brazil nuts, walnuts	0 or NEVER 1/16 cup 1/8 cup ¼ cup ½ cup ¾ cup 1 cup 1 ¼ cups 1 ½ cups 1 ¾ cups 2 cups								
Muesli bars	0 or NEVER 1 bar 2 bars 3 bars 4 bars								
Chocolate (including chocolate bars e.g. Moro bars)	0 or NEVER 1 small bar 2 small bars 3 small bars 4 small bars								
Lollies	0 or NEVER 2 lollies 4 lollies 6 lollies 10 lollies 15 lollies 20 lollies								
Potato chips/crisps, corn chips, Twisties etc.	0 or NEVER ½ cup 1 cup 2 cups 3 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	4 cups 5 cups 6 cups 7 cups 8 cups								
Meat pie, sausage roll or other savouries	0 or NEVER 1 meat pie or 2 small sausage rolls/savouries 2 meat pies or 4 small sausage rolls/savouries 3 meat pies or 6 small sausage rolls/savouries 4 meat pie or 8 small sausage rolls/savouries								
Butter, ghee coconut oil, coconut cream – as spreads or in cooking	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								
Margarine or vegetable oils – as spreads or in cooking	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	8 teaspoons								
Added salt to food and/or used salt in cooking	0 or NEVER 0.5 teaspoons 1 teaspoon 2 teaspoons 3 teaspoons 4 teaspoons 5 teaspoons 6 teaspoons 7 teaspoons 8 teaspoons								
Takeaway foods									
Hot potato chips or kumara chips/French fries/wedges	0 or NEVER ½ cup 1 cup 1.5 cups 2 cups 2.5 cups 3 cups 3.5 cups 4 cups								
Deep fried chicken and fish	0 or NEVER Palm size or ½ cup 2x palm size or 1 cup 3x palm size or 1.5 cups 4x palm size or 2 cups 5x palm size or 2.5 cups 6x palm size or 3 cups 7x palm size or 3.5 cups 8x palm size or 4 cups								
International takeaways e.g. Chinese, Thai, Indian	0 or NEVER 1 cup 2 cups								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
	3 cups 4 cups 5 cups 6 cups 7 cups 8 cups								
Pizza	0 or NEVER 1 medium slice pizza 2 medium slices pizza 3 medium slices pizza 4 medium slices pizza or ½ pizza 5 medium slices pizza 6 medium slices pizza 7 medium slices pizza 8 medium slices pizza or 1 whole pizza								
Bread based e.g. Kebab, sandwiches, wraps, Pita Pit, Subway, burger	0 or NEVER 1 medium 2 medium 3 medium 4 medium 5 medium 6 medium 7 medium 8 medium								
Sports food									
Sport's drinks e.g. Gatorade, Powerade	0 or NEVER 1 cup or 1/3 bottle 2 cups or 2/3 bottle 3 cups or 1 bottle 4 cups or 1 1/3 bottle 5 cups or 1 2/3 bottle 6 cups or 2 bottles								

Please fill in one category for each food or drink	Quantity – athlete can increase or decrease to desired amount	Less than once a month	1-3 times per month	Once per week	2-3 times per week	4-6 times per week	Once per day	2 to 3 times per day	4 plus times per day, please state number of times
Oral rehydration solutions / electrolyte replacements (e.g. SOS rehydrate, Gastrolyte)	0 or NEVER 1 cup or 1/3 bottle 2 cups or 2/3 bottle 3 cups or 1 bottle 4 cups or 1 1/3 bottle 5 cups or 1 2/3 bottle 6 cups or 2 bottles								
Sports bars (e.g. Powerbar)	0 or NEVER 1 bar 2 bars 3 bars 4 bars 5 bars 6 bars 7 bars 8 bars								
Sports gel (e.g. Leppin squeezy)	0 or NEVER 1 gel (25g) 2 gels (50g total) 3 gels (75g total) 4 gels (100g total) 5 gels (125g total) 6 gels (150g total) 7 gels (175g total) 8 gels (200g total)								
Sports confectionary (e.g. Sports beans)	0 or NEVER 1 piece 2 pieces 3 pieces 4 pieces 5 pieces 6 pieces 7 pieces								

Please fill in one category for each food or drink	**Quantity – athlete can increase or decrease to desired amount**	**Less than once a month**	**1-3 times per month**	**Once per week**	**2-3 times per week**	**4-6 times per week**	**Once per day**	**2 to 3 times per day**	**4 plus times per day, please state number of times**
	8 pieces 9 pieces 10 pieces								
Liquid meal supplements e.g. Sustagen Sport, Complan	0 or NEVER 0.5 cups/glasses or 125ml 1 cup/glass or 250ml 2 cups/glasses or 500ml 3 cups/glasses or 750ml 4 cups/glasses or 1 Litre 5 cups/glasses or 1.25L 6 cups/glasses or 1.5L 7 cups/glasses or 1.75L 8 cups/glasses or 2 Litres								
Protein powders (e.g. Whey protein)	0 or NEVER 1 scoop (25g) 2 scoops (50g) 3 scoops (75g) 4 scoops (100g) 5 scoops (125g) 6 scoops (150g) 7 scoops (175g) 8 scoops (200g)								
Other foods, please state food, quantity and how often it is consumed									
Other foods, please state food, quantity and how often it is consumed									

Appendix B: Standard order of procedures

SOP – Height - approx. 2-3 mins

1) Please use the transportable stadiometer (Secca) located in room 27.08 (BIA room).
2) Ask the participant to remove their shoes.
3) The participant is required to stand with their heels together and the heels, buttocks and upper part of the back touching the scale.
4) Make sure the participants head is level and they are looking straight ahead.
5) Bring the headboard down firmly on top of the participants head, compressing the hair as much as possible.
6) Record height.
7) Repeat the height measurement. If the measurement is not within 1% (~1.5cm) of the first measurement a third measure should be taken.
8) The mean value is used if two measurements are taken, and the median value is used if three measurements are taken.

SOP – Weight – approx. 2-3 mins

1) Please use the white Wedderburn scales located in room 27.08 (BIA room).
2) Make sure the scales are on a flat hard surface.
3) Ask the participant to remove their shoes and anything from their pockets.
4) Turn the scales on using the button located at the front of the scales in the middle.
5) Check the scale is reading zero.
6) Ask participant to step onto the centre of the scales without support and the weight distributed evenly on both feet.
9) When the scale stabalises please record weight.
10) Repeat the protocol. If the measurement is not within 1% (~0.5kg) of the first measurement a third measure should be taken.
11) The mean value is used if two measurements are taken, and the median value is used if three measurements are taken.

SOP – Training, supplement use and dietary questionnaire – approx.5 mins

1. Log into the following address: https://www.surveymonkey.com/r/training1
2. Give participants their ID # to be used in all online questionnaires.
3. Go through examples on the questionnaire with the participant to ensure correct detail.
4. Take notes of participants heaviest and lightest training days which will be used to allocate the days for the food and training records.
5. Ensure participant completes all the required sections.

SOP – Food frequency questionnaire – approx. 20 mins

1) Log into the following address: https://www.surveymonkey.com/r/ADI-FFQ
2) Read through **ALL** the instruction with the participant. Tell participants that the FFQ is based on the foods and beverages they consumed during the past 4 weeks.
3) **Provide another example** to check understanding – Flavoured milk – if you typically have 2 glasses (500ml) of flavoured milk on one day 3x per week you would select 2 cups or 500ml, 2-3x/week.
4) **Each food question relates to all food listed** (e.g. for onions, leeks or garlic), the participant should consider onions, leeks AND garlic when making their response (ie. they should not focus on just one of these vegetables).
5) Enter the participants ID.
6) Tell participant to ask the researcher if they have any questions while completing the FFQ.

SOP – Four day food and training record – approx. 10mins

1) Watch estimated food diary video located on desktop.
2) Demonstrated how to weigh food (optional for participant).
3) Explain drop box protocol to participant (Upload photos of meals to drop box).
4) Ask participant if they have any questions.
5) Provide participant with copy of four day food and training record.
6) Allocate participant 4 consecutive days (at least 1 weekend day, 1 rest day and participant's heaviest training day).
7) Provide participant with scales (optional).
8) Record set of scales participant is using.

Appendix C: Four day food record

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

4 Day Food & Training Record

Thank you very much for taking part in this study. We are extremely grateful for your time, effort and commitment!

If you have any questions, please contact Michele on 0211237191 / (09) 414 0800 ext 43859 or Kathryn on (09) 213 6662 or email athleteffq@massey.ac.nz

All information in this diary will be treated with the strictest confidence. No one outside the study will have access to this.

<u>What to do?</u>

- Record all that you eat and drink, and all training undertaken on the following dates ***(These days will be consecutive and will include at least 1 weekend day, 1 rest day and your heaviest training day).***

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- If possible record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.
- Include all meals, snacks, and drinks, even tap water.
- Include anything you have added to foods such as sauces, gravies, spreads, dressings, etc.
- Write down any information that might indicate size or weight of the food to identify the portion size eaten.
- Use a new line for each food and drink. You can use more than one line for a food or drink. See the examples given.
- Send photos of meals to our email athleteffq@massey.ac.nz. Please don't forget to quote your Study ID #.
- For training, record the type of training you were doing, the length of time, and the intensity (easy, medium, hard, very hard).
- Use as many pages of the booklet as you need.

Please eat as normally as possible - don't adjust what you would normally eat just because you are keeping a food record and be honest! Your food record will be identified with a number rather than your name.

<u>Describing food and drink</u>

- Provide as much detail as possible about the type of food eaten. For example **brand names and varieties / types** of food.

General description	**Food record description**
Breakfast example – cereal, milk, sugar	1 cup Sanitarium Natural Muesli 1 cup Pam's whole milk 1 tsp Chelsea white sugar
Coffee	1 tsp Gregg's instant coffee 1 x 200ml cup of water 2 Tbsp Meadow fresh light green milk
Pasta	1 cup San Remo whole grain pasta spirals (boiled)
Pie	Big Ben Classic Mince and Cheese Pie (170g)

- Give details of all the **cooking methods** used. For example, fried, grilled, baked, poached, boiled…

General description	Food record description
2 eggs	2 size 7 eggs fried in 2tsp canola oil 2 size 6 eggs (soft boiled)
Fish	100g salmon (no skin) poached in 1 cup of water for 10 minutes

- When using foods that are cooked (e.g. pasta, rice, meat, vegetables, etc), please record the **cooked portion** of food.

General description	Food record description
Rice	1 cup cooked Jasmine rice (cooked on stove top)
Meat	90g lean T-bone steak (fat and bone removed)
Vegetables	½ cup cooked mixed vegetables (Wattie's peas, corn, carrots)

- Please specify the **actual amount of food eaten** (e.g. for leftovers, foods where there is waste)

General description	Food record description
Apple	1 x 120g Granny Smith Apple (peeled, core not eaten – core equated to ¼ of the apple)
Fried chicken drumstick	100g chicken drumstick (100g includes skin and bone); fried in 3 Tbsp Fern leaf semi-soft butter

- **Record recipes** of home prepared dishes where possible and the proportion of the dish you ate. There are blank pages for you to add recipes or additional information.

Recording the amounts of food you eat

It is important to also record the quantity of each food and drink consumed. This can be done in several ways.

- By using household measures – for example, cups, teaspoons and tablespoons. E.g. 1 cup frozen peas, 1 heaped teaspoon of sugar.
- By weight marked on the packages – e.g. a 425g tin of baked beans, a 32g cereal bar, 600ml Coke
- Weighing the food – this is an ideal way to get an accurate idea of the quantity of food eaten, in particular for foods such as meat, fruits, vegetables and cheese.
- For bread – describe the size of the slices of bread (e.g. sandwich, medium, toast) – also include brand and variety.
- Using comparisons – e.g. Meat equal to the size of a pack of cards, a scoop of ice cream equal to the size of a hen's egg.
- Use the food record instructions provided to help describe portion sizes.
- If you go out for meals, describe the food eaten in as much detail as possible.

General description	Food record description
Cheese	1 heaped tablespoon of grated cheese 1 slice cheese (8.5 x 2.5 x 2mm) 1 cube cheese, match box size Grated cheese, size 10B

Example day

Time and place food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)** **Complete description of training**	**Amount consumed (units, measures, weight)**
7:55am *At home*	Sanitarium weetbix	2 weetbix
" "	Anchor Blue Top milk	150ml
" "	Chelsea white sugar	2 heaped teaspoons
" "	Orange juice (Citrus Tree with added calcium – nutrition label attached)	1 glass (275 ml)
10.00am In car	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00pm At home	Home made pizza (recipe attached)	1 slice (similar size to 1 slice of sandwich bread, 2 Tbsp tomato paste, 4 olives, 2 rashers bacon (fat removed), 1 Tbsp chopped spring onion, 3 Tbsp mozzarella cheese)
1.00pm At work	Water	500ml plain tap water
3.00pm At work	Biscuits	6 x chocolate covered Girl Guide biscuits (standard size)
5.00- 6.35pm At training	Gatorade, Fierce Berry Flavour	600ml bottle
6.00pm At home	Lasagne	½ cup cooked mince, 1 cup cooked Budget lasagne shaped pasta , ½ cup Wattie's creamy mushroom and herb pasta sauce, ½ cup mixed vegetables (Pam's carrots, peas and corn), 4 Tbsp grated Edam cheese
6.30pm At home	Banana cake with chocolate icing (homemade, recipe attached)	1/8 of a cake (22cm diameter, 8 cm high), 2 Tbsp chocolate icing
" "	Tip Top Cookies and Cream ice cream	1 cup (250g)
7.30pm At home	Coffee	1 tsp Gregg's instant coffee 1 x 300ml cup of water 2 Tbsp Meadow fresh blue top milk 2 tsp sugar

Describing your training

Please record all training undertaken while completing this diary. An example is provided below.

Sport / exercise	**Time of day**	**Duration of training**	**Intensity (Easy, Medium, Hard, Very Hard)**
Run *Netball training*	*6.30am* *5.00pm*	*30 minutes* *15 minutes team talk* *40 minutes skill-based* *30 minutes game*	*Medium* *Easy* *Medium* *Hard*

Date________________________________ DAY 1

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_________________________________ **DAY 1 continued**

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Example of Additional Recipe Sheet (was provided for Days 1-4)

Date________________________________ DAY 2

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date________________________________ **DAY 2 continued**

Time and place food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed**

Date________________________________ **DAY 3**

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date________________________________ **DAY 3 continued**

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date________________________________ **DAY 4**

Time and place food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed**

Date________________________________ DAY 4 continued

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date__________________________________ (spare pages)

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_________________________________ (spare pages)

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Training diary

Day 1 – Date ______________________________

Sport / exercise	**Time of day**	**Duration of training**	**Intensity (Easy, Medium, Hard, Very Hard)**
Run *Netball training*	*6.30am* *5.00pm*	*30 minutes* *15 minutes team talk* *40 minutes skill-based* *30 minutes game*	

Day 2 – Date ______________________________

Sport / exercise	**Time of day**	**Duration of training**	**Intensity (Easy, Medium, Hard, Very Hard)**

Day 3 – Date ______________________________

Sport / exercise	Time of day	Duration of training	Intensity (Easy, Medium, Hard, Very Hard)

Day 4 – Date ______________________________

Sport / exercise	Time of day	Duration of training	Intensity (Easy, Medium, Hard, Very Hard)

Appendix D: Condensed/amended food group list

Table 1 *Condensed/amended food group list*

Core Food Groups	Food Groups	Foods as described in the FFQ	Measure
Milk & Milk Products	Milk	Standard OR regular milk alternatives as a drink (e.g. hot drinks made with mainly milk (e.g. Latte), milk in protein shakes, milk added to breakfast cereals)	mls
		Low fat OR reduced fat milk (e.g. lite, trim, super trim) as a drink (e.g. hot drinks made with mainly milk (e.g. Latte), milk in protein shakes, milk added to breakfast cereals)	mls
		Standard OR regular milk alternatives added to hot drinks made with water (e.g. coffee, tea)	Tbsp
		Low fat OR reduced fat milk (e.g. lite, trim, super trim) added to hot drinks made with water (e.g. coffee, tea)	Tbsp
	Cheese	Cheese (e.g. tasty, mild, gouda, edam, mozzarella, feta, camembert, brie, blue or other specialty cheese)	Cups
		Cottage or ricotta cheese	Tsp
	Yoghurt	Yoghurt, plain or flavoured (including fromage frais)	Cups
	Discretionary dairy	Flavoured milk (e.g. milkshake, smoothies, iced coffee, Primo, Nesquik)	mls
		Breakfast drinks (e.g. Up and Go)	mls
		Cream, sour cream or cream cheese	Tbsp
		Ice cream	Cups
		Custard, dairy food or milk puddings (e.g. instant)	Cups
Breads	Wholegrain	Wholemeal or wheat meal bread or whole gain roll	Sandwich slice
	Non wholegrain	Plain white bread or roll (includes high fibre white bread, paraoa parai (fry bread), rewena bread, doughboys or Māori bread	Sandwich slice
		Fruit bread, fruit bun or iced bun	Medium bun
		Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	Medium
		Crumpet or English muffins	Medium crumpet
		Waffle or pancakes, scone, croissant, pikelet	Medium
		Bran, savoury or fruit muffin	Medium
		Crackers or crisp bread	Medium cracker
Breakfast Cereals	Wholegrain	Porridge, rolled oats, oat bran, oat meal	Cups
		Weetbix (all varieties)	Weetbix
		Muesli (all varieties), bran or bran based cereals (e.g. All Bran, Bran Flakes, Sultana Bran, Sultana Bran Extra)	Cups
	Sweetened	Cornflakes or rice bubbles	Cups
		Light and fruity cereals (e.g. Special K, Light and Tasty)	Cups
		Sweetened cereals (e.g. Nutrigrain, Fruit Loops, Honey Puffs, Frosties, Milo cereal, Coco Pops)	Cups

Starchy Foods		Rice, white or brown/wild	Cups
		Pasta, white (e.g. spaghetti, vermicelli, instant pasta) or wholemeal or noodles (e.g. instant, hokkien, udon)	Cups
		Canned spaghetti (e.g. Watties)	Cups
		Couscous / polenta	Cups
Meat & Proteins	Red Meat	Beef, lamb, hogget, mutton, pork, veal, vension, game - roast, chop, steak, schnitzel, corned beef (silverside) or beef mince dishes (e.g. rissoles, meatloaf, hamburger pattie)	Medium palm size
		Beef, lamb, hogget, mutton, pork or veal mixed dishes (e.g. casserole, stews, stirfry)	Cups
		Offal (e.g. liver, kidneys) or pate	Tbsp
	Processed Meats	Canned corned beef	Cups
		Sausage, frankfurter or saveloy	Medium sausage
		Ham or bacon	Medium slice of ham
		Salami, pastrami, chorizo, luncheon meats or brawn	Medium slice
	Chicken/ Poultry	Chicken or poultry (includes turkey, duck, mutton bird, quail)	Medium breast
		Chicken mixed dishes (e.g. stew, casserole, stir-fry)	Cups
		Crumbed chicken (e.g. nuggets, patties, pieces)	Medium piece
	Fish and Seafood	Snapper, tarakihi, hoki, cod, flounder, gurnard, kahawai, trevally, lemon fish, shark, trout, whitebait, eel (includes fresh,frozen or canned)	Medium palm size
		Frozen crumbed fish patties/cakes/fingers/nuggets/portions	Medium patty
		Shrimp, prawn, lobster, crayfish, crab, surumi, squid, octopus, calamari, cuttlefish, scallops, mussels, oysters, paua, clams, pipi, cockle	Cups
		Salmon, tuna, mackerel, sardines, anchovies, herring (includes fresh, frozen and canned)	Medium Palm size
	Eggs	Whole eggs (e.g. hard-boiled, poached, fried, scrambled), omelette or mixed egg dish (e.g. quiche, frittata, other baked egg)	Medium egg
	Legumes	Dahl, canned beans (e.g. baked beans, chickpeas, lentils) or soybeans	Cups
		Hummus	Tbsp
		Tofu	Cups
		Peanut butter or other nut spreads	Tsp
		Nuts + seeds - peanuts, almonds, cashew, pistachio, macadamia, brazil nuts, walnuts, sesame seeds	Cup
Vegetables	Starchy	Potato - boiled, mashed, baked or roasted	Cups
		Pumpkin - boiled, roasted or mashed	Cups
		Kumara - boiled, roasted or mashed	Cups
		Sweet corn	Cups
		Taro, cassava or breadfruit, or green bananas (e.g. plantain)	Cups
		Turnips, swedes, parsnip, yams, or beetroot	Cups

	Non-Starchy	Mixed frozen vegetables	Cups
		Green or runner beans	Cups
		Silver beet, spinach, kale, other green leafy vegetables (e.g. Whitloof, watercress, taro leaves, puha)	Cups
		Carrots	Cups
		Mushrooms	Cups
		Tomatoes	Cups
		Onions, celery, leeks (+ garlic, ginger)	Cups
		Cauliflower, broccoli, broccoflower, brussel sprouts, cabbage, red cabbage	Cups
		Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus or cucumber	Cups
		Capsicum (or peppers)	Cups
		Lettuce greens (e.g. mesculin, cos, iceberg)	Cups
Fruit	Whole	Apple	Medium (without core weight)
		Pear or nashi pear	Medium
		Bananas	Medium (without skin)
		Citrus fruit (e.g. orange, mandarin, tangelo, grapefruit, lemon)	Cups
		Stone fruit (e.g. peach, nectarine, plum or apricot)	Cups
		Tropical fruit (e.g. mango, paw-paw, persimmons, pineapple, water melon, rock melon)	Cups
		Grapes	Cups
		Strawberries and other berries (e.g. blueberries) or cherries	Cups
		Kiwifruit (all varieties)	Medium (without skin)
		Feijoas, tamarillos, rhubarb	
	Dried	Dried fruit (e.g. Sultanas, raisins, currants apricots, prunes, dates)	Small boxes
Beverages	Fruit Juice	Fruit juice (e.g. Just Juice, Fresh-up, Charlie's or Rio Gold)	mls
		Fruit drink (e.g. Choice, Rio Splice etc.), cordial or Powdered drinks (e.g. Thriftee, Raro, Vita-fresh)	mls
		Vegetable juice (e.g. tomato juice, V8 juice)	mls
	Water	Water (including unflavoured mineral water, soda water, tap water)	mls
		Coconut water	mls
		Flavoured water (e.g. sports water, Mizone, H2Go flavoured)	mls
	Tea & Coffee	Tea (e.g. English breakfast tea, Earl Grey)	mls
		Herbal tea or green tea	mls
		Coffee instant or brewed with or without milk (e.g. Nescafe, express), or specialty coffees (e.g. flat white, cappuccino, lattes)	mls

	Hot Chocolate	Hot chocolate drinks (e.g. milo, drinking chocolate, hot chocolate, Koko)	mls
	Soft drink, Energy drinks	Soft/fizzy/carbonated drinks (e.g. coke, lemonade)	mls
		Energy drinks (e.g. V, Monster, Red Bull)	Small can
	Low Calorie drinks	Sugar-free/low calorie /diet. Soft/fizzy/carbonated or energy drinks (e.g. diet sprite, sugarfree V)	mls
		Low-calorie / diet. Fruit drinks, cordial or powdered drinks	mls
	Alcohol	Beer or cider including low alcohol	mls
		Wine (red, white, champagne /sparkling wine / wine cooler), sherry or port	Small glass (330ml)
		Spirits, liquers	Shots
		Ready to drink (RTDs) (e.g. KGB, Vodka Cruiser, Woodstock bourbon)	Bottle
Fats, oils, sauces & condiments	Sauces & Condiments	Mayonnaise or creamy dressings (e.g. aioli, tartae sauce, white sauce/cheese sauce/ béarnaise) including low fat/calorie dressing)	Tbsp
		Salad dressing (e.g. French, Italian)	Cups
		Tomato sauce/ BBQ sauce/ sweet chilli/ mustard / chutney or relish	Tbsp
		Gravy homemade or instant	Cups
		Coconut milk (including lite)	Cups
	Fats & Oils	Butter, ghee, lard, palm oil coconut oil, coconut cream – as spreads or in cooking	Tsp
		Margarine or vegetable oils (e.g. olive oil, canola oil, rice bran oil, avocado oil, sunflower oil) – as spreads or in cooking	Tsp
		Avocado	Cups
Processed Foods	Cakes, puddings & biscuits	Cakes, loaves, sweet muffins	Medium muffin
		Sweet pies or pastries, tarts, doughnuts	Medium
		Other puddings or desserts (not including milk-based puddings) (e.g. cheesecake, pavlova)	Cups
		Plain biscuits/ cookies (e.g. Round wine, ginger nut)	Medium biscuit
		Fancy biscuits (e.g. chocolate, cream)	Medium biscuit
	Sugar & sweets	Sugar added to food/drinks	Tsp
		Jam, honey, marmalade or syrup	Tsp
		Ice blocks or jelly	Medium ice block
	Muesli bars	Muesli bars	Medium bar
	Chocolate & lollies	Chocolate including chocolate bars (e.g. Moro bars)	Small bar
		Lollies/sweets	Medium lolly
	Potato Chips	Potato chips/crisps, corn chips, Twisties	Cups
	Takeaway foods	Hot potato chips or kumara chips/French fries/wedges	Cups
		Deep fried chicken or fish	Cups
		International takeaways (e.g. Chinese, Thai, Indian)	Cups

		Pizza	Medium slice
		Bread based (e.g. Kebab sandwiches, wraps, Pita Pit, Subway, burger) takeaways	Medium
		Meat pie, sausage roll or other savouries	Medium pie
Sports Drinks		Sport's drinks (e.g. Gatorade, Powerade, Horley's Replace)	mls
		Oral rehydration solutions /electrolyte replacements (e.g. SOS rehydrate, Gastrolyte)	mls
Sport Foods/Supplements		Sports bars (e.g. Powerbar)	Medium bar
		Sports gel (e.g. Leppin squeezy)	Medium gel
		Sports confectionary (e.g. Sports beans)	Piece
		Liquid meal supplements (e.g. Sustagen Sport, Complan)	mls
		Protein powder (e.g Whey)	Scoop

Appendix E: Frequency Conversions

Table 2 *Frequency conversions for the FFQ*

Frequency of portions reported in the FFQ	Interpretation of frequency/day	Multiplying factor added to portion amount in the FFQ
Never	0	0
1 x / day	1	1
2-3 x /day	2.5	2.5
4+ x /day	-	Multiply by value reported
1 x / week	1/7	0.14
2-3 x / week	2.5/7	0.36
4-6 x / week	5/7	0.71
1-3 x / month	0.5/7	0.07
<1 x / month	0.125/7	0.02

Appendix F: Conversions into gram amounts

Table 3 *Weights (g) used for analysis of daily amount used for each food item from FoodWorks 9 for the FFQ and 4DFR*

Food Item	Measure	Gram amount (g)
	1 tsp	5
	1 Tbsp	15
Dairy		
Smoothie	100 ml	110
Flavoured milk	100 ml	106
Milk, standard, 3.3% fat (Anchor)	100 ml	103
	1 Tbsp	15.2
Low fat milk, lite, 1.5% fat (Anchor)	100ml	104
	1 Tbsp	15.4
Cream cheese, full fat sour cream	100 ml	100
Yoghurt, full fat (Anchor)	1 cup	263
Yoghurt, low fat (Meadow fresh)	1 cup	256.4
Yoghurt, assorted fruit (Fresh n' fruity)	1 pottle	125
Cheese, edam, Colby, tasty, cheddar, camembert	1 cup 1 sprinkle	118 19.2
Custard	1 cup	280
Assorted dairy desserts	1 cup	257.7
Milk shake	100 ml	70
Ice-cream, plain (e.g. vanilla)	1 scoop	66
Ice-cream with added components (e.g. cookies and cream, maple walnut)	1 cup	198
Magnum ice-block	1 medium	77
	1 mini	46
Hot chocolate (large)	350 ml	
Breads		
white bread	1 sandwich slice	32
	1 toast slice	38.5
Wholegrain bread	1 sandwich slice	34.5
	1 toast slice	37.3

Mixed grain bread	1 toast slice	38.3
Gluten-free bread	1 sandwich slice	41
Bread roll	1 medium bun/roll	51
Fruit bread, currant	1 slice	30.5
	1 bun	80
Specialty breads (e.g. bagel, naan, English muffin)	1 medium	90
Crackers	1 medium	6
Subway with meat, vegetables and sauce	1 foot long	315
Breakfast Cereals		
Rolled oats	1 cup	100
-prepared with water or milk	1 cup	260
Muesli	1 cup	45
Nutrigrain	1 cup	37.5
Weetbix	1 weetbix	16.8
Sweetened cereals (e.g. cocoa pops, fruit loops)	1 cup	46
Up and Go	250 ml	267.5
Starchy Foods		
Rice, white, boiled	1 cup	145
Rice, brown, boiled	0.5 cup	100
Pasta, spaghetti pasta, cooked	1 cup	151.5
	1 serving	155
Pasta, penne, assorted, cooked	1 cup	100.4
Quinoa, couscous, cooked	1 cup	142.8
Meats & Proteins		
Mince, beef	1 cup	129.8
Steak, cooked, lean	1 medium steak	160
Sausage	1 medium	62
Ham	1 medium slice	32
Bacon	1 medium rasher	18
Chicken breast, cooked	1 medium breast	150
Chicken drumstick, cooked	1 drumstick	45
Chicken stir fry	0.5 cup	100
Chicken, crumbed (e.g. KFC)	1 medium breast	140

Chicken nugget, deep fried	1 nugget	17.5
Canned fish	1 small can 1 large can	95 185
Fish (e.g. snapper)	1 fillet	100
Shrimp, squid, prawn, cooked	1 cup	142
Egg	Size 7	40
Egg whites	1 Tbsp	13.6
Lentils, kidney beans, cooked	0.5 cup	100
Baked beans, in sauce (Watties)	1 cup	263.2
Tofu, tempeh	1 cup	215
Vegetables		
Potato, with skin, baked	1 medium	162
Carrot	1 medium	110
Frozen mixed vegetables	1 cup	142.8
Green beans, peas	1 cup	150
Spinach, raw -cooked	1 cup 1 cup	42.9 142.8
Tomato, whole	1 medium	123
Onion	1 medium	174
Cucumber	1 medium slice	37.6
Avocado	1 medium/1 cup	160
Fruit		
Apple, without core	1 medium	148
Banana, without skin	1 medium	75.3
Stone fruit (e.g. nectarine, peach)	1 medium	96
Orange, without skin	1 medium	107.5
Mixed berries	0.5 cup	100
Dried fruit	1 box 1 handful	28 40
Drinks		
Fruit juice (e.g. orange)	1 cup	257.5
Flavoured drink (e.g. cordial powder added to water)	1 cup	250
Soft/fizzy drink	1 cup	260

Energy drink (e.g. V)	1 cup	265
Water	1 cup	250
Sports water	1 cup	260
Wine	1 standard glass (100ml)	99.2
Cider, 5%	1 regular bottle (330ml)	334.3
Beer, 5%	1 regular bottle (330ml)	331.7
Dressings and Sauces		
Salad dressing (Kraft)	1 Tbsp	15
Soy sauce	1 Tbsp	14.8
Mayonnaise, tomato sauce	1 Tbsp	18.8
Aioli	1 pottle/individual serve	12
Cakes, Biscuits, Puddings		
Biscuit, plain (e.g. arrowroot, gingernut)	1 medium	9
Biscuit, sweet (e.g. tim tam, squiggle)	1 medium	17
Cake, with icing	1 slice	60
Slice (e.g. caramel, lemon)	1 medium	80
Muffin (e.g. chocolate, blueberry)	1 medium	60
Miscellaneous		
Peanut butter, honey	1 Tbsp	19.8
Mixed nuts (e.g. cashews, almonds, walnuts)	1 cup 1 handful	150 36
Muesli bar	1 medium	40
Chocolate bar (e.g. Moro, Snickers)	1 bar (individual serving) 1 mini (Favourites) bar	62 18
Lolly (e.g. pineapple lump, minty)	1 standard	7
Potato chips	1 cup 1 handful	47.6 12
Mince pie	1 pie	171
Ice Block	1 medium	80

Assorted desserts/puddings (e.g. apple crumble)	1 cup	195
Quiche	1 individual serve	135
Takeaways		
Hash brown	1 medium	68
Hot chips	1 serve 1 handful	100 18.5
Pizza	1 slice	53
Deep fried chicken or fish	1 medium piece	115
Sushi	1 piece	42
Burger (McDonalds Big Mac or Burgerfuel small)	1 burger	200
Curry (e.g. butter chicken)	1 cup	257.5
Sports Drinks, Foods & Supplements		
Protein powder	1 scoop	25
Sports bar	1 medium	40
Sports Drinks (e.g. Powderade, E2)	750 ml	768.7
Sports gel	1 gel	25
Sports confectionary (e.g. Gu chomp, jelly confectionary)	1	6
Fortisip	1 bottle	260

Note: If FoodWorks did not provide gram amounts for varying portion sizes (e.g. small and large), the following conversion factors were applied to the 'medium' portion size reported to determine gram amounts for a 'small' and 'large' portion: 0.75 for small, and 1.25 for large (e.g. 1 medium apple of 148g * 0.75 = 111g – weight of a small apple).

Appendix G: Assumptions and decision made for the food record

***Table 4** Assumptions made when classifying food items from the 4DFR into food groups within the FFQ*

4DFR Food Item	Assumptions and decisions made of where to put in FFQ	Food group added to
Sourdough bread	Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	Bread
Hot cross buns	Fruit bread, fruit bun or iced buns	
Garlic bread	Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	
Croutons	Crackers or crisp bread	
Muffin split	Crumpet, English muffins	
Scroll, Danish	Waffle, pancake, scone, croissant, pikelets	
Pretzels	Crackers and crisp bread	
Croutons	Plain white bread or roll	
Corn thins	Crackers and crisp bread	
Pide bread	Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	
Gluten-Free bread	Plain white bread or roll	
Gluten-Free muffins	Bran, savoury or fruit muffin	
Soft cheese rolls	Focaccia, bagel, pita, panini, wrap, roti, chapatti or other speciality breads	
Pronutro (wheat-based cereal)	Porridge, rolled oats, oat bran, oat meal	Breakfast cereals
Homemade granola	Muesli (all varieties), bran or bran based cereals	
Homemade weetbix slice (made with flour, cocoa, sugar, butter)	Muesli bars	Cakes, biscuits and puddings
Brownie	Cakes, loaves, sweet muffins	
Cream doughnut	Sweet pies or pastries, tarts, doughnut	
Chocolate mint slice, caramel slice, ginger slice	Cakes, loaves, sweet muffins	
Crème brulee, pavalova	Other puddings or desserts	
Apple crumble	Other puddings or desserts	
Pavlova	Other puddings or desserts	
Blondie	Cakes, loaves, sweet muffins	
Creamy rice pudding	Other puddings or desserts	
Kidney bean cake (made with sugar, flour etc)	Cakes, loaves, sweet muffins	
Pizza shapes	Plain biscuits/cookies	
Alternative milks (e.g. soy, almond)	Regular milk alternatives	Dairy
Rice pudding	Milk desserts	
Milk powder	Standard or regular milk added to drinks	
Halloumi	Cheese	
Condensed milk	Custard, diary food or milk puddings	
Garlic yoghurt dressings	Yoghurt	

Condensed milk	Custard, dairy food or milk puddings	
Soy sauce, Worchester sauce	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	Dressing and sauces
Wasabi	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Vinegar	Salad dressing	
Stocks (e.g. beef stock)	Gravy homemade or instant	
Tomato paste, curry paste	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Pesto	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Hollandaise sauce	Mayonnaise or creamy dressings	
Apple cider vinegar	Salad dressings	
Ranch dressing	Salad dressings	
Curry sauce	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Mushroom sauce	Mayonnaise/creamy dressings	
Asian chilli lime dressing	Salad dressings	
Nandos peri peri sauce	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Korma sauce	Tomato sauce/ BBQ sauce/ sweet chilli/ mustard/ chutney or relish	
Ice	Water	Drinks
Tonic Water	Water	
Vegetable stock	Vegetable juice	
Bundaberg drinks (e.g. lemon lime and bitters, ginger beer)	Soft/fizzy/carbonated drinks	
milo, hot chocolate powder	Hot chocolate drinks – reported gram amount of power as was sometimes sprinkled on top of food	
E2	Fruit juice	
Fruit syrup juice	Fruit juice	
Mammoth iced coffee drink	Flavoured milk	
Tank juice	Fruit Juice	
Sparkling OH	Flavoured water	
Aloe vera juice	Fruit juice	
Iced tea (e.g. peach iced tea)	Herbal tea	
Water added to porridge or soups	Water	
Water added to tea, coffee or milos	Tea or Coffee or Hot chocolate drinks	
Fish pie	Frozen, crumbed fish patties	Fish and Seafood
Lime	Citrus fruit	Fruit
Lemon juice	Citrus fruit	
Passionfruit	Tropical fruit	
Goji berries	Dried fruit	
Chocolate or yoghurt covered fruit	Dried fruit	

Canned fruit in syrup (e.g. peaches)	Stone fruit	
Stewed apple	Apple	
Quince	Pears	
Banana chip	Dried fruit	
Tempeh	Tofu	Legumes
Vegetarian sausages (made with legumes)	Dahl or canned beans	
Mince chilli	Beef, lamb, hogget, mutton or veal mixed dishes	Meat & Eggs
Jack Links steak bar	Beef, veal, lamb, hogget, pork, mutton, venison, schnitzel or beef mince dishes	
Egg white	Egg	
Dumplings	Meat pie, sausage roll and other savouries	Miscellaneous
Psyllium husk	Nuts and seeds	
Tahini	Peanut butter or other nut spread	
Dukkah	Nuts and seeds	
Stevia	Sugar added to foods/drinks	
One square meal, bliss balls	Muesli bar	
Tasti protein bar	Muesli bar	
Popcorn	Potato chips	
LSA	Nuts and seeds	
marshmellows	Lollies/sweets	
Pineapple lumps	Chocolate	
Pork bun	Meat pie, sausage roll	
Chocolate coated nuts	Nuts and seeds	
Milo snack bar	Muesli	
Oat slice	Muesli	
Iso-whey pre-workout	Sports drinks	Sports Drinks
Electrolyte water	Oral rehydration solutions	
Protein bar	Sports bars	Sports Foods/Supplements
Carbless crunch protein bar	Sports bars	
BCAAs	Protein powder	
Risotto	Rice	Starchy Foods
Quinoa	Couscous/polenta	
Bulgar Wheat	Couscous/polenta	
Samosa	Deep fried chicken or fish	Takeaways
Hashbrown	Wedges/chips	
Sushi	International takeaways	
Burger	Bread based takeaways	
Store bought lasagne	Bread based takeaways	
Garlic, ginger	Onions, leeks, celery	Vegetables
Pickles, olives	Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus or cucumber	
Coleslaw	Cauliflower, broccoli, broccoflower, Brussel sprouts, cabbage, red cabbage	
Bok choy	Silverbeet, spinach, kale, other green lafy vegetables	

Sauerkraut	Cauliflower, broccoli, broccoflower, Brussel sprouts, cabbage, red cabbage	
Mung bean sprouts	Green/runner beans	
Sundried tomatoes	Tomatoes	
Guacamole	Avocado	
Radish	Turnips, swedes, parsnip, yams or beetroot	
Peas	Green/runner beans	
Green salad	Silverbeet, spinach, kale, other green lafy vegetables	
Kimchi	Cauliflower, broccoli, broccoflower, Brussel sprouts, cabbage, red cabbage	

Table 5 *Assumptions made for amounts not reported in the 4DFR*

Food item in 4DFR	Amount assumption made
Pinch of salt	½ tsp
1 egg white	0.7 whole egg
Fruit eaten with size unreported	1 medium
Relish on burger	2 Tbsp
1 handful (for nuts, spinach/lettuce/rocket, berries)	½ cup
Low carb protein bar (e.g. Aussie Bodies low carb, high protein bar)	80g
Cheese added to 1 cup macaroni. Curry sauce added to 1 cup butter chicken	½ cup
Whipped butter (1 sachet)	5.6g - https://mcdonalds.co.nz/menu/whipped-butter
Dried fruit and nut mix	¾ of total amount put in nuts and seeds category, ¼ in dried fruit
1 mouthful water (e.g. to swallow tablets)	50 ml
1 bottle of water	750 ml
Soy sauce with St Pierres sushi	1 Tbsp
Oil added to pan for cooking	1 Tbsp
Sprinkle of chia seeds	1 Tbsp
Daikon salad (radish and carrot)	½ of total amount in carrot, ½ in raddish
Honey mustard marinade on chicken drumstick	1 Tbsp marinade per drumstick
Tomato sauce added to burger	1 Tbsp
McDonalds McFlurry	286g - https://www.mcdonalds.com/ca/en-ca/product/mcflurry-oreo-regular-size-portion.html
Sauce added to Pita Pit	1 Tbsp
1 cup oats/porridge made with milk	½ cup milk
Cream cheese stuffed in 1x chicken breast	2 Tbsp
Drizzle of sauce (e.g. soy sauce)	1 Tbsp

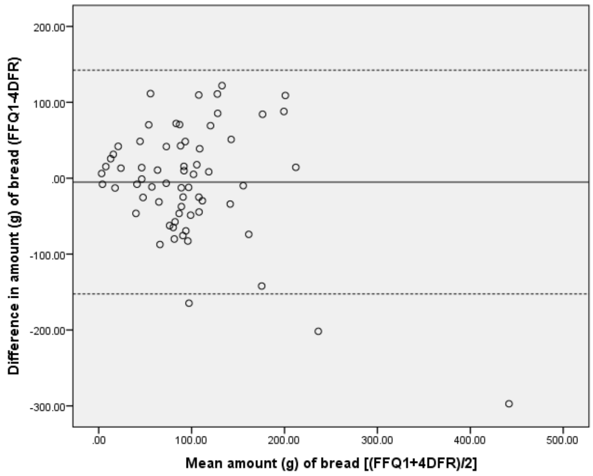
milk content of Flat Whites, Cappuccinos	60% of a bought coffee is milk: E.g. 250ml coffee = 150ml milk (e.g. 200ml glass = 120ml milk) https://www.caffesociety.co.uk/blog/what-is-a-flat-white-coffee. https://www.illy.com/en-us/company/coffee/how-prepare-cappuccino
1 can of tomatoes	400g - https://shop.countdown.co.nz/shop/searchproducts?search=canned+tomatoes
1 can corn	420g - https://shop.countdown.co.nz/shop/searchproducts?search=can+corn
1 can peaches	400g - https://shop.countdown.co.nz/shop/browse/canned-prepared-foods/fruit/peaches
Frozen mixed vegetable bag	400g https://naturallyorganic.co.nz/product-category/fruit-vegetables/vegetables/frozen-vegetables/
Tom Thumb Wheatmeal bun	51g - https://www.myfitnesspal.com/food/calories/paknsave-tom-thumb-bun-141144967
1 scoop Musclepharm protein powder	34.9g - https://www.nzmuscle.co.nz/shop/Shop+by+Brand/MusclePharm/MusclePharm+Combat+Protein+4Lb.html
1 scoop Musclepharm BCAAs	7.5g - https://www.bodybuilding.com/store/musclepharm/bcaa-3-1-2.html
1 can kidney beans	400g – range from 390-410g on Countdown website - https://shop.countdown.co.nz/shop/browse/canned-prepared-foods/vegetables/beans
Hawaiian pizza (Pizza Hut)	462g, 6 slices - https://www.pizzahut.co.uk/restaurants/r/SysSiteAssets/rebrand/food/nutritionalinformation/pzh2786_7926_p4-nutritional_booklet_210x297.pdf/
1 serving of 1 pouch meal replacement (USANA)	1 serving = 60g - https://www.amazon.com/USANA-Dutch-Chocolate-Nutrimeal-Replacement/dp/B007V84WXU
Pottle of spread (e.g. peanut butter) in hotels and hospitals	11g - https://starlinegroup.co.nz/shop-by-department/hotel-motel-amenities/spreads-sauces.html.
Calciyum drink carton	250ml - https://www.anchordairy.com/nz/en/products/flavoured-milk/anchor-calciyum-chocolate-flavoured-milk-250ml.html
Uncle Tobys oats single serve sachet	34g - https://shop.countdown.co.nz/shop/productdetails?stockcode=204987
The collective-straight up yoghurt	400g - https://www.thecollective.kiwi/yoghurt/pro-yo-skyr/boysenberry-pomegranate-pro-yo/.
Coffee (McDonalds)	Small – 292 ml Medium – 442 ml

	Large – 564 ml https://yourquestions.mcdonalds.ca/answer/how-many-ml-are-in-each-drink-size/
Coke (McDonalds)	Medium – 330 ml - https://yourquestions.mcdonalds.ca/answer/how-many-ml-are-in-each-drink-size/
Frozen packet butter chicken with rice meal	rice is 37% of 250g dish = 92.5g rice. Put butter chicken in chicken mixed dishes section in chicken category. https://shop.countdown.co.nz/shop/productdetails?stockcode=366343&name=super-snack-frozen-meal-butter-chicken
Soft serve ice-cream (McDonalds)	Assumed 1 cone (as the soft serve not in the cone is classified as a 'sundae'). The soft serve cone is ~90g total - https://mcdonalds.co.nz/menu/soft-serve-cone. Ice cream cones are ~5g in weight - https://shop.countdown.co.nz/shop/productdetails?stockcode=318710&name=homebrand-cones-cups&searchString=cone. So assumed had 85g ice-cream
Pizza bread (Countdown)	300g soft dough Italian style bread loaf topped with tangy cheese & onions and a coating of tomato sauce. Had ¾ = 225g (300g/4 x 3) - https://shop.countdown.co.nz/shop/productdetails?stockcode=286225&name=countdown-pizza-bread-italian
Cheese and crackers – 30g (Mainland)	put cheese (15g) and crackers (15g) into their separate sections - https://shop.countdown.co.nz/shop/productdetails?stockcode=739823, https://www.fatsecret.com.au/calories-nutrition/mainland/on-the-go-tasty-cheese-and-crackers/3-crackers-and-3-slices-of-cheese

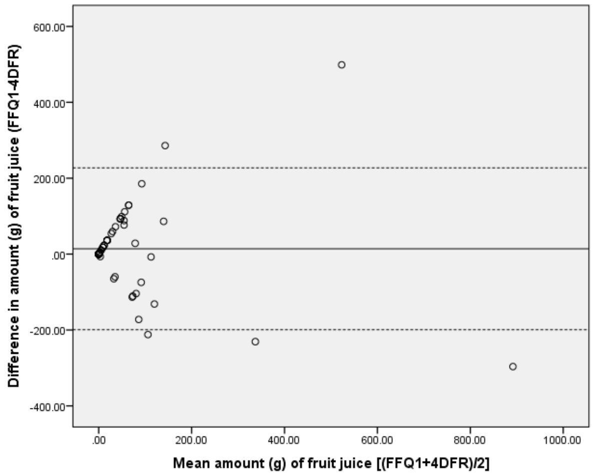
Appendix H: Supplementary results

Bland-Altman plots for validity

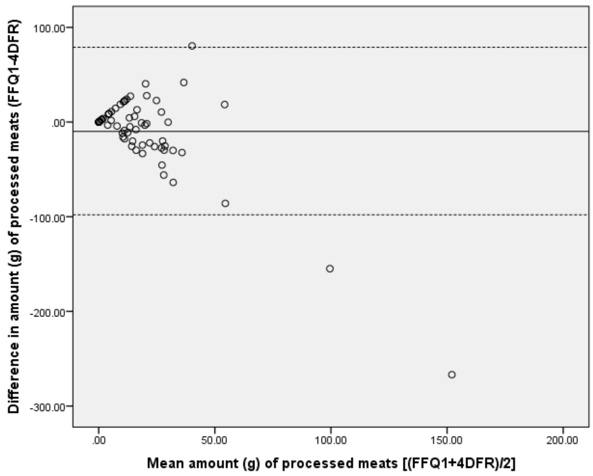
(A): Bland-Altman plot of bread



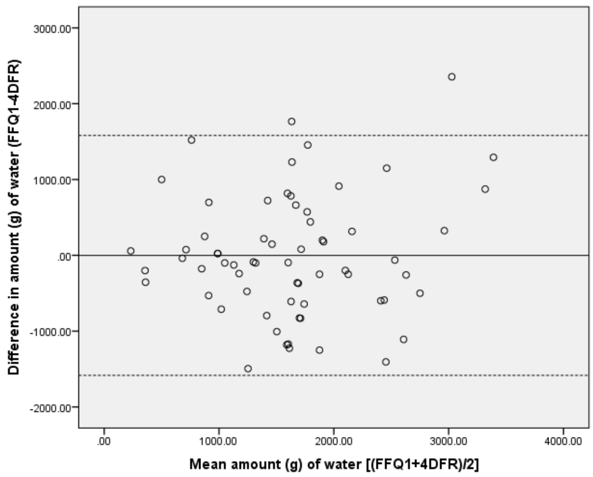
(B): Bland-Altman plot of fruit juice



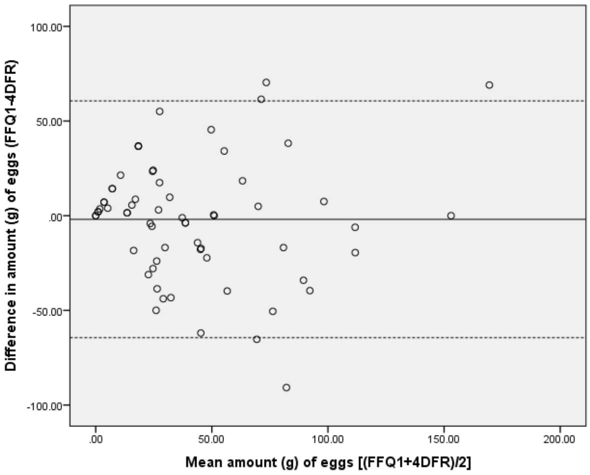
(C): Bland-Altman plot of processed meats



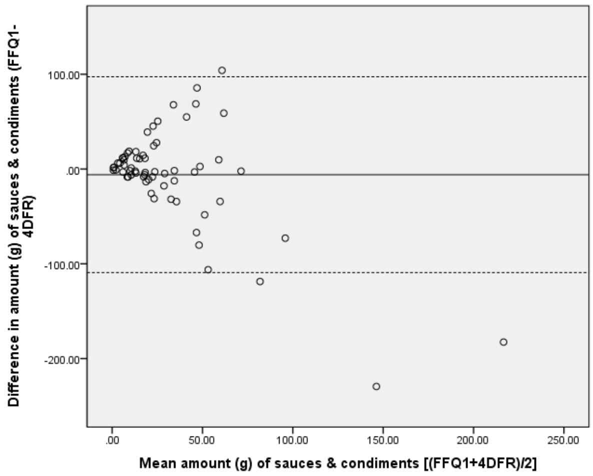
(D): Bland-Altman plot of water



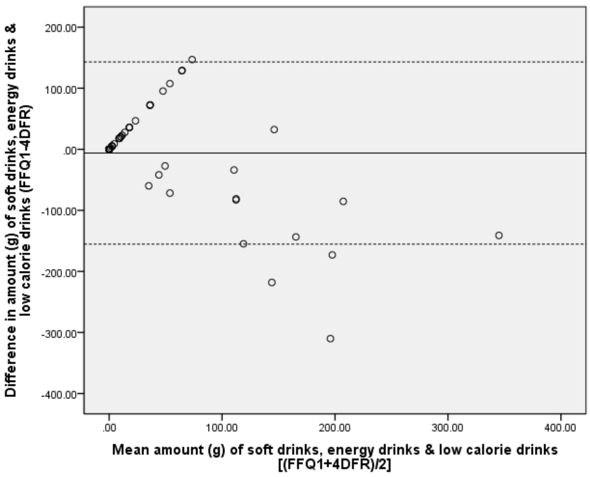
(E): Bland-Altman plot of eggs



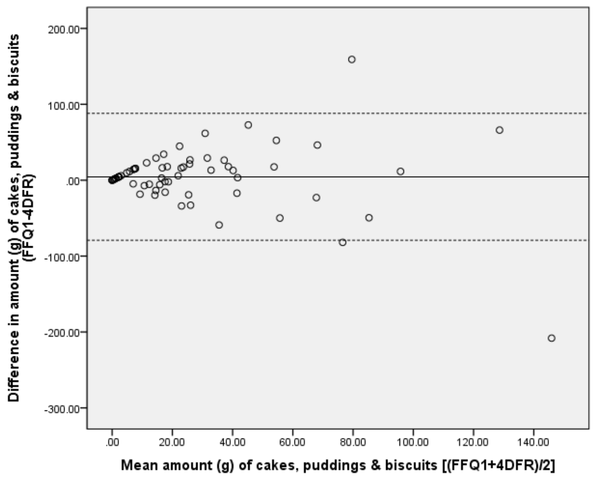
(F): Bland-Altman plot of sauces & condiments



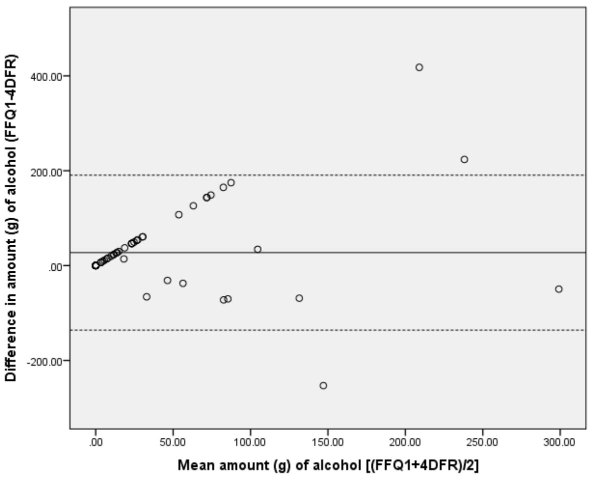
(G): Bland-Altman plot of soft drinks, energy drinks & low calorie drinks



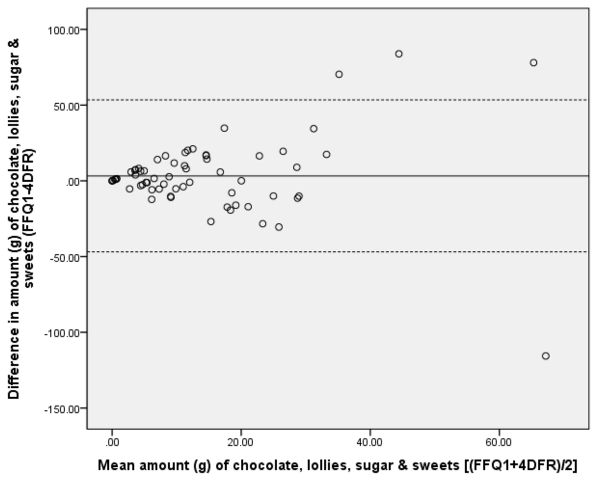
(H): Bland-Altman plot of cakes, puddings & biscuits



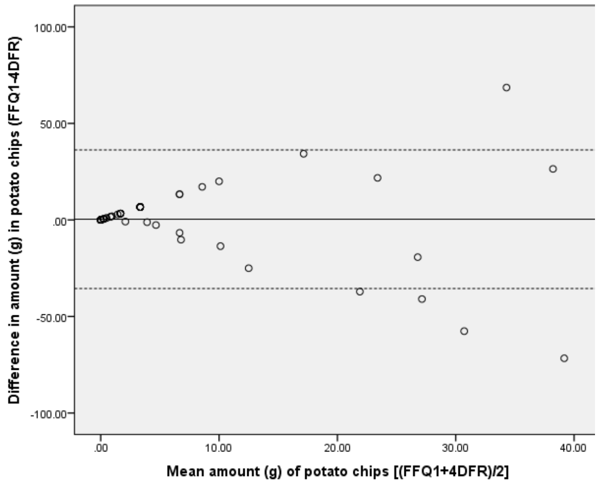
(I): Bland-Altman plot of alcohol



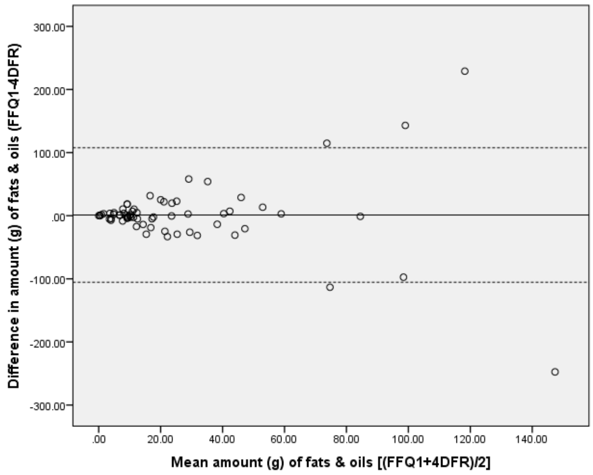
(J): Bland-Altman plot of chocolate, lollies, sugar & sweets



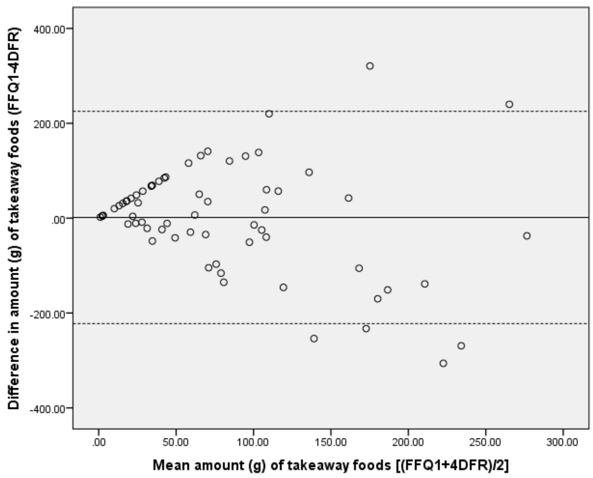
(K): Bland-Altman plot of potato chips



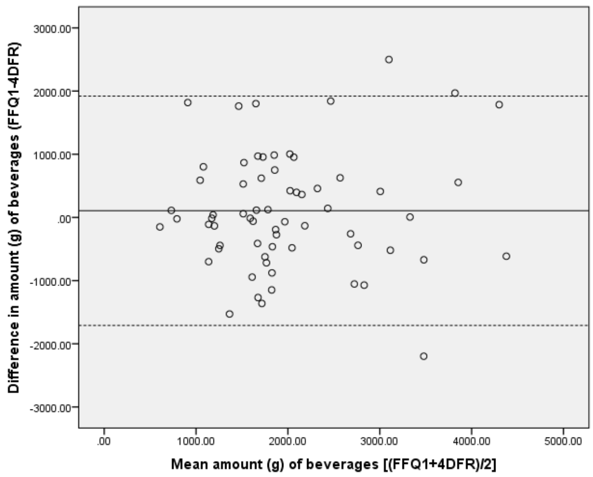
(L): Bland-Altman plot of fats & oils



(M): Bland-Altman plot of takeaway foods



(N): Bland-Altman plot of beverages



(O): Bland-Altman plot of sports foods/supplements

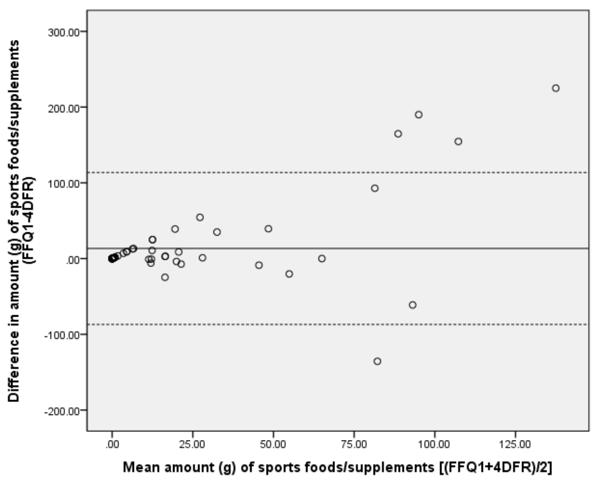
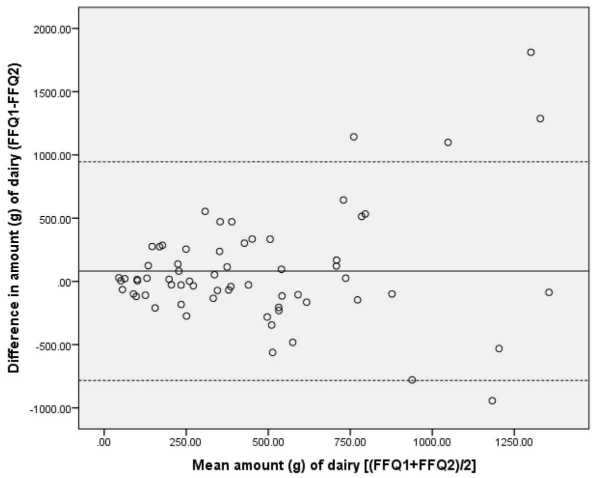


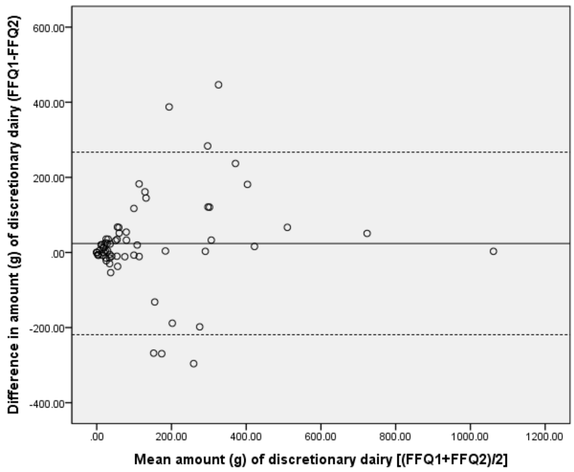
Figure H1 *Bland-Altman plots for validity of agreement between gram amounts of food groups for (A)bread (B) fruit juice (C) processed meats (D) water (E) eggs (F) sauces & condiments (G) soft drinks, energy drinks & low calorie drinks (H) cakes, puddings & biscuits (I) alcohol (J) chocolate, lollies, sugar & sweets (K) potato chips (L) fats & oils (M) takeaway foods (N) beverages and (O) sports foods/supplements. The mean difference is represented by the solid line and the limits of agreement (LOA) by the dashed lines (LOA = mean difference ± 1.96 standard deviations).*

Bland-Altman plots for reproducibility

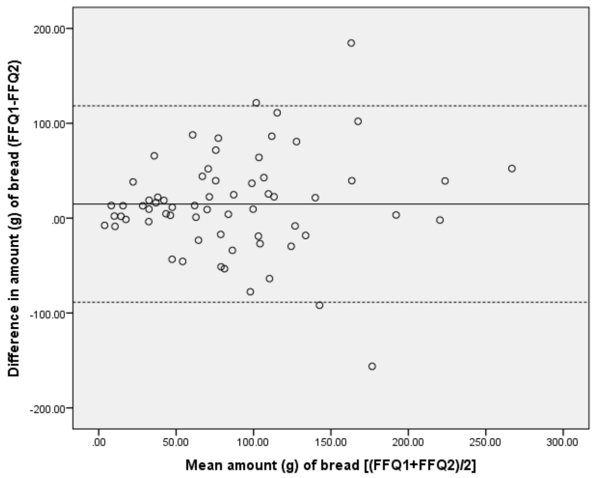
(A): Bland-Altman plot of dairy



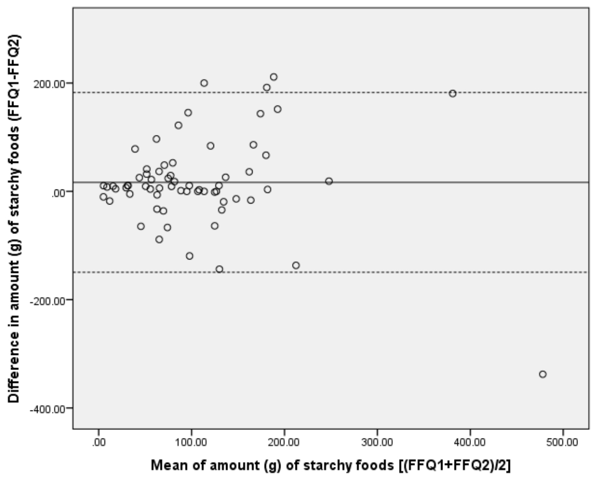
(B): Bland-Altman plot of discretionary dairy



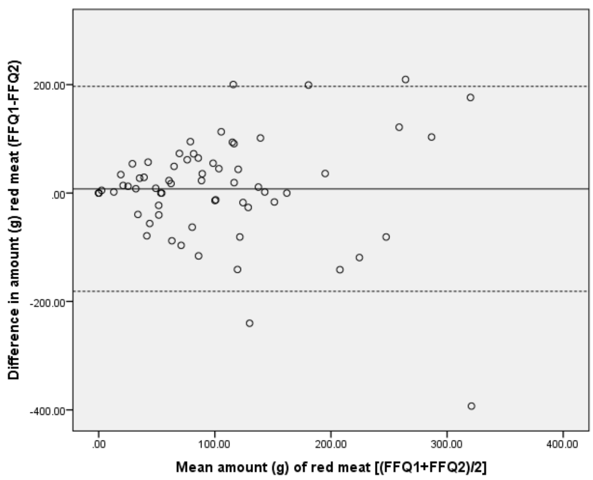
(C): Bland-Altman plot of bread



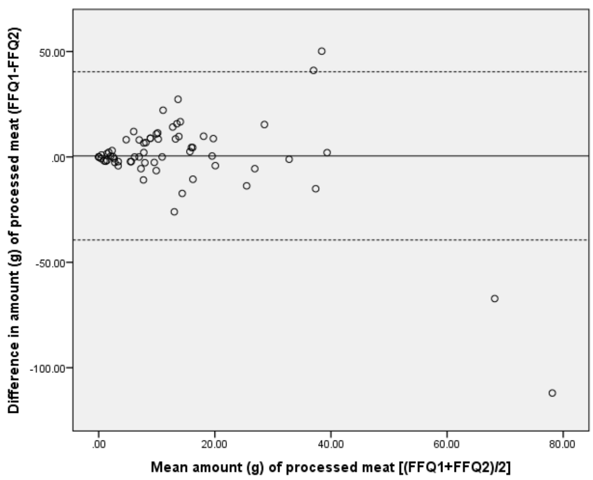
(D): Bland-Altman plot of starchy foods



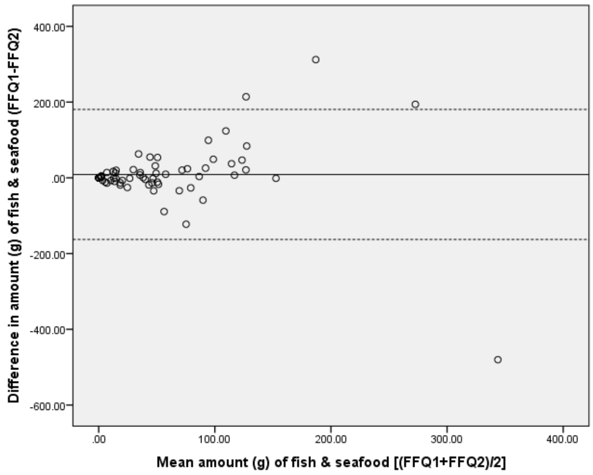
(E): Bland-Altman plot of red meat



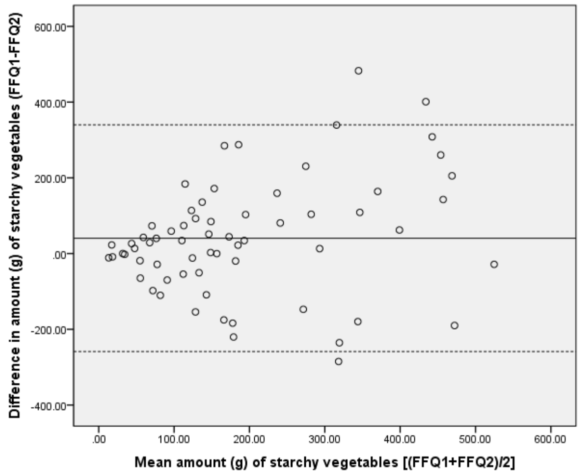
(F): Bland-Altman plot of processed meat



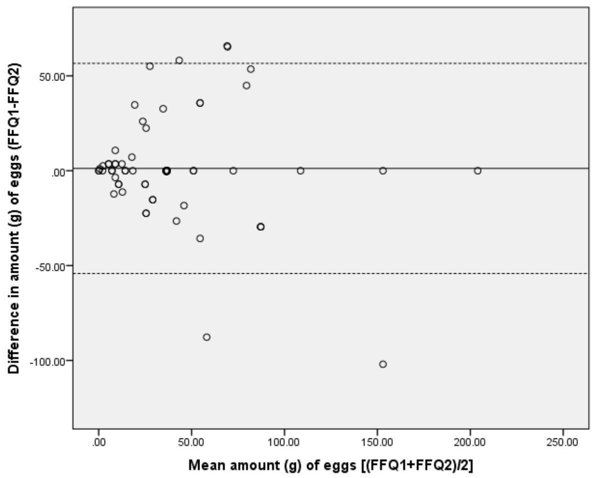
(G): Bland-Altman plot of fish & seafood



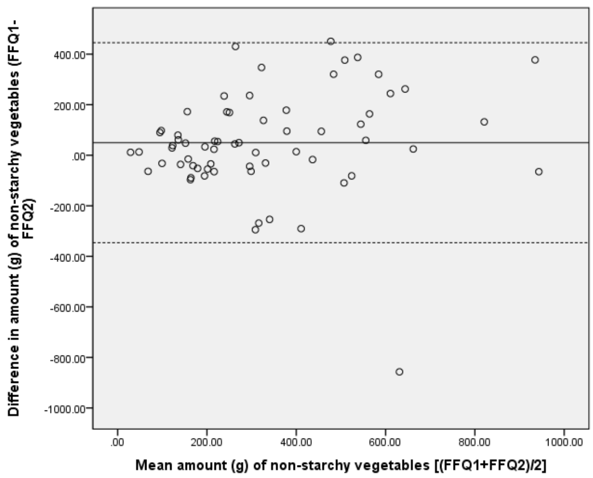
(H): Bland-Altman plot of starchy vegetables



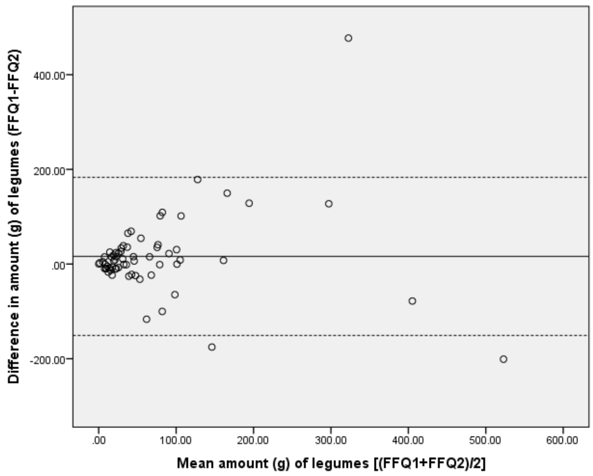
(I): Bland-Altman plot of eggs



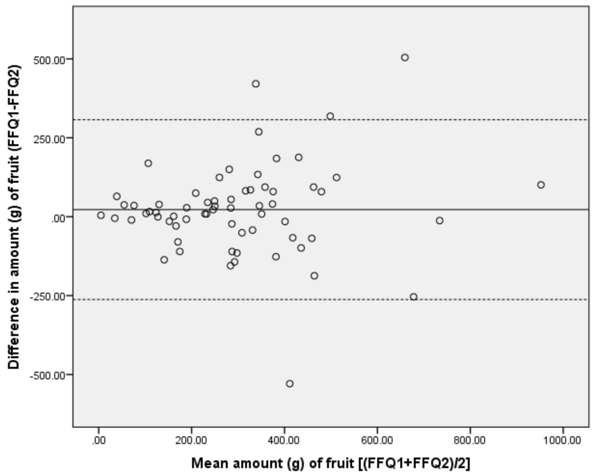
(J): Bland-Altman plot of non-starchy vegetables



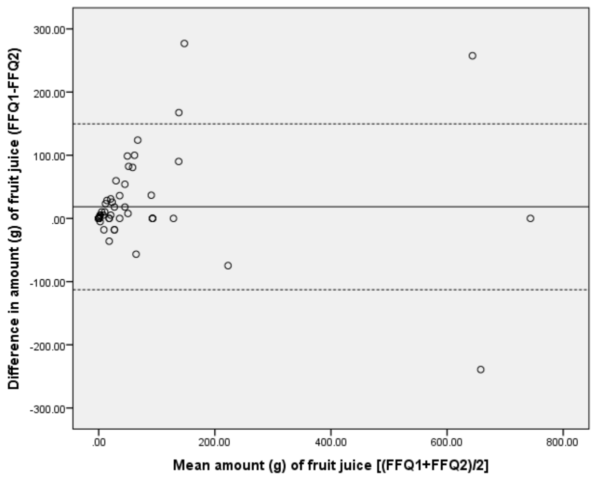
(K): Bland-Altman plot of legumes



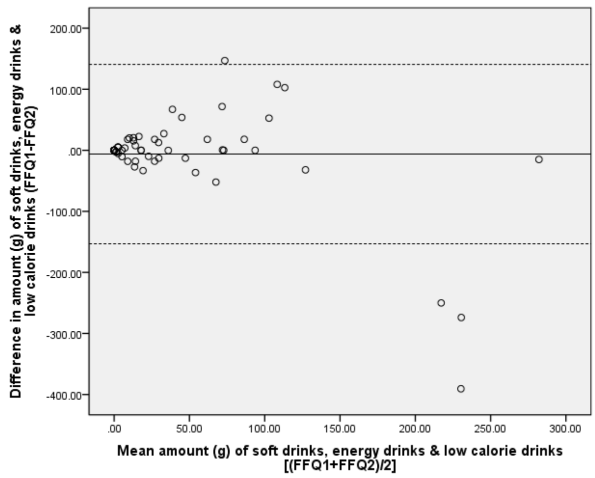
(L): Bland-Altman plot of fruit



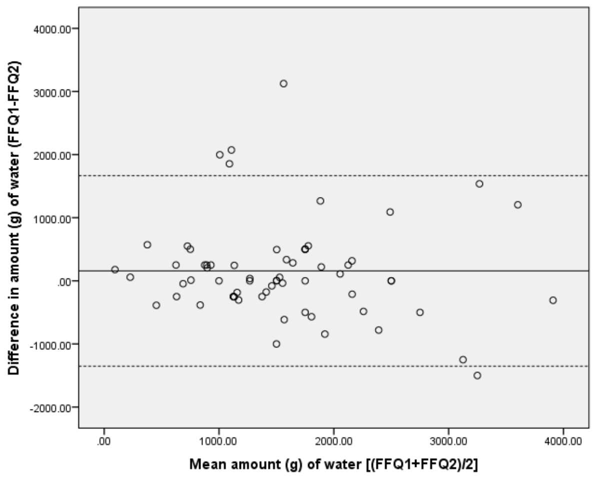
(M): Bland-Altman plot of fruit juice



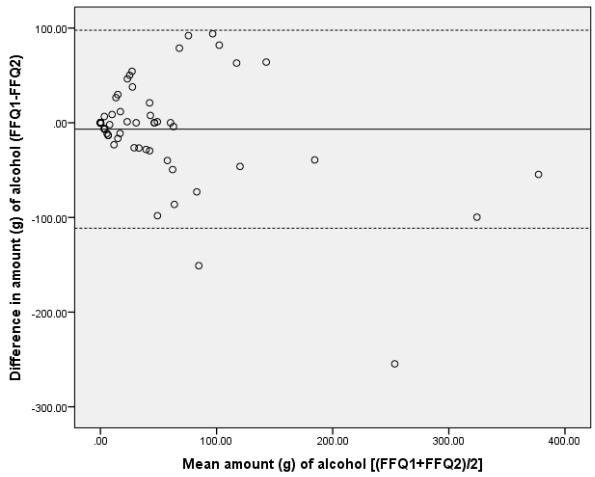
(N): Bland-Altman plot of soft drinks, energy drinks & low calorie drinks



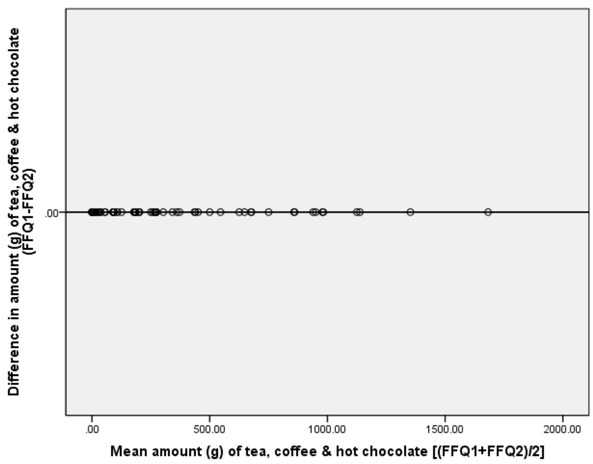
(O): Bland-Altman plot of water



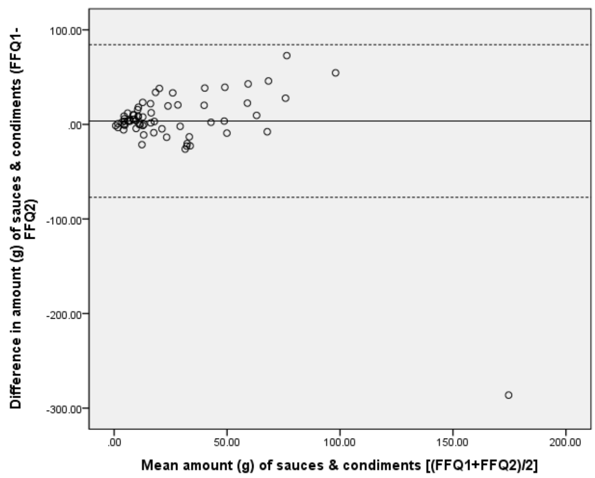
(P): Bland-Altman plot of alcohol



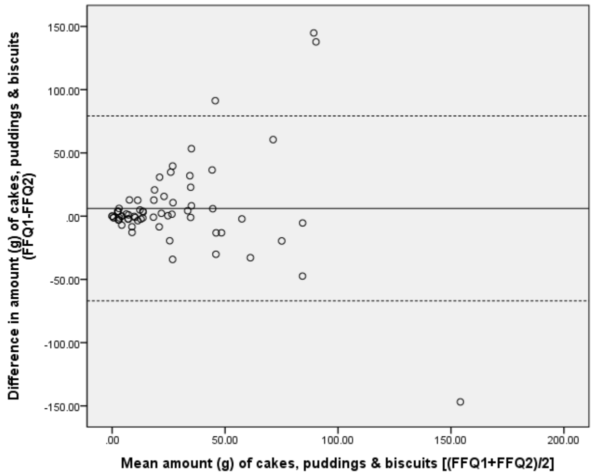
(Q): Bland-Altman plot of tea, coffee & hot chocolate



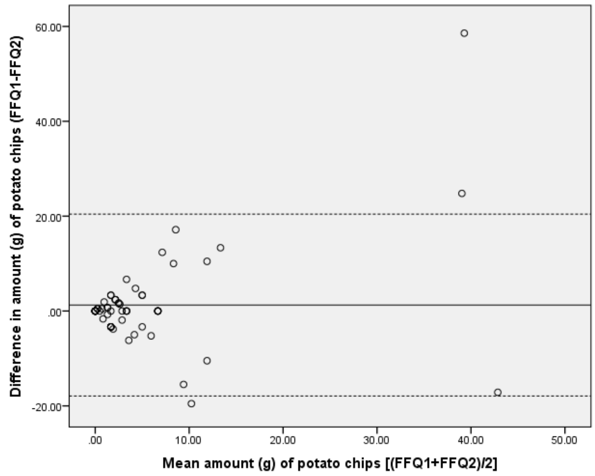
(R): Bland-Altman plot of sauces & condiments



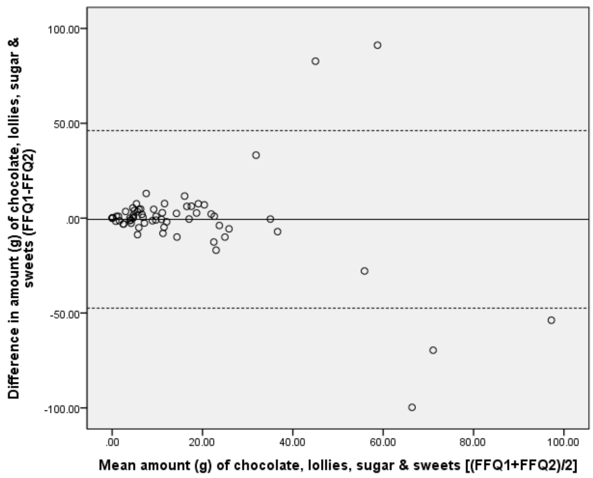
(S): Bland-Altman plot of cakes, puddings & biscuits



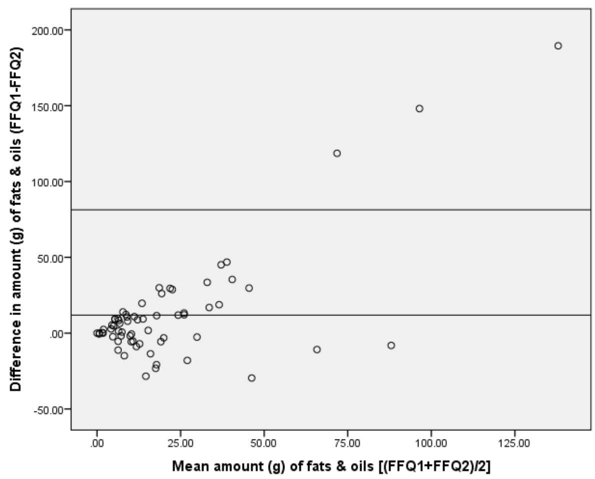
(T): Bland-Altman plot of potato chips



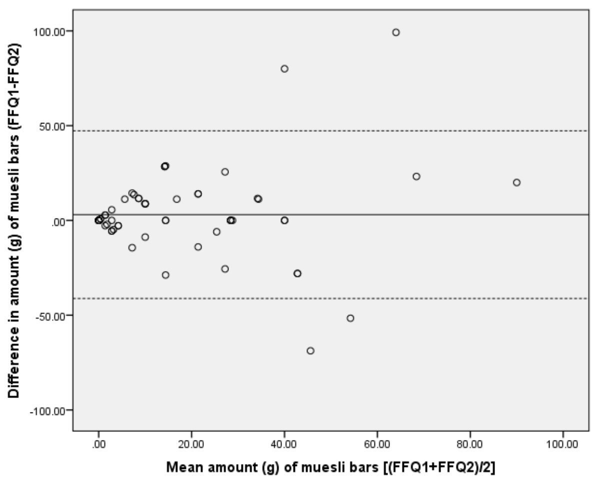
(U): Bland-Altman plot of chocolate, lollies, sugar & sweets



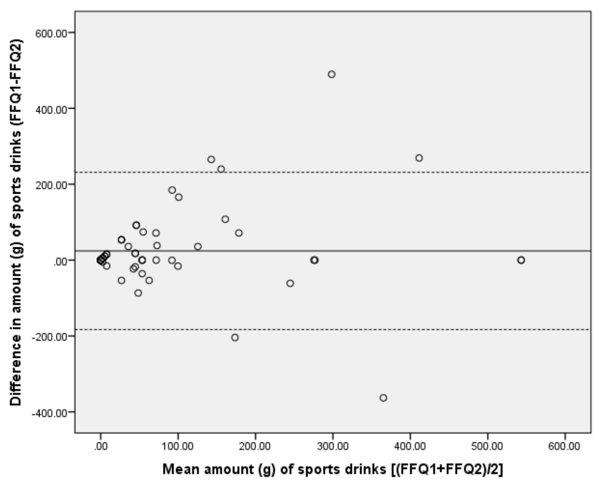
(V): Bland-Altman plot of fats & oils



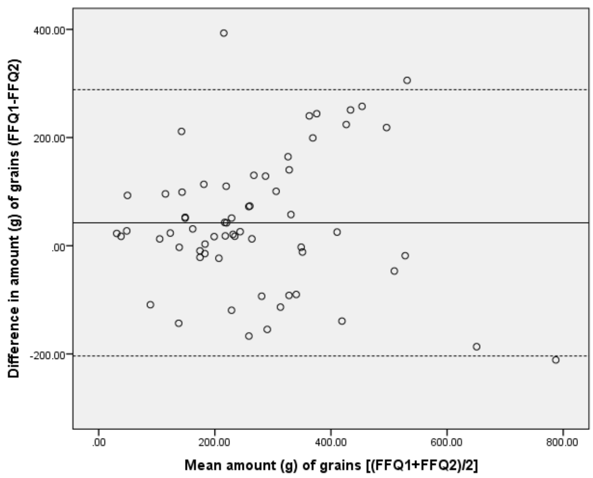
(W): Bland-Altman plot of muesli bars



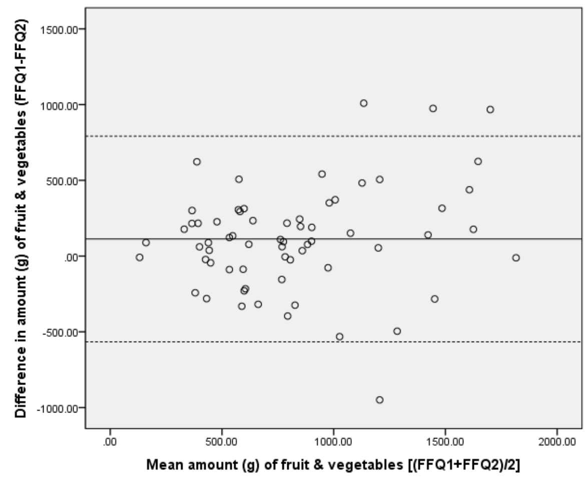
(X): Bland-Altman plot of sports drinks



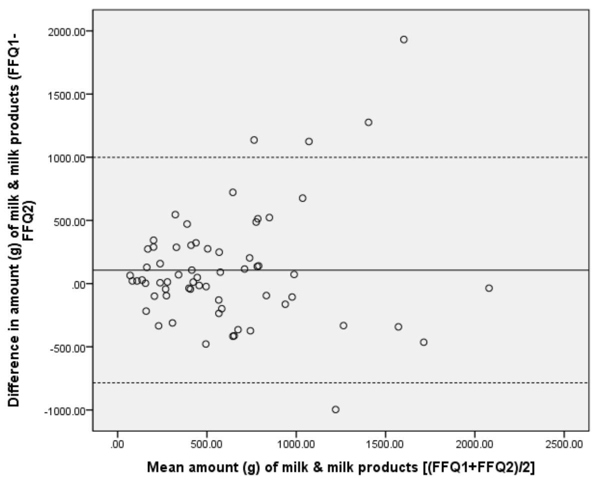
(Y): Bland-Altman plot of grains



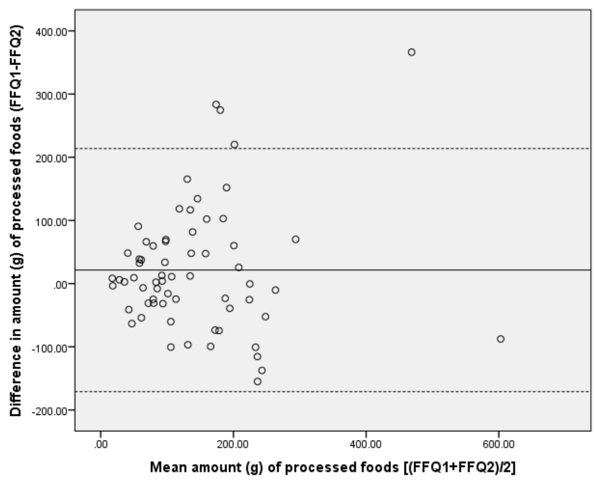
(Z): Bland-Altman plot of fruit & vegetables



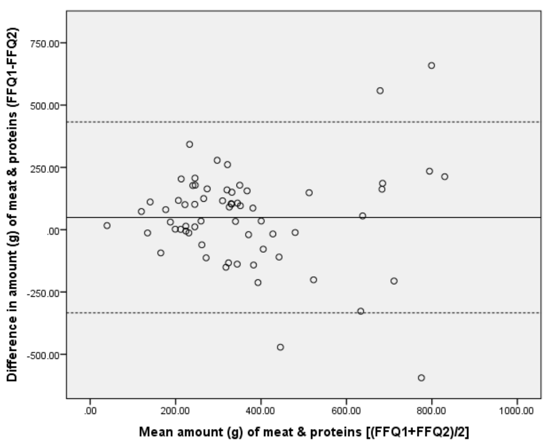
(AA): Bland-Altman plot of milk & milk products



(AB): Bland-Altman plot of processed foods & drinks



(AC): Bland-Altman plot of meat & proteins



(AD): Bland-Altman plot of beverages

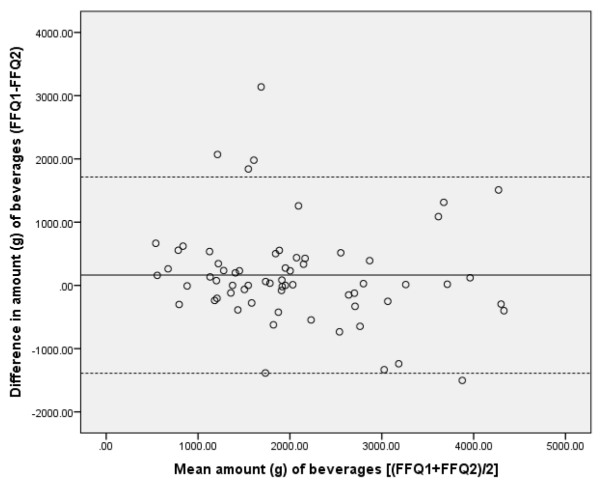


Figure H2 *Bland-Altman plots for reproducibility of agreement between gram amounts of food groups for (A)dairy (B) discretionary dairy (C) bread (D) starchy foods (E) red meat (F) processed meat (G) fish & seafood (H) starchy vegetables (I) eggs (J) non-starchy vegetables (K) legumes (L) fruit (M) fruit juice (N) soft drinks, energy drinks & low calorie drinks (O) water (P) alcohol (Q) tea, coffee & hot chocolate (R) sauces & condiments (S) cakes, puddings & biscuits (T) potato chips (U) chocolate, lollies, sugar & sweets (V) fats & oils (W) muesli bars (X) sports drinks (Y) grains (Z) fruit & vegetables (AA) milk & milk products (AB) processed foods & drinks (AC) meat & proteins and (AD) beverages. The mean difference is represented by the solid line and the limits of agreement (LOA) by the dashed lines (LOA = mean difference ± 1.96 standard deviations).*

Bland-Altman and linear regression tables

*Bland-Altman plots and linear regression analysis were only completed for food groups that were not statistically significant when the one sample t-test was performed, as discussed in Bland and Altman (1999).

Table 6 *Bland-Altman and linear regression analysis for daily food group intakes in gram from the FFQ and 4DFR (n=65)*

Food Group (g)	Mean Difference*	LOA[a]		Beta value	p-value
Bread (e.g. wholegrain, white, bagels, crackers)	-5.1	142.3	-152.5	-0.39	0.00
Starchy Foods (rice, pasta, canned spaghetti, couscous)	28.8	230.1	-172.5	0.09	0.64
Processed Meats (e.g. ham, bacon, sausages)	-9.9	78.9	-98.7	-1.49	0.00
Poultry	30.1	244.6	-184.3	0.42	0.03
Eggs	-1.9	60.6	-64.4	-0.01	0.90
Fruit Juice	14.0	227.4	-199.4	-0.08	0.00
Water	-1.2	1581.3	-1583.7	0.13	0.36
Soft Drinks, Energy Drinks & Low Calorie Drinks (e.g. cordials)	-6.2	143.1	-155.4	-0.67	0.00
Alcohol	27.3	190.6	-136.1	0.41	0.02
Sauces & Condiments	-5.9	97.3	-109.2	-0.94	0.00
Cakes, Puddings & Biscuits	4.4	88.0	-79.1	-0.26	0.13
Chocolate, Lollies, Sugar & Sweets	3.3	53.4	-46.9	0.12	0.61
Potato Chips	0.4	36.2	-35.5	-0.39	0.09
Fats & Oils	1.1	107.6	-105.4	-0.09	0.68
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curry's)	1.4	225.3	-222.4	-0.46	0.03
Sports Foods/Supplements (e.g. sports bars, protein powders)	13.3	220.4	-193.8	0.57	0.00

*Mean difference = FFQ – 4DFR
[a]LOA = 95% limits of agreement

Table 7 *Bland-Altman and linear regression analysis for daily core food group intakes in grams from the FFQ and 4DFR (n=65)*

Core Food Group (g)	Mean Difference*	LOA[a]		Beta Value	p-value
Fats, Oils, Sauces & Condiments	-4.8	154.2	-163.8	-0.35	0.11
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	-22.7	326.9	-372.3	0.15	0.21
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	105.6	1919.7	-1708.5	0.06	0.64

*Mean difference = FFQ – 4DFR
[a]LOA = 95% limits of agreement

Table 8 *Bland-Altman and linear regression analysis for daily food group intakes in grams from the FFQ1 and FFQ2 (n=65)*

Food Group (g)	Mean Difference*	LOA[a]		Beta value	p-value
Dairy (milk, cheese & yoghurt)	81.4	945.8	-783.1	0.29	0.07
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	24.0	267.0	-219.0	0.11	0.21
Bread (e.g. wholegrain, white, bagels, crackers)	14.9	118.4	-88.6	0.08	0.49
Breakfast Cereals (wholegrain & sweetened)	9.8	154.2	-134.6	0.13	0.32
Starchy Foods (rice, pasta, canned spaghetti, couscous)	16.5	182.4	-149.5	-0.09	0.48
Red Meat	7.7	196.8	-181.4	-0.02	0.91
Processed Meats (e.g. ham, bacon, sausages)	0.5	40.4	-39.4	-0.67	0.00
Poultry	21.3	169.0	-126.4	0.42	0.00
Fish & Seafood	8.9	180.7	-162.9	-0.07	0.66
Eggs	1.2	56.6	-54.1	-0.1	0.26

Food Group (g)	Mean Difference*	LOA[a]		Beta value	p-value
Legumes (beans, hummus, tofu, nuts & seeds)	16.2	183.3	-150.9	0.09	0.39
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	40.5	339.8	-258.8	0.31	0.03
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	49.6	445.3	-346.1	0.15	0.22
Fruit (whole & dried)	22.6	307.5	-262.4	0.09	0.39
Fruit Juice	18.4	149.7	-112.8	0.02	0.71
Water	157.0	1666.6	-1352.7	-0.11	0.39
Tea, Coffee & Hot Chocolate	0.0	-	-	-	-
Soft Drinks, Energy Drinks & Low Calorie Drinks (e.g. cordials)	-6.2	140.6	-153.0	-0.63	0.00
Alcohol	-6.8	97.8	-111.3	-0.28	0.00
Sauces & Condiments	3.6	84.3	-77.1	-0.59	0.00
Cakes, Puddings & Biscuits	6.1	79.2	-67.0	-0.03	0.83
Chocolate, Lollies, Sugar & Sweets	-0.7	46.1	-47.4	-0.36	0.02
Muesli Bars	3.0	47.3	-41.2	0.16	0.28
Potato Chips	1.2	20.4	-17.9	0.49	0.00
Fats & Oils	11.9	81.3	-57.6	1.05	0.00
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curry's)	11.7	144.8	-121.4	0.19	0.16
Sports Drinks (e.g. Powerade, Gastrolyte)	24.2	231.3	-182.9	0.12	0.34

*Mean difference = FFQ1 – FFQ2
[a]LOA = 95% limits of agreement

Table 9 *Bland-Altman and linear regression analysis for core food group intakes in grams from the FFQ1 and FFQ2 (n=65)*

Core Food Group (g)	Mean Difference*	LOA[a]		Beta value	p-value
Milk & Milk Products	106.6	998.7	-785.5	0.16	0.25
Grains (bread, breakfast cereals & starchy foods)	42.4	288.5	-203.8	-0.00	0.99
Meat & Proteins	49.3	432.1	-333.5	0.01	0.94
Fruit & Vegetables	112.7	791.4	-566.1	0.19	0.08
Fats, Oils, Sauces & Condiments	15.5	126.8	-95.8	0.21	0.20
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	23.8	233.3	-185.7	0.12	0.34
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	131.2	1876.0	-1613.6	-0.15	0.21

*Mean difference = FFQ1 – FFQ2
[a]LOA = 95% limits of agreement

Mean results

***Table 10** Comparison of mean daily food group intakes from FFQ1 and 4DFR (n=65)*

Food Group (g)	FFQ1 (mean ± SD)	Food Record (mean ± SD)
Dairy (milk, cheese & yoghurt)	514.6 ± 449.5	267.9 ± 201.6
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	157.6 ± 215.0	96.6 ± 138.2
Bread (e.g. wholegrain, white, bagels, scones, crackers)	94.1 ± 64.1	99.2 ± 87.6
Breakfast Cereals (wholegrain & sweetened)	81.7 ± 88.7	40.7 ± 50.9
Starchy Foods (rice, pasta, canned spaghetti, couscous)	111.9 ± 87.5	83.0 ± 82.7
Red Meat	107.3 ± 91.6	64.7 ± 64.2
Processed Meats (e.g. ham, bacon, sausages)	14.4 ± 15.6	24.3 ± 43.3
Poultry	97.4 ± 99.4 [a]	73.2 ± 89.5
Fish & Seafood	60.7 ± 75.2	26.1 ± 36.0
Eggs	40.8 ± 39.1	43.2 ± 39.7 [δ]
Legumes (beans, hummus, tofu, nuts & seeds)	78.6 ± 108.3	46.7 ± 56.5
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	210.9 ± 172.1	80.7 ± 106.6
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	354.2 ± 245.5	190.5 ± 154.8
Fruit (whole & dried)	311.4 ± 196.2	197.7 ± 140.5
Fruit Juice	64.7 ± 138.3	50.7 ± 148.2
Water	1638.3 ± 848.5	1639.5 ± 768.0
Tea, Coffee & Hot Chocolate	352.1 ± 383.1 [a]	247.7 ± 332.3
Soft Drinks, Energy Drinks & Low Calorie Drinks (e.g. cordials)	37.4 ± 53.9	43.6 ± 94.8

Food Group (g)	FFQ1 (mean ± SD)	Food Record (mean ± SD)
Alcohol	49.3 ± 81.5	22.0 ± 61.5
Sauces & Condiments	28.2 ± 27.7	34.1 ± 55.2
Cakes, Puddings & Biscuits	29.8 ± 33.6	25.3 ± 40.2
Chocolate, Lollies, Sugar & Sweets	15.8 ± 19.4	12.6 ± 18.2
Muesli Bars	18.2 ± 23.8	9.1 ± 12.4
Potato Chips	6.1 ± 12.0	5.7 ± 14.9
Fats & Oils	27.0 ± 39.4	25.9 ± 41.5
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curry's)	82.4 ± 75.8	81.0 ± 99.8
Sports Drinks (e.g. Powerade, Gastrolyte)	93.0 ± 140.6	22.9 ± 66.3
Sports Foods/Supplements (e.g. sports bars, protein powders)	25.4 ± 50.8	12.1 ± 27.1

[a]Data includes 64 participants due to the removal of extreme outliers

Table 11 *Comparison of mean daily core food group intakes in grams from the FFQ1 and 4DFR (n=65)*

Core Food Group (g)	FFQ1 (mean ± SD)	Food Record (mean ± SD)
Milk & Milk Products	672.3 ± 533.9	364.5 ± 280.7
Grains (bread, breakfast cereals & starchy foods)	287.7 ± 158.5	222.9 ± 136.1
Meat & Proteins	389.0 ± 208.4 [a]	279.8 ± 169.9 [a]
Fruit & Vegetables	876.5 ± 471.6	468.9 ± 296.2
Fats, Oils, Sauces & Condiments	55.3 ± 55.7	60.1 ± 68.2
Processed Foods & Drinks (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	170.1 ± 130.3	147.4 ± 151.8
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	2061.9 ± 989.8	1956.3 ± 941.3

[a]Data includes 64 participants due to the removal of extreme outliers

***Table 12** Comparison of mean daily food group intakes in grams from the FFQ1 and FFQ2 (n = 65)*

Food Group (g)	FFQ1 (mean ± SD)	FFQ2 (mean ± SD)
Dairy (milk, cheese & yoghurt)	503.1 ± 443.7	421.7 ± 360.8
Discretionary Dairy (e.g. flavoured milk, ice-cream, cream, custard)	148.5 ± 204.7	126.5 ± 187.1 [a]
Bread (e.g. wholegrain, white, bagels, scones, crackers)	93.9 ± 64.1	79.0 ± 59.9
Breakfast Cereals (wholegrain & sweetened)	82.4 ± 88.4	72.0 ± 79.5 [a]
Starchy Foods (rice, pasta, canned spaghetti, couscous)	112.7 ± 88.0	96.3 ± 94.7
Red Meat	106.2 ± 90.6	98.5 ± 91.7
Processed Meats (e.g. ham, bacon, sausages)	13.6 ± 13.2	13.1 ± 21.5
Poultry	96.9 ± 99.6 [a]	78.7 ± 73.7
Fish & Seafood	61.0 ± 75.0	52.1 ± 79.0
Eggs	40.4 ± 39.3	39.2 ± 43.1
Legumes	79.1 ± 108.0	62.9 ± 99.6
Starchy Vegetables (e.g. potato, pumpkin, sweet corn)	213.2 ± 172.0	172.7 ± 135.4
Non-Starchy Vegetables (e.g. carrots, broccoli, spinach)	356.7 ± 244.4	307.1 ± 216.6
Fruit (whole & dried)	309.8 ± 196.6	287.2 ± 182.0
Fruit Juice	71.5 ± 150.2	53.1 ± 147.2
Water	1641.5 ± 847.5	1484.5 ± 922.8
Tea, Coffee & Hot Chocolate	349.5 ± 380.7	349.5 ± 380.7
Soft Drinks, Energy Drinks & Low Calorie Drinks	36.9 ± 53.1	43.1 ± 87.1
Alcohol	43.6 ± 67.0	50.3 ± 86.5
Sauces & Condiments	28.0 ± 27.7	24.4 ± 41.8

Food Group (g)	FFQ1 (mean ± SD)	FFQ2 (mean ± SD)
Cakes, Puddings & Biscuits	30.3 ± 33.9	24.2 ± 34.7
Chocolate, Lollies, Sugar and Sweets	15.6 ± 19.3	16.3 ± 25.0
Muesli Bars	18.0 ± 23.7	15.0 ± 21.1
Potato Chips	5.6 ± 11.5	4.4 ± 7.8
Fats & Oils	27.1 ± 39.4	15.2 ± 16.9
Takeaway Foods (e.g. hot chips, deep fried foods, pizza, curry's)	80.9 ± 74.7	69.2 ± 64.4
Sport Drinks (e.g. Powerade, Gastrolyte)	94.2 ± 141.1	69.9 ± 129.3
Sports Foods/Supplements (e.g. sports bars, protein powders)	25.3 ± 50.8	11.8 ± 27.6

[a]Data includes 64 participants due to the removal of extreme outliers

Table 13 *Comparison of mean daily core food group intake in grams from the FFQ1 and FFQ2 (n=65)*

Core Food Group (g)	FFQ1 (mean ± SD)	FFQ2 (mean ± SD)
Milk & Milk Products	651.6 ± 515.7	554.0 ± 455.3 [a]
Grains (bread, breakfast cereals & starchy foods)	289.0 ± 158.6	249.8 ± 159.9
Meat & Proteins	386.8 ± 208.7 [a]	344.4 ± 212.6
Fruit & Vegetables	879.7 ± 470.5	767.0 ± 401.2
Fats, Oils, Sauces & Condiments	55.1 ± 55.8	39.6 ± 48.2
Processed foods (soft drinks & energy drinks; potato chips; cakes, puddings & biscuits; chocolate, lollies, sugar & sweets; muesli bars; takeaway foods)	167.5 ± 126.5	143.7 ± 114.9
Beverages (water; fruit juice; tea, coffee & hot chocolate; low calorie drinks)	2053.8 ± 972.6	1915.6 ± 1098.8

[a]Data includes 64 participants due to the removal of extreme outliers

References

Araújo, C., & Scharhag, J. (2016). Athlete: a working definition for medical and health sciences research. *Scandinavian Journal of Medicine & Science in Sports, 26*(1), 4-7.

Baker, L. B., Heaton, L. E., Stein, K. W., Nuccio, R. P., & Jeukendrup, A. E. (2014). Validity and relative validity of a novel digital approach for 24-h dietary recall in athletes. *Nutrition Journal, 13*, 41. doi:10.1186/1475-2891-13-41

Beck, K. L., Houston, Z. L., McNaughton, S. A., & Kruger, R. (2018). Development and evaluation of a food frequency questionnaire to assess nutrient intakes of adult women in New Zealand. *Nutrition & Dietetics*.

Bingham, S. A. (1987). The dietary assessment of individuals; methods, accuracy, new techniques and recommendation. *Nutrition Abstracts and Reviews (Series A), 57*, 705-742.

Black, A. E. (2001). Dietary assessment for sports dietetics. *Nutrition Bulletin, 26*(1), 29-42.

Bland, J. M., & Altman, D. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *The Lancet, 327*(8476), 307-310.

Bland, J. M., & Altman, D. G. (1999). Measuring agreement in method comparison studies. *Statistical Methods in Medical Research, 8*(2), 135-160.

Block, G., & Hartman, A. M. (1989). Issues in reproducibility and validity of dietary studies. *The American Journal of Clinical Nutrition, 50*(5), 1133-1138.

Bountziouka, V., Bathrellou, E., Giotopoulou, A., Katsagoni, C., Bonou, M., Vallianou, N., Panagiotakos, D. (2012). Development, repeatability and validity regarding energy and macronutrient intake of a semi-quantitative food frequency questionnaire: methodological considerations. *Nutrition, Metabolism and Cardiovascular Diseases, 22*(8), 659-667.

Bourke, B. E. P., Baker, D. F., & Braakhuis, A. J. (2018). Social Media as a Nutrition Resource for Athletes: A Cross-Sectional Survey. *International Journal of Sport Nutrition and Exercise Metabolism*(00), 1-7.

Braakhuis, A. J., Hopkins, W. G., Lowe, T. E., & Rush, E. C. (2011). Development and validation of a food-frequency questionnaire to assess short-term antioxidant intake in athletes. *International Journal of Sport Nutrition and Exercise Metabolism, 21*(2), 105-112.

Briggs, M. A., Rumbold, P. L., Cockburn, E., Russell, M., & Stevenson, E. J. (2015). Agreement between two methods of dietary data collection in male adolescent academy-level soccer players. *Nutrients, 7*(7), 5948-5960.

Buell, J. L., Franks, R., Ransone, J., Powers, M. E., Laquale, K. M., & Carlson-Phillips, A. (2013). National Athletic Trainers' Association position statement: evaluation of dietary supplements for performance nutrition. *Journal of Athletic Training, 48*(1), 124-136.

Burke, L., & Deakin, V. (2015). *Clinical Sports Nutrition* McGraw-Hill Education.

Cade, J., Thompson, R., Burley, V., & Warm, D. (2002). Development, validation and utilisation of food-frequency questionnaires–a review. *Public Health Nutrition, 5*(4), 567-587.

Cade, J. E., Burley, V., Warm, D., Thompson, R., & Margetts, B. (2004). Food-frequency questionnaires: a review of their design, validation and utilisation. *Nutrition Research Reviews, 17*(1), 5-22.

Capling, L., Beck, K., Gifford, J., Slater, G., Flood, V., & O'Connor, H. (2017). Validity of dietary assessment in athletes: a systematic review. *Nutrients, 9*(12), 1313.

Casa, D. J., Stearns, R. L., Lopez, R. M., Ganio, M. S., McDermott, B. P., Walker Yeargin, S., Armstrong, L. E. (2010). Influence of hydration on physiological function and performance during trail running in the heat. *Journal of Athletic Training, 45*(2), 147-156.

Cohen, J. (1988). Statistical power analysis for the behavioural sciences. In: Hillsdale, NJ: erlbaum.

Contento, I. R. (2010). *Nutrition education: linking research, theory, and practice*: Jones & Bartlett Publishers.

De Keyzer, W., Dekkers, A., Van Vlaslaer, V., Ottevaere, C., Van Oyen, H., De Henauw, S., & Huybrechts, I. (2012). Relative validity of a short qualitative food frequency questionnaire for use in food consumption surveys. *The European Journal of Public Health, 23*(5), 737-742.

Erdman, K. A., Tunnicliffe, J., Lun, V. M., & Reimer, R. A. (2013). Eating patterns and composition of meals and snacks in elite Canadian athletes. *International Journal of Sport Nutrition and Exercise Metabolism, 23*(3), 210-219.

Fallaize, R., Forster, H., Macready, A. L., Walsh, M. C., Mathers, J. C., Brennan, L., Lovegrove, J. A. (2014). Online dietary intake estimation: reproducibility and validity of the Food4Me food frequency questionnaire against a 4-day weighed food record. *Journal of Medical Internet Research, 16*(8).

Feskanich, D., Rimm, E. B., Giovannucci, E. L., Colditz, G. A., Stampfer, M. J., Litin, L. B., & Willett, W. C. (1993). Reproducibility and validity of food intake measurements from a semiquantitative food frequency questionnaire. *Journal of the American Dietetic Association, 93*(7), 790-796.

Field, A. (2009). *Discovering statistics using SPSS*: Sage publications.

Fogelholm, M., & Lahti-Koski, M. (1991). The validity of a food use questionnaire in assessing the nutrient intake of physically active young men. *European Journal of Clinical Nutrition, 45*(5), 267-272.

FoodWorks 9 Professional. (2016). Retrieved from; http://www.xyris.com.au

Gemming, L., Utter, J., & Mhurchu, C. N. (2015). Image-assisted dietary assessment: a systematic review of the evidence. *Journal of the Academy of Nutrition and Dietetics, 115*(1), 64-77.

Gibson, R. S. (2005). *Principles of nutritional assessment*: Oxford university press, USA.

Godois, A. d. M., Coelho-Ravagnani, C. d. F., Raizel, R., & Verly-Junior, E. (2018). Development of a Food Frequency Questionnaire for Brazilian athletes. *Nutrition & Dietetics*.

Goulet, J., Nadeau, G., Lapointe, A., Lamarche, B., & Lemieux, S. (2004). Validity and reproducibility of an interviewer-administered food frequency questionnaire for healthy French-Canadian men and women. *Nutrition Journal, 3*(1), 13.

Greenfield, H., & Southgate, D. A. (2003). *Food composition data: production, management, and use*: Food & Agriculture Org.

Heaney, S., O'Connor, H., Gifford, J., & Naughton, G. (2010). Comparison of strategies for assessing nutritional adequacy in elite female athletes' dietary intake. *International Journal of Sport Nutrition and Exercise Metabolism, 20*(3), 245-256.

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41*(1), 3.

IMB Corp. (2015). IMB SPSS Statistics for Windows, Version 21.0. Armonk, NY: IMB Corp.

Jeukendrup, A., & Gleeson, M. (2018). *Sport Nutrition*: Human Kinetics.

Jonnalagadda, S. S., Benardot, D., & Dill, M. N. (2000). Assessment of under-reporting of energy intake by elite female gymnasts. *International Journal of Sport Nutrition and Exercise Metabolism, 10*(3), 315-325.

Krebs-Smith, S. M., Heimendinger, J., Subar, A. F., Patterson, B. H., & Pivonka, E. (1995). Using food frequency questionnaires to estimate fruit and vegetable intake: association between the number of questions and total intakes. *Journal of Nutrition Education, 27*(2), 80-85.

Kurka, J. M., Buman, M. P., & Ainsworth, B. E. (2014). Validity of the Rapid Eating Assessment for Patients for assessing dietary patterns in NCAA athletes. *Journal of the International Society of Sports Nutrition, 11*(1), 42.

Logan-Sprenger, H. M., Palmer, M. S., & Spriet, L. L. (2011). Estimated fluid and sodium balance and drink preferences in elite male junior players during an ice hockey game. *Applied Physiology, Nutrition, and Metabolism, 36*(1), 145-152.

Lombard, M. J., Steyn, N. P., Charlton, K. E., & Senekal, M. (2015). Application and interpretation of multiple statistical tests to evaluate validity of dietary intake assessment methods. *Nutrition Journal, 14*(1), 40.

Longnecker, M. P., Lissner, L., Holden, J. M., Flack, V. F., Taylor, P. R., Stampfer, M. J., & Willett, W. C. (1993). The reproducibility and validity of a self-administered semiquantitative food frequency questionnaire in subjects from South Dakota and Wyoming. *Epidemiology*, 356-365.

Magkos, F., & Yannakoulia, M. (2003). Methodology of dietary assessment in athletes: concepts and pitfalls. *Current Opinion in Clinical Nutrition & Metabolic Care, 6*(5), 539-549.

Mahan, L. K., & Raymond, J. L. (2016). *Krause's food & the nutrition care process-e-book*: Elsevier Health Sciences.

Margetts, B. M., & Nelson, M. (1997). *Design concepts in nutritional epidemiology*: OUP Oxford.

Maruyama, K., Kokubo, Y., Yamanaka, T., Watanabe, M., Iso, H., Okamura, T., & Miyamoto, Y. (2015). The reasonable reliability of a self-administered food frequency questionnaire for an urban, Japanese, middle-aged population: the Suita study. *Nutrition Research, 35*(1), 14-22.

Masson, L. F., McNeill, G., Tomany, J., Simpson, J., Peace, H. S., Wei, L., Bolton-Smith, C. (2003). Statistical approaches for assessing the relative validity of a food-frequency questionnaire: use of correlation coefficients and the kappa statistic. *Public Health Nutrition, 6*(3), 313-321.

Maughan, R., Greenhaff, P., & Hespel, P. (2011). Dietary supplements for athletes: emerging trends and recurring themes. *Journal of Sports Sciences, 29*(sup1), S57-S66.

Maughan, R. J. (2009). Nutrition Needs of Athletes. *Olympic Textbook of Science in Sport*, 87.

Mettler, S., Mannhart, C., & Colombani, P. C. (2009). Development and validation of a food pyramid for Swiss athletes. *International journal of Sport Nutrition and Exercise Metabolism, 19*(5), 504-518.

Meyer, F., Szygula, Z., & Wilk, B. (2016). *Fluid balance, hydration, and athletic performance*: CRC Press.

Ministry of Health. (2011). *A Focus on Nutrition: Key findings of the 2008/09 New Zealand Adult Nutrition Survey*. Wellington: Ministry of Health.

Ministry of Health. (2015). *Eating and Activity Guidelines for New Zealand Adults*. Wellington: Ministry of Health.

Morente-Sánchez, J., & Zabala, M. (2013). Doping in sport: a review of elite athletes' attitudes, beliefs, and knowledge. *Sports Medicine, 43*(6), 395-411.

Morton, R. W., McGlory, C., & Phillips, S. M. (2015). Nutritional interventions to augment resistance training-induced skeletal muscle hypertrophy. *Frontiers in Physiology, 6*, 245.

Mullen, B. J., Krantzler, N. J., Grivetti, L. E., Schutz, H. G., & Meiselman, H. L. (1984). Validity of a food frequency questionnaire for the determination of individual food intake. *The American Journal of Clinical Nutrition, 39*(1), 136-143.

Naska, A., Lagiou, A., & Lagiou, P. (2017). Dietary assessment methods in epidemiological research: current state of the art and future prospects. *F1000 Research, 6*.

Nelson, M., Atkinson, M., & Meyer, J. (1997). *A photographic atlas of food portion sizes*: MAFF publications London.

New Zealand Food Composition Database 2017. *New Zealand Food Composition Database: New Zealand FOODfiles™ 2016 Version 01.* The New Zealand Institute for Plant & Food Research Limited and Ministry of Health.

Nogueira, J. A., & Da Costa, T. H. (2004). Nutrient intake and eating habits of triathletes on a Brazilian diet. *International Journal of Sport Nutrition and Exercise Metabolism, 14*(6), 684-697.

Pedišić, Ž., Vranešić Bender, D., & Mišigoj Duraković, M. (2008). Construction and reproducibility of a questionnaire aimed for evaluation of dietary habits in physically active individuals. *Collegium Antropologicum, 32*(4), 1069-1077.

Rodriguez, N. R., DiMarco, N. M., & Langley, S. (2009). Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. *Journal of the American Dietetic Association*, *109*(3), 509-527.

Rumbold, P., Gibson, A. S. C., Stevenson, E., & Dodd-Reynolds, C. (2011). Agreement between two methods of dietary data collection in female adolescent netball players. *Appetite, 57*(2), 443-447.

Salvini, S., Hunter, D. J., Sampson, L., Stampfer, M. J., Colditz, G. A., Rosner, B., & Willett, W. C. (1989). Food-based validation of a dietary questionnaire: the effects of week-to-week variation in food consumption. *International Journal of Epidemiology, 18*(4), 858-867.

Schoeller, D. A. (1995). Limitations in the assessment of dietary energy intake by self-report. *Metabolism, 44*, 18-22.

Scoffier, S., Gernigon, C., Billi, E., & d'Arripe-Longueville, F. (2013). Development and preliminary validation of a new instrument to assess eating behaviors: The virtual self-service restaurant (VSSR). *Science & Sports, 28*(3), 140-145.

Simpson, A., Gemming, L., Baker, D., & Braakhuis, A. (2017). Do Image-Assisted Mobile Applications Improve Dietary Habits, Knowledge, and Behaviours in Elite Athletes? A Pilot Study. *Sports, 5*(3), 60.

Spronk, I., Heaney, S. E., Prvan, T., & O'Connor, H. T. (2015). Relationship between general nutrition knowledge and dietary quality in elite athletes. *International Journal of Sport Nutrition and Exercise Metabolism, 25*(3), 243-251.

Statistics New Zealand. (2014). *2013 Census QuickStats about culture and identity*. Wellington.

Subar, A. F., Thompson, F. E., Smith, A. F., Jobe, J. B., Ziegler, R. G., Potischman, N., Kruse, L. (1995). Improving food frequency questionnaires: a qualitative approach using cognitive interviewing. *Journal of the American Dietetic Association, 95*(7), 781-788.

Sunami, A., Sasaki, K., Suzuki, Y., Oguma, N., Ishihara, J., Nakai, A., Tada, Y. (2016). Validity of a semi-quantitative food frequency questionnaire for collegiate athletes. *Journal of Epidemiology, 26*(6), 284-291.

SurveyMonkey INC (2016). SurveyMonkey. Retrieved from www.surveymonkey.com

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. *Journal of the Academy of Nutrition and Dietetics, 48*(3), 543-568.

Thompson, F. E., & Subar, A. F. (2013). Dietary assessment methodology. In *Nutrition in the Prevention and Treatment of Disease (Third Edition)* (pp. 5-46): Elsevier.

Tipton, K. D., & Wolfe, R. R. (2004). Protein and amino acids for athletes. *Journal of sports sciences, 22*(1), 65-79.

Tooze, J. A., Krebs-Smith, S. M., Troiano, R. P., & Subar, A. F. (2012). The accuracy of the Goldberg method for classifying misreporters of energy intake on a food frequency questionnaire and 24-h recalls: comparison with doubly labeled water. *European Journal of Clinical Nutrition, 66*(5), 569.

United States Olympic Committee. (2010). *Athletes Plate Easy*. Retrieved from http://www.teamusa.org/About-the-USOC/Athlete-Development/SportPerformance/Nutrition/Resources-and-Fact-Sheets.aspx

Ward, K. D., Hunt, K. M., Berg, M. B., Slawson, D. A., Vukadinovich, C. M., McClanahan, B. S., & Clemens, L. H. (2004). Reliability and validity of a brief questionnaire to assess calcium intake in female collegiate athletes. *International Journal of Sport Nutrition and Exercise Metabolism, 14*(2), 209-221.

Wardenaar, F., Steennis, J., Ceelen, I., Mensink, M., Witkamp, R., & de Vries, J. (2015). Validation of web-based, multiple 24-h recalls combined with nutritional supplement intake questionnaires against nitrogen excretions to determine protein intake in Dutch elite athletes. *British Journal of Nutrition, 114*(12), 2083-2092.

Watson, E. O., Heath, A. L. M., Taylor, R. W., Mills, V. C., Barris, A. C., & Skidmore, P. M. (2015). Relative validity and reproducibility of an FFQ to determine nutrient intakes of New Zealand toddlers aged 12–24 months. *Public Health Nutrition*, *18*(18), 3265-3271.

Westerterp, K., Saris, W., Van Es, M., & Ten Hoor, F. (1986). Use of the doubly labeled water technique in humans during heavy sustained exercise. *Journal of Applied Physiology, 61*(6), 2162-2167.

Wheeler, C., Rutishauser, I., Conn, J., & O'Dea, K. (1994). Reproducibility of a meal-based food frequency questionnaire. The influence of format and time interval between questionnaires. *European Journal of Clinical Nutrition, 48*(11), 795-809.

Willett, W. (2012). *Nutritional Epidemiology*: Oxford University Press.

Willet, W. (1998). Implications of total energy intake for epidemiologic analysis. *Nutritional Epidemiology*, 273-301.

Willett, W. C. (1994). Future directions in the development of food-frequency questionnaires. *The American Journal of Clinical Nutrition, 59*(1), 171S-174S.

Willett, W. C., Sampson, L., Stampfer, M. J., Rosner, B., Bain, C., Witschi, J., Speizer, F. E. (1985). Reproducibility and validity of a semiquantitative food frequency questionnaire. *American Journal of Epidemiology, 122*(1), 51-65.

Wong, J. E., Parnell, W. R., Black, K. E., & Skidmore, P. M. (2012). Reliability and relative validity of a food frequency questionnaire to assess food group intakes in New Zealand adolescents. *Nutrition Journal, 11*(1), 65.

Zhu, F., Bosch, M., Woo, I., Kim, S., Boushey, C. J., Ebert, D. S., & Delp, E. J. (2010). The use of mobile devices in aiding dietary assessment and evaluation. *IEEE Journal of Selected Topics in Signal Processing, 4*(4), 756-766.

Ziegler, P. J., Jonnalagadda, S. S., Nelson, J. A., Lawrence, C., & Baciak, B. (2002). Contribution of meals and snacks to nutrient intake of male and female elite figure skaters during peak competitive season. *Journal of the American College of Nutrition, 21*(2), 114-119.