Low Energy Availability in Elite Female Athletes: Risks and Remediation

By

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TABLE OF CONTENTS

ABSTRACT

Background

Low energy availability (LEA) occurs due to a mismatch between energy intake and energy expenditure. Consequently, there is inadequate energy to support basic physiological functions. Leanness sport athletes can be at risk of LEA due to high energy expenditure during training and competition, and restricted dietary intake. These athletes often face pressure to maintain a lean physique, leading to a preoccupation with maintaining a lean body composition, achieved through restriction of dietary energy intake.

Research on LEA has primarily focused on sports that emphasise a lean body physique, however athletes from other sports may also be at risk of LEA. This PhD project involved a comparison of endurance, aesthetic, and team sports athletes. The aims were to identify the prevalence and manifestation of LEA in these sports as well as testing the effectiveness of a ‘Food First’ motivational interviewing (MI) intervention to remediate LEA.

Methods

This project comprised four studies involving a literature review, validation of a dietary supplements intake questionnaire and a pilot study to trial a qualitative investigation into determinants of food choice among a range of athletes from different sports. These studies were used to inform the fourth study investigating LEA prevalence and the effectiveness of a ’Food First’ MI intervention.

Dietary intake, exercise energy expenditure and body composition were all measured at baseline and completion of the study to calculate energy availability (EA). Participants with LEA at baseline received the intervention (‘Food First’ personalised MI) and others received a general sports nutrition infographic as a control. A dietary supplements intake questionnaire (developed in chapter 3) was completed by all participants to assess the contribution of dietary supplement intakes to nutrition status. The MI intervention aimed to address LEA and correct any nutrient deficiencies identified through changes to dietary intake without reliance on supplements.

Results

Results demonstrated that LEA was prevalent among all sports, not just sports focused on a lean body composition such as endurance and aesthetic sports. The manifestation of LEA was investigated through the analyses of nutrient and food group intakes which showed that athletes with LEA commonly had low carbohydrate and inadequate dairy food intakes. The intentional or unintentional restriction of these foods were linked to the occurrence of LEA across each of the sports groups. Complementary qualitative data indicated the main influences on food choice were external including family, friends and demands of their sport.

The MI intervention was successful in increasing the energy availability of athletes with LEA from all sports, but not enough to surpass the LEA threshold of 30 kcal.kg FFM.dy^{-1}.

Conclusion

Further research is required to improve the 'Food First' MI intervention to successfully remediate LEA in female athletes. Athletes may require more education on the importance of adequate dietary intake, particularly carbohydrate rich foods and dairy foods. The intervention may need to be extended to family and friends as major influencers on food choice and to allow for more sessions with each athlete to provide further education and follow-up on their progress.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed...

Date................01/07/2023..................

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Lastly Mum, my hero, inspiration, backbone, cheerleader, and the main reason I have been able to finish this PhD. I am forever grateful for everything that you do.

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 INTRODUCTION

Low energy availability (LEA) occurs in athletes when there is a mismatch between energy intake and energy expenditure, causing both performance and health consequences (Mountjoy et al., 2018a). It is well documented in the literature that low energy availability is prevalent amongst female athletes. Much of the research has focused on female athletes from leanness-focused sports such as endurance sports that favour a high power-to-weight ratio (Melin et al., 2015; Melin et al., 2016) or sports with an aesthetic component such as gymnastics (Silva & Paiva, 2015; Civil et al., 2019; Costa et al., 2019). Low energy availability in other sports such as team sports has not been well researched. This is likely due to the belief that these sports place less emphasis on body composition and that athletes are therefore less likely to restrict their nutrition intake (Wright et al., 2014). These findings were supported by a review of the literature that was undertaken prior to designing this PhD project, outlined in chapter 2.

This PhD project aimed to directly compare the prevalence of low energy availability among female athletes from endurance, aesthetic and team sports, using the same methods to measure exercise energy expenditure, nutrition intake and body composition in each sport (chapter 5). Athletes' dietary supplement use habits were also analysed using a questionnaire that was validated in chapter 3. The manifestation of low energy availability and determinants of food choice among athletes were investigated using qualitative research methods that were piloted in chapter 4. The intervention study of the PhD, reported in chapter 5, involved investigating the effectiveness of a 'Food First' motivational interviewing (MI) intervention to remediate LEA.

1.1 Energy Availability

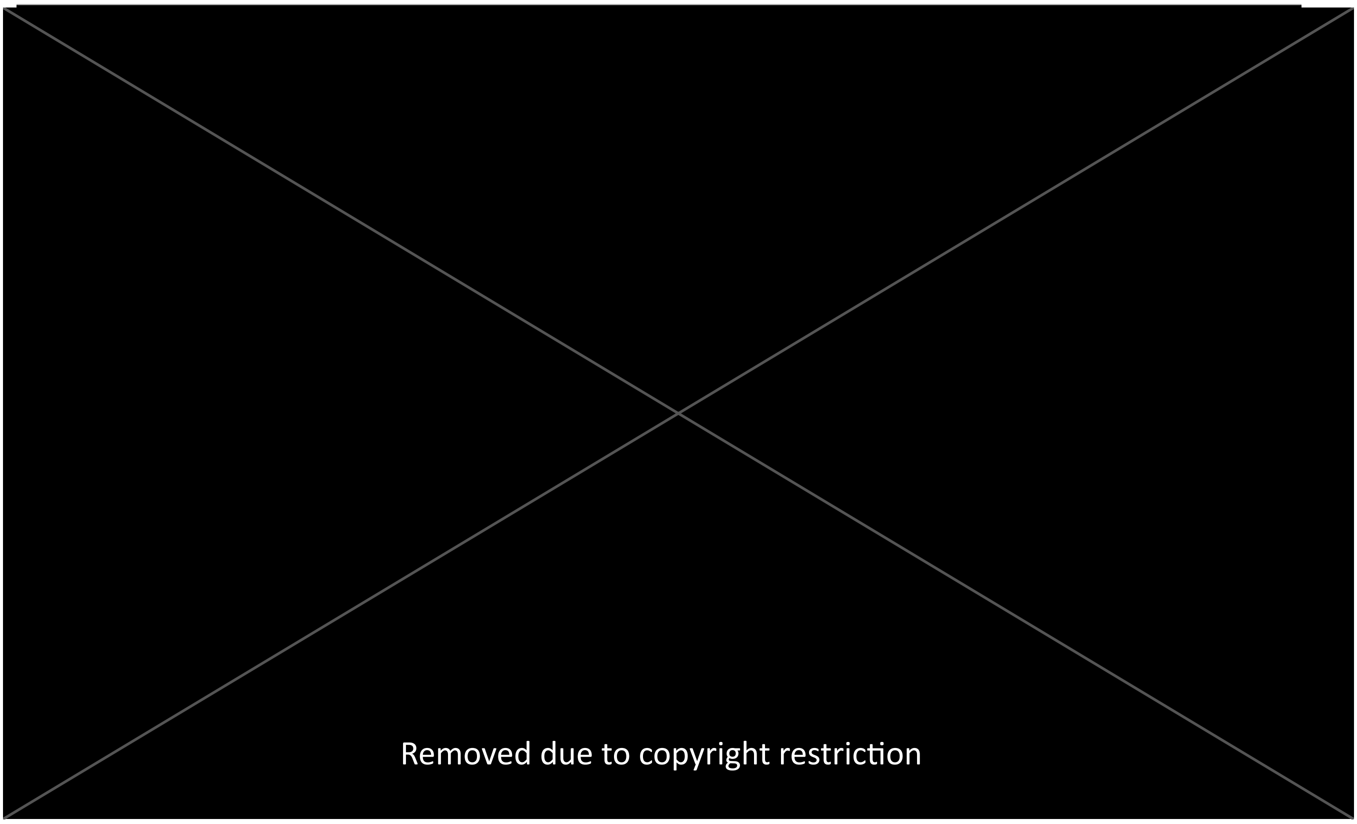
Energy availability is the amount of energy remaining for the body's physiological functions after energy expended during exercise has been accounted for. Energy availability is calculated using energy intake (EI), exercise energy expenditure (EEE) and fat-free mass (FFM) (Mountjoy et al., 2018a).

Energy Availability (EA) =

[Energy Intake (EI) (kcal) – Exercise Energy Expenditure (EEE) (kcal)] / Fat-Free Mass (FFM) (kg) (Mountjoy et al., 2018a)

Several methods can be used to measure energy availability parameters. Energy intake (EI) is a measure of overall energy provided through food and beverage intake. This can be measured using different methods such as weighed food and beverage records over several non-consecutive days to provide a quantitative record of daily intakes, estimated prospective dietary records which collect current diet for a specified period of time, 24-hour recalls that capture all food and beverages consumed in the past 24-hours through a structured interview, and food frequency questionnaires which are lists of food and beverages that require respondents to record how frequently the foods are consumed. Exercise energy expenditure (EEE) is the energy expended during planned physical exercise. This can be measured using tri-axial accelerometers which use predictive equations to convert the data collected into metabolic equivalents (METs), activity logs recording details such as session length and rate of perceived exertion (RPE), and heart rate monitors which can be used to estimate energy expenditure based on the assumption that there is a linear relationship between heart rate and oxygen consumption. Body composition can be measured to calculate fat-free mass (FFM) using skinfold measurements at 7-sites measured by an ISAK-accredited anthropometrist, dual-energy X-ray absorptiometry (DXA) scans which use low-dose x-rays to measure lean muscle mass and bone mineral content to calculate FFM, and bioelectrical impedance analysis (BIA) which uses electrical impedance to estimate total body water which can be used to calculate FFM.

Low energy availability is a precursor to Relative Energy Deficiency in Sport (RED-s) which refers to the impairment of physiological functions caused by relative energy deficiency, involving metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health (Mountjoy et al., 2014). The term RED-s evolved from the term Female Athlete Triad which was characterised by low energy availability with or without disordered eating, menstrual dysfunction and low bone mineral density or osteoporosis (Barrack et al., 2013; Mountjoy et al., 2014). The evolution from the Female Athlete Triad to RED-s acknowledges the complexity of the outcomes related to low energy availability (Mountjoy et al., 2014). It was identified that bone health and menstrual function were not the only health parameters affected by low energy availability, health consequences also affecting other physiological systems such as cardiovascular, gastrointestinal and metabolic systems (figure 1)(Mountjoy et al., 2014; Mountjoy et al., 2018a). As well as including more health consequences the update to RED-s recognised that performance consequences were also an outcome of LEA (figure 2) (Mountjoy et al., 2014; Mountjoy et al., 2018a). The transition from the Female Athlete triad to RED-s importantly acknowledged that male athletes can also be affected by LEA (Mountjoy et al., 2014; Mountjoy et al., 2018a). This is supported by research which has shown that RED-s can occur in both male and female athletes, however the biological response may be different (Viner et al., 2015; Tenforde et al., 2016; Mountjoy et al., 2018a; Tenforde et al., 2018). The threshold and duration of LEA in males to leading to RED-s requires further research as currently most research on LEA has been done on populations of female athlete (Mountjoy et al., 2018a). The prevalence of LEA and consequently RED-s is likely higher in female athlete populations due to higher rates of eating disorders (Martinsen & Sundgot-Borgen, 2013) and greater participation in aesthetic sports such as gymnastics (Beals & Manore, 2002; Silva & Paiva, 2015). Research has supported this, although the exact difference between the prevalence of LEA and RED-s in female and male athletes is unknown (Loucks, 2007; Mountjoy et al., 2018a).



(Mountjoy et al., 2018a)

1.2 Low Energy Availability (LEA)

Low energy availability (LEA) is caused when there is a mismatch between energy intake and exercise energy expenditure (Melin et al., 2019). This happens when the energy expended through exercise outweighs energy intake leaving inadequate energy for physiological functions (Civil et al., 2019). This disparity between energy intake and expenditure is multi-factorial and likely caused by restrictive eating behaviours, disordered eating, poor nutrition knowledge, lack of time and organization, financial struggles and lack of food preparation skills (Melin et al., 2015; Melin et al., 2016; Devlin et al., 2017; McCormack et al., 2019; Zabriskie et al., 2019; Brown et al., 2020b). As well as these factors, many female athletes are also impacted by societal body image expectations and feel the need to achieve an 'athletic' body shape (Stoyel et al., 2021). Dietary restriction to maintain a particular body shape has also been exacerbated by social media, which often makes a comparison between athletes' own body, diet and lifestyle with their peers or other athletes (Wells et al., 2015; Stoyel et al., 2021; Scott et al., 2022).

Female athletes are at an increased risk of low energy availability due to the substantial amounts of energy expended during training and competition (Melin et al., 2016; Mountjoy et al., 2018a). Energy intake needs to be manipulated across the sports season to match the changes in energy expenditure (Reed et al., 2014; Zanders et al., 2018). This requires an understanding of sports nutrition principles to have the knowledge to increase and decrease energy intake to match variations in daily energy requirements (Reed et al., 2014; Zanders et al., 2018; Condo et al., 2019; Jenner et al., 2019; Zabriskie et al., 2019).

Female athletes may experience LEA due to restricting their dietary intake to manipulate body composition (Laramée et al., 2017; Mountjoy et al., 2018a). This is due to the pressure some female athletes experience to perform well and maintain a certain body composition that is preferable for their sport. For example endurance sports are considered a 'leanness' sport as a lean body composition is favoured to increase power-to-weight ratio and potentially move more efficiently (Melin et al., 2015; Melin et al., 2016; McCormack et al., 2019; Beermann et al., 2020). Aesthetic sports also favour a lean body composition as this provides an advantage when performing certain movements and is perceived to be more visually appealing to judges when performing at an elite level (Silva & Paiva, 2015; Schaal et al., 2017; Civil et al., 2019; Costa et al., 2019). Alternatively, evidence suggests some team sports place less focus on a lean body composition and are considered a 'non-leanness sport' (Wright et al., 2014; Zanders et al., 2018; Zabriskie et al., 2019).

1.3 Nutrition Sequelae of LEA

Apart from low energy intake there are other nutrition characteristics that are often linked to LEA. Individuals with LEA commonly fail to meet macronutrient intake recommendations, which are the energy-providing nutrients in the diet (Melin et al., 2016). Carbohydrates and fat are the macronutrients that are commonly avoided when trying to maintain a lean body composition to avoid weight gain (Bisogni et al., 2012; Masson & Lamarche, 2016; Melin et al., 2016; Eck & Byrd-Bredbenner, 2019). The avoidance of carbohydrate foods is due to the common misbelief that they are fattening, which is particularly concerning as carbohydrates are the main fuel source used for high intensity exercise (Eck & Byrd-Bredbenner, 2019). Athletes who demonstrate LEA instead choose low-energy density, high-volume, high-fibre foods to increase satiety and decrease energy intake (Melin et al., 2016; Brown et al., 2020a; Challis et al., 2020; Villa et al., 2021; Graybeal et al., 2022a; Fahrenholtz et al., 2023). As a result, these athletes may fail to meet the carbohydrate intake recommendations required to perform prolonged sub-maximal or intermittent high-intensity exercise (Burke et al., 2013).

Micronutrient deficiencies are also common in LEA due to limited dietary intakes or avoidance of certain food groups. For example, fat soluble vitamins (A, D, E & K) may be deficient due to an avoidance of dietary fat to prevent body weight gain (Bisogni et al., 2012; Melin et al., 2016; de Oliveira et al., 2021; Kontele et al., 2022). Dietary calcium intake is often inadequate due to the avoidance of dairy products for their perceived fat content and misguided belief that they cause body weight gain (Condo et al., 2019; Eck & Byrd-Bredbenner, 2019; Jenner et al., 2019; Beermann et al., 2020; Villa et al., 2021; Matt et al., 2022). Inadequate dietary iron intake and iron deficiencies are also common among female athletes with LEA, mainly caused by iron losses during menses and inadequate dietary iron intake. Dietary iron inadequacy may be due to the avoidance of animal protein foods, due to taste preference or the perception that they are 'fattening' (Robertson et al., 2014; Melin et al., 2016; Beermann et al., 2020; Matt et al., 2022).

1.4 Consequences of LEA

There are consequences to both athlete health and sports performance that occur as a result of LEA. Due to the lack of energy available to support physiological functions, there are many health consequences that occur such as poor bone health, menstrual dysfunction, metabolic adaptations (i.e. decreased resting metabolic rate), psychological difficulties (i.e. depression, disordered eating), compromised immune system, cardiovascular disturbances (poor lipid profile, low blood pressure) and gastrointestinal disturbances (delayed gastric emptying, constipation, increased transit time) (Day et al., 2015; Melin et al., 2015; Fahrenholtz et al., 2018; Heikura et al., 2018; Mountjoy et al., 2018a; Civil et al., 2019). LEA is also detrimental to sports performance and has been associated with increased injury risk, particularly bone stress fractures, decreased training response, impaired muscle strength, poor endurance performance, decreased glycogen stores, impaired judgement, decreased coordination, trouble concentrating, irritability and depression (Mountjoy et al., 2018a).

Due to the poor outcomes for both performance and health, it is important that LEA is addressed in female athlete populations. As a dietitian or health practitioner it is important to understand the manifestation of LEA in order to identify and address the issue. However, there are few studies on how LEA manifests in female athletes and whether the manifestation differs between different types of sports such as leanness and non-leanness sports. This is a major focus of this PhD project (Chapter 5).

1.5 Manifestation of LEA

Low energy availability may be either intentional or unintentional depending on an athlete's circumstances and consequent food choices. Food choices among female athletes may be affected by many factors, both personal and external. For example, the known or perceived effects of different foods on sports performance can modify food choices among individual athletes (Birkenhead & Slater, 2015; Akah et al., 2020; Pelly et al., 2022). Time availability around training and competition to be able to shop, prepare and eat food can be another factor that may influence habitual food intake (Birkenhead & Slater, 2015; Stickler et al., 2016). The nutrition attitudes of coaches, sports staff and teammates may be a deciding influence on food choice for many athletes (Stickler et al., 2016; Stokes et al., 2018; Scott et al., 2022). Sport-specific nutrition beliefs associated with the preferred physique within their sport may also be a strong factor that leads to modified food intake among female athletes (Birkenhead & Slater, 2015; Thurecht & Pelly, 2020; Eck & Byrd-Bredbenner, 2021; Stoyel et al., 2021).

Food choices are important for athletes as they can affect both health and performance, particularly if the choices made lead to LEA (Akah et al., 2020; Thurecht & Pelly, 2020; Pelly et al., 2022). Unintentional LEA may occur when factors such as time availability or lack of nutrition knowledge cause athletes to make poor food choices, leading to inadequate nutrition intake (Loucks, 2004; Reed et al., 2014; Stickler et al., 2016). Intentional LEA may occur when athletes feel pressured to maintain a certain physique for their sport and consequently make food choices to restrict their nutrition intake (Wells et al., 2015; Thurecht & Pelly, 2020; Stoyel et al., 2021). In order to address LEA it is important to understand the determinants of food choice within different athlete populations. This led to the design of a qualitative pilot study that aimed to investigate the determinants of food choice among female athletes from both leanness and non-leanness sports (Chapter 4).

1.6 Supplement Intake Behaviours in Female Athletes

The use of dietary supplements has increased in popularity and become progressively more prevalent among athlete populations (Knapik et al., 2015; Maughan et al., 2018). Female athletes concerned about energy intake and who are likely at risk of LEA may be particularly drawn to supplement use due to the perceived ability to correct nutrient deficiencies without increasing energy intake. It is not uncommon for athletes to take high-dose dietary supplements daily (Benardot et al., 2014; Knapik et al., 2015), while giving minimal attention to their food choices, and taking supplements without understanding the potential effects or correct dose and timing (Casazza et al., 2018). A common use of supplements is to correct nutrient deficiencies without having to alter diet, although it is often misunderstood that this is not a long-term solution and that nutrient deficiencies will return once supplement use has ceased (Shakur et al., 2012), unless appropriate dietary changes have been made. If taken long-term there is also an increased risk of toxicity occurring for some supplements such as vitamin E and B6, even when taken in the recommended doses (Robertson et al., 2014). For these reasons it is recommended that supplements are used under the supervision of an appropriate health professional, and that nutrients are derived from food sources rather than supplements where possible (Benardot et al., 2014; Robertson & Mountjoy, 2018; McCubbin et al., 2020). A healthy diet cannot be replaced by dietary supplements (Moss et al., 2021). The aim of the study presented in Chapter 3 was to validate a dietary supplement intake questionnaire that was used in the main study of this PhD (Chapter 5) to investigate dietary supplements use among endurance, aesthetic and team sport athletes and determine if there is a link between participants with LEA and high dietary supplement use. In addition, investigations were conducted during the main PhD study (Chapter 5) to determine whether nutritional adequacy was met with supplement use when dietary nutrient intakes were inadequate, using the validated dietary supplement intake.

1.7 Food First Motivational Interviewing

Motivational interviewing uses a client-centred approach to increase intrinsic motivation and decrease uncertainty to improve health behaviours (Hardcastle et al., 2017; Lee & Lim, 2019). Through uncovering emotional barriers motivational interviewing may improve the outcomes of nutrition education and counselling interventions (Bentley et al., 2021). The use of motivational interviewing in athlete populations with LEA is not prominent in the literature (Bentley et al., 2021), which was an identified gap addressed in this PhD project during the main study (Chapter 5). In addition to motivational interviewing, a 'food first' approach was used during this study, focusing on the use of food rather than supplements to address nutrient inadequacies.

Interventions to address nutrition related concerns such as LEA in female athlete populations often focus on general sports nutrition education to improve nutrition knowledge. However, the use of general education alone has had poor outcomes and is not always effective in improving nutrition intakes (Valliant et al., 2012; Day et al., 2015; Nascimento et al., 2016; Laramée et al., 2017; Rossi et al., 2017). For example, education may have variable outcomes in diverse populations (e.g., according to sport, age, gender) or for different nutrients (e.g. macronutrients or micronutrients) (Nascimento et al., 2016; Rossi et al., 2017; Elias et al., 2018). Improvement in nutrition knowledge may also not directly translate into changes in nutrition intake and dietary habits (Day et al., 2015; Laramée et al., 2017; Pelly et al., 2022). To improve the outcome of nutrition education in this PhD project, a personalised motivational counselling technique was implemented with the intention of addressing nutrient deficiencies among female athletes identified with LEA. The outcomes of this MI nutrition intervention are reported in Chapter 5.

Research Aims

1. To determine the prevalence of LEA among elite female athletes from sports with different body composition requirements (Chapter 2 & 5)

2. To validate a dietary supplements intake questionnaire for use by female athletes to capture the frequency of dietary supplement intake and quantify nutrient intakes from supplements (Chapter 3)

3. To explore the determinants of food choice among elite female athletes with and without LEA (Chapter 4 & 5)

4. To determine how LEA manifests through dietary manipulation by examining food and beverage choices among elite female athletes identified with LEA (Chapter 5)

5. To evaluate the effectiveness of 'Food First' motivational interview counselling to remediate identified nutrient deficiencies associated with LEA in elite female athletes (Chapter 5)

Research Questions

1. Is LEA more prevalent among elite female athletes from lean body-composition sports than female athletes from other sports?

2. Are there demonstrated improvements in dietary risk factors for LEA following 'Food First' motivational interview counselling in participants identified with LEA?

Research Hypotheses

1. Null Hypothesis (H_0): There are no differences in the prevalence of Low Energy Availability in lean or non-lean body composition sports.

   Alternate Hypothesis (H_A): Low energy availability is more prevalent among female athletes from lean body-composition sports than female athletes from other sports.

2. Null Hypothesis (H_0): There are no improvements in the dietary risk factors among female athletes identified with LEA following 'Food First' motivational interview counselling.

   Alternate Hypothesis (H_A): There are improvements in the dietary risk factors of female athletes identified with LEA following 'Food First' motivational interview counselling.

CHAPTER 2 SCOPING REVIEW

2.1 Introduction

Female athletes are at risk of inadequate nutrition and related health and sports performance consequences, mainly due to increased nutrient requirements to meet the needs of training and competition. Further risks are associated with dietary restrictions to manipulate body composition. These factors increase the risk of low energy availability (LEA). Female athletes who strive to achieve a lean body composition for their sport are at greatest risk of LEA (Civil et al., 2019; Costa et al., 2019). For example athletes competing in endurance sports may restrict their dietary intakes to meet lean body composition goals (Melin et al., 2015; Melin et al., 2016) to maximise their power-to-weight ratio for performance efficiency. Aesthetic sport athletes prefer a lean figure that may be favoured by judges (Silva & Paiva, 2015) and perceived improvements in their sports performance. Some evidence suggests athletes such as those participating in team sports are typically considered at lower risk of LEA due to placing less focus on maintaining a certain body composition for their sport (Wright et al., 2014), although this evidence is equivocal.

Research on energy availability in athlete populations is prominent in the literature, with many studies having reported the prevalence of LEA in populations of female athletes (Logue et al., 2018; Logue et al., 2020). However, few studies have compared the energy availability of athletes from different sports within the same study. Most studies use different methods to measure the variables used to calculate energy availability (i.e., energy intake, exercise energy expenditure and fat-free mass). Comparison of results from different studies may lead to errors or bias that could be eliminated by direct comparison within a study using the same methods to measure the variables used to calculate LEA.

Apart from investigating the prevalence of LEA in female athlete populations, no studies have reported on its dietary manifestations. Exclusion of perceived energy-dense foods may be one method used by female athletes to manipulate their body composition to meet a perceived ideal or improve performance. Increasing dietary intakes of low energy, high fibre foods may be another method used to meet body composition goals. This is important information which to date has been underreported in the current literature. An advantage of understanding the dietary manifestations of LEA may be useful to assist athletes with appropriate dietary changes to improve their energy availability and possibly reverse their LEA status. Investigation of the dietary manifestations of LEA among identified female athletes is a novel and key focus of this PhD project.

A further key difference in LEA prevalence is whether or not LEA is intentional or inadvertent. For example, female athletes could be intentionally restricting energy intake to lose weight to meet body composition goals, or they could be unintentionally under-fuelling due to a lack of nutrition knowledge.

There is a paucity of published qualitative and quantitative research reports about the manifestations of LEA in female athletes from different sports. In this PhD project, in-depth investigations of dietary choices and factors that may influence these choices are an important advancement in understanding LEA. With this information at hand, an intervention used to reverse LEA could be tailored to the sport and individual female athletes' requirements. It may also help to identify any differences in LEA manifestation among athletes from different sports, and whether there are certain factors within sports that increase the risk of LEA.

This scoping review will identify relevant studies that have investigated the occurrence of LEA across different types of sports, including endurance, aesthetic, and team sports. Findings from studies that have reported LEA among female athletes will be compared and critiqued within the scope of LEA prevalence, poor health outcomes linked to LEA, and dietary habits in these athlete populations.

2.2 Search Strategy

The electronic databases SPORTDiscus, Medline, CINAHL and Scopus were searched for peer-reviewed scientific literature in the relevant area of low energy availability. The keywords (TI Title and AB Abstract) used to search the databases included: (1) 'Athletes, Female', (2) 'Low Energy Availability', (3) 'Female Athlete Triad', 'Relative Energy Deficiency', (4) 'Aesthetic Sport' OR 'Endurance Sport' OR 'Team Sport'. Hand searches of relevant but ineligible articles such as systematic reviews and consensus statements were conducted to provide further literature.

2.2.1 Eligibility Criteria

The resulting articles from searches were considered if they were published within the last 9 years (2014 – 2023), written in the English language, peer-reviewed and available in full-text. Two independent reviewers critically appraised and screened the studies for relevance to the objectives of this scoping review. Studies included were those conducted among female athletes, competing at an elite level. Elite were classified as athletes competing at state, national and international levels within their sport type. Articles that focused on young adolescents, recreational or high school level athletes were excluded from this review.

The inclusion criteria also required that the studies measured and calculated LEA using energy intake, exercise energy expenditure and body composition measurements. The equation used was Energy Availability (EA) = [Energy Intake (EI) (kcal) – Exercise Energy Expenditure (EEE) (kcal)] / Fat Free Mass (FFM) (kg).

2.2.2 Data Extraction

Summary Tables were created to record the following data: authors, publication year, sample size, sport type, athletes' age-group, methods used to measure energy intake, exercise energy expenditure and body composition, energy availability (kcal/kg FFM/day) and the percentage of participants found with LEA (Appendix 1). Articles were classified into categories depending upon the type of sport, including endurance, aesthetic, and team sports. The numerical data extracted included group means for relevant data variables, and percentages to represent the prevalence of LEA. These data were compared both within and between the different sport categories. For example, the mean energy availability of endurance athletes was compared to that of other endurance athlete studies, but then also to the mean energy availability found in aesthetic and team sport athlete studies.

2.2.3 Search Results

Electronic database searches resulted in a total of 157 articles. Of these articles 82 were duplicates and a further 24 were removed upon initial screening. Assessing article abstracts for eligibility resulted in the removal of 23 articles and further assessment of full-text articles excluded another 20 articles. Throughout this process the reference lists of articles were scanned for other relevant articles not found in database searches, resulting in the addition of 10 articles. In total there were 18 articles included in the review, 8 additional articles were added that were published after the original search resulting in 26 articles. This review discusses the key themes that emerged from the included articles.

2.3 Results

2.3.1 Energy availability

Energy availability is defined as the amount of energy remaining for metabolic processes and general body functions after accounting for the energy expended during exercise (Mountjoy et al., 2018a). Low energy availability (LEA) occurs when there is a mismatch between energy intake and expended energy leaving inadequate energy for the body's physiological systems (Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019). This may lead to a decrease in sports performance due to a number of different factors, including increased risk of injury, decreased training response, impaired endurance performance, decreased muscle strength and low glycogen stores (Mountjoy et al., 2018a). LEA also increases the risk of several ill-health consequences among female athletes. These may include some or all of the following; menstrual dysfunction, impaired bone health, disordered eating, gastrointestinal problems, metabolic adaptation to conserve energy and poor immune function (Day et al., 2015; Fahrenholtz et al., 2018; Mountjoy et al., 2018a; Civil et al., 2019).

Energy Availability (EA) of at least 45 kcal.kg FFM.dy^{-1} (188 kJ.kg FFM.dy^{-1}) is required for sedentary women to maintain optimal physiological function (Melin et al., 2015; Civil et al., 2019). Severe endocrine and metabolic alterations occur when EA decreases to <30 kcal.kgFFM.d^{-1}(125 kJ/.kgFFM.d^{-1}) for only a short period of time (5 days) (Melin et al., 2015). EA <45 kcal.kg FFM.dy^{-1} is commonly described as at risk of LEA, and <30 kcal.kgFFM.dy^{-1} as manifest LEA (Melin et al., 2015; Civil et al., 2019). All athletes need adequate energy intake during training and competition, especially when training load is increased, to avoid fatigue, injury, and illness (Melin et al., 2016). Therefore, athletes may be at increased risk of LEA due to their high energy expenditure during training and competition.

Inadequate energy intake to support the increased requirements of training and competition can occur due to several reasons, which may be unintentional or intentional. Unintentional low energy intake may be due to poor sports nutrition knowledge (Day et al., 2015; Zanders et al., 2018; Civil et al., 2019) concurrent with underestimated energy requirements for the volume or type of exercise performed. Further difficulties with the estimation of energy requirements among athletes is the variation in energy expenditure across a season, such as changes in training volume from pre-season to mid-season. Energy intakes need to be tailored to each phase of the season, and requires an understanding of sports nutrition to increase and decrease energy intake to match energy expenditure (Reed et al., 2014; Zanders et al., 2018; Condo et al., 2019; Jenner et al., 2019; Zabriskie et al., 2019). Other reported reasons for unintentional inadequate energy intake include lack of time for food shopping and preparation, financial hardship, and poor cooking skills (Devlin et al., 2017; Zabriskie et al., 2019; Brown et al., 2020a).

Inadequate energy intake can also be intentional to manipulate body composition. Athletes competing in leanness sports such as endurance and particularly aesthetic sports may purposefully restrict their energy intake to maintain a lean body composition to meet expectations in their sport (Melin et al., 2015; Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019). There are specific sports that favour a lean or slim body composition with the perception that this will enhance performance. Endurance sport athletes prefer a lean body composition for energy efficiency and a higher power-to-weight ratio (Melin et al., 2016; Beermann et al., 2020) with the goal to maximise performance. Similarly, aesthetic sport athletes favour a lean body composition but with different goals, including performance of technical movements and aesthetic appeal to judges (Silva & Paiva, 2015; Civil et al., 2019; Costa et al., 2019). A focus on achieving and maintaining a lean body composition can lead athletes to restrict their energy intakes and avoid foods that they perceive as 'bad' or 'fattening' (Eck & Byrd-Bredbenner, 2019). This may then lead to LEA due to a mismatch between energy intake and energy expenditure (Melin et al., 2019).

2.3.2 Poor Health Consequences

There are many poor health outcomes associated with LEA among female athletes. These may include menstrual dysfunction, impaired bone health, disordered eating, gastrointestinal problems, metabolic adaptation to conserve energy and poor immune function (Day et al., 2015; Fahrenholtz et al., 2018; Mountjoy et al., 2018a; Civil et al., 2019). When there is inadequate energy available for normal physiological function, metabolic adaptations automatically occur to reduce the overall amount of energy used in an attempt to restore energy balance (Melin et al., 2015; McCormack et al., 2019). This may involve a reduction in resting metabolic rate (RMR) and non-exercise activity thermogenesis (NEAT), and increased workload efficiency to help restore energy balance (Fahrenholtz et al., 2018). A review of each of these factors associated with poor health outcomes among athletes with LEA is beyond the scope of this PhD project. Therefore, dietary factors that directly influence the LEA-associated poor health outcomes are the focus of this review.

Among female athletes with LEA, low bone mineral density (LBMD) is linked to low energy availability and inadequate nutrient intakes associated with energy restriction (Goodwin et al., 2014; Heikura et al., 2018; Mountjoy et al., 2018a; McCormack et al., 2019). LEA can lead to increased bone turnover (Day et al., 2015) leading to LBMD by impairing bone microarchitecture (Civil et al., 2019). The effect of LEA on bone health is mediated by endocrine factors including the estrogen-dependent pathway, in which hypo-oestrogenism associated with low body fat mass increases the rate of bone resorption. Also via the oestrogen-independent pathway by suppressing insulin, IGF-1, and leptin, which reduces bone formation (Melin et al., 2015). These perturbations have been reported to occur at an energy availability of 30 kcal.kgFFM.dy^{-1} or less (Heikura et al., 2018).

Through negatively impacting bone accrual, LEA can adversely affect peak bone mass and lead to bone stress injuries (McCormack et al., 2019). Young adult female athletes with LEA may not optimise bone mineral accrual to achieve an adequate peak bone mass (Civil et al., 2019), thereby increasing their risk of bone stress injuries and potential impairment to sports performance (Melin et al., 2015; McCormack et al., 2019).

A critical dietary factor linked to LEA that negatively affects BMD is inadequate intake of nutrients required for bone health. Calcium plays an essential role in bone structure and health (Goodwin et al., 2014) and dietary intakes of this micronutrient reportedly do not meet recommendations among many female athletes (Goodwin et al., 2014; Costa et al., 2019; McCormack et al., 2019). This can increase the risk of LBMD and development of stress fractures, which can have detrimental effects on sports performance and long-term bone health (Heikura et al., 2018; Mountjoy et al., 2018a; Tenforde et al., 2018; Costa et al., 2019). Athletes from 'leanness' sports are at greater risk of inadequate dietary calcium intakes, as calcium rich foods are often avoided due to the perception that they are high in fat and therefore 'fattening' (Bisogni et al., 2012; Eck & Byrd-Bredbenner, 2019; Villa et al., 2021) which is anathema to athletes striving for a lean body composition. Vitamin D also affects bone health through regulating the uptake of dietary calcium, particularly when dietary calcium intakes are inadequate (Burke & Deakin, 2010; Todd et al., 2014), a scenario often observed among athletes with LEA (Goodwin et al., 2014; Costa et al., 2019; McCormack et al., 2019). Dietary intakes of vitamin D (ergocalciferol) are less important to calcium status and bone health, as much of the Vitamin D synthesis (cholecalciferol) in young adults occurs through the reaction of sunlight (UVB rays) on the skin (Todd et al., 2014). However, some athletes may not be exposed to adequate sunlight due to exclusively training indoors or wearing sun protection such as sunscreen or sun protective clothing while training outdoors (Larson-Meyer & Willis, 2010; Zürcher et al., 2018). If dietary intakes are inadequate for these athletes, they may be at risk of low Vitamin D status and associated LBMD. In these instances, attention to intakes of Vitamin D-rich foods or even supplementation are indicated.

2.3.3 Type of Sport

Endurance Sport Athletes

Endurance sport athletes strive for a lean body composition to increase power-to-weight ratio, to assist with energy efficient movement (Melin et al., 2015; Melin et al., 2016; McCormack et al., 2019). The energy requirements of female endurance athletes vary considerably depending upon type of activity (e.g., running, walking, cycling) and training load, although have been reported to reach up to 4000 kcal/day (16,720 kJ/day) (Melin et al., 2016). However, the energy intakes of female endurance athletes have been reported as similar or lower than sedentary women (7535-9209 kJ/d) (Beidleman et al., 1995; Melin et al., 2016).

Low energy intakes among female endurance athletes may be unintentional due to difficulties eating enough during periods of high volume training, causing energy expenditure to exceed energy intake (Melin et al., 2015). However, intentionally restrictive eating behaviours are common in these sports which are often referred to as thin build or leanness sports (McCormack et al., 2019). Due to excess body weight influencing performance by decreasing the power-to-weight ratio, athletes restrict food intake to maintain a low body weight (Melin et al., 2016). The combination of high energy expenditure and low energy intake from food increases the risk of LEA in these female endurance athletes. Restrictive eating habits may also lead to subsequent macro and micronutrient deficiencies due to the removal or restriction of certain foods from the diet. Female endurance athletes experiencing LEA often report inadequate carbohydrate intakes due to the inaccurate belief that carbohydrates are fattening (Eck & Byrd-Bredbenner, 2019; Matt et al., 2022). This is particularly concerning as carbohydrates are critical to support endurance exercise (Holtzman & Ackerman, 2021; Moore et al., 2021).

Studies measuring LEA found that within populations of endurance sport athletes mean energy availability ranged from 23.8 ± 8.9 to 42.5 ± 12.1 kcal.kg FFM.dy^{-1} (Viner et al., 2015; Melin et al., 2016). Similar to the main study of this PhD, studies on endurance athletes have split the participant group into those with LEA (<30 kcal.kgFFM.dy^{-1}) and without LEA (>30 kcal.kgFFM.dy^{-1}) (Heikura et al., 2018; Kinoshita et al., 2021), to investigate the difference between athletes in these groups. The mean energy availability of those with LEA was 24 ± 6 kcal.kg FFM.dy^{-1} and 16.5 ± 7.5 kcal.kg FFM.dy^{-1} and for those without LEA 38 ± 8 kcal.kg FFM.dy^{-1} and 44.3 ± 6.6 kcal.kg FFM.dy^{-1} (Heikura et al., 2018; Kinoshita et al., 2021). The difference between the EA of athletes with and without LEA was statistically significant for both studies, demonstrating that energy availability ranged widely within these populations and prompting further investigation into why this is.

Aesthetic Sport Athletes

Aesthetic sports such as gymnastics, trampolining, synchronised swimming, ballet and DanceSport are examples of sports that emphasise leanness as a necessary factor for successful competitive performance (Schaal et al., 2017). Aesthetic sports typically consider a lean body composition to be advantageous for artistic expression and performance of powerful movements in a graceful manner (Civil et al., 2019). Leanness has also been described as valuable for technical performance and more visually or aesthetically pleasing for judges' assessment at an elite level (Silva & Paiva, 2015).

The emphasis on being lean for visual appeal often leads to preoccupation with physique among these female athletes, with some reportedly restricting their energy intake to reach the desired lean physique (Costa et al., 2019). It is commonly reported that aesthetic sport athletes have inadequate carbohydrate intakes (Civil et al., 2019; Costa et al., 2019; Brown et al., 2020a; Challis et al., 2020; Villa et al., 2021). Carbohydrate foods may be restricted by athletes to decrease energy intake to manipulate body composition for their sport (Costa et al., 2019), subsequently causing LEA. Aesthetic athletes are expected to maintain a high volume of training, maintaining strength, flexibility and both aerobic and anaerobic capacity (Schaal et al., 2017; Costa et al., 2019). The combination of restricted intake and a demanding physical training load places these athletes at an increased risk of LEA.

Within aesthetic sport groups it was found that mean energy availability of athletes ranged from 12.2 ± 11.3 – 38 ± 13 kcal.kg FFM.dy^{-1} (Civil et al., 2019; Torres-McGehee et al., 2021). Of the articles included in this scoping review, the lowest mean energy availability among all sports was found in aesthetic sport athletes, 12.2 ± 11.3 kcal.kg FFM.dy^{-1} in a population of ballet dancers (Torres-McGehee et al., 2021). This value was consistent with the literature which has demonstrated that female aesthetic athletes are at risk of LEA due to participating in a sport that is preoccupied with physique (Schaal et al., 2017; Civil et al., 2019; Costa et al., 2019).

Team Sport Athletes

Team sport athletes are generally considered at a lower risk of LEA than athletes from endurance and aesthetic sports which are typically more leanness focused sports (Wright et al., 2014).

However, emerging evidence suggests team sport athletes can still present with LEA and consequential health and sports performance concerns (Devlin et al., 2017; Braun et al., 2018; Zanders et al., 2018; Condo et al., 2019; Jenner et al., 2019; Zabriskie et al., 2019; Magee et al., 2020).

Team sport athletes may fail to meet increased energy requirements by eating less than required during training and competition periods (Reed et al., 2014; Braun et al., 2018; Zanders et al., 2018; Zabriskie et al., 2019; Moss et al., 2021). Energy requirements change within team sports between individual athletes depending upon many factors such as position, level of competition, individual training demands and body composition goals (Devlin et al., 2017; Condo et al., 2019; Jenner et al., 2019; Zabriskie et al., 2019). These factors suggest greater inter-individual variability in energy requirements compared to individual endurance or aesthetic sports. Team sport athletes may lack nutrition knowledge to periodise their nutrition intake to daily energy expenditure (Condo et al., 2019). This may lead to inadequate energy and nutrient intakes, particularly carbohydrates which should be increased on training days to support high intensity efforts (Jenner et al., 2019; Renard et al., 2021).

The energy availability of female team sport athletes was found to range from 23 ± 9 to 47.6 ± 5.2 kcal.kg FFM.dy^{-1} for team sport athletes (Zanders et al., 2018; Zabriskie et al., 2019). A study on female soccer players split participants into those with LEA (<30 kcal.kgFFM.dy^{-1}) and without LEA (>30 kcal.kgFFM.dy^{-1}) (Reed et al., 2014). The energy availability of players throughout the season were 19.7 ± 4.3 (EA <30) vs. 52.3 ± 5.0 (EA >30) during pre-season and 19.5 ± 2.1 (EA <30) vs. 43.0 ± 3.2 (EA >30) mid-season (Reed et al., 2014). These differences were found to be statistically significant, demonstrating that there was a large range of energy availability throughout the season (Reed et al., 2014). This contrasts with the common assumption that all team sport athletes are less at risk of LEA due to these sports traditionally placing less pressure on body composition (Wright et al., 2014). These findings prompt the need for investigation into why team sport athletes are presenting with low energy availability, and whether the reason for LEA in these athletes differs from athletes who participate in leanness sports such as endurance and aesthetic sports.

Other Sports

It is important to note that athletes from other sports besides endurance, aesthetic and team sports may also be at risk of low energy availability. It is well documented that female athletes from weight-restricted or weight-category sports such as combat sports, weightlifting, lightweight rowing or horse racing take part in weight-making practices which may put them in a state of LEA (Dolan et al., 2011; Sundgot-Borgen & Garthe, 2011; Sundgot-Borgen et al., 2013; Reale, 2018; Gillbanks et al., 2022; Langan-Evans et al., 2022). These athletes likely take part in chronic or acute weight loss phases to compete in weight divisions below their day-to-day body weight to gain a competitive advantage (Sundgot-Borgen & Garthe, 2011; Sundgot-Borgen et al., 2013; Reale, 2018; Langan-Evans et al., 2022). Other athletes from sports that also don't fit into the categories of endurance, aesthetic and team sports may also be at an increased risk of LEA due to body composition pressures or expectations within their sport. Studies have reported that athletes from sports such as athletics, swimming, rock climbing, equestrian and fitness physique sports are also at risk of LEA (Torres-McGehee et al., 2011; Sygo et al., 2018; Melin et al., 2019; Mathisen et al., 2020; Wiggers et al., 2022; Klein et al., 2023; Monedero et al., 2023).

2.3.4 Prevalence of LEA

The prevalence of LEA among the different types of sports has been investigated by studies included in this review, expressed as the percentage of athletes demonstrating LEA (<30 kcal.kgFFM.dy^{-1}). The highest LEA prevalence was 96.2% which was found in a population of ballet dancers (Torres-McGehee et al., 2021), categorised as an aesthetic sport, which typically promotes a lean body composition and an expectation for a high prevalence of LEA. Surprisingly, the lowest prevalence of LEA was 12% in a group of endurance athletes (Melin et al., 2016). This latter finding does not fit with other evidence (Goodwin et al., 2014; Day et al., 2015; Heikura et al., 2018; Beermann et al., 2020; Kinoshita et al., 2021; Matt et al., 2022) for dietary restriction and inadequate energy intakes among female athletes in this sport. However, the prevalence of LEA among female endurance athletes in other studies ranged from 12 – 60% (Melin et al., 2016; Matt et al., 2022), with a similar wide range of LEA prevalence among aesthetic sport athletes was 22 – 96.2% (Civil et al., 2019; Torres-McGehee et al., 2021), and 16 - 67% prevalence range in team sport athletes (Reed et al., 2014; Magee et al., 2020). This large variability in the prevalence of LEA in each of these different sports suggests many differences in factors contributing to LEA occurrence between individuals. Determination of the factors that influence food choices associated with LEA is clearly important, as the evidence from these studies suggests the influence of the type of sport alone is not consistent. This variability in LEA prevalence across different types of sport was a deciding factor for this PhD project to examine the various influences on food choice in athletes from different sports, to determine whether a single factor or group of factors other than type of sport leads to LEA in female athletes.

The percentage of female athletes *at risk* of LEA (<45 kcal.kg FFM.dy^{-1}) was also identified in many studies (Goodwin et al., 2014; Day et al., 2015; Civil et al., 2019; Prus et al., 2022), although no at risk data was found for team sport athletes. Consistent with the prevalence of manifest LEA, considerable variability among at risk female athletes was found among female endurance sport athletes. A percentage range of female endurance athletes *at risk* of LEA was 92% to 56%, (Goodwin et al., 2014; Day et al., 2015) which is consistent with the hypothesis that endurance athletes strive for a lean body composition to maximise their sports performance using dietary methods that place them at risk of LEA. Among populations of female aesthetic sport athletes, 66 – 90% were *at risk* of developing manifest LEA (Civil et al., 2019; Prus et al., 2022). Similar to female endurance sport athletes, these results are consistent with the hypothesis that dietary restriction to achieve a lean body composition may be a critical contributing factor in the development of manifest LEA.

2.3.5 Measurement of LEA

The studies reviewed here measured energy intake, exercise energy expenditure and body composition data to calculate the energy availability of athletes. However, different methods were used among the studies to measure each of these parameters. The comparison of data from different studies is therefore unreliable due to the use of different measurement methodologies. For example, the different methods used to measure energy intake included 24hr recall, both weighed and estimated portion size prospective dietary records, and food frequency questionnaires. Energy expended during exercise was measured using different methods, including tri-axial accelerometers, activity logs and heart rate monitors. Body composition was also measured using different methods, including skinfold measurements, dual-energy X-ray absorptiometry (DXA) scans and bioelectrical-impedance analysis (BIA).

The prevalence and contributing data to LEA across two different types of leanness sports (endurance and aesthetic sport) with a typical non-leanness sport (team sport) have not been compared within one study, putting in question the veracity of comparative data from different studies. With the use of different methodologies across each sport to determine LEA, systematic bias may be a factor in data measurement and determination of prevalence. The potential measurement inconsistency was a motivating factor in the design of the study presented in this

PhD thesis, in which the measurement and prevalence of LEA was compared across different types of sport using the same methodologies.

2.4 Discussion

2.4.1 Prevalence of LEA

As demonstrated by the findings of this scoping review, Low Energy Availability (LEA) is prevalent among elite female athletes. The average energy availability of most of the athlete populations was below the recommended energy availability threshold (>45 kcal.kg FFM.dy^{-1}) for normal physiological function in females (Melin et al., 2015; Civil et al., 2019).

The high prevalence of LEA in elite female athletes was further shown by the percentage of athletes found to be either experiencing (<30 kcal.kgFFM.d^{-1}) or at risk of LEA (<45 kcal.kgFFM.d^{-1}), regardless of type of sport. This was a surprising finding, as historically the prevalence of LEA has been restricted to leanness sports in which a lean body composition is required. It was identified that up to 81% (Torres-McGehee et al., 2021) of female athletes across all sport types were diagnosed with LEA, and up to 92% (Goodwin et al., 2014; Day et al., 2015) were at risk of LEA, using the accepted diagnostic equation: Energy Availability (EA) = [Energy Intake (EI) (kcal) – Exercise Energy Expenditure (EEE) (kcal)] / Fat Free Mass (FFM) (kg) (Mountjoy et al., 2018a). This puts these athletes at risk of not only decreases in sport performance but also the health consequences linked to LEA, including menstrual dysfunction and low bone mineral density (LBMD) with an increased risk of bone stress injuries (Mountjoy et al., 2018a; Melin et al., 2023).

There were similarities found when comparing the incidence of LEA between endurance and aesthetic (leanness sports), and team sports (non-leanness sports). Much of the literature has focused on endurance and aesthetic sports due to the perceived pressures on these athletes to maintain a lean body composition (Day et al., 2015). None of the reported studies to date have directly compared the prevalence of LEA among these leanness and non-leanness sports within one study. Further investigation is required to compare leanness with non-leanness sports to determine whether there is a greater risk of LEA in sports that focus on maintaining a lean body type compared to those that do not. This gap in the literature was one of the aspects that informed the rationale for comparisons with the traditionally non-leanness team sport group in this PhD project.

The reported prevalence of LEA among female athletes leads to questions about the dietary manifestation and risk factors that may lead to the occurrence of LEA in all female athlete populations. As leanness is advantageous for performance in many sports, LEA is commonly linked to the intentional restriction of food to achieve a lean body composition (Melin et al., 2015). Ill-advised weight loss dietary practices may also be encouraged when appropriate nutrition services are unavailable or nutrition knowledge is inadequate (Civil et al., 2019). However, unintentional under eating is another risk factor for LEA, particularly in time poor athlete populations who have reduced eating opportunities (Civil et al., 2019). It is common for athletes to be ignorant of ensuring energy balance or inadvertently restricting energy intake (Goodwin et al., 2014). Elite female athletes often complete large volumes of training, leading to LEA due to difficulty meeting nutrition requirements during these heavy training periods (Melin et al., 2015). The paucity of evidence from the literature was another factor that informed investigations in this PhD project about the dietary manifestations of LEA. This was conducted through assessment of the contribution of formally identified Food Groups to overall nutritional intakes. This information may assist with providing more effective dietary advice to athletes identified with LEA.

2.4.2 Measurement of LEA

When analysing data measuring LEA, it must be accepted that there will be some errors in the measurement of energy availability. There are many limitations in the measurement of energy intake and exercise energy expenditure in real-world settings. There are no set guidelines for the calculation of energy availability in free-living athlete populations, including which methods should be used to measure energy intake, exercise energy expenditure and body composition/fat free mass (Civil et al., 2019). As well as these measurement limitations, the assessment of energy availability places a large burden on athletes who are time poor (Heikura et al., 2018). Energy intake is typically based upon self-reported food intake records, which often systematically underestimate energy intake (Fahrenholtz et al., 2018). Exercise energy expenditure can also be misrepresented, with athletes often overestimating their perceived effort or energy expended (Fahrenholtz et al., 2018). The use of activity tracking devices may also possibly underestimate energy expenditure by ~100-600kcal/day (Heikura et al., 2018).

The studies included in this scoping review used a variety of data collection methods. Energy intake was measured using weighed food diaries, prospective dietary records, food frequency questionnaires, 24hr recalls and dietary record apps. It is acknowledged there are specific errors or bias associated with each of these dietary intake methods. For example, weighed food diaries can lead to alterations in usual food intake due to the burden of weighing all foods consumed as well as underreporting of dietary intakes (Garden et al., 2018). Therefore habitual food intake may not be truly represented with this type of dietary intake record. Prospective dietary records may also be burdensome for busy athletes, leading to systematic under-reporting. In particular, snack foods may be omitted either purposefully or simply forgotten, especially if the athlete waits until the end of the day to complete their food diary (Burke, 2015). As this methodology requires usual household measurements to estimate amounts of foods and beverages consumed, measurement error is also likely to occur (Burke, 2015). Food Frequency questionnaires, including semi-quantitative questionnaires, are better employed in epidemiological studies, to gauge usual food intakes over 12 months by large populations. This dietary method does not provide the type of detail required for nutrient intake assessments, often leading to over-estimation of habitual nutrient intakes (Beck et al., 2020). Dietary recall methods such as the 24-hour recall are prone to systematic error, with both under-and overreporting of particular foods, depending upon the motivation of individual athletes, as well as the skill level of the interviewer (Jackson et al., 2008; Capling et al., 2017). In addition, the burden of remembering all foods and beverages consumed during the previous 24-hours may lead to forgotten dietary items. Dietary record apps are the modern methods for recording dietary intakes, and their relative ease of use with a smart phone may decrease reporting errors (König et al., 2022). However, the various available apps are as prone to systematic error as prospective dietary records, as estimates of amount of foods and beverages rely on the skills of individuals to visualise portion sizes (König et al., 2022), and upon their reporting honesty. Digital photography-based dietary records using smart phones are purportedly useful to reduce the burden of estimating portion sizes of foods and beverages (Höchsmann & Martin, 2020), but similar to any self-report method, various dietary items can be purposefully or accidently omitted. It is important to consider the type of dietary record apps available via smart phones. Commercial apps may provide nutrient information as items are entered into the app. This may alter food choices as the participant sees a 'tally' of energy and nutrient intakes during a day's entries. Research-specific apps are available, which hide the cumulative total energy and nutrient intake data as dietary items are entered into the app to potentially minimising nutrition-data mediated changes to habitual dietary choices. Nonetheless, young adult females are more likely to feel comfortable using dietary intake record apps on their smart phones, due to the ubiquitous use of these phones for many purposes throughout their days.

Exercise energy expenditure was measured using accelerometers, heart rate monitors and activity logs. The use of tri-axial accelerometers to measure energy expenditure is an accepted method, although accuracy assessments at different movement speeds suggest there are some minor limitations to the accuracy of this method (Stenbäck et al., 2021). Wrist-worn heart rate monitors to predict energy expenditure also have limitations, in which biobehavioral variables may introduce noise to the interpretation of measurements (Nelson et al., 2020). Nonetheless all devices have their intrinsic limitations when predicting energy expenditure (O'Driscoll et al., 2020), which need to be acknowledged when interpreting biometric results for energy expenditure calculations.

Body composition can be measured using dual-energy X-ray absorptiometry (DXA), for which the primary intrinsic biases relate to the state of hydration of participants and methods used to interpret results from the different body compartments (Barone et al., 2022). Bio-electrical impedance analysis is a less expensive and more portable method for assessing body composition, but similar to DXA, accurate results depend upon the state of hydration of participants (Wasyluk et al., 2019). The sum of selected skinfold site thickness is likely the most inexpensive and portable method of body composition measurement and is therefore of practical use outside a research facility. However, specific bias may arise with the use of this body composition measurement, including inter-individual operator variability and the acknowledged inherent bias in the Siri equation to express body fat as a percentage of total mass from a sum of a specific number of anatomical skinfold sites. Nonetheless, accuracy of the skinfold method in estimating percentage body fat compares favourably with DXA (Cedillo et al., 2022) and air displacement plethysmography (Tinsley, 2021). Each of these methods of body composition assessment have specific limitations and may lead to over or underestimation of fat mass and fat-free mass.

The LEA data from different studies may not be directly comparable due to the different methods or equipment used to measure the dietary energy intake, exercise energy expenditure and body composition variables that are required to calculate LEA. These differences formed the rationale behind use of standardised measurement tools across each representative sport in this PhD project, to ensure limited methodological error in comparisons of each variable.

2.4.3 Literature Gaps

The presented evidence has demonstrated that LEA is prevalent in elite female athletes, particularly among leanness focused sports such as aesthetic and endurance sports (Logue et al., 2018; Logue et al., 2020). While separate studies have identified the prevalence of LEA within different sports, there have been few direct comparisons within the same study of the occurrence of LEA between different types of sports including traditionally non-leanness sports such as team sports. This PhD project was designed to determine whether athletes from leanness sports are at greater risk of LEA than non-leanness sports, and whether there are dietary risk factors within particular sports that lead to a higher prevalence of LEA.

Absent from the literature are investigations of how LEA manifests in athletes. For example, what causes athletes to have inadequate energy intake to support their energy expenditure during exercise. LEA may be caused by restrictive eating, and/or heavy training loads with high energy requirements that are difficult to meet from diet alone, but factors that influence dietary habits of elite female athletes with LEA remain relatively unexplored. Qualitative research examining the determinants of food choice and the dietary habits of athletes have been included in this PhD project to gain an understanding of why and how low energy availability manifests in elite female athletes. This knowledge may inform future dietary interventions to address LEA in elite female athletes, both in research and sports nutrition practice.

The prevalence of LEA and subsequent health problems in elite female athletes have been identified in this scoping review. However, methods of addressing LEA in these athletes has received limited attention in the literature. Athletes need to be appropriately educated about LEA and associated negative health and sports performance risks. A particular focus on adequate nutrition practices is required, particularly around sport and exercise that demand high energy expenditure. Apart from education, nutrition counselling techniques such as motivational interviewing (MI) may be an effective tool to support and motivate athletes to make behaviour changes in line with the education provided. It is important that any interventions are individualised to the athlete, taking into consideration different activity levels, lifestyle, and personal preferences. There is a distinct gap in the literature about the most effective nutrition education methods to address LEA. This omission informed a novel approach in this PhD project which investigated the effectiveness of MI in remediating LEA in diagnosed elite female athletes.

1.5 Conclusion

This scoping review aimed to provide current evidence of the research conducted on Low Energy Availability (LEA) in elite female athletes, with identification of gaps in the relevant literature. The evidence presented showed LEA is prevalent across many sports, and not restricted to those that place a heavy focus on a lean body composition. However, although variable, the prevalence of LEA identified in sports not traditionally recognised as at risk suggests either a more widespread occurrence of this condition among elite female athletes than previously considered, or inconsistencies in measurement techniques which may over-identify LEA prevalence in different sports. In addition, comparisons of LEA prevalence between different sports within one study was not offered in the literature. This inconsistent evidence informed a more systematic approach in this PhD project to the measurement and identification of LEA in different sports, with a comparison between leanness and non-leanness sports within the one study.

To decrease or prevent LEA in elite female athlete populations it is important that athletes are provided with evidence-based nutrition education and are motivated to make changes to their dietary behaviours. This may enable them to make sustainable and informed decisions about food choices. As current evidence has shown, education alone may not be effective in effecting dietary change, while individually-focused information and use of counselling techniques such as motivational interviewing may strengthen dietary interventions. Individualised dietary interventions can be informed by evidence about determinants of food choice. This was an aim included in this PhD project, to address the paucity of information available about factors that influence dietary behaviours in elite female athletes.

Athletes with LEA may experience negative effects on sports performance and poor health outcomes as a result of their restrictive dietary practices. LEA within elite female athlete populations must be accurately identified and remediated through effective and sustainable changes to dietary behaviours.

CHAPTER 3 VALIDATION OF A DIETARY SUPPLEMENTS INTAKE QUESTIONNAIRE

3.1 Introduction

Dietary supplements are frequently used in athlete populations for various reasons. These may include support for intense training, enhanced performance, aids to recovery, an adjunct to manipulate physique and assistance with injury rehabilitation (Knapik et al., 2015; Sato et al., 2015; Solheim et al., 2017; Garthe & Maughan, 2018; Maughan et al., 2018). For example micronutrients including vitamins and minerals may be taken to avoid deficiencies and support general health, oils such as Omega-3 PUFAs found in fish oil may decrease inflammation, probiotics can be taken to benefit gut health, protein supplements support lean mass gain and muscle recovery, and other performance supplements such as carbohydrate gels, sports drinks or caffeine are used as ergogenic aids (Garthe & Maughan, 2018; Maughan et al., 2018).

The use of a questionnaire to measure supplement intake may be used to capture athletes' supplement intakes without recording their entire dietary intake, thereby reducing participant burden. The inclusion of supplement categories and lists also provides a prompt for athletes to remember and record all supplement intakes, including those taken away from meal or routine times. Studies investigating the prevalence of dietary supplement use in athlete populations have often used questionnaires without testing their validity and reliability in the specific study population (Shaw et al., 2016; Whitehouse & Lawlis, 2017; El Khoury et al., 2019). Few studies were found in the literature that validated questionnaires designed to measure supplement intakes in athlete populations (Braakhuis et al., 2011; Wardenaar et al., 2015; Kakutani et al., 2019; Larson-Meyer et al., 2019; Barrack et al., 2020). Among these questionnaires some were designed to measure intakes of particular groups of supplements rather than all dietary supplements, such as protein supplements (Wardenaar et al., 2015), vitamin D supplements (Larson-Meyer et al., 2019) or antioxidant supplement intakes (Braakhuis et al., 2011), while others investigated overall dietary supplement use and focused on the prevalence and determinants of dietary supplement use (El Khoury et al., 2019; Kakutani et al., 2019; Barrack et al., 2020). These questionnaires were not suitable for use in the study described in Chapter 5 in this thesis, as they do not quantify the nutrients provided by dietary supplement intakes and were designed for use in countries other than Australia, listing supplement names and brands unique to these countries but not necessarily available to Australian athletes.

Few studies were found that validated a supplements intake questionnaire in a population of Australian athletes, and specifically female athletes competing at an elite level. Shaw et al. (2016) investigated the overall dietary supplement practices of elite Australian swimmers, including females, but they used an older questionnaire validated by Baylis et al. (2001). The questionnaire was modified to capture more contemporary supplement intake information but was not revalidated after these modifications had been made (Shaw et al., 2016). Whitehouse and Lawlis (2017) used a questionnaire from a US Masters' research thesis to investigate protein supplement use in adolescent Australian athletes. Although the questionnaire was modified to reflect Australian terminology and refined to focus on protein supplements, the questionnaire was not validated after these modifications were made.

Validation of Dietary Supplements Intake Questionnaires is important to ensure collection of data of specific interest, and reliable results when repeated in different athlete populations, and applies to the target population. In this study the validity of the Dietary Supplements Intake Questionnaire was determined using face validity, construct validity and reliability.

Face validity refers to whether a method appears to measure the concept it is intended to capture and whether it is relevant to the target population (Taherdoost, 2016). Fleiss' Kappa is a measure of inter-rater agreement, which is an indicator of face validity. The test determines the agreement between two or more raters in their assessments of a common variable using categorical responses. Good inter-rater agreement indicates that most of the raters have given the same responses, and a Kappa of 0.60 or above indicates acceptable inter-rater agreement (Taherdoost, 2016).

Construct validity determines whether a method measures the concept that it is intended to measure. It compares two methods that are supposed to measure the same concept to determine whether they are related and therefore their use could be deemed interchangeable. In this study construct validity was used to determine whether the Dietary Supplements Intake Questionnaire measures dietary supplement intakes as accurately as the 'gold standard' prospective food and supplements record (F&SD). Linear regression was used to assess the relationship between two continuous variables to determine whether the dependent variable (the questionnaire) can be predicted based on the independent variable (Food and Supplement Intake Diary, F&SD) (Giavarina, 2015). Bland Altman plots were also used to compare two supplement intake recording methods. These plots are often used alongside linear regression analysis to identify whether one of the methods is systematically over or underestimating the concept being measured (Giavarina, 2015).

Reliability or test-retest repeatability refers to whether a method measures stable and consistent results when repeated under similar circumstances for a given individual (Taherdoost, 2016). The reliability of the Dietary Supplements Intake Questionnaire was tested using correlation to compare the responses to the questionnaire when repeated. The correlation was analysed rather than linear regression as the results used the same method repeated, rather than two different methods. Correlation analysis requires the variables to be interchangeable, while linear regression further analyses the relationship between two variables and aims to understand how one variable affects another. Correlation was also used by previous validation studies to analyse reliability (Braakhuis et al., 2011; Barrack et al., 2020).

Use of the Dietary Supplement Intake Questionnaire in the study presented in Chapter 5 assisted with the investigation of low energy availability in female athletes. A robust assessment of supplement intakes is required when assessing participants' overall dietary adequacy, including the contributions from supplements to total nutrient intakes. The questionnaire used in Chapter 5 was validated in a group of young adult, elite female athletes, as this was the target population for this PhD project. However, the questionnaire can also be used among any athlete population, as a useful validated clinical and research tool. It has been designed to capture the frequency of intakes and types of supplements commonly available to athletes in the Australian market, with region-specific names and brands of each supplement.

The primary aim of the study presented in this chapter was to validate a dietary supplements intake questionnaire for use by female athletes to capture the frequency of dietary supplement intake and quantify nutrient intakes from recorded supplement intakes. A secondary aim was to determine if there are differences in supplement choices between different types of sports (lean versus non-lean sports).

3.2 Methods

3.2.1 Participants and Recruitment

Adolescent and young adult female athletes (18 – 25 years) were recruited to participate in this study. Participants were randomly recruited from convenience populations of endurance runners and Australian Football League Women (AFLW) players, representing elite endurance and team sports respectively. These sports were targeted to represent both lean and non-lean sports, as supplement intake choices and patterns may differ among these different sports.

Recruitment methods included a short oral presentation by the principal researcher (PhD candidate) to each sport group as well as social media posts on their relevant club websites, providing contact details for the project. Interested volunteers contacted the principal researcher via email for an information sheet and consent form, which were sent via return email.

Inclusion criteria for participation in the study were female athletes currently training and competing at a state or national level in endurance (distance runners) or team sport (AFLW). Exclusion criteria included athletes currently injured and unable to train or compete, as this may affect their habitual supplement intakes.

Initially 29 eligible participants volunteered for this study (17 endurance runners and 12 AFLW players). However, attrition occurred prior to commencement and between the first and second dietary supplements intake questionnaires. A total of 18 young adult females competing at a state or national level participated in this study (11 endurance athletes and 7 AFLW players). The sample size required for questionnaire validation was based upon other validation studies on athlete populations reported in the literature. Sample sizes in similar validation studies varied between 23 and 84 participants (Wardenaar et al., 2015; El Khoury et al., 2019; Barrack et al., 2020). Although the sample size for our study population was smaller than those reported in the literature, each athlete group represented a homogeneous sub-population, with similar ages, level of sport (i.e. competing at a state or national level) and the same gender, thereby limiting the statistical effect of large variability intrinsic to larger population studies.

Experts in the field of nutrition and dietetics research working at the university were asked to review the questionnaire. This was required to assess the face validity of the questionnaire. Seven experts volunteered to review the dietary supplements intake questionnaire.

3.2.2 The Questionnaire

The dietary supplements intake questionnaire was designed by the principal researcher based on a previous unvalidated questionnaire, with the purpose of measuring the supplement intakes of Australian athletes, in particular female athletes training at an elite level. The questionnaire consisted of two sections; Section A recorded demographic information and Section B recorded participants' supplement intakes. Within section B different categories of supplements were listed, including vitamins, minerals, herbals, gut health, oil and seed supplements, weight loss/appetite suppressants, protein supplements and sports performance supplements (Table 1).

Table 1 Supplement categories included in the Dietary Supplements Intake Questionnaire

Supplement category	Description	Examples
Vitamins	Single and multi-vitamins	Multi-Vitamin, Vitamin C, Vitamin B Complex, Vitamin D
Minerals	Single and multi-minerals	Multi-Mineral, Magnesium, Calcium, Iron
Herbals	Naturally occurring herbal compounds	Curcumin, echinacea and ginger
Gut Health	Supplements marketed to help improve the microbiome and gut health	Probiotics, prebiotics, symbiotics
Oils and Seeds	Plant and animal products used for their fat content	Fish oils, plant seeds (chia, flax, hemp)
Weight Loss/ Appetite Suppressants	Supplements marketed as helping with weight loss	Shakes (weight loss or detox), fat burners and laxatives
Protein	Animal or plant protein	Powder, branched chain amino acids (BCAA's), bars, drinks, and other protein fortified foods
Performance	Supplements taken to enhance sport performance	Carbohydrate gels/powders, sport drinks, creatine, caffeine, and pre-workout products

Participants recorded the type of supplements and brands they used, frequency of use (i.e., daily, weekly, monthly), form of the supplement (i.e., tablet, liquid, powder) and the dose (i.e., how many tablets, how much powder/liquid per use). This detail was designed to facilitate accurate calculation of nutrient contributions to overall nutritional assessments.

Participants completed the Dietary Supplements Intake Questionnaire on two separate occasions (Q1 and Q2), one month apart, to test for reliability (test re-test repeatability). Participants also completed an 8-day food and supplements intake diary (F&SD) which included prompts to record dietary supplement intake throughout. This was completed at the same time as the first questionnaire (Q1) to determine the robustness of the retrospective questionnaire when compared to a valid prospective dietary and supplements intake record. The F&SD was completed on 8 random days over 4 weeks, including 2 different weekend days, while the questionnaire (Q1) was completed during this same 4-week period. Portion sizes were estimated using usual household measures to quantify food and beverage intakes. The distribution and selection of recorded days aimed to capture an accurate representation of participants' habitual dietary and supplement intakes.

Seven experts in the field of nutrition and dietetics research were recruited to review the questionnaire. Reviewers (raters) assessed whether each question was relevant to the target population and overall use of the questionnaire. Reviewers' feedback was used to determine the face validity of the Dietary Supplements Intake Questionnaire.

3.2.3 Statistical Analyses

Statistical analyses were completed to determine reliability, content, and face validity of the Dietary Supplements Intake Questionnaire. Responses were analysed using SPSS Statistics Version 25. Face validity was initially determined by assessment of inter-rater agreement about feasibility, readability, consistency of style and formatting of the questionnaire. The Fleiss' Kappa coefficient test was used to statistically assess inter-rater agreement.

Construct validity was tested using linear regression to determine agreement between the first Dietary Supplement Intake Questionnaire (Q1) and the supplements intakes records in the 8-day food and supplements intake diary (F&SD). Nutrient contributions from the supplements and food and beverages were analysed separately using FoodWorks Nutrition Management system version 10 (Xyris software, Sydney). Nutrient contributions from supplements were added manually to the dietary analyses for a snapshot of nutrient adequacy as an additional information source. Construct validity was further assessed using Bland Altman plots to quantify the agreement between the Q1 and the F&SD by evaluating the mean differences for specific supplement categories.

Reliability of the questionnaire was also measured using linear regression. Repetition of the questionnaire by the same participant population, a month apart, was used to identify whether repeated completion of the supplement intake questionnaire was consistent. Linear regression was used to compare the repeated questionnaires (Q1 & Q2), with a correlation coefficient of 0.80 indicating adequate repeatability.

3.2.4 Face Validity

Face validity of the Dietary Supplements Intake Questionnaire was measured using Fleiss' Kappa. This statistical test measured the inter-rater agreement of seven experts in the field of nutrition and dietetics research, who gave binary (Y/N) responses to whether questions included in the questionnaire were relevant to the target population. As there were more than two raters, Fleiss' Kappa was used instead of Cohen's Kappa. Cohen's Kappa statistic is the original measurement of inter-rater agreement, and Fleiss Kappa is an extension of Cohen's Kappa that is used when there are three or more raters.

3.2.5 Construct Validity

Construct validity of the Dietary Supplements Intake Questionnaire was measured using linear regression analysis to determine the strength of the similarity between two continuous variables. For this study the continuous variables were the number of supplements reported by participants using the Dietary Supplement Intake questionnaire and the 8-day Food and Supplement Intake Diary (F&SD). The questionnaire was the dependent variable, and the F&SD was the independent variable.

Further investigation of the mean differences between the Dietary Supplements Intake Questionnaire records and the F&SD was determined with Bland Altman plots. The differences between the two methods are plotted on the y-axis and the mean of the two measurements is plotted on the x-axis. The average difference of the two methods is plotted as the mean difference line, along with upper and lower lines representing the limits of agreement (95% confidence interval). The plotted data points represent the mean and difference of the two methods for individual participants. A bias towards one of the methods is indicated if most of the points are either above or below the mean difference line. If data points are scattered both above and below the line, there is no consistent bias indicated towards either of the methods. The limits of agreement (95% confidence intervals) on the Bland Altman plots also need to be considered, as wide limits indicate poor agreement whereas narrow limits indicate equivalence between the two methods.

3.2.6 Reliability

Reliability was measured using linear regression to calculate the correlation between participant responses to the Dietary Supplements intake Questionnaire recorded on two separate occasions (Q1 & Q2). This test was deemed appropriate to determine the correlation coefficient between Q1 and Q2 as the number of supplements reported by participants is a continuous variable. A method is accepted as reliable if the correlation coefficient was equal to or greater than 0.80, indicating that 80% or more of the data collected by repetition of the method was equivalent. A value less than 0.8 indicates weaker reliability and suggests that there was likely considerable measurement error.

3.2.7 Ethics

Prior to the study ethics approval was gained from the Flinders University Human Research Ethics Committee (project no. 8426). Athletes were required to complete written informed consent to participate in this study.

3.3 Results

3.3.1 Face Validity

Table 2 Fleiss' Kappa (κ)

Kappa for overall questionnaire rating*	-0.016
Lower 95% CI	-0.087
Upper 95% CI	0.055

***** a Kappa ≥ 0.60 indicates acceptable inter-rater agreement

The results shown in Table 2 indicated poor inter-rater agreement between the seven experts, κ= -0.016 (95% CI, -0.087 to 0.055). This kappa value (-0.016) was not statistically significant from zero (*p* = 0.659), which indicates that the agreement between raters was no better than chance. A kappa value of zero to minus 0.10 is interpreted as no agreement, but this inter-rater test result shows neither the Kappa value nor lower confidence interval were below this range (Table 2).

Construct Validity

Figures 1-7 show results from the comparison of recorded supplement intakes in the F&SD and the Dietary Supplements Intake Questionnaire. The F&SD is the independent variable on the x-axis, representing the 'gold standard' against which to compare athletes' abilities to accurately recall their usual dietary supplement intakes. The Dietary Supplements Intake Questionnaire is the dependent variable on the y-axis. There is a linear trendline shown in Figures 1-7 and the R^2 value for each line of best fit, which represents the relationship between the two variables. An R^2 value close to 1.000 indicates a strong positive linear relationship. For our purposes, this means the Dietary Supplements Intake Questionnaire is equivalent to the prospective food & supplements diary record for recording dietary supplements intakes. Data points represent individual participants' intakes recorded in the Supplements Questionnaire (y) and the F&SD (x). Some data points overlap and are not immediately obvious as multiple participants reported the same supplement intakes in both methods. Hence, the numbers shown in Figure 1-7 above each data point indicate the number of data points (i.e., participants) with the same x and y values.

Regression analyses are not shown for the team sport athletes' intakes of vitamin, mineral, herbal, gut health, or oil & seed supplements. There was an insufficient number of participants in the team sport group (n=7) who reported intakes of these supplements to produce a line of best fit or regression coefficient (R^2). Regression analyses are not shown for weight loss supplements as only one endurance participant reported using a weight loss supplement. No weight loss supplements were recorded by team sport athletes.

Figures 1 - 7: Regression analyses for reported supplements intakes in Q1 compared to the Food and supplements intake diary (F&SD) records.

Figure 1 Vitamin Supplements

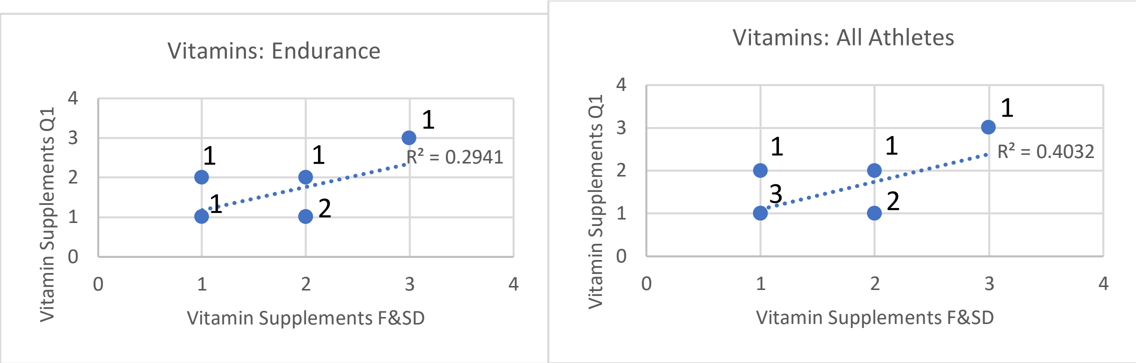


Figure 2 Mineral Supplements

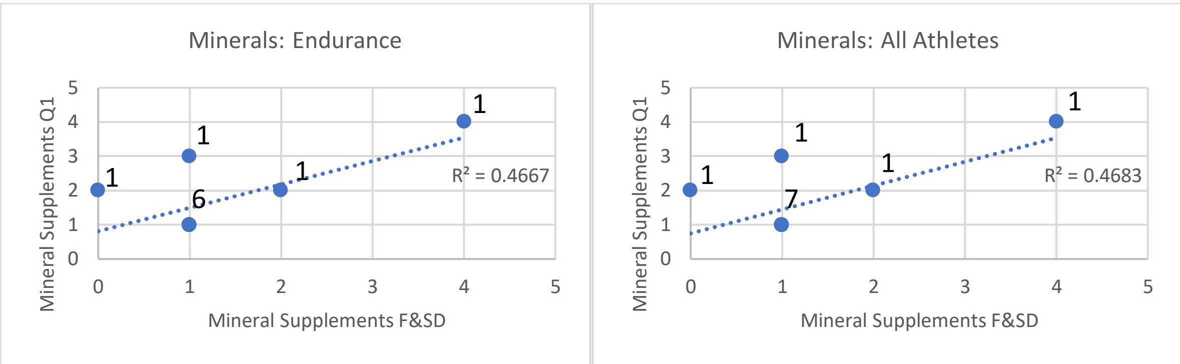


Figure 3 Herbal Supplements

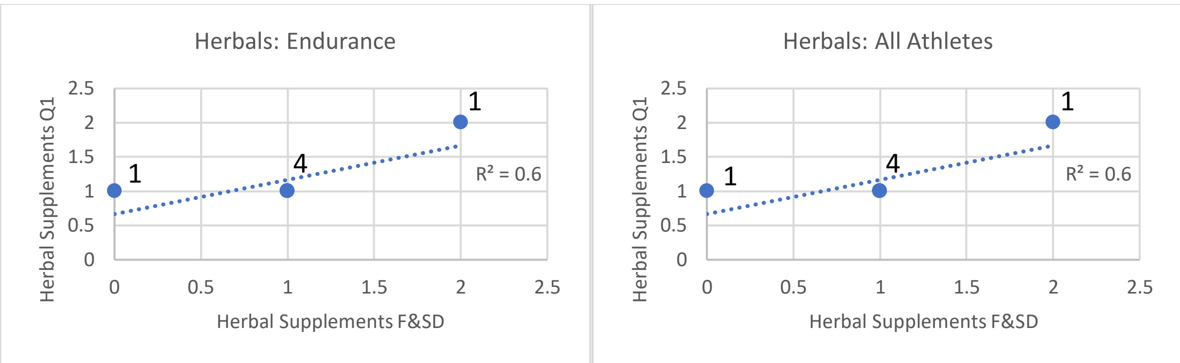


Figure 4 Gut Health Supplements

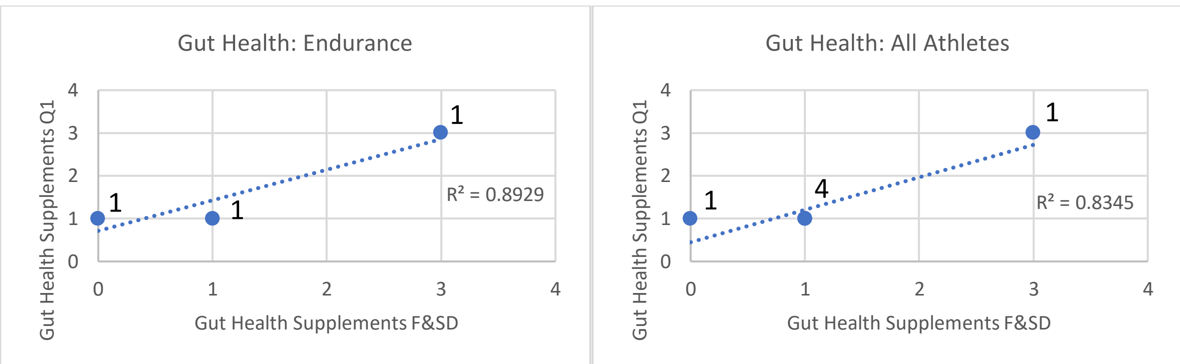


Figure 5 Oils and Seeds Supplements

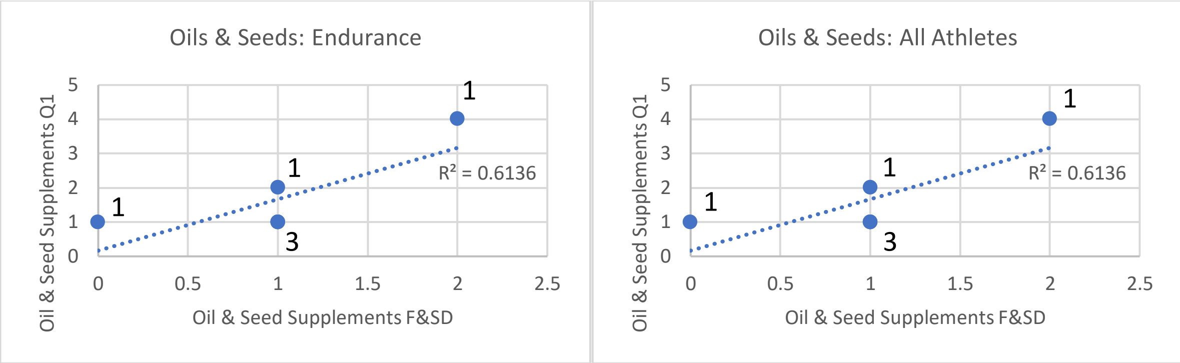


Figure 6 Protein Supplements

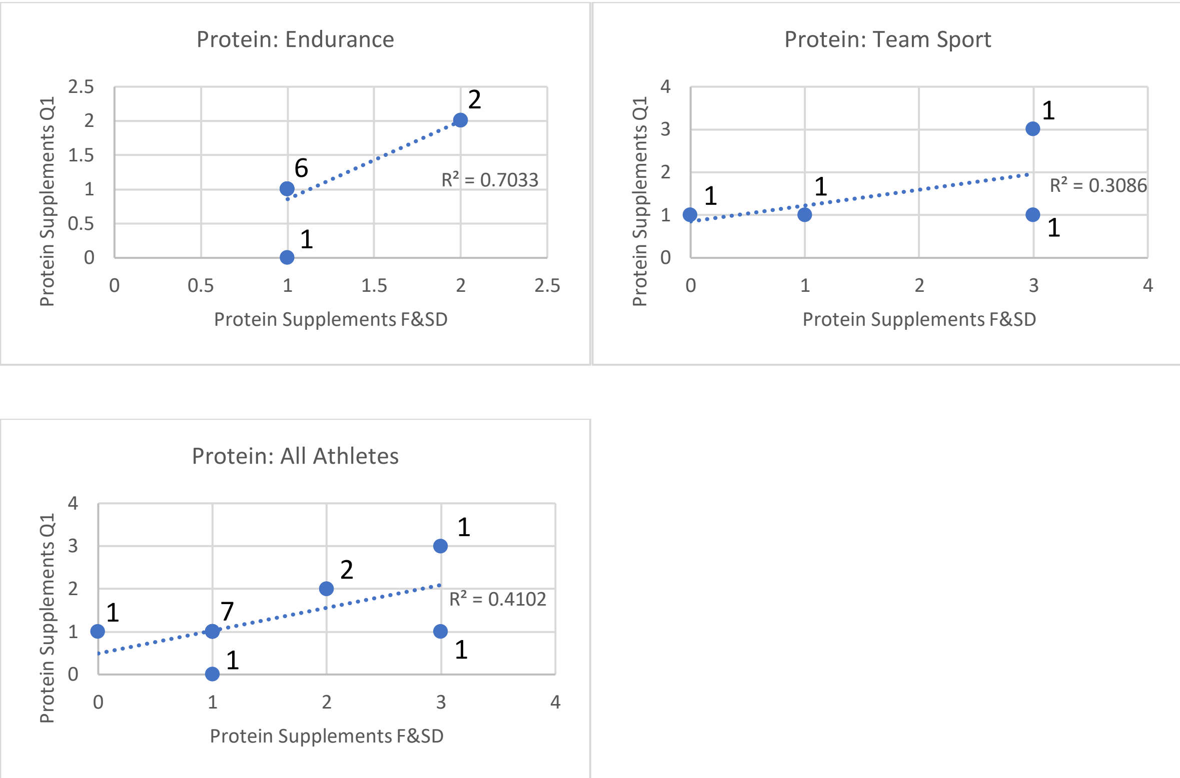
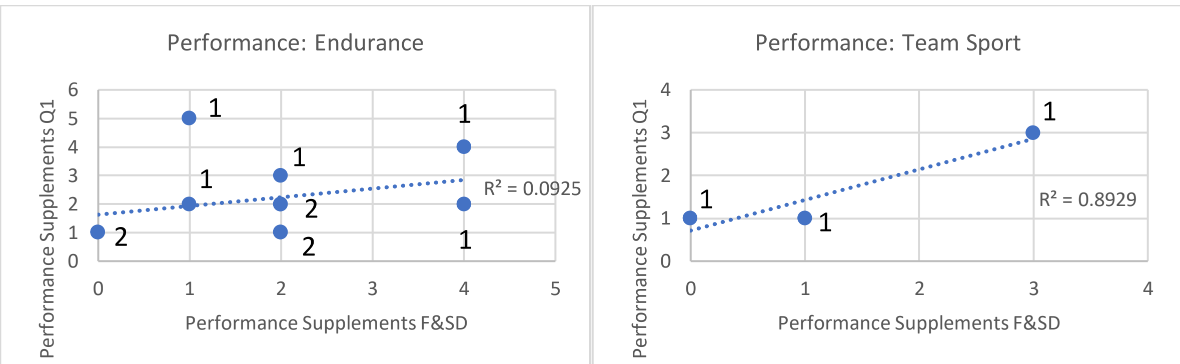
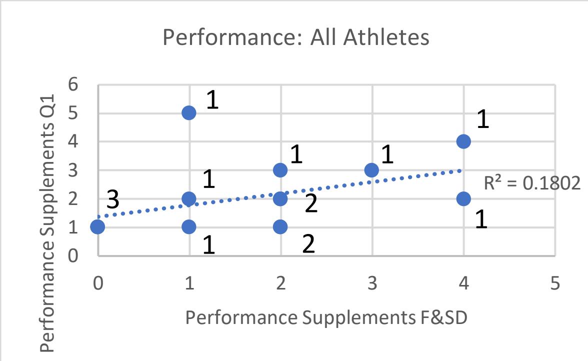


Figure 7 Sports Performance Supplements





Figures 1-7 show regression analyses for the supplement intakes of endurance, team sport and all athletes combined, comparing intakes recorded by the dietary supplements questionnaire (Q1) and the food and supplements diary (F&SD). The supplement intakes of endurance and team sport athletes were compared to explore the difference between the two sports as a secondary aim of the study. It was also necessary to analyse the sport groups combined data to increase the sample size and validate the questionnaire for use in different athlete populations.

Endurance athletes recorded good agreement between the two methods for herbal (R^2 = 0.6000), gut health (R^2 = 0.8929), oil & seed (R^2 = 0.6136) and protein supplements (R^2 = 0.7033) (Figures 1-7). The team sport athlete group only showed good agreement for performance supplements (R^2 = 0.8929), while the combined athlete group data demonstrated good agreement for herbals (R^2 = 0.6000), gut health (R^2 = 0.8345) and oils & seeds (R^2 = 0.6136) supplement categories.

Bland Altman plots analysing the relationship between Q1, and the F&SD are shown in Figures 8-14. These were used alongside linear regression to determine whether either the questionnaire or the F&SD were systematically over or underestimating supplement intakes. The y-axis represents the difference between the reported supplement intakes measured by the two methods and the x axis represents the mean of the results collected by the two methods. Similar to the linear regression figures there are data points on the Bland Altman plots that overlap due to several participants reporting the sample supplement intakes in both measurement instruments. The numbers shown on Figures 8-14 above each data point indicate the number of data points that overlap due to having the same x and y values. Bland Altman plots are not shown for team sport athletes for vitamin, mineral, herbal, gut health, oil & seed, and weight loss supplements, as few or no team sport athletes reported these supplements.

Figures 8 - 14: Bland-Altman Plots for reported supplements intakes in Q1 compared to the Food and supplements intake diary (F&SD).

Figure 8 Comparisons of Vitamin supplement Intakes for Q1 and F&SD

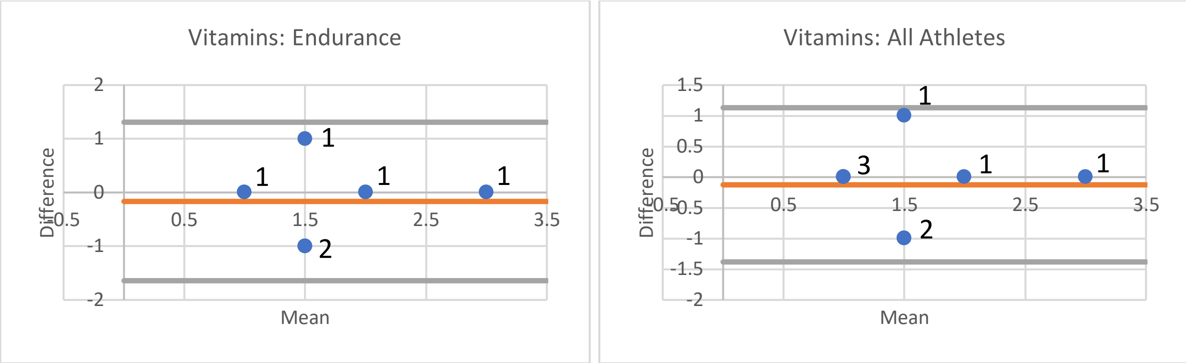


Figure 9 Comparison of Mineral supplement intakes for Q1 and F&SD

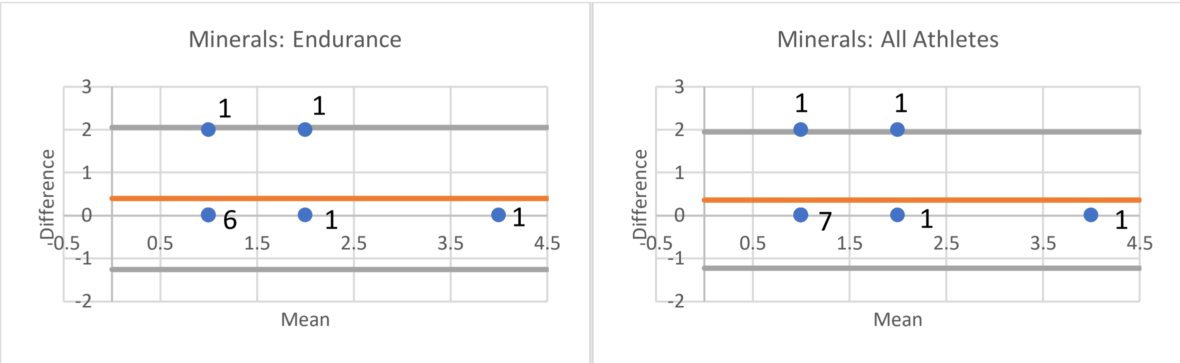


Figure 10 Comparison of Herbal supplement intakes for Q1 and F&SD

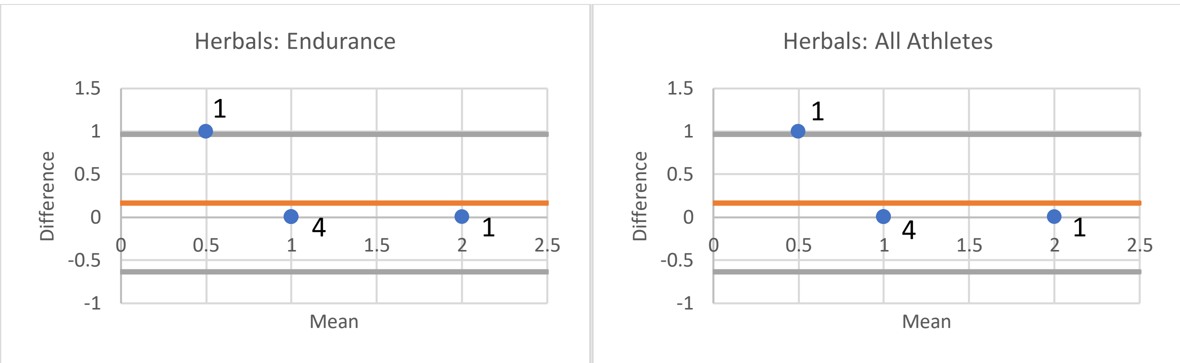


Figure 11 Comparison of Gut Health supplement Intakes for Q1 and F&SD

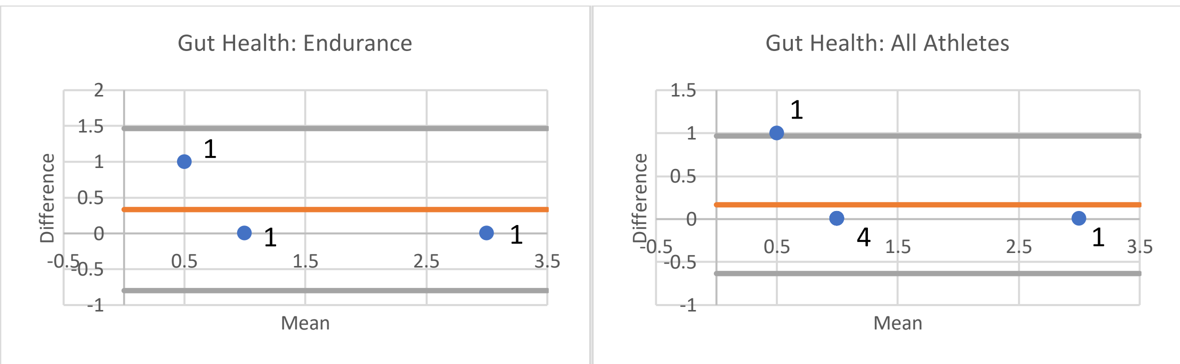


Figure 12 Comparison of Oils & Seeds supplement intakes forQ1 and F&SD

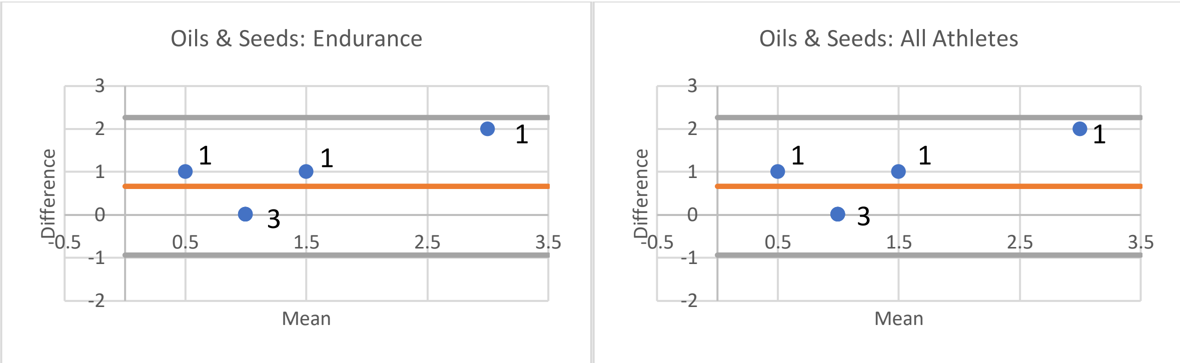


Figure 13 Comparison of Protein supplement intakes for Q1 and F&SD

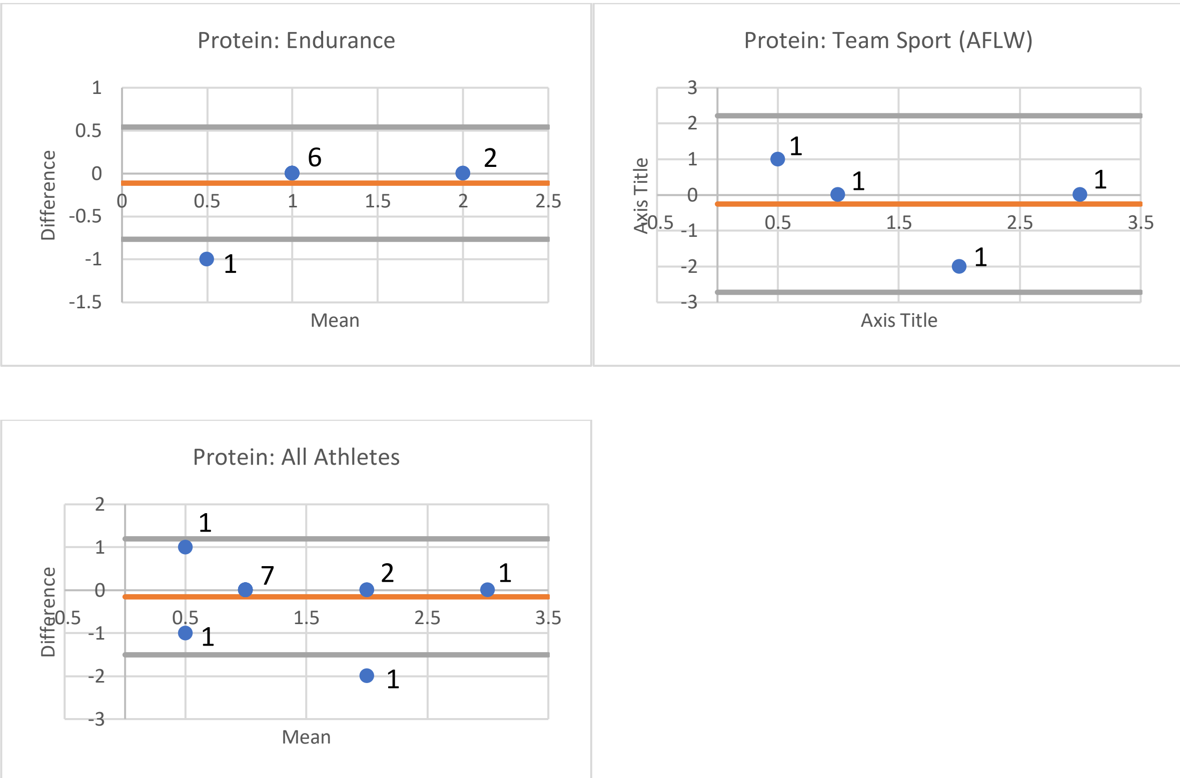
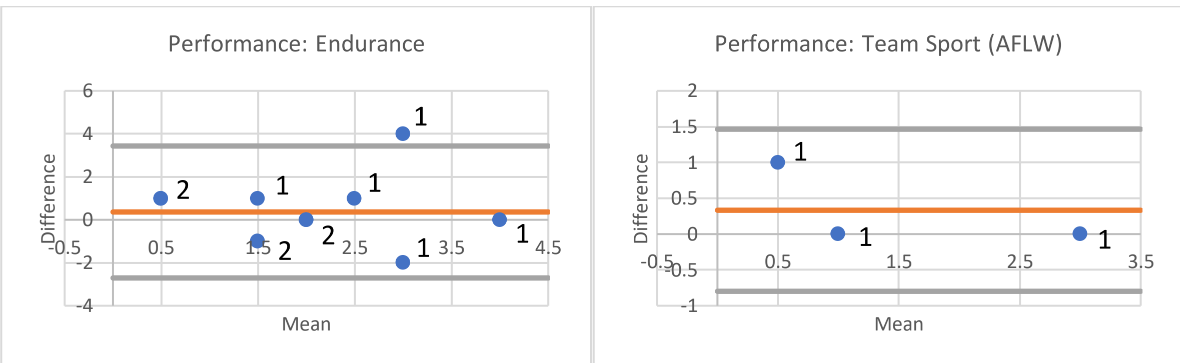
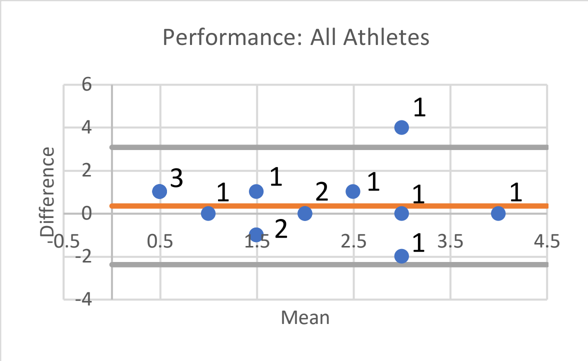


Figure 14 Comparison of Performance supplement intakes for Q1 and F&SD





Figures 8-14 show Bland Altman plots to further compare supplement intake results recorded by the dietary supplements questionnaire (Q1) and the food and supplements intake diary (F&SD). These results show that proportional bias was not indicated for any supplements reported by the athletes. However, there were wide limits of agreement for some supplement categories, indicating poor agreement between the methods. The Bland Altman plots for the endurance athletes demonstrated wide limits of agreement for most supplements (vitamins 95% CI, -1.642 to 1.309, minerals 95% CI, -1.253 to 2.053, gut health 95% CI, -0.798 to 1.465, oil & seed 95% CI, -0.934 to 2.267, performance supplements 95% CI, -2.707 to 3.434). Team sport athletes showed wide limits of agreement for both protein (95% CI, -2.716 to 2.212) and performance supplements (95% CI, -0.798 to 1.465). All athletes combined also showed wide limits of agreement for most supplements (vitamin 95% CI, -1.045 to 1.490, mineral 95% CI, -1.222 to 1.949, oil & seed 95% CI, -0.934 to 2.267, protein 95% CI, -1.504 to 1.196, performance 95% CI, -2.373 to 3.087), indicating poor agreement between the supplement intakes measured by Q1 and the F&SD.

Bland-Altman plots for weight loss supplements are not shown as only one endurance athlete and no team sport athletes reported these supplements intakes.

3.3.2 Reliability

Reliability was measured using linear regression analyses to calculate the correlation between the supplement intakes recorded in the Dietary Supplements Intake Questionnaire when repeated by the same participants on two separate occasions (Q1 & Q2), one month apart. The questionnaire was considered reliable if the calculated correlation coefficient (R) was 0.80 or above (Braakhuis et al., 2011; Oluwatayo, 2012; Barrack et al., 2020). Table 3 shows the correlation coefficients for each supplement category for the athlete groups (endurance and team sport), as well as for both groups combined. It was necessary to analyse the groups combined to represent the variability in supplement intakes between different types of athletes, validating the questionnaire for use in varied athlete populations. Data was not computed for all supplements because there were fewer than 2 dependent variables, meaning that less than two athletes reported taking supplements from that category.

Table 3 Correlation (R) between Q1 and Q2 for separate and combined athlete groups

	Endurance Athletes (Runners) n = 11	Team Sport (AFLW) n = 7	Combined Athlete Groups n = 18
Vitamins	0.700	-	0.731
Minerals	0.955	-	0.955
Herbals	-	-	-
Gut Health	1.000	-	1.000
Oils and Seeds	0.944	-	0.944
Weight loss	-	-	-
Protein	0.933	0.577	0.723
Performance	0.651	1.000	0.641

3.4 Discussion

This dietary supplement intake questionnaire was designed for specific use among Australian athletes, with supplement brands available in Australia. The purpose of the questionnaire was to determine the contribution supplements make to overall nutrient intakes. This information can be used to inform supplement use among athlete populations, and whether nutrient requirements could be met by food alone.

The results of this study were analysed to assess the face validity, construct validity and reliability of a Dietary Supplements Intake Questionnaire for athletes. Overall, the results showed good face and construct validity, and moderate reliability. This section will discuss the results and the modifications that are indicated to improve the validity of the questionnaire.

3.4.1 Face Validity

The result of the Fleiss' Kappa statistical test (Table 2) indicated poor inter-rater agreement about the face validity of questions in the dietary supplements questionnaire. However, only two of the seven experts disagreed with the relevance of two demographic questions, about education level and living situation. The negative Fleiss' Kappa result failed to represent that five of the seven raters responded positively to all questions. All raters commonly agreed with the type of supplements included in the questionnaire and the detail required for each supplement. This information could be argued as being more relevant to the primary aim of the questionnaire, which was to accurately record the dietary supplement intakes of athletes. Nonetheless, in the spirit of good face validity, the demographic questions were omitted from the subsequent questionnaire used in a later study presented in this thesis, as these questions did not value-add to the outcomes for the later study.

The use of Fleiss's Kappa is novel to this study. Two validation studies on similar questionnaires have measured face validity, but they used different statistical tests to assess the results. One reported the questionnaire was reviewed for face validity by only one expert rater (Barrack et al., 2020), while another enlisted ten experts but only calculated the median response (El Khoury et al., 2019) rather than statistical analysis. As these studies did not use a Fleiss' Kappa statistical test to calculate inter-rater agreement the outcomes cannot be compared.

3.4.2 Construct Validity

Dietary supplement intakes were analysed using linear regression to establish the relationship between supplement intakes measured by Q1 and the F&SD. This analysis determined whether the two methods measured the same intakes (Figures 1-7), using the F&SD as the independent variable for comparative purposes. In a similar athlete study Larson-Meyer et al. (2019) used backward linear regression to compare dietary and supplemental vitamin D intakes using a questionnaire with serum vitamin D concentrations as an objective independent variable for comparative purposes. In the validation study presented here, the F&SD was deemed a useful independent variable for comparative purposes. The overall purpose of the study was to determine whether the Dietary Supplements Intake Questionnaire might be a suitable replacement for the F&SD, thereby reducing the burden on athletes when they are also recording their dietary and beverage intakes.

Athlete groups were analysed individually and then combined using linear regression analyses (Figures 1-7). Data was combined to increase the sample size and validate the questionnaire for use among different athlete populations. The supplement intakes reported by endurance athletes in Q1 and the F&SD that demonstrated good agreement included herbals (Figure 3), gut health (Figure 4), oils & seeds (Figure 5) and protein supplements (Figure 6). However, vitamin (Figure 1), mineral (Figure 2) and performance (Figure 7) supplements showed poorer agreement, which may have been due to inconsistent intakes of the vitamin, mineral and performance supplements among each sport group compared to the other supplement categories, rather than poor agreement between the methods. Indeed, vitamin, mineral and performance supplements are reportedly often taken by athletes intermittently rather than routinely , depending upon their reasons for supplement use at a given time. For example, vitamin supplements have been used by athletes with the perception they aid immunity during seasonal outbreaks of common infections (Ghazzawi et al., 2023), while multivitamins are one of the most commonly consumed supplements by elite female athletes during periods of heavy training and at competition times, but not necessarily routinely (Wardenaar et al., 2017; Aguilar-Navarro et al., 2021). Similarly, magnesium may be sporadically used when an athlete experiences muscle cramping (Wardenaar et al., 2017), but not routinely as a prophylactic to prevent cramping. Performance supplements are also not necessarily taken on a regular basis, but rather when they are considered to be useful for training and competition performances (Garthe & Maughan, 2018; Maughan et al., 2018; Aguilar-Navarro et al., 2021). Supplements such as sports drinks, protein powders, BCAA/amino acids, energy bars/drinks, caffeine and creatine are often taken in the belief they will enhance sports performance and recovery (Knapik et al., 2015; Wardenaar et al., 2017). The frequency of use for these supplements may not be reflected accurately by the conventional daily, fortnightly, or monthly options provided in this Dietary Supplements Intake Questionnaire. The questionnaire was subsequently modified for future use to capture non-routine supplement intakes.

Team sport athletes did not report intakes of all supplement categories (Figures 1-7). Herbal, oil & seed, and weight loss supplement intakes were not reported by this group. Vitamin, mineral and gut health supplements were reported by few team sport athletes leading to insufficient numbers of responses to produce a regression line of best fit and the coefficient of variation (R^2) for these supplements. This was in accordance with other studies that reported the prevalence of dietary supplement use is lower among team sport athletes compared to other types of athletes (Giannopoulou et al., 2013; Baltazar-Martins et al., 2019; Barrack et al., 2020). Protein and performance supplements were the only supplement categories reported by sufficient numbers of team sport athletes to be analysed using linear regression. Performance supplements showed good agreement between the Supplement Questionnaire and the F&SD, but protein supplements showed poor agreement. Many of the team sport athletes underestimated the amount of protein supplements they consumed in Q1, reporting a higher number of protein supplements in the F&SD. This evidence suggest that athletes may not recognise what is classified as a protein supplement in the questionnaire, as this category also includes protein-fortified foods such as protein bars and protein recovery drinks which are modified by the addition of isolated proteins. As protein supplementation is one of the most common forms of supplementation used by team sport athletes (Condo et al., 2019; Barrack et al., 2020; Sánchez-Oliver et al., 2020; Oliveira et al., 2022), it is important that athletes understand what is categorised as a protein supplement. As this supplements questionnaire was used in a subsequent study within this thesis, the questionnaire was modified to provide a more in-depth description of the types of protein supplements and protein-fortified foods included in this supplement category.

As the number of athletes recruited for the different sports groups were lower than comparable published studies, and as the primary aim of this study was to validate a dietary supplements intake questionnaire specifically for all types of athletes, responses to Q1 and the F&SD were combined for both athlete groups (Figures 1-7). This was done to determine whether the relatively small sample sizes for each representative athlete group introduced selection bias in interpretation of their results. A relatively larger sample size (n=18) may represent the inherent variability in supplement intakes among different types of athletes, which needs to be incorporated into a robust questionnaire to be used by all athletes. The combined athlete group data demonstrated good agreement between the F&SD (independent variable) and the supplements questionnaire for herbals (Figure 3), gut health (Figure 4) and oils & seeds (Figure 5) supplement categories, suggesting these supplements are more regularly consumed and therefore less likely to be overlooked when completing a questionnaire. Vitamins (Figure 1), minerals (Figure 2), protein (Figure 6) and performance supplements (Figure 7) all recorded poor agreement between the two measurement tools due to these supplement categories recording the most inconsistent intakes in both sports. Only one (endurance) athlete reported weight loss supplements, hence there were an insufficient number of responses to perform regression analysis. Most of the published studies

(Braakhuis et al., 2011; Wardenaar et al., 2015; Larson-Meyer et al., 2019) have used correlation rather than linear regression to compare methods measuring reported supplements use, and therefore the results from the study reported here cannot be directly compared with these other studies. One study used linear regression to compare independent with dependent variables in Vitamin D supplement intakes (Larson-Meyer et al., 2019), but the independent variable was unrelated to diet, which limits the veracity of results comparisons with the study presented here.

In addition to linear regression and consistent with other questionnaire validation studies in athlete populations (Wardenaar et al., 2015; Larson-Meyer et al., 2019), Bland Altman plots were used in this study to further investigate the construct validity of the dietary supplements questionnaire. This was achieved by analysing the difference between supplement intakes recorded in the questionnaire and the F&SD. The use of Bland Altman plots in this study added value to the linear regression analysis by identifying whether one of the methods being compared is systematically over or underestimating. Other studies also analysed combined sports groups (Wardenaar et al., 2015; Larson-Meyer et al., 2019), while this study analysed combined sports groups data as well as endurance and team sports separately, to determine the robustness of the dietary supplements intake questionnaire across sports and within discrete sport groups.

Bland Altman plots for the endurance athlete group (Figures 8-14) indicated agreement between the dietary supplements questionnaire (Q1) and the F&SD. There was no proportional bias shown for any of the supplements reported by endurance athletes. Proportional bias would have been shown if there were more data points above or below the mean difference line indicating that one method consistently measured higher values compared to the other. However, in the study reported here the Bland Altman plots did demonstrate wide limits of agreement for most supplements, including vitamins (Figure 8), minerals (Figure 9), gut health (Figure 11), oil and seed supplements (Figure 12) and performance supplements (Figure 14). This indicates that there was poor agreement between the intakes of these supplements reported by endurance athletes for Q1 compared to the F&SD, as the difference between intakes measured by the methods was highly varied between athletes. Wide limits and poor agreement were also found by the other studies using Bland Altman plots to compare methods measuring nutrient intakes (Wardenaar et al., 2015; Larson-Meyer et al., 2019), suggesting a common limitation in capturing true dietary intakes, which in this study was the prospective F&SD (Rutishauser, 2005; Jackson et al., 2008; Willett, 2012; Capling et al., 2017).

Bland Altman plots for team sport athletes' supplement intakes (Figure 8-14) showed no indication of proportional bias. However, results for both protein (Figure 13) and performance supplements (Figure 14) also showed wide limits of agreement, suggesting poor agreement between the supplements questionnaire (Q1) and F&SD. The dietary supplements questionnaire may not accurately represent true protein intake as it does not necessarily capture incidental intakes of protein supplements around exercise and training that were recorded by the prospective F&SD. The questionnaire recorded supplements taken routinely and will be modified to capture supplement intakes that cannot be represented by the conventional daily, fortnightly, monthly options that were provided in the prototype.

To address this anomaly, the supplements questionnaire reported in this study was modified to include an option that allows participants to record intermittent supplement intakes such as 'around exercise' or 'during competitions. This is particularly important in the context of team sport athletes, as others have found that sports drinks, energy bars, caffeine products and protein supplements are commonly used in these populations around training and exercise rather than routinely (Muñoz et al., 2020; Sánchez-Oliver et al., 2020; Oliveira et al., 2022).

Bland Altman plots were also used to analyse the agreement between the supplements questionnaire (Q1) and F&SD for all athletes combined (Figures 8-14). Athlete groups were combined to represent the supplement intakes of different athlete groups, to test the robustness of the questionnaire across different types of sports. Proportional bias was not indicated for any supplements reported by all athletes. Results showed wide limits of agreement for vitamin supplements (Figure 8), minerals (Figure 9), oil & seed supplements (Figure 12), protein (Figure 13), and performance supplements (Figure 14). Despite the absence of proportional bias, these results indicated poor agreement between the supplement intakes measured by Q1 compared to the F&SD, mostly likely due to irregular supplement intakes not captured in the questionnaire.

3.4.3 Reliability

Reliability analysis using linear regression found good reliability in repeated application of the supplements questionnaires (Q1 and Q2) (Table 3) for specific supplement categories. Reliability results for endurance athletes showed a correlation coefficient (R^2) of 1.000 for gut health supplements, while a similar reliability result was the outcome among team sport athletes for performance supplements (Table 3). The combined athlete group also showed good test-retest reliability between Q1 and Q2 for gut health supplements (Table 3). It is unusual that an R value of

1.000 was produced as it requires the repeated questionnaire to record exactly the same results both times for each participant. These results may have been a consequence of the relatively small sample size and only few participants reporting these specific supplements decreasing the chance of variability. The few participants that did report using these supplements were routine supplement users, producing the same results for both questionnaires (Q1 & Q2). A small sample size is considered to be acceptable in this research setting due to the homogeneity of participant groups included in the sample populations. The participants were all female athletes aged between 18-25 years old, who train and compete in their sport at an elite level. In addition, within a sport the athletes would participate in the same training and competition regimens, minimising the variability in measurement parameters. However, it is acknowledged that inter- and intra-individual supplement intake variability exists, which had a negative effect on statistical analyses of the supplement questionnaire data.

Table 3 shows a good correlation ($R^2 \geq 0.80$) was found among the endurance sport group for repeatability of Q1 and Q2 for intakes of mineral, gut health, oils & seeds, and protein supplements, suggesting that the questionnaire was a reliable instrument for measuring intakes of these supplement categories. It must be acknowledged that the aforementioned limitations to protein supplement identification would have been present in both Q1 and Q2, but from a validation perspective, the questionnaire was a reliable instrument for certain supplement categories. However, vitamin and performance supplements showed poorer correlations between Q1 and Q2 than for the other supplement categories This may be indicative of the unpredictable intake of vitamins and performance supplements, which were shown to be taken sporadically rather than routinely. Modifications to the questionnaire rectified this limitation found in the current questionnaire, ready for use in another study reported in Chapter 5 in this thesis. Vitamin supplements use by elite athletes have been reported by others (Wardenaar et al.,2017; Casazza et al., 2018; Barrack et al., 2020; Aguilar-Navarro et al., 2021) only when deemed by individual athletes to be required, such as to aid immunity when the athlete feels unwell. Similarly, sports performance supplements tend to be taken on a perceived needs basis, most often associated with increases in training volume and at competition times (Garthe & Maughan, 2018; Maughan et al., 2018; Aguilar-Navarro et al., 2021). This sporadic use of vitamin and performance supplements seems to be relatively common among elite athletes, requiring modifications to the supplements questionnaire presented here, to facilitate reporting of non-routine supplement intakes.

Table 3 also shows the results among team sport athletes for test-retest reliability of the Dietary Supplements Intake Questionnaire. Correlations between Q1 and Q2 for reported intakes for performance supplements showed good test-retest reliability, but reported protein supplement intakes did not reach the acceptable level of agreement between Q1 and Q2 ($R^2 \geq 0.80$. Participants may have consumed different protein supplements in Q1 compared to Q2, depending upon their identification of supplement type and possible variability in doses at the different time points. The future version of this questionnaire will address this lack of clarity in protein supplement descriptions.

Correlations between Q1 and Q2 could not be analysed for vitamin, mineral or gut health supplements (Table 3) as insufficient numbers of participants reported these supplement intakes in either questionnaire. None of the team sport athletes reported herbal, oils & seeds, nor weight loss supplements in either questionnaire.

Similar test-retest reliability results were reported by others (Braakhuis et al., 2011; Kakutani et al., 2019; Barrack et al., 2020). The correlation coefficients recorded in this study (0.577 - 1.000) (Table 3) were similar to those reported by others, 0.60 – 0.82 (Kakutani et al., 2019) and 0.78–1.00 (Barrack et al., 2020) when reliability testing was applied to various questionnaires. A notable difference between studies was the interval between questionnaires, with one study reporting a shorter inter-questionnaire period of less than or equal to 1 week (Braakhuis et al., 2011) to 2-3 weeks before the questionnaire was repeated (Kakutani et al., 2019). In the validation study reported here the time interval between Q1 and Q2 (test-retest) was one month, based on a study design described by Oluwatayo (2012), which allowed sufficient 'wash-out' time so that participants are less likely to remember their supplement intake records from first test (Q1), but not too much time that supplement habits have changed (Oluwatayo, 2012).

Questionnaire reliability results for the endurance and team sport athletes were also combined to represent a cross-section of different types of sport (Table 3), as the supplement questionnaire was designed for use by all types of athletes. Results for this combined athlete group showed good correlations between Q1 and Q2 for mineral, gut health, and oils & seeds supplements, reflecting the consistent results for these supplement intakes among each sport type. However, agreement between Q1 and Q2 was poor for vitamin, protein, and performance supplements, consistent with the different contributions from each sport type. Merging of the supplement intake results from both sport types at the Q1 and Q2 time points is probably not useful to the reliability testing of the supplements questionnaire, as the contributions from only 2 types of sport with small sample sizes does not provide a useful representative sample across many types of sport. Nonetheless, results from the supplements questionnaire reliability testing indicated that two different sports had different outcomes in reporting supplement intakes. This variability between just two sports suggests modifications to the supplement questionnaire is required to ensure identification of supplement types is clear, and the ability to report intermittent or non-routine supplement intakes is included.

3.4.4 Limitations

Upon analysing the questionnaires (Q1 and Q2) and food and supplements diary (F&SD) it was found that the frequency of intakes for some supplements could not be accurately captured or described using the conventional daily, fortnightly, monthly options provided in the current version of the questionnaire. Specifically related to athletes, some supplements may be taken based upon training load and competition rather than being taken according to time or routine. These results suggest that there needs to be a modification to the part of the questionnaire recording the frequency of supplement intakes to reflect irregular supplement intakes around sporting commitments and performance.

The supplement questionnaire did not have an option for participants to select if they did not take any supplements from a particular category, such as 'I do not take any of these supplements' or 'zero supplement taken from this category'. The omission data or questions left blank was interpreted during statistical analyses as missing data, instead of zero. The addition of the option to select 'zero supplement intake' would strengthen the questionnaire by allowing for 'zero' to replace missing or blank data. The requirement of recording a 'zero' would also provide participants with an extra prompt to record supplement intakes, ensuring that a supplement category has not been accidentally omitted or forgotten.

Another limitation of the study is the comparison of the Supplement Questionnaire to the 8-day Food and Supplement Diary. Food diaries are generally kept for 1-7 days, requiring the participant to record all food and beverages consumed on the chosen days (Johnson, 2002; Rutishauser, 2005). Eight-day food diaries randomised over 4 weeks were used to measure dietary intake during this study. Increasing the number of days recorded above this can cause the detail of the dietary intake data recorded to decline as the process becomes increasingly monotonous for participants (Johnson, 2002). The 8-day food diary has been frequently validated by others for the measurement of dietary intakes (Johnson, 2002; Rutishauser, 2005), but not including dietary supplement intakes. Consequently the 8-day Food and Supplement Diary is only a representation of the prospective measurement of food and supplements intake. Nonetheless it could be argued that supplements still represent 'intakes', although not necessarily foods or fluids. The rationale for using the F&SD as a 'gold standard' was the anticipation that by recording food and fluid intakes, participants would be prompted to include dietary supplements, as per instructions included in the food diary.

3.5 Conclusion

Validation testing of the Supplements Questionnaire in different athlete groups showed good agreement between expert assessors on Face Validity, with only two of the seven experts disagreeing with the inclusion of demographic questions about level of education and living situation. As this information is not directly relevant to obtaining information about dietary supplement use in elite female athletes, a future version of the questionnaire will omit these questions.

Regression analyses demonstrated a robust Construct validity for some dietary supplement categories (herbal, gut health, and oils & seeds), while others (vitamin, mineral, protein, and performance supplements) require extensions to the detail in the questions to provide clarity about types of supplements for athletes. Additional information about protein and sports performance supplements has been added to the questionnaire for future use.

Assessment of Reliability of the questionnaire exposed key elements for modification about frequency of supplement use, with new questions to cover irregular use of all supplement categories now included in the modified version of the questionnaire.

Although this questionnaire was developed and validated for use with elite female athletes, the supplement intake questions were not gender specific nor explicitly directed towards elite athletes in specific sports. Overall, validation of the Dietary Supplements Questionnaire shows it would be appropriate to use in all athlete populations for research and practice, but identified modifications were required to include opportunities to record irregular supplement intakes, and more descriptive options in the protein and sports performance supplements category.

With relevant modifications to facilitate recording of irregular supplement intakes and more descriptive options in the protein supplements category, this supplements questionnaire was ready for use in a subsequent study in this PhD project presented in Chapter 5. The modified Dietary Supplements Intake Questionnaire was used to assess participants' supplement intakes and their contribution to overall dietary adequacy.

CHAPTER 4 DETERMINANTS OF FOOD CHOICE AMONG DIFFERENT ATHLETE GROUPS: A QUALITATIVE STUDY

4.1 Introduction

Individuals make up to two hundred and twenty choices about food and diet every day which are affected by a number of factors (Birkenhead & Slater, 2015). It is important to identify these determinants to help understand why certain choices are made. This information can inform nutrition professionals when providing appropriate dietary advice to individuals. The factors influencing food choices include but are not limited to taste, personal preference, health ideals, convenience, cost, nutritional knowledge, beliefs and media (Birkenhead & Slater, 2015; Stickler et al., 2016; Akah et al., 2020; Thurecht & Pelly, 2020; Eck & Byrd-Bredbenner, 2021). Due to their participation in sport, athletes can be influenced by additional factors including the effect of specific foods and dietary supplements on performance, time available around sport to prepare and eat food, coaches, staff and teammates' attitudes about nutrition, the physique preferred within the sport and the overall culture within sports (Birkenhead & Slater, 2015; Thurecht & Pelly, 2020; Eck & Byrd-Bredbenner, 2021). The culture within sports refers to “a shared set of values, characteristics, attitudes and beliefs that help guide the activities, decisions and behaviours of individuals” (Birkenhead & Slater, 2015, p. 1517). Sports culture can affect athletes’ food choices when there are strong traditions or beliefs that may outweigh recommended nutrition practices (Birkenhead & Slater, 2015; Pelly et al., 2022). For example, in aesthetic sports the value placed on maintaining a lean body composition may lead to nutrition compromises and inadequate dietary intake.

Food choices are particularly important for athletes as they affect both health and performance (Akah et al., 2020; Thurecht & Pelly, 2020; Pelly et al., 2022). Poor food choices can lead to inadequate energy intake and micronutrient deficiencies. Due to these energy and nutrient deficiencies athletes put themselves at risk of health consequences such as menstrual dysfunction, poor bone health, supressed metabolic rate, gastrointestinal problems, and lowered immunity (Mountjoy et al., 2018a). Performance can also be negatively affected due to factors such as decreased endurance, increased risk of injury, decreased strength, impaired judgement, and decreased glycogen stores (Mountjoy et al., 2018a). Inadequate energy intake may be unintentional due to athletes’ lack of nutrition knowledge or underestimating the amount of food required to meet their everyday needs and sports requirements (Loucks, 2004; Reed et al., 2014;

Stickler et al., 2016). However, athletes in sports that emphasise leanness may also purposely restrict food intake in an attempt to achieve a lean body composition for performance or sport-specific aesthetic reasons (Birkenhead & Slater, 2015; Robertson & Mountjoy, 2018; Logue et al., 2020; Eck & Byrd-Bredbenner, 2021).

Prolonged inadequate energy intake can lead to low energy availability (LEA) if the amount of energy expended is greater than the amount of energy provided by dietary intake (Stickler et al., 2016; Logue et al., 2018; Jagim et al., 2022). LEA increases the risk of poor health consequences and poor sports performance (Mountjoy et al., 2018a) and has been found across various types of sports including individual, team, contact and non-contact sports (Logue et al., 2020; Jagim et al., 2022). Although it is well documented that LEA is prevalent among female athletes (Joy et al., 2014; Logue et al., 2020; Jagim et al., 2022), there has been limited research on whether the energy restriction is intentional.

Athletes face increased pressure to meet the expectations of what they perceive an 'athlete body' or 'lifestyle' should look like (Stoyel et al., 2021). Being in the public spotlight may also contribute to individuals feeling the need to maintain an athletic body shape and lifestyle which is valued or expected of them as athletes (Taniyev & Gordon, 2022). The pressures to maintain body shape and associated eating habits have been identified as drivers of dietary restriction in female athletes (Wells et al., 2015; Stoyel et al., 2021). Social media has exacerbated the pressure to maintain a lean or athletic body composition through the online sharing of pictures and comments, increasing comparison and awareness of others' body shape, diet or training (Stoyel et al., 2021; Scott et al., 2022). The way these pressures affect athletes from different types of sports must be explored as they may contribute to low energy availability by negatively impacting athletes' eating patterns (Bratland-Sanda & Sundgot-Borgen, 2013).

This pilot study, therefore, aimed to investigate the determinants of food choice among female athletes from both leanness and non-leanness sports, identifying potential determinants that may lead to low energy availability. The study piloted semi-structured interview questions prior to their use in a later study in this PhD project. The information presented in this chapter informed the investigation of the manifestation of LEA in female athletes from different sports, presented in Chapter 5.

4.2 Methods

This descriptive qualitative study utilised an interpretivist epistemology and relativist ontology to investigate determinants that may influence athletes' food choices. The philosophical positioning taken is an interpretivist paradigm with an ontological approach of relativism based on the understanding that reality is subjective and created through human action and interaction (Scotland, 2012). Epistemology refers to "the study of the origin, nature and limits of knowledge" (Hall, 1996, p. 69). Epistemology is a philosophical perspective "concerned with the nature and scope of knowledge, its presuppositions and basis, and the general reliability of claims to knowledge" (Harding, 1989, p. 22). It addresses questions such as "who can be a 'knower' and what can be known, what constitutes and validates knowledge, and what the relationship is or should be between knowing and being (that is, between epistemology and ontology)" (Stanley & Wise, 2013, p. 26). Using an interpretivist epistemological approach follows the assumption that knowledge is produced by understanding the society or community of those being studied, focusing on their individual perspectives and interpretations (Al-Saadi, 2014). An interpretivist approach is concerned with examining personal lived experience and endeavours to understand the subjective world experienced by individuals (Smith & Sparkes, 2016; Kivunja & Kuyini, 2017).

Ontology is the study of 'being' and 'what is', regarding the nature of existence and structure of reality (Crotty, 1998). It is concerned with the assumptions made to believe that something is real, and beliefs about the kind and nature of reality (Al-Saadi, 2014; Kivunja & Kuyini, 2017). A relativist ontological approach was used, following the view that reality is subjective and differs between individuals (Scotland, 2012). Further, assumptions are made that there are multiple realities that can be explored through the interactions of the researcher and the individuals participating in the study (Kivunja & Kuyini, 2017). An interpretivist epistemology and relativist ontology approach were chosen for this study as it allowed investigation of the multiple realities that athletes' experience within the same objective reality. The study focused on the different experiences of the football players' and DanceSport athletes' reality of nutrition and food choice.

4.2.1 Participants

The participants included in the study were female volunteers (aged between 21 - 32) from convenience samples of aesthetic and team sport athletes. National level DanceSport Competitors (n=4) represented an elite aesthetic sport, which is described in the literature as a leanness sport (Slater et al., 2017; Robertson & Mountjoy, 2018; Fostervold Mathisen et al., 2022; Jagim et al., 2022). South Australian National Football League (SANFL) Women's players (n=6) represented an elite team sport, described as a non-leanness sport. All participants had been training and competing at a state or national level, although the competition had recently ceased due to COVID-19 restrictions and lockdowns. Smaller sample sizes are common when using an interpretive approach as it involves close analysis of each participant transcript to gain a detailed and personalised understanding (Smith & Sparkes, 2016). Many studies using this approach have sample sizes of ten or less (Smith & Sparkes, 2016). A small sample size was also appropriate due to the nature of the study being a pilot. Qualitative pilot studies generally accept a small sample size of between five and twenty participants, with a guideline of around 12 participants being recommended (Julious, 2005; O'Cathain et al., 2015). During recruitment 10 participants volunteered to take part in the study. This sample size was appropriate given 5-20 participants has been deemed acceptable for qualitative research (O'Cathain et al., 2015), and no new information arising from the tenth interview as data saturation had been reached. It is noted that the use of data saturation to determine sample size may not be appropriate in all study contexts, however is still commonly used in sport and health qualitative research (Braun & Clarke, 2021).

4.2.2 Procedure

Ethical approval was granted by the Flinders University Human Research Ethics Committee (Project No. 8552). Recruitment involved the principal researcher attending the athletes' training or practice session to give a short presentation about the purpose and requirements of the study. Participants were provided with an information sheet and opted into the study by emailing the researcher to volunteer and provide their written informed consent to participate.

Semi-structured interviews were conducted by the principal researcher to investigate the factors influencing athletes' food choices and dietary habits. An interview guide with questions and topics to be explored during interviews was used to maintain some consistency between individual interviews (Kvale & Brinkmann, 2009)(Appendix 7). This guide also allowed the interviewer to ask spontaneous questions to expand on the topics of interest, encouraging participants to elaborate on certain points, or for the conversation to flow in different directions led by the participant (Merriam & Tisdell, 2016). The interview guide listed questions that investigated the determinants of food choice, including food preferences, lifestyle, routine, the influence of family, partners or friends on food choices, nutrition knowledge, previous nutrition input/advice and the impact of sport on their food choices (Kvale & Brinkmann, 2009; Merriam & Tisdell, 2016).

All interviews were conducted remotely due to COVID-19 restrictions on in-person contact. Interviews took place via video call and lasted between twenty to forty minutes. The interviews were voice recorded and later transcribed verbatim by the principal researcher.

4.2.3 Data Analysis

Thematic analysis was used to interpret the data, taking a relativist reflexive approach. This involved investigating how participants make sense of their reality and grouping the sorts of realities that are produced and constructed (Braun & Clarke, 2022). It is understood that there is no single reality, but instead a group of realities that are no more real or true than the others (Braun & Clarke, 2022). Interview transcripts were thematically analysed, following the six steps of thematic data analysis (Braun & Clarke, 2006; Clarke & Braun, 2013; Braun et al., 2016). These steps involved data familiarization, coding, theme development, revision, naming, and reporting themes (Braun & Clarke, 2006; Clarke & Braun, 2013). During this study, data familiarisation involved the transcription of data by the principal researcher. The data was double-blind coded by the principal researcher and co-supervisor. Whilst there were minimal conflicts during the coding process, a discussion between the principal researcher and the co-supervisor was had regarding the merging of some sub-themes with small amounts of data to create bigger themes. For example, the decision was made to merge the sub-theme of 'cost', which only appeared to be an issue for two participants into the organisation and meal preparation theme. The themes were then refined and updated accordingly by the principal researcher before being reported. The thematic analysis was inductive, codes were identified within the data rather than starting with a predefined set of codes to fit the data. However, it is acknowledged that in practice, thematic analysis involves some elements of deductive as well as inductive analysis rather than either/or choices (Robertson et al., 2013). As is usual practice, the analysis occurred through the interaction of the data with the reviewers' theoretical assumptions, discipline knowledge, research skills and experience (Smith & Sparkes, 2016).

4.2.4 Methodical Rigour

Creswell and Miller (2000) identified nine strategies for maintaining validity and trustworthiness in qualitative research, and three of these (audit trail, member checking and thick and rich description) were used during this study. An audit trail was used which involved note-taking after interviews and keeping a record of meetings and decisions made about the study. Member checking involved sending participants their transcribed interview, allowing for feedback or alterations. It must be acknowledged that member checking has been questioned as a reliable measure of validity as it does not ensure that the data collected is valid or trustworthy (Smith & McGannon, 2018). Given participants are not expected to have research expertise, or may have inadequate time to review transcripts there is a risk that they may simply agree with the results presented (Smith & McGannon, 2018). However, the use of member checking has been shown to benefit participants, helping them feel valued by validating their experience and providing a different perspective (Rager, 2005; Harper & Cole, 2012). Member checking was used in this study due to the personal nature of the data and the ethical obligation to confirm with participants that they were comfortable sharing this information. A thick and rich description of data was produced by directly quoting participants' responses. The purpose of this was to improve the authenticity of the data, making readers feel as though they experienced what was being described by participants (Creswell & Miller, 2000). This was particularly important as an interpretivist approach is concerned with examining personal lived experience and endeavours to understand the subjective world experienced by individuals (Smith & Sparkes, 2016; Kivunja & Kuyini, 2017).

4.3 Results & Discussion

Four main themes emerged through the investigation of participants' eating habits and the determinants of the decisions made regarding food choice. These themes included external influences on food choices, nutrition knowledge and education, environment and routine, and sport. Within each of these main themes, sub-themes emerged, further defining the determinants of food choice among athletes.

4.3.1 External Influences on Food Choice

Individuals' perceptions of food and diet are gained through interactions with people under the specific social, political and economic conditions of society (Coakley et al., 2008). Habits, beliefs and perceptions about food may not be directly taught or learned but subconsciously picked up from other people with whom the individual interacts (Coakley et al., 2008). In this study the sub-themes that arose under the external influences on food choice were good/'healthy' foods, bad/'unhealthy' foods, family/partners/friends, effect of food on the body, and restrictive eating.

Good/'Healthy' foods

Many of the team sport athletes described choosing foods they perceived as 'healthy' such as vegetables and fruits because they had to or felt they needed to, rather than because they genuinely enjoyed eating them. Participant 1 described "I don't really enjoy brussel sprouts but if they’re there I’ll eat them, I know that they're good for me”. Similarly, participant 4 stated “sometimes I won't feel like eating fruit, but like I know I have to anyway.” These participants forced themselves to eat these foods to maintain a perceived balanced diet, while participant 3 asserted that ‘healthy foods’ “will help you to be successful in life”.

Similar to the footballers (team sport athletes), the dancers (aesthetic sport athletes) emphasised that they included a lot of ‘healthy’ foods in their diet, including lots of fruit and vegetables in their meals every day. Two dancers also explained that they genuinely enjoy eating salads and vegetables (participants 9 & 10), justifying why they choose to eat them so often: “not to sound kind of like I'm trying to be good, but I actually do generally like to have a really nice salad” (participant 9). The dancers chose foods that they perceived were suitable for an aesthetic sport athlete, but also seemed to seek further approval by stating that they genuinely enjoyed these low calorie, high nutritional value foods that are perceived as ‘healthy’ by Western society. Dance is a performing art which requires artistry and expression as well as physical and technical skill, thus placing emphasis on maintaining an aesthetic figure (Brown et al., 2017; Prus et al., 2022). Simultaneously restricting energy intake to maintain a lean body composition and expending large amounts of energy puts these athletes at risk of low energy availability (Mountjoy et al., 2018a).

Participants from both sports groups chose to include foods in their diet that they perceived as ‘good’ or ‘healthy’ foods for multiple reasons. Social interactions seemed to have a marked impact, with participants alluding to their need to eat certain ‘healthy’ foods to be successful or gain approval. Similarly, other studies reported athletes repeatedly stated that they ate ‘balanced meals’ and maintained a balanced diet by consuming fruit and vegetables (Stickler et al., 2016; Eck & Byrd-Bredbenner, 2021).

The Australian Guide to Healthy Eating (National Health and Medical Research Council, 2013) promotes the inclusion of ‘healthy’ foods such as fruit, vegetables, whole grains, lean protein sources and unsaturated fats, although these population based guidelines are likely not appropriate for athletes who may have higher energy and nutrient requirements (Capling et al., 2020). Athletes may feel the need to maintain a lean body composition because ‘leanness equals performance’ (Schofield et al., 2022, p. 10) and that body fat is ‘bad’ (Schofield et al., 2022, p. 11). It was also evident that some participants placed emphasis on eating foods that they perceived to be ‘good’ or ‘healthy’. However, many participants also expressed that they genuinely enjoyed ‘healthy’ foods. Stokes et al. (2018) found that athletes feel positive and focussed when they ate healthily, leading to perceived improvements in performance. The experience of the athletes in this pilot study indicates positive interactions with food when consuming foods they believe to be healthy. Regardless of whether the 'healthy' foods assist them to maintain a lean body composition, they enjoyed eating these foods which therefore led to a positive experience.

Bad/'Unhealthy' foods

Many of the football players (team sport) avoided foods such as pasta, chocolate, cheese, and carbohydrate heavy foods, and spoke about them in a negative context. These energy-dense foods may not be recommended in large amounts for individuals with a sedentary lifestyle, however, athletes have high energy requirements due to high energy expenditure associated with daily training and competition (Eck & Byrd-Bredbenner, 2021). Athletes may need to consume more of these energy-dense foods to meet energy requirements, despite being conflicted by the health and diet recommendations aimed at the general public (de Borja et al., 2021; Graybeal et al., 2022b). The restriction of these foods could be driven by diet culture which demonises these foods (Ladyka et al., 2022) and links them to weight gain or undesirable body composition (Wasserfurth et al., 2020; Graybeal et al., 2022b; McHaffie et al., 2022). The negative connotations associated with these foods are evident in the following participant quote; “well why would you put in too much of something that it's not very good for you” (participant 3). Participant 2 described feeling a lack of control when eating ‘bad’ foods; eating lots of the food when she allowed herself to have it and then afterwards feeling the need to compensate by training harder or doing extra physical activity. This reported behaviour suggests disordered eating or possibly an undiagnosed clinical eating disorder, but it was outside the scope of this study to explicitly investigate these types of eating behaviours. The athletes’ experiences of eating perceived unhealthy foods suggest it is “not worth it so I may as well not eat it” (participant 2) and “it's more about *not* eating things than eating things” (participant 4).

The experiences of the dancers (aesthetic sport) suggest they perceive foods negatively to a greater extent than the football players (team sport). This indicates that they may be more heavily influenced by the negative connotations associated with certain foods and therefore may have a poor relationship with these foods. Torres-McGehee et al. (2021), Jagim et al. (2022) and Leonkiewicz and Wawrzyniak (2022) found that dancers or aesthetic sport athletes limit the consumption of fats and carbohydrates. Dance sport athletes in this study indicate that carbohydrates, bread, pasta, cheese, dairy foods, sugar, fat and heavier or stodgier foods were perceived as ‘naughty’ foods and were completely avoided or restricted in the diet. The dancers in this study restricted foods perceived as unhealthy in their diets, and only consumed them occasionally or limited them to the weekends. They had rules around these foods; “I try to not have pasta and bread and that kind of stuff during the week, then on the weekends I kinda just allow whatever” (participant 9). One participant avoided frozen and packaged foods under the perception that they are ‘unhealthy’ (participant 7), indicating a lack of nutrition knowledge. Dancers have been found to have poor nutrition knowledge (Brown et al., 2017; Fostervold Mathisen et al., 2022) therefore based on the experiences of the dancers in this study, education around the nutritional value of foods may be of benefit to minimise the restriction of certain foods.

The avoidance and restriction of foods by both types of athlete groups is likely another indication of the pressure they experience to maintain what they perceive as a healthy lifestyle. Schofield et al. (2022) found that individuals felt that to live up to the expectations of being an athlete they needed to be ‘fit and healthy’. Participants’ experiences as athletes led to times when greater restriction of foods was required as indicated by participant 4 who stated, “chocolate, waffles, burgers, I love all of those but like limit myself to eating them especially during season, 'cause I know they're not good for you”. These findings were confirmed by other studies that found athletes avoided ‘unhealthy’ foods that made them feel lethargic, decreased their performance or lead to consequences during training and competition (Eck & Byrd-Bredbenner, 2021; Schofield et al., 2022). The reality of an aesthetic sport creates pressure to be lean, therefore the experience of this group of athletes is to make compromises nutritionally to maintain a lean body composition to improve performance while looking aesthetically pleasing (Birkenhead & Slater, 2015). The expectations for athletes within aesthetic sports can lead to unhealthy thoughts or behaviours becoming normalised within the sports culture (de Bruin & Oudejans, 2018). The increased restriction and strictness of the dancers’ diets may be a result of the culture within the sport which places emphasis on strong bodies that are also lean and lightweight (Fostervold Mathisen et al., 2022). For example, in this study one dancer stated “you lean down a lot with the dancing. It's a very lean sport, you’re still muscly but lean” (participant 9).

Influence of Significant Others

Most of the football players’ (team sport) food choices were influenced to some degree by significant others such as their partners, family, or friends. Two players (participants 1 & 3) had partners interested in or working in health who had influenced their eating behaviours. Players stated that their partners calorie counted or did their own nutrition research online. However, due to the abundance of deceptive nutrition information online it is unclear whether they accessed evidence-based resources. Without nutrition qualifications or a high level of nutrition knowledge it is difficult to identify what information is reliable. Conversely, participant 2 who was vegetarian for ethical reasons said her partner ate vegetarian when he was with her which indicates her influence on her partner rather than being influenced herself. Players who lived at home (participants 1 & 4) were heavily influenced by their families, most of whom still relied upon their parents to do the meal planning, shopping, and food preparation. Only one player (participant 5) had children, meaning that her reality revolved around choosing convenient food options. She described that she "eats the same as them [her children] because it's easier".

The dancers' (aesthetic sport) food experiences were also influenced by a variety of different people in their lives. One dancer still lived at home and ate meals prepared by her mother (participant 9), another had children therefore her reality revolved around accommodating for them when shopping and preparing food (participant 8). One of the dancers lived with her dance partner who had a large influence on her eating habits as he cooked all her food (participant 7). The dance partners' family members, who had no nutrition qualifications, also had an impact by giving nutrition advice such as "halve it if it's bad". Friends were also mentioned as an influence by multiple dancers, one quoting that her friend had told her "sugar melts the skin off your face" (participant 8) leading her to have a negative perspective on added sugar and sugary foods.

Confirming previous studies, the football players' and dancers' health behaviours and nutrition knowledge were influenced by people close to them whether it was a partner, family, or friends (Stickler et al., 2016; Schofield et al., 2022; Vázquez-Espino et al., 2022). The reality of the younger athletes indicates they relied upon family to do the food shopping and preparation, while the older athletes' experiences were influenced by a partner or children when making food choices. The athletes appeared to trust and value the nutrition advice given by those close to them, even though they did not have nutrition qualifications. These findings support Stickler et al. (2016) who found that athletes learned nutrition knowledge and accepted nutrition knowledge from various sources regardless of the reliability. This was especially concerning for the dancers who experienced pressure to maintain the lean body composition valued within their sport culture and were therefore more likely to follow fad diets or unhelpful nutrition advice. It is important that athletes understand that in their reality as an athlete they have different nutrition requirements to the general population, especially when competing at an elite level. Family, or partners involved in making food choices also need to be made aware of the different requirements so that they can support the athlete. The culture within the aesthetic sport reality also needs to change, placing less pressure on maintaining a lean body composition by restriction food intake, and more emphasis on eating for health.

Effect of food on the body

Some of the football players (participants 1, 2, & 4) experienced physical discomfort when they ate certain foods. The players described feeling sick or unwell when they ate dairy products and other perceived unhealthy foods high in fat and/or sugar. Due to this they restricted or avoided these foods, especially close to training and games. Eating too much was another reason players gave for feeling unwell due to food. Participant 2 preferred eating more at night as it did not matter if she felt sick because she was "only going to bed".

The dancers were highly aware of foods that made them feel uncomfortable, and strictly avoided or reduced foods that felt "heavy" in their stomach. The list of foods avoided was more extensive than those avoided by the footballers, including most carbohydrate foods, wheat, dairy and bananas. The dancers were particularly wary of these foods prior to competition days, when they experienced the greatest pressure to have a lean body composition, and often followed a very restrictive diet in the lead-up to a competition. This was similar to another study finding that dancers had LEA during the period leading up to a competition (Prus et al., 2022). They were all highly conscious of changes in their body and how they reacted to certain foods, "I try and listen to my body, and if my body reacts to something then I know not to eat it" (participant 10). The experience of their body changing led to the dancers being rigid about their food choices, especially around competition. One dancer explained that she perceived a difference in her body when she includes carbohydrates in her diet, describing that her body holds onto carbs and that her waist changed (participant 9). While the storage of carbohydrate as muscle glycogen is associated with obligatory water storage, it is unlikely there are any measurable changes in body composition unless energy intake is also increased substantially over a period of time (Acheson et al., 1988; Burke & Deakin, 2010).

Both the football players and dancers avoided foods such as carbohydrates, dairy and high fat and/or sugar foods due to experiencing discomfort or feeling unwell when eating those foods. This supports previous findings that athletes chose certain foods and portion sizes prior to sport and would allow sufficient time for the food to digest properly (Stokes et al., 2018; Akah et al., 2020;

Thurecht & Pelly, 2020) before training or competition. The football players were less likely to omit the foods completely, instead avoiding them close to training and games so that performance was not affected by feeling unwell. The dancers were more restrictive and would omit foods from their diet permanently. They were also conscious of how certain foods were perceived to affect their body composition and were highly aware of how their body seemed to react to certain foods. This leads aesthetic sport athletes such as dancers to be more prone to LEA due to the restrictive nature of their diets.

Restrictive eating

Dieting was mentioned by some but not all football players during interviews. They identified fad diets such as the keto diet (participant 1) and adopting vegetarian eating after being influenced by the 'Game Changers' Netflix documentary (participant 3). The footballers also experienced periodic dieting to lose weight after injury or time off (participants 5 & 3). Weight loss methods included the 'Light and Easy' pre-prepared meals program, macronutrient tracking using the app 'My Fitness Pal' and experimenting with fat burner supplements (participants 5 & 3).

Dieting was common within the dancers' reality. One participant reported following an intermittent fasting regimen, having been influenced by fellow dancers to follow this diet (participant 9). At times this meant she was not eating before early training sessions, which may have had a negative impact on her training performance due to a lack of available exercise fuel. The reality of another dancer involved restricting her eating most days and allowing herself more freedom on the weekend or particular 'cheat days'. "Every Friday is like a 'cheat day', we go to the pub for a glass of wine or something like that, I might have a salt and pepper squid or something that I wouldn't have every day. Like maybe a burger, the dips platter or something like that. Not the greasiest most disgusting thing on the menu, but I definitely let myself have a treat" (participant 7). Further interview investigation would have been useful to define what this participant meant by 'freedom' in relation to food choices on her 'cheat days'. In addition, investigation of whether this dietary pattern was something she had adopted due to others' influence, or whether she regarded this 'freedom' eating as a reward for her restricted eating days would be worthwhile. Therefore, the interview guide in the main study will be adapted to include more follow up questions to elicit more information from participants.

While fad diets and dieting for weight loss was experienced by both participant groups, the intent of the dieting differed between groups. The footballers' motivation for dieting was generally related directly to performance or to losing weight after periods of lower activity (e.g., injury or pregnancy). The dancers experienced chronic dieting due to the reality of participating in a sport that values a lean physique. Restrictive dietary regimens were successfully used to maintain a lean body composition and decrease fat mass, but reportedly have little direct benefit on athletic performance (Levy & Chu, 2019; Correia et al., 2020). In the reality of leanness sports such as dancing, where an aesthetically pleasing physique receives positive attention from judges, athletes are more likely to restrict their food intake to meet body composition goals (Birkenhead & Slater, 2015; Thurecht & Pelly, 2020). Severe restrictions on food intake can lead to the disruption of hunger and satiety cues and possibly lead to disordered eating or bingeing (Williams, 2016).

4.3.2 Nutrition knowledge and information

The nutrition knowledge and information provided to or sought by the athletes was another main theme that impacted athletes' food choices and habits. Research has found that there is an association between nutrition knowledge and healthy dietary habits (Vázquez-Espino et al., 2022). Sub-themes related to nutrition knowledge among participants included previous nutrition knowledge and internet/ apps/ social media as sources of nutrition information.

Previous nutrition knowledge

Most of the footballers reported some knowledge of nutrition, mainly obtained from nutrition professionals delivering nutrition education sessions at the football club. However, the nutrition information was not individualised and covered what they described as general or 'stock standard' information (participant 3) rather than being sport specific. Participant 5 mentioned that seeing a dietitian for individualised information would be helpful as in her experience it was "a bit tricky knowing when to eat and what you should eat" on game days. Only one player (participant 2) had previously sought advice from a dietitian when she was younger due to becoming a vegetarian. This participant had also been given nutrition information by a doctor, due to experiencing an iron deficiency. Sixty per cent (n = 4) of the players had also gained knowledge through studying nutrition during a high school subject or undergraduate university topic (participants 1, 3, 4 & 6). This provided a basic level of general nutrition knowledge but was not specific to athletes. It did however give them some confidence that they knew what they should be eating. "I did nutrition in high school, I know that's not the same as a dietitian, but I have a pretty good idea of what I should be eating" (participant 4).

The dancers were less experienced in nutrition, none had studied nutrition subjects at high school or university, and most had not sought nutrition information or advice from qualified nutrition health professionals. Only one dancer had previously seen a nutritionist and reported having a negative experience. The dancer explained that she and her dance partner were both put on a lot of supplements and told to cut out many foods from their diet, "I lost a lot of weight on it, but I just felt awful, we were both very small [underweight] after" (participant 7). Despite not having any formal nutrition qualifications the dancers perceived they had a good understanding of nutrition. When asked if she had received nutrition advice before a participant answered "never, literally just [her dance partner] and I sort of figure it out", when asked how she replied, "I think just through like Google research" (participant 7). Vázquez-Espino et al. (2022) found that athletes with poor nutrition knowledge overestimated their nutrition competence which is evident in the responses of participants in the current study.

Research has found that there is a poor level of nutrition knowledge among athletes (Jagim et al., 2022; Vázquez-Espino et al., 2022). The dancers had limited nutrition knowledge due to a lack of interaction and education from nutrition professionals and preferred to focus on aesthetics due to the reality of their sport focusing on aesthetics. Due to poor nutrition knowledge, the dancers were therefore more likely to follow fad diets and unreliable nutrition advice in an attempt to manipulate their physique. As suggested by another study, providing knowledge on basic nutrition needs may improve dancers' dietary habits (Fostervold Mathisen et al., 2022), for example the brief nutrition presentation with a dietitian similar to the sessions provided to the football players. Most of the football players seemed to understand the basics of nutrition and knew the types of foods they needed to eat to support their football performance. Although research has found that nutrition knowledge and education may not translate directly into practising appropriate nutrition habits (Aycock, 2021; Pelly et al., 2022).

Internet / Apps / Social Media

The football players used a variety of sources of nutrition information. The web search engine Google was commonly used to search for information "I use different apps on my phone, or I'll google 'how many calories does this have in it?'" (participant 5). Players described that they avoid what was perceived as less reliable sources such as WebMD and Wikipedia (participant 2 & 3). Despite this they still relied upon 'fitness based' websites to provide 'credible' sources of information even though they were aware these websites were not evidence-based; "Women's

Health and that kind of thing, like even though they're not necessarily scientific as such, but I don't think that they could publish stuff which was a lie" (participant 3). Social media platforms such as Instagram were also mentioned, one player stating that she follows 'fitness influencers' but does not completely trust what they say "I don't really believe what [influencer] says because again at the end of the day she's just an Instagram influencer. I use her recipes but I'm not really 100%" (participant 3). Even though potentially inappropriate nutrition information was accessed it is positive that the football player was wary and indicated that she did not trust the credibility of Instagram influencers. Grey literature has criticised the role of Instagram influencers in the nutrition and health sphere (Sherman, 2019), showing that the public perception of unqualified people disseminating inappropriate nutrition information may be changing.

Many of the dancers reported using the internet to source nutrition information. Google was used to investigate the diets of other athletes (participant 7), as well as an online subscription to 'healthy mummies' which gave access to a database of recipes aimed at helping with weight loss after pregnancy (participant 8). Only one of the dancers had a health education background. This gave her a better understanding of the reliability of nutrition information but reported she did not have time to seek this information. "I would go on to places like PubMed and things like that and do research. I don't just generally search the Internet" (participant 10).

Most of the participants used unreliable sources of nutrition information, such as search engines and social media. This was similar to a previous study that found athletes use many information sources such as Google, medical websites, Facebook, and other online sites (Stickler et al., 2016) that are not necessarily evidence-based. The media may play a role in what is perceived as 'healthy', sharing messages and using captions such as 'think of that feeling you'll get when you've reached your goal weight' (Prichard et al., 2018, p. 790), 'skinny girls look good in clothes' (Prichard et al., 2018, p. 790), 'excuses don't burn calories' (Prichard et al., 2018, p. 790), '#thinspiration', 'clean eating' and '#fitspiration' (Raggatt et al., 2018; Prichard et al., 2020). A report in the grey literature (Sherman, 2019) highlighted the problems created by unqualified influencers disseminating nutrition advice via popular social networks, reinforcing the participants' scepticism as well as analyses from the peer-reviewed literature. Some participants were university educated and had a better understanding of where to seek appropriate information, however others were influenced by nutrition information regardless of where it was sourced. Another study found similar results that athletes' food choices were influenced by online nutrition information whether it was accurate or not (Stickler et al., 2016). This highlights the importance of sports clubs and sports organisations providing their athletes with appropriate nutrition information and training about how to determine which information is reliable. Athletes need to be aware that there is false or misleading information readily available online, and to be cautious about the information they are given by anyone who is not a qualified nutrition professional.

4.3.3 Environmental Factors and Routine

The environmental factors and routine theme highlights the practicalities affecting food choices. For example, commitments or responsibilities that need to be considered when making food choices can be a barrier to some choices. The sub-themes included routine and organisation/ meal preparation.

Routine

Participants from both groups followed routines set around commitments such as work, university, and training. In the football players' experience, mealtimes and eating opportunities were affected by work and study commitments. Some had dedicated lunch breaks (participant 1 & 3), while others did shift work (participant 5) or worked long hours and had little time available to eat (participant 6). Football commitments also affected mealtimes as training was often late in the day and coincided with usual evening mealtimes, "training is literally like from 6:00 to 8:30, sometimes then I don't get home till 9:30 and then like I'm eating dinner at 9:30" (participant 3). The reality of their schedule affected food choices as they had to choose what was most convenient or had limited options available. This often resulted in snacking on foods rather than having a full meal or choosing the quickest food to prepare such as toast or two-minute noodles and potentially compromising on good nutrition. None of the players discussed choosing takeaway options.

Similar to the football players, work and dance practice were the main commitments that affected dancers' mealtimes. Some were given a set lunch break and others had to quickly eat whenever a free moment arose. The evening mealtime for most was later than usual on the nights they had dance practice, "dinner can sometimes just be a little bit later because I'm usually practising till late, so I get home later" (participant 10). However, this meant that they simply ate a later evening meal as they were all either coming home to a meal cooked for them or had prepared something earlier. The realities of their sport led to dancers not being willing to compromise on their nutrition and therefore made sure their preferred foods were available when they got home.

The footballers and dancers experienced commitments such as work or university that impacted most participants' eating habits, especially at mealtimes. In comparison to athletes with full-time sports careers, training and competition were not the sole focus for the participants and mealtimes and snacks had to be balanced around other commitments. Some had flexible routines, while others were more rigid and required more organisation. The reality for semi-professional athletes and most participants in this study was a busy schedule due to the demands of training and work or study, leading many to use strategies such as planning ahead to ensure they can make appropriate food choices (Birkenhead & Slater, 2015). Of the two groups, the footballers were less organised and often made food choices in the moment, whereas the dancers were more prepared ensuring that the preferred foods were available at specific times. This may be due to the rigidity of the dancers' food choices or limited diets, which required them to be organised so that the desired foods were always available.

Organisation / Meal Preparation

Many of the footballers' reality involved full-time jobs or balancing study and a part-time job, as well as football. Due to lack of time, organisation was important to ensure that appropriate food choices were made. Participant 2 used meal preparation to make sure that she was eating the "right types of foods". However, participant 6 was less organised and found she often forgot to take snacks or buy particular foods on her way to training and games. This meant this participant either went without snacks or potentially had to compromise on nutrition and choose from the limited options available at the club.

Meal preparation was also used by some of the dancers as a strategy to ensure they had nutritionally appropriate meals prepared for the week, without having to factor in cooking time each night. This way they did not have to rely upon take-away food options or eating out and could ensure the foods were to their preference. "I really dislike cooking, so I will do a mass cook up like once a week and have it all sort of in the freezer or in the fridge ready to go" (participant 8).

In the reality being of an athlete, organisation is important to maintain a nutritionally adequate diet for their sport. Athletes with a busy schedule often report time constraints as a factor that leads to less desirable food choices due to convenience (Stickler et al., 2016). Being disorganised and lack of meal planning led to nutritional compromises when the ideal meals or snacks were not available, such as eating snack foods instead of a meal or choosing fewer nutritional foods. For example, one participant stated "there would be times during the day when I wasn't able to eat lunch during the day. So I'd have breakfast and then maybe snack on like an apple or something for the entirety of the day" (participant 6). This was more common among the football players, as the dancers were less willing to 'compromise' on nutrition. Further investigation through guided interviewing may have determined the types of food choices the participant's considered as nutritional 'compromises'. Due to lack of nutrition knowledge, perceived poor food choices may not always be as 'bad' as considered by respondents, as outlined by Mete et al. (2019). Practical nutrition education for all athletes can empower them to make appropriate food choices for health and to support their specific sport.

4.3.4 Sport Performance

The most prominent main theme from both sports groups was sports performance. Competing at an elite level, all the athletes were dedicated to their sport and prioritised performance. Most athletes were aware of how nutrition affected their performance and how they felt physically. Within this sports theme the identified sub-themes emerged, which included eating patterns in season/ prior to competition, game/ competition day routine, and coaches/ teammates.

Eating patterns in season/ prior to competition

A large impact on football players' attitudes towards food and eating depended upon whether they were in or out of the training/competition season. In-season football was an incentive to eat well and make 'healthy' food choices, "like the pressure in football is that I don't want to get dropped, so therefore you're doing everything you can" (participant 3). As interviews took place during a COVID-19 lockdown players' experiences had changed, many placing less focus on their food choices and perceiving that their diet did not matter as much since they were not currently playing. The off-season or COVID-19 lockdown seemed to have a marked influence on the players' food choices as they allowed themselves more freedom around food when they were not playing football, reinforcing a link between food choices and sports performance. During the football season many participants restricted the types of foods they ate, quoting that they needed to "respect what goes into your body" (participant 6) but they "always want the diet I've got in offseason" (participant 4). Others experienced eating more when they were in season due to higher energy expenditure during training and competition. Exceptions were often made around foods that they usually avoided, particularly carbohydrates, as athletes knew they could improve performance. One participant followed a routine, eating more carbohydrate rich foods before competition to make sure they were eating sufficient amounts of carbohydrates to meet their requirements. "I'll have spaghetti the night before because of carbs. And then beans on toast or Weet-Bix for breakfast. Then just like a light sugary snack before the game. So it's like a routine but to make sure I'm getting enough carbs" (participant 4). However, with a demonstrated lack of nutrition education evident among many of the football players, it would be interesting to investigate how the players determined their carbohydrate requirements.

It was evident that the dancers experienced pressure to 'lean down' and maintain a specific physique for their dancing. The reality of most dancers involved restricting their dietary intakes, especially in the lead-up to competitions. This included avoiding carbohydrates; "if I cut down my carbs then it's easier for me to lean down if I need to for dancing" (participant 9). Individual dancers had different perceptions of how their diet would change if they stopped dancing. Participant 9 discussed being more relaxed with their diet and including more carbohydrate-rich foods, while participant 10 would decrease the amount of food eaten due to exercising less.

Whether or not participants were actively training or practising their chosen sport was a factor that impacted the food choices made across both groups. This finding contrasted with a study that reported Division I college athletes from a variety of sports had little variation in diet between on and off-season (Eck & Byrd-Bredbenner, 2021). Within the competition season the football players chose foods they considered would help them 'feel good' and perform well. The dietary habits of some footballers were similar to that of endurance runners who increased their energy intake when there was an increase in training to support performance (Stickler et al., 2016). The dancers chose foods they perceived would help to maintain a lean physique. This often involved restricting dietary intakes to maintain a lean physique, but this practice may increase their risk of nutrient deficiencies and low energy availability. It is recommended that dancers and other aesthetic sport athletes are educated by sports nutrition professionals on the nutrient requirements for their training and competition and are provided with practical examples of how to adequately fuel for their sport. It is also important that they are made aware of the consequences of inadequate nutritional intake and potential low energy availability, and to encourage them to avoid food restriction as a means to maintain a lean body composition.

Game/ competition day routine

Some football players were specific about food eaten on game and training days, depending on their experience of how these foods made them feel and perform. Many made exceptions around foods they usually avoided and had pasta, a large meal or more food the night or day before a competition so that they 'felt good' during games (participants 1 & 4 in particular). A few players avoided eating large quantities of food before a game so that they did not feel 'too full' during the game (participants 3, 5, & 6). Most of the participants reported that after games, they knew they needed to eat to refuel, and often ate what they described as 'big meals' that were protein-rich. Consciously drinking water throughout the day prior to a game was also a priority for most.

Within the dancers' reality it was common to alter their diet in preparation for competition. Most decreased carbohydrate intake such as rice and pasta and focused on including protein and vegetables instead. When asked why, one participant replied that the dietary changes were "probably more a physique type thing than a performance thing" (participant 8) and another commented it was because "I don't like to feel too heavy on comp day" (participant 9). Dairy was also restricted by a few who avoided milk and yoghurt (participants 7, 8 & 9), although this dietary restriction seemed to be consistent with daily food omissions rather than a competition-related dietary practice; "I've kind of cut out normal milk at the moment. It kind of upset my stomach a little bit. I'm not lactose or anything" (participant 9). Some took a more extreme approach and limited their diet to only protein shakes and vegetable soup to maintain a lean body composition in the lead-up to a competition; "probably about 8 weeks before a comp, I would pretty much just live on my veggie soup" (participant 9). This restrictive dietary practice related to ensuring a lean body physique was achieved or maintained in preparation for competition days. On competition days the dancers avoided eating 'heavy' foods, which usually meant carbohydrate- or dietary fibre-rich foods. Instead, they chose 'little sugar fixes' instead such as muesli bars or fruit to maintain energy levels. This particular dietary practice highlights the need for nutrition education as muesli bars and fruit are carbohydrate- and dietary fibre-rich foods, contradicting what the athletes stated that they were avoiding. Participant 10 mentioned avoiding high-fat and protein foods close to competition days due to a previous experience when they made her feel sick.

All participants were quite specific about their routine and the foods eaten on game or competition days. This finding was similar to other studies which found athletes are more concerned about whether foods will help them perform rather than the taste of foods (Birkenhead & Slater, 2015; Akah et al., 2020; Pelly et al., 2022). Some of the football players followed a specific dietary routine that worked for them, and others were more relaxed about their food choices. The dancers were all very strict with their dietary choices leading up to and on competition days, avoiding foods that 'felt heavy in the stomach' such as carbohydrates and dairy foods. These restrictive dietary practices are supported by other studies that found inadequate calcium intakes due to the avoidance of dairy foods, and low carbohydrate intakes in populations of dancers (Brown et al., 2017; Challis et al., 2020). The omission of dairy foods without adequate calcium-rich replacement foods is concerning as inadequate energy and calcium intakes can lead to low bone mineral density and bone injuries such as stress fractures (Prus et al., 2022). This is an outcome that would negatively impact dancers' medium to long-term competitive futures. Following such extreme diets during training and competition seasons may lead to both nutrient and energy deficiencies, leading to low energy availability and the associated poor health consequences such as menstrual dysfunction, poor bone health, suppressed metabolic rate and poor immunity (Mountjoy et al., 2018a).

Coaches/ teammates

The football players had experienced coaching staff encouraging players to eat carbohydrate foods before games, but that the advice was very 'general' or 'blasé'. "They just say make sure you're preparing properly, have some carbs before the game" (participant 1). One player (participant 1) had been influenced by a past experience with a surf lifesaving coach who had educated her on sugar and how much is in different foods. This led her to limit the amounts of high-sugar foods in her diet, specifically sports drinks which her coach disapproved of. This education provided by the coach is potentially harmful as athletes' high energy requirements, particularly during and around exercise, cannot always be met with 'healthy' foods alone, requiring products such as sports drinks (Chauhan et al., 2022; Reinhard & Galloway, 2022) to facilitate carbohydrate intake at the same time as meeting fluid requirements. When asked about the impact of teammates one player responded, "we find it interesting to find out what things work best for teammates" (participant 5). However, it was also mentioned that younger players asked the older or more experienced players about their dietary routines and what works best for them (participants 1 & 5). This suggests that a mentoring role for more experienced players should be encouraged within the football club as a formal part of the player group dynamic.

The dancers had experienced fellow dancers, especially their dance partners and coaches, influencing their eating habits and food choices. Participant 7 had become more diet conscious and lost weight since being paired with their current partner, who cooks and prepares food for her. There is always a risk of body-shaming behaviours in competitive DanceSport, where a reliance on both partners to achieve physical as well as performance 'perfection' can lead to restrictive dietary practices (Harman, 2018). Group discussions also occurred, during which some dancers encouraged others to take part in popular fad diets such as intermittent fasting. The younger dancers were susceptible, and easily influenced by these discussions, “I'm influenced easily, not easily but if some people tell me that something is really working for them then I just give it a go I guess” (participant 9).

Participants from both sports groups experienced being influenced by coaches and fellow teammates. The dancers were heavily influenced by fellow group members, while the footballers were somewhat interested in fellow teammates' food choices and habits but not largely influenced. The football players spent a lot of time together and talked about nutrition with each other occasionally. More commonly the younger players asked for advice and opinions from players with more experience, which was similar to other studies (Stickler et al., 2016; Scott et al., 2022). The dancers discussed nutrition with each other and looked to fellow dancers and their coaches for dietary advice. There seemed to be more peer pressure within the dancers group compared to the football players, to follow popular diets and advice recommended by others, supporting the findings that peers are enablers and have a large impact on food choices (Stokes et al., 2018). Conversely, for the football players, teammates and coaches were reportedly not a major influence, which contrasted with studies in similar sports that found cross-country and rugby union athletes were influenced by and trusted nutrition information provided by coaches (Stickler et al., 2016; Stokes et al., 2018).

4.4 Limitations

It is acknowledged that this pilot study has several limitations. Two sports were represented, football representing team sports and dance representing aesthetic sports. The opinions of these athletes may not be a true representation of all team or aesthetic sport athletes, instead being characteristic of their type of sport and environments. A broader study involving participants from a wider variety of representative sports would help determine whether these influences and opinions are widespread or unique to the two sports represented in this pilot study.

Due to the study taking place during the COVID-19 pandemic, the method was modified to conduct interviews via video call rather than in person. This decreased the ability of the interviewer to interpret and react to body language or cues. The flow of conversations was also disrupted at times due to the time lag or video call cutting out. It is recommended that future studies conduct interviews face-to-face to allow for clearer flow and interpretation of conversations. More in-depth questioning or pursuit of participants’ responses, as indicated in the discussion of the results of this study, could have also facilitated a deeper understanding of the various influences on food choice, including factors unique to the types of representative sports.

This pilot study provided valuable insight into the interview techniques required to elucidate meaningful in-depth information about the influences of various factors on food choices among athletes. The interview techniques learned by the principal researcher in this pilot study will be adopted in the final study in this PhD project, reported in Chapter 5.

4.5 Conclusion

Participants from both groups were affected by multiple determinants of food choice. There were some shared experiences for the football players and dancers in terms of food choice, however the realities of the separate sports led to multiple realities that affected the determinants of food choice.

The footballers and dancers were all affected by external influences on food choice, for example most felt pressure to choose perceived socially accepted foods, were somewhat influenced by team-mates, fellow-competitors and family or friends and, were susceptible to restrictive dietary practices.

In terms of nutrition knowledge and information sources, the football players seemed to have better nutrition knowledge than their aesthetic sport peers, however, most participants across both sports did not know how to identify reliable nutrition information. Environment and routine also influenced most participants' food choices, the dancers being more reliant upon sticking to a routine and being organized.

Footballers were focused on sports performance and therefore made food choices according to how they would affect performance. Some of these choices had been influenced by their interactions within the community and society such as choosing good/'healthy' foods and avoiding bad/'unhealthy' foods, but most choices were predominantly motivated by performance outcomes. The dancers valued sports performance but were also fixated on leanness and achieving an aesthetic physique due to the reality of being a leanness sport athlete. Food choices such as the restriction of food, may have compromised dance performance to maintain a lean body type. Nonetheless, the dietary findings from this study concur with the current broader literature that indicated athletes from aesthetic or leanness sports face greater pressure than less body-aware or non-leanness sports to maintain a lean body composition. It was noteworthy that the determinants of food choice affecting athletes were similar across all themes apart from sports performance.

The yearly brief group sessions that the footballers had with a Sports Dietitian appear to have been of benefit to their nutrition knowledge and food choices, even though they were perceived as individually unhelpful. These sessions may have helped to remind the footballers of the appropriate nutrition practices for their sport. More importantly, it may have also discredited misguided nutrition information or fads that may have been followed by some of these athletes. The dancers did not have access to information presented by a Sports Dietitian or Nutritionist, which may have partly contributed to the differences between the nutrition beliefs of the participant groups. It is recommended that the dancers are provided similar group nutrition sessions by a qualified sports dietitian to positively impact their food choices.

This study informed further qualitative research completed as part of this PhD project with different athlete groups. Knowledge and experience in qualitative interview techniques gained from this pilot study were employed in similar semi-structured interviews used to investigate the determinants of food choice in groups of endurance, aesthetic, and team sport athletes. Findings from this Pilot Study highlighted the significance of partners' influence on food choice and that restriction of certain foods was common. Therefore prior to the main study , the interview guide used during this pilot study was modified with additional questions to elicit more information on topics such as the influence of partners, what participants defined as freedom around food choices, what was considered as a nutrition compromise and why participants decided to restrict certain foods. The modifications to the interview guide will enable areas of importance that have emerged from the pilot study to be explored in greater detail. Reflection by the Principal research on how they could use probing questions such as "Have you ever restricted your food intake? What made you decide to do this?" and "Have you ever tried to change your body composition? Why? How?" have framed the interview guide to generate more detailed answers from participants in the main study.

CHAPTER 5 PREVALENCE OF LEA AND EFFECTIVENESS OF A 'FOOD FIRST' MOTIVATIONAL INTERVIEWING DIETARY INTERVENTION

5.1 Introduction

Low energy availability (LEA) can be prevalent among female athletes as the high energy demands of sport place female athletes at greater risk of LEA than the general population (Mountjoy et al., 2014; Mountjoy et al., 2018a). High intensity training or long endurance sessions use large amounts of energy and consequently may leave inadequate energy for physiological functions, leading to LEA (Civil et al., 2019). LEA can also be a consequence of low energy intake that is inadequate to support the energy demands of training and exercise (Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019). This is concerning as LEA can lead to both health and performance consequences in female athletes. Sports performance may decline due to increased risk of injury, decreased training response, low glycogen stores, impaired endurance performance and decreased muscle strength (Mountjoy et al., 2018a). LEA also increases the risk of health concerns such as menstrual dysfunction, impaired bone health, disordered eating, gastrointestinal problems, decreased metabolism and poor immunity (Mountjoy et al., 2018a).

Some female athletes face added pressure to maintain a lean body composition that may be advantageous to their sport, which may lead to restrictive eating behaviours and poor food choices (Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019). Endurance sports are often referred to as a leanness sports as athletes favour a lean body composition to increase their power-to-weight ratio (Melin et al., 2015; Melin et al., 2016; McCormack et al., 2019). These athletes may find it difficult to meet energy intake requirements during periods of high training volume but may also restrict food intake to maintain a lean body composition (Melin et al., 2015; Melin et al., 2016; McCormack et al., 2019). Aesthetic sports are also classified as leanness sports due to athletes commonly favouring a slim figure for artistic expression and advantage when performing certain movements (Silva & Paiva, 2015; Schaal et al., 2017; Costa et al., 2019). The pressure on these athletes to maintain a lean body composition for visual appeal often leads to preoccupation with physique and restriction of energy intake to maintain the 'desired' physique (Civil et al., 2019; Costa et al., 2019). Athletes from other sports, such as team sports, are referred to as non-leanness sports due to presumably receiving less scrutiny of their body composition. These athletes are subsequently believed to be at a lower risk of LEA (Wright et al., 2014; Braun et al., 2018; Zanders et al., 2018; Zabriskie et al., 2019). However, it is increasingly recognised that these athletes may still experience LEA and the negative performance and health outcomes (Devlin et al., 2017; Condo et al., 2019; Jenner et al., 2019; Magee et al., 2020). The energy requirements of team sport athletes often change across the different phases of a sport season, requiring nutrition intake to be adapted accordingly (Devlin et al., 2017; Condo et al., 2019; Jenner et al., 2019). Athletes may fail to match increased energy expenditure with energy intake, eating less than required during high periods of training and competition (Reed et al., 2014; Braun et al., 2018; Zanders et al., 2018; Zabriskie et al., 2019). This can lead to these athletes inadvertently experiencing LEA (Wright et al., 2014; Zanders et al., 2018).

LEA has been found to be prevalent mainly among leanness sports (endurance and aesthetic), but emerging evidence suggests some female athletes in non-leanness sports (predominantly team sports) meet the EA criteria (Goodwin et al., 2014; Reed et al., 2014; Wright et al., 2014; Day et al., 2015; Viner et al., 2015; Melin et al., 2016; Heikura et al., 2018; Zanders et al., 2018; Civil et al., 2019; Zabriskie et al., 2019; Magee et al., 2020; Kinoshita et al., 2021; Torres-McGehee et al., 2021; Prus et al., 2022). It is therefore important that LEA is addressed to avoid the associated negative performance consequences and ill-health sequelae for these athletes.

Nutrition education is often used to correct nutrition related concerns, although the use of nutrition education alone as an intervention has had mixed success in changing dietary behaviours (Valliant et al., 2012; Day et al., 2015; Nascimento et al., 2016; Laramée et al., 2017; Rossi et al., 2017). Improving nutrition education and knowledge also may not directly translate into the intended dietary intake changes (Day et al., 2015; Laramée et al., 2017). Therefore, this PhD project incorporated motivational interviewing in an attempt to increase the effectiveness of an intervention aimed at decreasing the prevalence of LEA. This is a counselling technique that increases intrinsic motivation and decreases uncertainty by using a client-centred approach (Hardcastle et al., 2017; Lee & Lim, 2019). This was a novel aspect of the PhD project as the use of motivational interviewing in athlete populations with LEA is not prominent in the literature.

The intervention designed for this PhD project used an evidence-based approach, following recommendations from studies that investigated low energy availability in female athletes (Thein-Nissenbaum & Hammer, 2017; Logue et al., 2018; Mountjoy et al., 2018a; Robertson & Mountjoy, 2018; Melin et al., 2019; Kuikman et al., 2021). A novel aspect of this PhD project involved taking a 'Food First' approach which involved encouraging the use of food rather than supplements to address nutrient deficiencies, as supplement use is common among athletes to support perceived and real nutrient inadequacies from dietary sources (Knapik et al., 2015; Maughan et al., 2018; Moss et al., 2021). By emphasising food choices instead of supplement intakes, overall nutrient adequacy can be achieved with the appropriate relative amounts of macro-and micronutrient intakes, thereby avoiding potential nutrient imbalances. Nutrition studies with athletes to date have not emphasised the importance of food as the preferred source of nutrients compared to dietary supplements use.

This led to the research questions for this PhD project that were addressed by this study:

1. Is LEA more prevalent among elite female athletes from lean body-composition sports than female athletes from other sports?
2. Are there demonstrated improvements in dietary risk factors for LEA following 'Food First' nutrition counselling in participants identified with LEA?

The aims of the project were therefore:

6. To determine the prevalence of LEA among elite female athletes from sports with different body composition requirements.
7. To determine how LEA manifests among elite female athletes identified with LEA.
8. To explore the determinants of food choice among participants with and without LEA.
9. To evaluate the effectiveness of a 'Food First' motivational interview to reduce nutrient deficiencies associated with LEA in elite female athletes.

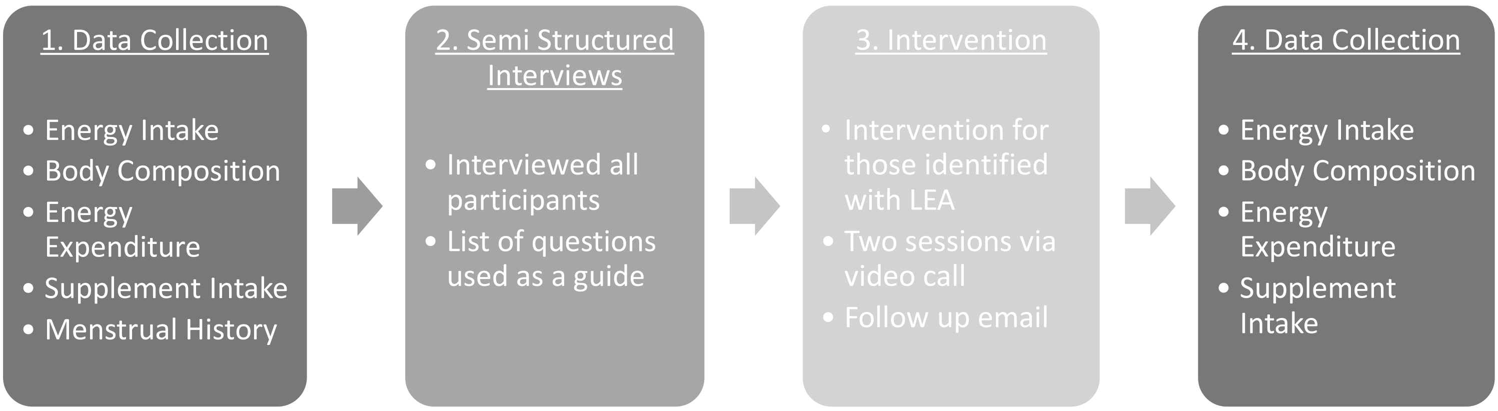
5.2 Methods

5.2.1 Study Design

This was a mixed method study as both quantitative and qualitative data were collected and combined to gain a better understanding of the research questions. The study involved two data collection periods approximately two months apart as well as semi-structured interviews that were completed during the baseline data collection. Data collection periods were two months apart to allow three weeks for allocated participants to complete the intervention, and then another month before repeating data collection to test the effectiveness of the intervention. Baseline quantitative data collected in the first data collection period was used to calculate participants' energy availability. This data was used to allocate participants to the intervention or control group, with those meeting low energy availability (LEA) criteria allocated the intervention group while those with adequate energy availability allocated to the control group. Participants in the intervention group received two individualised 'food first' dietary education sessions over video call that incorporated motivational interviewing to improve compliance and the effectiveness of the intervention sessions. These were followed up with an email to check in on participants' progress. Participants in the control group received a standard sports nutrition education infographic with information generalised to their sport (Appendix 9-11). Semi-structured interviews (Appendix 7) were designed to investigate the determinants of food choice across both the intervention and control athlete groups, and whether any differences were associated with the prevalence and non-prevalence of LEA.

Female athletes aged between 17 and 50 years participated in this study. Participants represented endurance (n=9) , aesthetic (n=6), and team sports (n=6). These different sports were included to determine whether the type of sport impacted athletes' food choices and dietary habits, and whether LEA was a phenomenon unique to a particular sport.

Diagram 1 Study Design



Recruitment

The athletes were recruited from convenience populations of long-distance and trail runners (endurance sports), tumblers and trampolinists (aesthetic sports), and soccer players (team sport). Both endurance and aesthetic sport athletes were recruited to represent leanness sports, as these sports traditionally favour a lean body composition that has a high power-to-weight ratio and are perceived as aerodynamic and aesthetically pleasing. Team sport athletes were recruited to represent a traditionally non-leanness sport as they tend to favour muscle strength and agility over a lean physique and are considered to be at lower risk of LEA (Wright et al., 2014).

Recruitment methods involved contacting sports club officials via phone call or email to ask whether they were willing to pass on information to athletes interested in participating, and to obtain permission to recruit from their athlete groups. Upon written approval from relevant club staff and coaches the study was presented to prospective participants using mixed methods. How participants received the recruitment information about the study depended on their availability. Aesthetic and team sport athletes received a short oral presentation at the beginning of one of their training sessions. The endurance athletes, who trained independently, received a study information sheet that was circulated by the club on their social media pages or via email. Athletes interested in participating were required to contact the principal researcher via email to assess eligibility and obtain a detailed Participant Information Sheet and Consent form. Written informed consent was required for participation in this study. Ethical approval was provided by the Flinders University Human Research Ethics Committee (Project number 4785).

Inclusion and Exclusion Criteria

To be included in the study athletes were required to train and compete at an elite level in either endurance (distance or trail running), aesthetic (trampoline or tumbling) or team sports (soccer). Elite sport was classified as competing at a state level or above. It was also preferred that participants were aged between 18-25 years as most athletes competing at an elite level within these sports were in this age bracket. However, this age range was increased up to 50 years in the endurance sport group due to difficulty recruiting sufficient numbers of participants. All but one of the endurance athletes recruited were older than 25 years. Participants who disclosed having an eating disorder or disordered eating at recruitment were included, although it is acknowledged that these eating behaviours may create bias towards LEA in these participants.

Athletes were excluded if they were injured, in the off-season at the time of data collection, retired, or had been unable to train and compete for an extended period due to other reasons which may have affected their energy expenditure and energy availability status.

All athletes were reminded that participation was voluntary and that they could withdraw at any stage without penalty if they felt uncomfortable or were unable to complete the study for other reasons. Coaches, support staff and athletes within each sport were not informed about which of the athletes were participants in this study, but individuals were permitted to disclose their participation if they chose to do so.

Twenty-eight eligible participants were recruited for the study, ten endurance runners, seven gymnasts and eleven soccer players. Sample size calculations based on data collected in a similar but unrelated study suggested at least ten participants per group were ideal to achieve meaningful statistical assessment. However, this was unachievable for this study due to the limited availability of local elite athletes as many were training and competing interstate or overseas for other opportunities within their sport. This was particularly relevant within the aesthetic sports group, many of whom were training or competing at national and international sports institutes during the data collection period. Some athletes who had been training and competing interstate or overseas had moved home to Australia during COVID lockdown but were not training locally within their sport due to COVID border restrictions. Unfortunately, these athletes were unavailable at the time of the study data collection.

Attrition occurred between the first and second data collection points, partly due to COVID restrictions delaying the start of data collection and elongating the time between data collection periods for some participants. Twenty-one participants with completed the study, including nine endurance sport athletes, six aesthetic sport athletes and six team sport athletes. Each sport was also divided into intervention and control groups, based on their LEA status, which further decreased the number of participants in each group.

Given that attrition limited final participant numbers, particularly in the aesthetic sport control group, further recruitment was actively pursued. However, suitable elite sport participants were not available due to COVID lockdowns or training interstate. External interstate participation was not possible as participants were required to have body composition measurements taken using standardised equipment and were required to wear an accelerometer that was personally fitted.

5.2.2 Quantitative Data Collection

Energy intake (accessed via dietary intake), exercise energy expenditure and fat-free mass were determined to calculate energy availability. Other quantitative data collected included additional anthropometric data, and participants' ages, macronutrient intakes, micronutrient intakes, and food group intakes. Dietary supplement intake data was also collected using the validated questionnaire presented in Chapter 3.

Energy and Nutrient Intake

Food and fluid intakes were collected and nutrient intakes were calculated using a FoodWorks™ Research Food Diary app and FoodWorks™ Professional nutrition assessment software version 10

(Xyris Pty Ltd, Brisbane, QLD, Australia). Participants recorded their food and fluid intakes for seven consecutive days using the Research Food Diary app. Unlike commercial online food diaries, this electronic food diary did not disclose any analytical data such as energy (kcal or kJ) or nutrient content of recorded intakes. Food and fluid intakes were collected over consecutive days for this study, to match the same days that exercise energy expenditure was measured using accelerometers. Continuous days energy expenditure measurements were required to capture variability in training and competition days.

Participants estimated their food and fluid intake portion sizes using usual household measures (e.g. cup or spoon measures), rather than weighing foods, as the latter can increase bias towards eating foods that are easy to weigh instead of habitual food choices. Participants sent their recorded food and fluid intakes from the Research Food Diary app to the principal researcher who analysed the data using FoodWorks™ Professional nutrition assessment software. The principal researcher checked the recorded food and fluid intakes before analysis and followed up with participants about inconsistencies or unusual data. The nutrient data of interest included total energy, dietary protein, fat, carbohydrates, fibre, calcium and iron. Dietary quality was also assessed according to the Australian Guide to Healthy Eating, identifying recorded foods by their food groups. These food groups included fruits, vegetables, meats and alternatives, bread and cereals, dairy and alternatives and discretionary foods (National Health and Medical Research Council, 2013).

Food and fluid intakes were measured during baseline data collection period and upon completion of the study two months later. During the time between the first and final data collections participants in the intervention groups received the motivational interview dietary education sessions while those allocated to the control groups received the standard sports nutrition education infographic.

Exercise Energy Expenditure

Energy expenditure was measured using Actigraph GT3X+ tri-axial accelerometers (ActiGraph LLC GT3X+, Pensacola, FL, USA), which recorded acceleration information to estimate the intensity of vertical, anteroposterior and mediolateral movements (Day et al., 2014). Participants wore an accelerometer during the same 7 days that food and fluid intakes were recorded. The accelerometer was worn on or just above the right hip, secured by an elastic belt. The device was worn continuously for the 7-day study period apart from during activities that would submerge the accelerometer in water (e.g. showering or swimming) or while sleeping to avoid discomfort (Brown et al., 2017; Civil et al., 2019). Sixty-second sample epochs were collected by the devices at a 30Hz sample rate. Data from the accelerometers was analysed using ActiLife software version 6 (Actigraph LLC, Pensacola, FL, USA). Energy expenditure from physical activity was estimated using the Freedson V3 Combination algorithm, from the vector magnitude counts per minute of the three axes. The main data of interest was exercise energy expenditure which was reported for the total time wearing the accelerometer, per day and per hour.

Anthropometry

Body composition was measured using a bioelectrical impedance analysis (BIA) scale (Tanita InnerScan Body Composition Monitor Model BC-541, Tanita Australia, Kewdale, WA, Australia). Participants' height, weight, age and activity level were required to complete the measurements. A stadiometer was used by the PhD candidate to measure the height of participants. The relevant data collected by the BIA scale included weight, fat percentage, muscle mass, total body water percentage and bone mass. Fat-free mass (FFM) was calculated from this data using the equation, FFM = (weight [kg] * (1 - (body fat [%]/ 100)) (Mountjoy et al., 2014; Maughan et al., 2018; Mountjoy et al., 2018a; Mountjoy et al., 2018b; Robertson & Mountjoy, 2018; Sygo et al., 2018; Melin et al., 2019). It was important that fat-free mass was determined as this was required to calculate the energy availability for participants.

Dietary Supplements Intake Questionnaire

Participants' reported supplement intakes were quantified using the Dietary Supplements Intake Questionnaire designed and validated for use in this PhD project and described in Chapter 3 of this thesis. The questionnaire was available as an online platform using Qualtrics™ software(Qualtrics XM, Seattle, WA, USA), allowing participants to complete questions electronically. The questionnaire was separated into the following supplement categories which included Vitamins, Minerals, Herbals, Gut Health, Oils & Seeds, Weight Loss, Protein, and Performance Supplements such as sports drinks, caffeine and carbohydrate gels. Participants reported the supplements taken from each category, and recorded the brand, physical form taken (e.g. powder, tablet, capsule), dose, and frequency of use for each supplement. These data allowed for the quantification of supplement intakes that were added to nutrient intakes from food to assess overall nutrient adequacy.

5.2.3 Qualitative Data Collection

The qualitative component utilised an interpretivist epistemology and relativist ontology and centred around the understanding that reality is subjective and created through human action and interaction (Scotland, 2012). Interpretivist epistemology focuses on the perspectives and interpretations of individuals, and makes the assumption that knowledge is created through understanding the community of the individuals studied (Al-Saadi, 2014). This was paired with a relativist ontological approach which makes the assumption that reality differs between individuals and is subjective (Scotland, 2012). It is also assumed there are multiple realities that can be investigated through researcher's interactions individual participants (Kivunja & Kuyini, 2017).

Qualitative data was collected using semi-structured interviews that were conducted by the principal researcher with all athletes. An interview guide was used (Appendix 7) that was adapted from the Pilot Study on the determinants of food choice (Chapter 4), by adding specific questions about food restriction and body composition manipulation. The guide helped to maintain some consistency between the interviews, while also allowing for the inclusion of unplanned questions to expand on topics and encourage participants to elaborate on certain points (Kvale & Brinkmann, 2009; Merriam & Tisdell, 2016). The questions included in the guide aimed to investigate the determinants of food choice and supplement use in participants both with and without identified LEA. Initially the interviews were conducted face-to-face, although this changed to online interviews via zoom to accommodate COVID restrictions. The semi-structured interviews were completed during the baseline data collection period as results were used to influence the intervention sessions provided to participants with LEA. The recurring themes found during interviews were made a focus of the intervention sessions and information from individual participants' interviews were used to individualise the advice provided. All interviews were voice recorded and transcribed verbatim by the principal researcher prior to analysis.

5.2.4 The Motivational Interview Intervention

Participants identified with low energy availability from each sport were allocated to the intervention groups. The use of a motivational interview (MI) aimed to increase energy availability through dietary advice and subsequent dietary changes for these participants. The MI intervention involved individual nutrition counselling sessions using the 'Food First' motivational interviewing approach. The motivational interviewing technique used a client-centred counselling technique to encourage intrinsic motivation and decrease uncertainty, aimed at improving health-related behaviours, as described by (Hardcastle et al., 2017; Lee & Lim, 2019). The 'spirit' of motivational interviewing refers to components that were the focus when delivering the intervention to individuals, which include collaboration, evocation, autonomy, and compassion (Hardcastle et al., 2017; Mack et al., 2021). The use of motivational interviewing was chosen for the intervention as other studies with athletes have shown general education alone is not effective to promote dietary change (Day et al., 2014; Laramée et al., 2017). It has been suggested that motivational interviewing may strengthen nutrition support and counselling by uncovering emotional barriers (Bentley et al., 2021). The use of motivational interview techniques to address LEA in athlete populations has also not been well documented in the literature, as highlighted by one study indicating that further research on the use of the MI technique is required (Bentley et al., 2021).

Prior to conducting the MI intervention, intensive training was undertaken by the PhD candidate to develop skills in motivational interviewing. This included courses in 'Supporting workforce practice change: A pilot study of a Motivational Interviewing virtual-client software tool for health professionals' and 'Motivational Interviewing in Practice'. The intervention involved two nutrition counselling sessions a week apart, conducted via an online platform familiar to each participant (Zoom or Microsoft Teams) and a check-in email a week after the second session. The aim of the first session was to provide participants with recommendations to increase energy availability and address any nutrient deficiencies identified from the baseline dietary analyses. Both the quantitative and qualitative data collected were used to individualise the recommendations and dietary information provided to each participant. During the MI interventions, participants were encouraged to suggest their own dietary changes guided by individualised recommendations from the PhD candidate.

Three different motivational interviewing techniques were used during the sessions to support dietary change. The OARS technique (Open-ended questions, Affirmation, Reflective statements and Summary statements) was used to engage participants (Hardcastle et al., 2017; Lee & Lim, 2019; Mack et al., 2021). DARN questions (Desire, Ability, Reason and Need) were used to evoke motivation to change (Hardcastle et al., 2017). Lastly a plan for remedial dietary change was developed through CATs (Commitment, Activation and Taking steps) (Hardcastle et al., 2017). During the follow-up sessions the recommendations and plans made by participants were revisited, discussing how successful the participants had been in making dietary changes planned in the initial session. Further use of motivational interviewing techniques was used to assess and problem-solve any barriers to making the required dietary changes.

The participants identified to be at lower risk of LEA (>30 kcal.kg FFM.d^{-1}) were allocated to the control groups. These participants received the standard nutrition education infographic with generic sports nutrition information that was adapted to be relevant to each sport (Appendix 9-11).

5.2.5 Quantitative Data Analysis

Energy availability was calculated using the equation EA = [EI (kcal) – EEE (kcal)] / FFM (kg) (Mountjoy et al., 2014; Mountjoy et al., 2018a). Low energy availability was defined as <30 kcal/kg FFM, risk of LEA 30 – 45 kcal/kg FFM and adequate EA >45 kcal/kg FFM (Mountjoy et al., 2014; Mountjoy et al., 2018a).

Statistical Analyses

Quantitative data statistical analyses were completed using IBM SPSS® Statistics software (Version 28). The data sets were checked for normality using the Shapiro-Wilk test which is appropriate for small sample sizes.

One-way ANOVA with Tukey's HSD post hoc tests were conducted to determine whether energy availability, nutrient intake and food group values differed between the endurance, aesthetic and team sport groups. These tests were completed both prior to and post the MI counselling in the intervention groups and prior to and post exposure to the generic nutrition infographic in the control groups.

Intra-group comparison of baseline and study completion data for each sport's intervention and control group was performed using a repeated measures ANOVA with a Greenhouse-Geisser correction. The Bonferroni test was used for post-hoc analysis, with the alpha level of significance set at $p < 0.05$.

5.2.6 Qualitative Data Analysis

The six steps of thematic data analysis was used to analyse the qualitative data (Braun & Clarke, 2006; Clarke & Braun, 2013; Braun et al., 2016; Smith & Sparkes, 2016), which was trialed and presented in Chapter 4. These steps included data familiarization, coding, theme development, revision, naming, and reporting themes (Braun & Clarke, 2006; Clarke & Braun, 2013; Smith & Sparkes, 2016). Double-blind coding was completed with the PhD project co-supervisor. The principal researcher and the co-supervisor independently coded a subset of the transcripts (n=30) and then compared codes to ensure consistency of coding. Any disagreements regarding the naming of the codes were settled through discussion between the principal researcher and co-supervisor until a consensus was reached. Identified themes were related back to the quantitative data and used to support the results found within these data. Unlike the study described in Chapter 4, a more deductive approach to thematic analysis was taken as the identified themes were used to support the pre-existing quantitative data results. However, it is acknowledged that thematic analysis involves some elements of inductive as well as deductive analysis rather than one or the other (Robertson et al., 2013).

The strategies used to maintain the validity and trustworthiness of the qualitative research completed, included recording an audit trail, member checking and thick and rich description (Creswell & Miller, 2000). The use of an audit trail involved taking notes after interviews and recording decisions about the study during meetings (Creswell & Miller, 2000). Member checking required sending participants their interview transcripts for feedback or changes to be made. The use of member checking has been critiqued as a strategy to maintain validity or trustworthiness as participants may not have research expertise (Smith & McGannon, 2018). They may therefore simply agree with the data presented as they lack knowledge or time to review the transcripts thoroughly (Smith & McGannon, 2018). However, member checking may benefit participants by helping them feel valued by validating their experience (Rager, 2005; Harper & Cole, 2012). Due to the personal nature of the data collected member checking was used in this study to confirm with participants whether they were comfortable sharing this information. Directly quoting participants' responses was used to produce a thick and rich description of data. This improved the authenticity of the data, assisting readers to understand the experience that was being described by participants (Creswell & Miller, 2000).

5.3 Results

5.3.1 Participant Characteristics

Participant Characteristics at Baseline

Table 3 Participant Characteristics at Baseline - Intervention and Control Groups.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Age (years)	35.4 ± 8.5[1]	21.6 ± 3.1	23.0 ± 1.7	34.5 ± 5.0[2]	17.0	20.7 ± 0.6
Height (cm)	166.6 ± 6.5	164.2 ± 10.1	169.8 ± 3.4	170.5 ± 7.8	157.0	166.7 ± 8.1
Weight (kg)	63.1 ± 8.9	62.2 ± 12.9	62.4 ± 6.9	61.9 ± 5.7	51.7	64.0 ± 11.6
Fat (% FM)	21.5 ± 6.7	24.2 ± 4.2	20.4 ± 4.6	16.2 ± 4.0	22.4	21.7 ± 6.8

[1]*Statistically significant, age of intervention endurance athletes significantly higher than aesthetic and team athletes (p = 0.005).*
[2]*Age of the endurance, aesthetic and team sport control groups (p=0.022), post hoc analyses incomplete due to inadequate sample size.*

Table 1 shows the mean ± SD of the participant characteristics at baseline for the intervention and control groups from each sport. Results from the inter-sport baseline participant characteristics analyses showed the age of the endurance sport intervention group (35.4 ± 8.5 years) was significantly higher than the aesthetic sport (21.6 ± 3.1 years; $p = 0.007$) and team sport groups (23.0 ± 1.7 years; $p = 0.036$). The aesthetic sport control group consisted of only one participant, therefore mean and standard deviation values were not relevant. Similar to the intervention group, analyses of the control groups data showed the mean age of the endurance sport group (34.5 ± 5.0 years) was significantly higher than the mean age of the team sport control group ($p = 0.022$). There were no significant differences between any of the sports groups for height, weight and FFM. Post hoc analyses could not be completed for comparisons with the aesthetic sport control group due to the small sample size of this group (n=1).

Participant Characteristics upon Study Completion

Table 4 Participant Characteristics upon study completion – Intervention and Control Groups.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Age (years)	35.4 ± 8.5[1]	21.6 ± 3.1	23.0 ± 1.7	34.5 ± 5.0	17.0	20.7 ± 0.6
Height (cm)	166.6 ± 6.5	164.2 ± 10.1	169.8 ± 3.4	170.5 ± 7.8	157.0	166.7 ± 8.1
Weight (kg)	63.2 ± 9.2	63.1 ± 11.5	63.6 ± 6.1	62.1 ± 4.0	52.3	61.4 ± 8.2
Fat (% FM)	21.6 ± 4.1	24.6 ± 4.6	24.7 ± 6.4	16.9 ± 1.1	24.4	22.3 ± 2.9

[1]Statistically significant, age of intervention endurance athletes significantly higher than aesthetic and team athletes (p = 0.005).
[2]Age of the endurance, aesthetic and team sport control groups (p=0.022), post hoc analyses incomplete due to inadequate sample size.

Age (years) and height analyses were not repeated at this completion time point as these parameters would not have changed during the data collection period. The other participant characteristic data (weight, and fat mass (FM %) showed no significant differences between all groups (Table 2).

5.3.2 Energy Availability

Energy Availability at Baseline

The mean energy availability (EA) for the Intervention groups in each sport (Table 3) was below the cut-off value that identifies low energy availability (LEA <30 kcal.kgFFM.d^{-1}). There were no significant differences between EA for the intervention groups at baseline for each sport or between the control groups for each sport.

Despite athletes from both the intervention and control groups acknowledging they were aware of the need to have adequate energy to fuel optimal performance, 77.7% of the endurance sport athletes in the intervention group had a calculated LEA below the accepted cut-off, with an LEA of 20.5 ± 5.42 kcal.kgFFM.d^{-1}. These athletes described making a more conscious effort to eat enough, especially the day or night before a long run or event, and reported they used exercise as an excuse to eat more, but may not have eaten adequately at other times, leading to their LEA.

One runner from the endurance sport intervention group mentioned that running helped her to feel less guilty for eating carbohydrates or more food as she was expending more energy, “I reason with myself that you know that you are exercising and you’re running more and you’re burning more energy, so it is OK [to eat more]” (Intervention participant E2). Another athlete commented that she ate more in preparation for a long run but was not as concerned about other meals “I just know that I need to have a certain amount of energy if I’m doing a longer run, for day-to-day meals that aren’t training, not so much” (Intervention participant E6).

Mean EI (3113.9 ± 881.9 kcal) and also EA (40.9 ± 1.9 kcal.kgFFM.d^{-1}) data for the endurance sport control group was significantly higher than their intervention group counterparts (EI $p = 0.018$, EA $p = 0.009$) (Table 3). The mean EA for the endurance sport control group was above the LEA threshold, although within the moderate risk of LEA range (30-45 kcal.kgFFM.d^{-1}) (Table 3). These athletes reported they were aware that if they do not fuel adequately for a run, it affected performance, “I had nothing in the tank – my legs were heavy and everything felt yuck” (Control participant E5).

The mean EA for the aesthetic sport intervention group (15.8 ± 9.4 kcal.kgFFM.d^{-1}) was lower than the endurance and team sports intervention groups, although these differences were not significant (Table 3). Most of the aesthetic intervention athletes reported increased food intake on training days, although not consistently; “I’ll know that if I’m training if I haven’t had enough intake cause I’ll start feeling really lethargic and then I’ll realise that I’ve missed something today or whatever” (Intervention participant A5). Many of these athletes also commented that they would eat less if they stopped training and competing due to expending less energy. One of the aesthetic intervention sport athletes felt that currently they did not work hard enough during sessions to burn large amounts of energy; “I suppose my sport’s a bit different because it is a high intensity sport but you get a lot of rest times – you don’t burn up as much energy as one might think”.

The aesthetic sport control group athlete (n=1) had a higher EI (2160.4 kcal) than their intervention group counterparts (1468.7 ± 109.9 kcal) ($p = 0.001$) (Table 3), but statistical analyses were not possible due to the small sample size (n=) in this sport group. Nonetheless, this aesthetic sport control group athlete reported consistently eating more, even in situations where she felt uncomfortable; “Sometimes like at school my friends have tiny lunches, it used to affect me more but now I try to not think about it that much. I know that I train more and I need more energy” (Control participant A3).

Table 5 Energy Availability data at Baseline – Intervention and Control Groups.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
FFM (kg)	49.2 ± 4.5	46.8 ± 8.1	49.6 ± 4.5	51.8 ± 2.3	40.1	49.6 ± 5.8
EEE (kcal)	861.2 ± 257.7	771.7 ± 344.2	518.0 ± 29.2	808.0 ± 1142.7	431.4	-
EI (kcal)	1870.4 ± 413.8[1]	1468.7 ± 109.9	1561.3 ± 45.1	3113.9 ± 881.9[1]	2160.4	1508.5 ± 216.6
EA ($kcal.kgFFM.d^{-1}$)	20.5 ± 5.4[2]	15.8 ± 9.4	21.1 ± 1.3	40.9 ± 1.9[2]	43.1	-
LEA prevalence (% of each grp)	77.7	83.3	50.0	-	-	-

[1]*Mean EI for the endurance intervention group was significantly lower (p = 0.018) than the endurance control group.*

[2]*Mean EA for the endurance intervention group was significantly lower (p = 0.009) than the endurance control group.*

Table 3 shows the mean energy availability of the team sport intervention group was 21.1 ± 1.3 kcal.kgFFM.d^{-1}. Despite showing a mean EA that qualified as LEA, team sport intervention group athletes described that they were conscious of their food choices around training and games; "maybe just conscious decisions about making sure there is more protein on my plate or making sure that I've had enough carbohydrates in if I've had a big session" (Intervention participant T7).

Exercise energy expenditure (EEE) data were not available for all team sport athletes due to accelerometer malfunctions. Therefore, EA could not be calculated for these participants and by default they were placed into the control group. The mean EI for these athletes was not significantly different to their intervention group team sport counterparts (intervention 1561.3 ± 45.1 kcal.dy^{-1}; control 1508.5 ± 216.6 kcal.dy^{-1}), suggesting that athletes from both the intervention and control groups may have had similar dietary habits. The team sport control group athletes reportedly allowed themselves to eat energy dense foods, as they were less likely to lead to weight gain due to the large amounts of energy expended; "like dessert, I still probably have more of that kind of thing than I should, I know that I can because I'm not going to get fat" (Control participant T5). One control group athlete also mentioned they had not fuelled themselves adequately in the past and consequently felt quite fatigued; "I was always tired and I'd come home from school and I'd have a nap before training. I thought that wasn't normal. I was way under-fuelling at that time" (Control participant AG).

Energy Availability upon Study Completion

Upon completion of the study, the intervention groups did not show any significant differences between sports for mean energy availability (EA) (Table 4). The control groups demonstrated significant inter-sport differences for mean energy intake (EI, kcal.dy^{-1}) ($F = 14.161$, $p = 0.030$) and EA ($F = 25.925$, $p = 0.013$) upon completion of the study (Table 4), but post hoc analysis could not be completed to show the direction of the difference due to the small sample size of these control groups. However, the data show the mean EI (1445.2 ± 242.1 kcal.dy^{-1}) and mean EA (17.5 ± 3.7 kcal.kgFFM.d^{-1}) of the team sport control group were lower than the endurance and aesthetic sports control groups (Table 4). Intra-group comparison found there was a significant difference between the exercise energy expenditure (EEE) of the endurance sport intervention group (737.5 ± 136.9 kcal) and endurance sport control group (1270.7 ± 395.5 kcal) ($p = 0.012$). There was also a significant difference between the EA of the team sport intervention group (31.6 ± 4.8 kcal.kgFFM.d^{-1}) and the team sport control group (17.5 ± 3.7 kcal.kgFFM.d^{-1}) ($p = 0.016$) (Table 4).

Table 6 Energy Availability at study completion – Intervention and Control Groups.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
FFM (kg)	49.3 ± 5.3	47.3 ± 7.4	47.7 ± 3.9	51.7 ± 2.7	39.5	47.7 ± 6.4
EEE (kcal)	737.5 ± 136.9[1]	710.4 ± 559.8	362.5 ± 83.4	1270.7 ± 395.5[1]	442.3	624.4 ± 319.2
EI (kcal)	2002.0 ± 390.5	1815.8 ± 280.6	1708.3 ± 56.4	2431.8 ± 161.2	2309.7	1445.2 ± 242.1
EA (kcal.kgFFM.d^{-1})	25.4 ± 5.7	24.7 ± 12.7	31.6 ± 4.8[2]	22.4 ± 3.4	47.2	17.5 ± 3.72[2]

[1]*Mean EEE for the endurance intervention group was significantly lower (p = 0.012) than the endurance control group.*

[2]*Mean EA for the team sport intervention group was significantly higher (p = 0.016) than the team sport control group.*

Energy Availability at Baseline vs. Study Completion – Summary Table

For the intervention groups (Table 5) it was found that mean energy intake (EA kcal.dy^{-1}) was significantly higher at study completion compared to baseline for the aesthetic (F = 8.081, p = 0.047) and team sport (F = 410.231, p = 0.002) athletes. Similarly, mean energy availability (EA kcal.kgFFM.dy^{-1}) was significantly higher at study completion compared to baseline for each of the sports in the intervention group (endurance F = 6.969, p = 0.039; aesthetic F = 10.555, p = 0.031; team F = 26.248, p = 0.036). However, at study completion the mean EA for the endurance and aesthetic sport groups remained below the LEA threshold (<30 kgFFM.d^{-1}), while the team sport EA was slightly higher than this threshold.

For the control groups (Table 5) there were no significant differences in EA between baseline and study completion across each sport, even though the mean EA for the endurance sport control group decreased between baseline and study completion. The aesthetic sport group singular participant increased their EA at study completion compared to baseline, but this change was also not significant. Nonetheless, this increase in EA remained above the LEA threshold (<30 kgFFM.d^{-1}) but with n=1 participant in this group, mean and standard deviation could not be calculated. There was a lack of EEE or EA data for the team sport control group at baseline for comparison with end-point data due to accelerometer malfunctions, although end-point data showed the mean EA was below the LEA threshold.

Table 7 Energy Availability Data – Intervention and control groups Baseline vs. Study Completion.

	Intervention						Control					
	Endurance (n=7)		Aesthetic (n=5)		Team (n=3)		Endurance (n=2)		Aesthetic (n=1)		Team (n=3)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
FFM (kg)	49.2 ± 4.5	49.3 ± 5.3	46.8 ± 8.1	47.3 ± 7.4	49.6 ± 4.5	47.7 ± 3.9	51.8 ± 2.3	51.7 ± 2.7	40.1	39.5	49.6 ± 5.8	47.7 ± 6.4
EEE (kcal)	861.2 ± 257.7	737.5 ± 136.9	771.7 ± 344.2	710.4 ± 559.8	518.0 ± 29.2	362.5 ± 83.4	808.0 ± 1142.7	1270.7 ± 395.5	431.4	442.3	-	624.4 ± 319.2
EI (kcal)	1870.4 ± 413.8	2002.0 ± 390.5	1468.7 ± 109.9	1815.8 ± 280.62	1561.3 ± 45.1	1708.3[2] ± 56.44	3113.9 ± 881.9	2431.8 ± 161.2	2160.4	2309.7	1508.5 ± 216.6	1445.2 ± 242.1
EA (kcal.kgFFM.d^{-1})	20.5 ± 5.42	25.4[1] ± 5.71	15.8 ± 9.4	24.7 ± 12.73	21.1 ± 1.3	31.6[3] ± 4.85	40.9 ± 1.9	22.4 ± 3.4	43.1	47.2	-	17.5 ± 3.7

[1] *Mean EA for the intervention group endurance sport athletes at completion significantly higher than baseline (p = 0.039).*

[2] *Mean EI for the intervention group team sport athletes at completion significantly higher than baseline (p = 0.002).*

[3] *Mean EA for the intervention group team sport athletes at completion significantly higher than baseline (p = 0.036).*

5.3.3 Nutrient Intakes

Nutrient Intakes at Baseline

Table 8 Nutrient intakes at baseline – Intervention and Control groups.

	Sport Nutrition Recommendations or RDI	Intervention			Control		
		Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Protein ($g.kg.dy^{-1}$)	Endurance: 1.2-2.0 Aesthetic: 1.5-1.7 Team: 1.2-2.0	1.3 ± 0.2	1.2 ± 0.3	1.0 ± 0.3	1.9 ± 0.6	2.0	1.1 ± 0.3
Supplements ($g.kg.dy^{-1}$)		0.06 ± 0.11	0.08 ± 0.10	0.11 ± 0.08	0.23 ± 0.33	0	0.02 ± 0.03
Fat (%EI)	Endurance: <20 Aesthetic: 20-25 Team: 20-35	36 ± 5	33 ± 6	33 ± 7	34 ± 2	30	29 ± 2
Carbohydrate ($g.kg.dy^{-1}$)	Endurance: 5-7 Aesthetic: 5-7 Team: 5-7	3.1 ± 0.8	2.7 ± 0.9	2.9 ± 0.6	5.5 ± 3.2	5.2	2.9 ± 0.4
Supplements ($g.kg.dy^{-1}$)		0.04 ± 0.05	0.00 ± 0.01	0.09 ± 0.08	0	0	0.09 ± 0.10
Fibre ($g.dy^{-1}$)	25	26.7 ± 7.1	17.8 ± 7.7	21.5 ± 11.2	37.2 ± 7.1[1]	35.1	17.5 ± 3.8[1]
Calcium ($mg.dy^{-1}$)	1,000	875.6 ± 80.8[2,4]	595.4 ± 121.6[2]	456. 8 ± 72.8[2]	1272.5 ± 11.5[3,4]	1142.8	510.5 ± 111.1[3]
Supplements ($mg.dy^{-1}$)		0	0	0	0	0	0

Iron (mg.dy^{-1})	18	10.7 ± 4.2	6.4 ± 1.9	7.6 ± 1.8	16.0 ± 5.8	17.5	6.7 ± 3.2
Supplements (mg.dy^{-1})		5.91 ± 11.44	5.00 ± 5.14	0.87 ± 1.50	0	0	0

[1]Mean dietary fibre intake for the endurance control group was significantly higher than the team sport control group (p=0.046

[2]Mean dietary calcium intake for the endurance intervention group was significantly higher than aesthetic and team intervention groups (p = 0.001).

[3]Mean dietary calcium intake for the endurance control group was significantly higher than the team sport control group (p=0.005)

[4]Mean dietary calcium intake for the endurance intervention group was significantly lower than the endurance control group (p = 0.001*).*

Table 6 shows inter-group comparisons for mean nutrient intakes at baseline from dietary as well as supplement intakes. Sport-specific macronutrient recommendations, fibre Estimated Average Requirement (EAR) and micronutrient Recommended Daily Intake (RDI) were determined as follows. Endurance sport recommendations (Logue et al., 2018; Holtzman & Ackerman, 2021); Aesthetic sport recommendations (Robertson & Mountjoy, 2018); Team Sport recommendations (Renard et al., 2021); Micronutrients (National Health and Medical Research Council, 2017); Other (Thomas et al., 2016; Mountjoy et al., 2018a; Moore et al., 2021).

Protein

There were no significant differences in dietary protein intakes between each sport in the intervention group (Table 6). However, although the endurance sport athletes in the intervention group (1.3 ± 0.2 $g.kg.dy^{-1}$) met their protein dietary requirements, the aesthetic (1.2 ± 0.3 $g.kg.dy^{-1}$) and team sport (1.0 ± 0.3 $g.kg.dy^{-1}$) athletes did not. Additional contributions from protein supplements were negligible in each of these sports (Table 6) and failed to elevate total protein intakes to meet their requirements in the aesthetic and team sports in the intervention group.

Similar to the intervention groups, there were no significant differences in dietary protein intakes between each sport in the control group (Table 6). In this group, the mean dietary protein intakes for the endurance (1.9 ± 0.6$g.kg.dy^{-1}$) group and singular aesthetic sport athlete (2.0$g.kg.dy^{-1}$) met requirements, whereas the team sport athletes did not (1.1 ± 0.3 $g.kg.dy^{-1}$). The additional contribution from supplements in the team sport group did not increase the total protein intake sufficiently to meet requirements (Table 6).

There were also no significant differences in dietary protein intakes between the intervention and control groups for each sport.

During semi-structured interviews with endurance athletes in both the intervention and control groups, they spoke of having protein after exercise for recovery, as well as a part of daily meals, which supported the quantitative data showing adequate protein intakes (Table 6).These athletes also spoke of prioritising protein after training sessions, “after I’ll have something protein like a protein shake” (Intervention participant E10) and “if I’ve done a big run, it’s always carbs, give me a burger, anything like that, a decent meal, with lots of protein” (Control participant E5). The importance of protein for recovery was also supported by an endurance sport athlete in the control group, who stated she put “a higher focus on proteins just for recovery of muscles” (Control participant A3). Endurance sport athletes in the intervention group preferred “balanced” meals that included vegetables and a protein component, “I try to look for balance, so if I get lunch on the way home, I will try to get something that has some protein and veggies in it" (Intervention participant E3) and "protein in particular, I consciously make sure that I get it in my diet especially like on training day" (Intervention participant T8).

Although the team sport athletes in the control group failed to meet their dietary protein requirements, there was an awareness about adding protein into their diet. Team sport athletes were also aware of eating protein after training and games, "I have been told to eat something protein filled soon after training and games, I've heard that that is good" (Control participant T3)

Fat

There were no significant differences in dietary fat intakes between the sports within or between each of the intervention and control groups (Table 6). However, within the intervention group both the endurance (36 ± 5 %EI) and aesthetic sport (33 ± 6 %EI) athletes exceeded their recommended maximum recommended dietary fat intakes (Table 6). Despite this most of the endurance athletes described avoiding high-fat foods such as battered or fried foods, chips, bacon, cheese, and chocolate, "Because they [fatty dessert foods] are not that good for me – if I've got a day off, in the evening after training then I would, but too much sugar and fat doesn't make you feel that good afterwards" (Control participant T5). The prevailing attitude towards dietary fat intake among the endurance sport athletes in the intervention group was summarised by the following comment , "you don't want high fat or chilli or that sort of stuff because it is just going to play with your guts later" (Intervention participant E3). Aesthetic sport athletes in the intervention group mentioned avoiding perceived high-fat foods such as ice cream, cakes, and chocolate due to perceiving them as 'unhealthy'. When asked why they avoided these foods they replied, "just because I know that they aren't good for you" (Intervention participant A1) or "because it is classified as an unhealthy food" (Intervention participant A2). Mean dietary fat intake for the team sport intervention group (33 ± 7 %EI) was within the recommended range (Table 6), albeit near the upper recommendation limit.

Among the control groups, mean dietary fat contributions to total energy intakes exceeded the recommended maximum in the endurance sport group (34 ± 2 %EI) and the single aesthetic sport athlete (30 %EI) (Table 6) who nonetheless commented during interview that she did not eat fatty foods daily but that having them "in moderation it is fine" (Control participant A3). The mean dietary fat contributions to total energy intakes for the team sport athletes (29 ± 2 %EI) was within the recommended range (Table 6). Intake of various supplements containing fat were not reported by any of the athletes.

Carbohydrate

There were no significant differences in mean daily carbohydrate intakes between sports in the intervention group (Table 6). However, the mean dietary carbohydrate intakes among the intervention groups showed the endurance sport group (3.1 ± 0.8 g.kg^{-1}) was below the recommended intake range (Table 6). Despite this quantitative finding, the following comments were attributed to these endurance sport athletes; "I'm quite regimented in my running and if I've got a really tough session, I'll carb load the night before and I'll have a big bowl of gluten-free pasta or something like rice and something quite big, but I wouldn't necessarily have that before a day that I know I'm not running" (Intervention participant E10), and "if I have a big training week ahead then I know, I don't feel guilty buying a loaf of bread that I'll devour over the week" (Intervention participant E2). Carbohydrate supplement intakes in this sport group (0.04 ± 0.05g.kg.dy^{-1}) did not add to the dietary carbohydrate intakes in sufficient amounts to achieve the recommended intake.

Similar to the endurance sport intervention group, the aesthetic sport intervention group athletes did not meet carbohydrate requirements (2.7 ± 0.9 g.kg^{-1}) (Table 6). Interview comments from these athletes included "I have been told off by my doctor that I need to carb up" (Intervention participant, A6).

The mean dietary carbohydrate intakes for the team sport intervention group did not meet the recommended daily carbohydrate intake range (2.9 ± 0.6 g.kg^{-1}) (Table 6). This inadequate intake was partly explained by the following comments from this athlete group; "Say for a double day I don't plan to eat more because I've got a double day (training – gym and a training session as well) I don't have the knowledge to know that I've got to eat more carbs or whatever, I just generally eat more" (Intervention participant T1), while another reported "I'll go a bit lower calories and lower carbs [on non-training days] because I'm not as tired or as hungry" (Intervention participant T8).

Among the intervention groups, endurance and team sport athletes had a mean carbohydrate supplement consumption of 0.04 ± 0.05g.kg.dy^{-1} and 0.09 ± 0.08g.kg.dy^{-1} respectively (Table 6). These mean daily supplement intakes did not add to total carbohydrate intakes sufficiently to meet requirements. The aesthetic sport athletes in the intervention group did not report any carbohydrate supplement intakes.

Among the control group sports, there were no significant differences in mean daily carbohydrate intakes between participating sports. Although the mean daily carbohydrate intake for team sport participants was lower than that for endurance sport participants, the large variance in this latter group precluded any statistical difference (Table 6). Due to the low participant number (n=1) in the aesthetic sport control group, statistical analysis was not possible. Nonetheless, both the control group endurance athletes (5.5 ± 3.2g.kg.dy^{-1}) and single aesthetic sport athlete (5.0g.kg.dy^{-1}) met their daily carbohydrate requirements from food alone (Table 6), while the team sport athletes in the control group did not meet their daily carbohydrate requirements (2.9 ± 0.4g.kg.dy^{-1}) (Table 6). These quantitative data for mean carbohydrate intakes were supported by interview comments from the endurance sport group; "I used to years ago eat more protein and less carbs but then the more I run, the more I crave that stuff – a sandwich or a bread roll or rice or potatoes" (Control participant E5) and "[wanting to know] what to eat for dinner the night before a race, how much carbs do you need to eat when you are carb loading for a marathon" (Control E9). Similarly, the aesthetic sport athlete in the control group commented; "[being aware of] more carbs for energy" and "Before training I'll have a big meal otherwise I'll get so hungry by the end of it, so that will be like a pasta or carb based" (Control participant A3). However, the following comment from the control group team sport athletes partly explained their inadequate mean daily carbohydrate intake; "If I don't have training then I won't fuel up on carbs, if I do have training then I will, after training I like to eat protein and stuff" (Control T9).

Addition of reported supplement intakes for the team sport group control group (0.09 ± 1.0g.kg.dy^{-1}) (Table 6) did not contribute to the mean daily carbohydrate intake sufficiently to meet requirements. Neither the endurance nor aesthetic sport athletes in the control group reported consuming carbohydrate-containing supplements.

Statistical comparisons between the intervention and control group endurance sports showed no significant difference in mean daily carbohydrate intakes, even though the endurance sport control group had a higher mean daily intake than the endurance sport intervention group (Table 6). Similar to the inter-sport comparisons within the control group, the large variance in the endurance sport control group precluded any detection of a significant difference when carbohydrate intakes were compared with their intervention group counterparts.

Dietary Fibre

An Estimated Average Intake (EAR) for dietary fibre was used in Table 6 in lieu of RDI, as there is insufficient epidemiological evidence to provide an RDI for dietary fibre (NHMRC, 2006).

Statistical analysis of the inter-sport baseline nutrient intakes of the intervention groups showed no significant differences between sports. The mean dietary fibre intake for the endurance sport athletes in intervention group (26.7 ± 7.1 $g.dy^{-1}$) showed they met their daily fibre recommendation (Table 6). This quantitative assessment was supported by the following interview comments from this group; "I really enjoy healthy food, I really love it…I can't not have veggies… I'll crave veggies" (Intervention participant E8) and "fibrous foods make me feel lighter on the day and I just find that I digest fruits and vegetables and plant proteins better" (Intervention participant E10). However, neither the aesthetic (17.8 ± 7.7$g.dy^{-1}$) nor team sport (21.5 ± 11.2 $g.dy^{-1}$) athletes in the intervention group met their recommended daily fibre intakes (Table 6).

Intakes of dietary fibre supplements were not mentioned by any of the sports group participants in the intervention group.

Among the control group sports, both the endurance (37.2 ± 7.1$g.dy^{-1}$) and aesthetic sport (35.1$g.dy^{-1}$) participants met their daily dietary fibre recommendation, but the team sport participants did not (17.5 ± 3.8$g.dy^{-1}$) (Table 6). This was reflected by a significant difference between these two sports, with the mean daily fibre intake marginally significantly higher than their team sport counterparts (F = 10.138, p = 0.046) (Table 6). The aesthetic sport group was not included in the statistical analyses, as there was only one remaining participant representing this sport.

None of the athletes across the participating sports in this control group made any comments about dietary fibre in the qualitative interview part of this study, nor were supplement intakes reported among the control group sports participants.

There were no significant differences between the endurance sport intervention and control groups, nor between the team sport intervention and control groups.

Calcium

Analysis of the baseline dietary calcium intakes for the different sports in the intervention group showed a significant difference between sport groups for dietary calcium intake (F = 24.678, p = 0.001). Post hoc analysis determined the mean daily calcium intake for the endurance sport group (875.6 ± 80.8$mg.dy^{-1}$) was significantly higher than the aesthetic sport (595.4 ± 121.6$mg.dy^{-1}$) (p = 0.001) and team sport groups (456.8 ± 72.8$mg.dy^{-1}$) (p = 0.001) (Table 6). However, none of the sports in the intervention group achieved the recommended daily dietary calcium intake (Table 6), and calcium supplement intakes were not reported by any of the participating sports athletes in the intervention group (Table 6). None of the participants in the intervention group commented specifically about their dietary calcium awareness nor intakes.

Among the control group, dietary calcium intake recommendations were met by the endurance sport group (1272.5 ± 11.5mg.dy^{-1}) but not by the team sport group (510.5 ± 111.1 mg.dy^{-1}) (Table 6). The single aesthetic sport participant (1142.8mg.dy^{-1}) did meet their dietary calcium recommended intake. Similar to the intervention group, calcium supplement intakes were not reported by any of the sports athletes in the control group, nor were any comments about dietary or supplemental calcium mentioned by this group during the qualitative interviews.

Baseline analyses found a significant difference between control group sports for calcium intake (F = 47.547, p = 0.005), but post hoc analysis could not be completed to determine the direction of difference due to one group having only one case (aesthetic control n=1). Nonetheless, post hoc analysis between the endurance and team sports in the control group showed a significantly higher dietary calcium intake for the endurance group (p=0.005) (Table 6).

Baseline statistical comparisons between each intervention and matching control group sport showed a significantly lower mean dietary calcium intake for the endurance intervention group compared to the control group (p = 0.001) (Table 6). Although the aesthetic sport intervention group had a mean daily dietary calcium intake lower than their control group counterpart, statistical analysis was not possible due to insufficient participants in the latter sport group (Table 6). There was no significant difference in mean daily dietary calcium intakes between the team sport intervention and control groups (Table 6).

Iron

There were no significant differences between the intervention sports groups for mean dietary iron intakes (Table 6). In addition, none of these intervention group sports athletes met their dietary iron recommended intakes, despite reported supplement intakes (Table 6). However, none were sufficient to increase total iron intakes to the recommended threshold. (Table 6). These results were supported by the following comments from endurance sport intervention group athletes; "I have sought help from sports doctors [for previous low serum iron levels] and I have also seen a doctor of internal medicine – trying to figure out what is happening to my iron" (Intervention participant E8) and "I take tablets, but I know that they cause constipation and that sort of thing, so I am trying to sort it out without taking anything" (Intervention participant E4). This comment about iron was provided by an aesthetic sport athlete in the intervention group; "sometimes I will take an iron supplement just because being female in a high impact sport you tend to get very low on iron" (Intervention participant A5) and the following comment from a team sport athlete in the intervention group; "I get iron infusions done – my iron is pretty low" (Intervention participant T7). It was not clear in the dietary supplements questionnaire whether or not this participant considered iron infusions as supplementation.

Among the control group sports, although the endurance sport mean dietary iron intake (16.0 ± 5.8mg.dy^{-1}) was higher than that of their team sport counterparts (6.7 ± 3.2mg.dy^{-1}), the variability in dietary iron intakes among the endurance sport control group meant a significant difference was not achieved (Table 6). In addition, neither of these sports' athletes met their recommended intakes (Table 6). Statistical comparisons with the aesthetic sport control group were not valid, due to the low number of participants (n=1) in this represented sport. Mean dietary iron intakes showed none of the control group sports met their recommended intakes (Table 6), although the single aesthetic sport participant did achieve a dietary iron intake (17.5mg.dy-1) just below the recommendation (Table 6). None of the athletes in the control group sports reported supplement intakes for iron during the data collection period, although this comment from a control group athlete suggested otherwise; "I also used to struggle getting lots of iron, I was getting iron infusions but now that is getting better, the last blood test was OK – it was just figuring out ways to get enough iron" (Control participant A3).

However, the aesthetic sport intervention group athletes took iron supplements (5.00 ± 5.14 mg.dy^{-1}) (Table 6) which helped them meet recommendations.

Statistical analyses for mean dietary iron intakes in matching sports between the intervention and control groups showed no significant differences for the endurance and team sports (Table 6). The Aesthetic sport groups were unable to be compared, due to a lack of sufficient participants in the aesthetic sport control group (n=1).

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Nutrient Intakes upon Study Completion

Table 9 Nutrient intake data upon study completion – Intervention and Control Groups.

	Sport Nutrition Recommendations/ RDIs:	Intervention			Control		
		Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Protein ($g.kg^{-1}$)	Endurance: 1.2-2.0 Aesthetic: 1.5-1.7 Team: 1.2-2.0	1.40 ± 0.30	1.40 ± 0.30	1.30 ± 0.40	1.70 ± 0.10[1]	1.90	1.20 ± 0.10[1]
Supplements ($g.kg^{-1}$)		0.06 ± 0.09	0.11 ± 0.24	0.17 ± 0.05	0.20 ± 0.28	0	0.05 ± 0.09
Fat (%EI)	Endurance: <20 Aesthetic: 20-25 Team: 20-35	33.00 ± 5.00	32.00 ± 3.00	26.00 ± 8.70	28.00 ± 6.00	28.00	31.00 ± 4.00
Carbohydrate ($g.kg^{-1}$)	Endurance: 5-7 Aesthetic: 5-7 Team: 5-7	3.40 ± 0.60[2]	3.30 ± 1.00	2.80 ± 0.40	4.80 ± 0.70[2,3]	5.50	2.60 ± 0.30[3]
Supplements ($g.kg^{-1}$)		0.08 ± 0.10	0	0.07 ± 0.07	0.06 ± 0.08	0	0.03 ± 0.05
Fibre ($g.dy^{-1}$)	25	27.80 ± 6.90	27.20 ± 11.10	22.40 ± 13.60	38.80 ± 6.00[4]	39.10	15.80 ± 4.90[4]
Calcium ($mg.dy^{-1}$)	1,000	909.20 ± 230.80	679.50 ± 213.00	728.80 ± 221.20	1070.30 ± 342.10	1334.70	468.50 ± 135.30
Supplements ($mg.dy^{-1}$)		13.60 ± 35.98	0	0	0	0	0
Iron ($mg.dy^{-1}$)	18	10.90 ± 4.50	8.30 ± 1.60	9.40 ± 4.70	12.50 ± 0.60	18.50	6.40 ± 2.00
Supplements ($mg.dy^{-1}$)		6.00 ± 11.49[5]	3.00 ± 6.71	3.33 ± 5.77	4.89 ± 5.30[5]	0	0

[1]*Mean dietary protein intake for the endurance control group was significantly higher than the team sport control group (p=0.013)*

[2]*Mean carbohydrate intake for the endurance intervention group was significantly lower than the endurance control group (p = 0.022).*

[3]*Mean dietary carbohydrate intake for the endurance control group was significantly higher than the team sport control group (p=0.018)*

[4]*Mean dietary fibre intake for the endurance control group was significantly higher than the team sport control group (p=0.029)*

[5]*Mean iron supplement intake for the endurance intervention group was significantly lower than the endurance control group (p = 0.002).*

Recommended intakes shown in Table 7 were based on the following sources. Endurance Recommendations (Logue et al., 2018; Holtzman & Ackerman, 2021); Aesthetic Recommendations (Robertson & Mountjoy, 2018); Team Sport Recommendations (Renard et al., 2021); Micronutrients (National Health and Medical Research Council, 2017); Other (Thomas et al., 2016; Mountjoy et al., 2018a; Moore et al., 2021)

Following the individualised 'Food First' dietary counselling, there were no significant differences in nutrient intakes between the endurance, aesthetic, and team sports in the intervention group at study completion (Table 7). Similarly, but after standard dietary education, there were no significant differences between the control group sports(Table 7) at study completion. Comparisons for each sport between intervention and control groups showed the only significant difference was a significantly higher ($p=0.02$) mean carbohydrate intake for the endurance sport control group (4.8 ± 0.7 g.kg.dy^{-1}) compared to the intervention group (3.4 ± 0.6g.kg.dy^{-1}) at study completion (Table 7).

Sport-specific protein recommendations were met from food alone by the endurance (1.4 ± 0.3 g.kg.dy^{-1}) and team sports (1.3 ± 0.4 g.kg.dy^{-1}) athletes in the intervention group, but not by the aesthetic sport athletes (1.4 ± 0.3g.kg.dy^{-1}) (Table 7). However, the mean additional protein contribution from supplements (0.11 ± 0.24 g.kg.dy^{-1}) assisted these aesthetic sport athletes in meeting their daily protein intake target (1.5-1.7 g.kg.dy^{-1}) (Table 7), although the large variance in protein supplement intakes suggested not all athletes in this sport group consumed protein supplements. Among the control group sports, all met their respective dietary protein recommended intakes from food alone, even though protein supplement intakes were reported by the endurance and team sport athletes at study completion (Table 7).

The mean percentage energy contribution from dietary fat among the endurance sport athletes was above the recommended maximum (<20%EI) for both the intervention (33 ± 5%EI) and control (28 ± 6%EI) groups (Table 7). Similarly, the aesthetic sport athletes in both the intervention group (32 ± 3%EI) and the single control group participant(28 %EI) showed a percentage energy contribution from fat higher than their sport-specific recommended maximum intake (20 – 25%EI) (Table 7). However, the team sport athletes in the intervention (26.0 ± 8.7%EI) and control (31 ± 4%EI) groups had a mean percentage energy contribution from dietary fat below their recommended maximum (20 – 35 %EI) (Table 7). None of the participants reported supplemental fat intakes.

The mean daily carbohydrate recommendation (5-7 $g.kg.dy^{-1}$) at study completion was not met by any of the sports in the intervention group, even after contributions from carbohydrate supplement intakes (Table 7). Similarly, this carbohydrate recommendation was not met by control group athletes in the endurance (4.8 ± 0.7 $g.kg.dy^{-1}$) and team (2.6 ± 0.3 $g.kg.dy^{-1}$) sports, despite contribution from carbohydrate supplements (Table 7). However, the single participant in the aesthetic sport group met her daily carbohydrate recommended intake (5.5 $g.kg.dy^{-1}$) from food alone(Table 7), as no supplement intake was reported. However, this result cannot be interpreted as typical of non-LEA aesthetic sport athletes due to insufficient representation from this sport in the control group.

Among the intervention group sports, mean dietary fibre intakes for the endurance (27.8 ± 6.9 $g.dy^{-1}$) and aesthetic (27.2 ± 11.1 $g.dy^{-1}$) athletes met the recommended 25.0 $g.dy^{-1}$ but the intervention group team sport athletes (22.4 ± 13.6 $g.dy^{-1}$) did not meet this recommended daily fibre intake (Table 7). None of the athletes reported fibre supplement intakes (Table 7).

Recommended dietary calcium (1,000 $mg.dy^{-1}$) and iron (18 $mg.dy^{-1}$) intakes were not met by any of the intervention sport groups, nor by the team sport control group (Table 7), but the single aesthetic sport athlete in the control group did meet the recommended daily intakes for both calcium and iron from food alone. Only one of the endurance sport participants in the intervention group reported calcium supplement intake (13.6 ± 35.98 $mg.dy^{-1}$), but this did not have a positive effect on the group mean daily calcium intake (Table 7). Iron supplements were reported by more participants than calcium supplement intakes, with the endurance sport participants in both the intervention (6.00 ± 11.49 $mg.dy^{-1}$) and control (4.89 ± 5.30 $mg.dy^{-1}$) groups reporting supplemental iron intakes (Table 7), albeit variable intakes between individuals in each group. Among the aesthetic sport participants, the intervention group showed mean iron supplement intakes of 3.00 ± 6.71 $mg.dy^{-1}$ while the single control group participant reported no iron supplement intakes (Table 7). The team sport intervention group showed mean iron supplement intakes of 3.33 ± 5.77 $mg.dy^{-1}$, but none were reported by the team sport control group (Table 7). Despite these variable calcium and iron supplement intakes, none were sufficient to assist participants in any of the sport groups to meet their requirements when added to their dietary intakes.

Nutrient Intakes at Baseline vs. Study Completion – Summary Table

Table 10 Nutrient Intake data – Intervention and control groups Baseline vs Study Completion.

	Intervention						Control					
	Endurance (n=7)		Aesthetic (n=5)		Team (n=3)		Endurance (n=2)		Aesthetic (n=1)		Team (n=3)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Protein ($g.kg^{-1}$)	1.3 ± 0.2	1.4 ± 0.3	1.2 ± 0.3	1.4 ± 0.3	1.1 ± 0.3	1.3 ± 0.4	1.9 ± 0.6	1.7 ± 0.1	2.0	1.9	1.1 ± 0.3	1.2 ± 0.1
Supplements	0.06 ± 0.11	0.06 ± 0.09	0.08 ± 0.10	0.11 ± 0.24	0.11 ± 0.08	0.17 ± 0.05	0.23 ± 0.33	0.20 ± 0.28	0	0	0.02 ± 0.03	0.05 ± 0.09
Fat (%EI)	35.9 ± 4.8	32.9 ± 4.9	32.7 ± 4.6	32.2 ± 2.6	32.9 ± 6.8	25.5 ± 8.7	33.6 ± 2.1	27.8 ± 5.5	29.9	28.4	28.6 ± 1.7	31.2 ± 3.7
Carbohydrate ($g.kg^{-1}$)	3.1 ± 0.8	3.4 ± 0.6	2.7 ± 0.9	3.3 ± 1.0	2.9 ± 0.6	2.8 ± 0.4	5.5 ± 3.2	4.8 ± 0.7	5.2	5.5	2.9 ± 0.4	2.6 ± 0.3
Supplements	0.04 ± 0.05	0.08 ± 0.10	0	0	0.09 ± 0.08	0.07 ± 0.07	0	0.06 ± 0.08	0	0	0.09 ± 0.10	0.03 ± 0.05
Fibre ($g.dy^{-1}$)	26.7 ± 7.1	27.8 ± 6.9	17.8 ± 7.7	27.2 ± 11.1	21.5 ± 11.2	22.4 ± 13.6	37.2 ± 7.1	38.8 ± 6.0	35.1	39.1	17.5 ± 3.8	15.8 ± 4.9
Calcium ($mg.dy^{-1}$)	875.6 ± 80.8	909.2 ± 230.8	595.4 ± 121.6	679.5 ± 213.0	456. 8 ± 72.8	728.8 ± 221.2	1272.5 ± 11.5	1070.3 ± 342.1	1142.8	1334.7	510.5 ± 111.1	468.5 ± 135.3
Supplements	0	13.60 ± 35.98	0	0	0	0	0	0	0	0	0	0
Iron ($mg.dy^{-1}$)	10.7 ± 4.2	10.9 ± 4.5	6.4 ± 1.9	8.3 ± 1.6	7.6 ± 1.8	9.4 ± 4.7	16.0 ± 5.8	12.5 ± 0.6	17.5	18.5	6.7 ± 3.2	6.4 ± 2.0
Supplements	5.91 ± 11.44	6.00 ± 11.49	5.00 ± 5.14	3.00 ± 6.71	0.87 ± 1.50	3.33 ± 5.77	0	4.89 ± 5.30	0	0	0	0

Intra-sport differences between baseline and study completion are shown in Table 8, with the completion data representing inference of any effects of the ‘Food First’ dietary counselling sessions among the intervention group participants, and inference of any effects of the standard dietary education infographic among the control groups.

Upon study completion, there were no significant differences for any of the nutrient intakes between intervention and control groups compared to baseline data (Table 8). Pre- versus post-nutrient intake data could not be statistically tested with the aesthetic sport control group due to only one athlete remaining in this group (Table 8).

Supplement intakes seemed mainly unaffected by the ‘Food First’ dietary counselling (intervention), except the endurance sport intervention group, for whom mean calcium supplement intakes actually increased from zero to 13.60 ± 35.98 $mg.dy^{-1}$ (Table 8), and iron supplement intakes also increased among the team sport intervention group from 0.87 ± 1.50 $mg.dy^{-1}$ to 3.33 ± 5.77 $mg.dy^{-1}$, although the large variability in the reported supplement intakes precluded statistical analyses (Table 8). The standard dietary education infographic (control) also did not seem to affect supplement intake behaviours among the control group sports participants (Table 8). There were no other notable changes to supplement intakes between baseline and study completion.

Total energy intakes were not presented in Tables 6, 7 nor 8, as these data were more relevant to the energy availability data presented in Tables 3, 4 and 5. A comparison of pre-versus post-study total energy intakes (EI) for each sport in the intervention and control groups are shown in Table 5.

5.3.4 Food Groups

Food Groups at Baseline

Table 11 The number of serves from each Food Group at baseline – Intervention and Control.

Food groups (serves.d^{-1})	AGHE* serves.d^{-1} Females 19-50yrs	Intervention			Control		
		Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Grains/ Cereals	6	4.8 ± 1.8	4.6 ± 1.8	4.8 ± 1.6	5.3 ± 2.5	7.2	5.3 ± 0.6
Fruit	2	1.2 ± 1.0	1.4 ± 1.0	1.0 ± 0.8	2.4 ± 0.4[1]	1.2	0.4 ± 0.3[1]
Vegetables	5	4.6 ± 2.2	3.1 ± 2.1	4.2 ± 2.3	6.2 ± 3.7	4.4	3.4 ± 2.1
Lean Protein	2.5	1.9 ± 1.0	1.9 ± 0.4	1.8 ± 0.7	3.2 ± 2.2	1.5	1.5 ± 1.1
Dairy	2.5	1.5 ± 0.4[2,3]	1.3 ± 0.4	0.8 ± 0.1[3]	2.3 ± 0.4[2]	1.6	0.9 ± 0.2
Discretionary Foods:							
Oil Equivalent (tsp)	0 – 10 tsp.d^{-1}	8.4 ± 2.5[4]	4.2 ± 1.8[4]	6.1 ± 1.8	10.2 ± 3.5	5.4	5.6 ± 2.0
Solid Fat (tsp)		6.0 ± 1.5[5]	5.7 ± 2.7	5.9 ± 2.9	12.9 ± 7.0[5]	8.2	4.2 ± 1.0
Added Sugar (tsp)		4.4 ± 3.0	6.3 ± 7.6	3.5 ± 2.0	19.7 ± 21.2	6.7	4.4 ± 3.7

[1]*Mean fruit intake for the endurance sport control group was significantly higher than the team sport control group (p=0.018).*
[2]*Mean dairy intake for the endurance sport intervention group was significantly lower (p = 0.045) than the endurance control group.*
[3]*Mean dairy intake for the endurance sport intervention group was significantly higher than team sport intervention group (p = 0.020).*
[4]*Mean oil equivalents intake for the endurance sport intervention group was significantly higher than aesthetic sport intervention group (p = 0.020).*
[5]*Mean solid fat intake for the endurance intervention group was significantly lower than the endurance sport control group (p = 0.026).*
**AGHE: Australian Guide to Healthy Eating (National Health and Medical Research Council, 2013)*

Table 9 shows the inter-sport comparisons of baseline food group intakes (mean serves per day) for the intervention and control groups. Food group intakes were compared to the Australian Guide to Healthy Eating (AGHE) recommended serves per day for their specific gender and age groups.

Grains/Cereals

There were no significant differences in grains/cereals daily intakes at baseline between any of the sports in either the intervention or control groups, apart from the aesthetic sport control group.

Statistical analyses for this latter group were not possible due to the inadequate number of participants (n=1) in this sport group.

Nonetheless, the daily grains and cereals food group recommendations (6 serves.dy^{-1}) were not met by the endurance sport intervention (4.8 ± 1.8 serves.dy^{-1}) nor control groups (5.3 ± 2.5 serves.dy^{-1}) (Table 9). During semi-structured interviews the endurance sport athletes in the intervention group spoke about prioritising the grains and cereal foods around training sessions and races, although it was unclear how much they were included in their day-to-day meals "I do make up lots of pasta for the race, before, potatoes and stuff like that" (Intervention endurance participant E1). They also spoke about feeling guilty for eating bread (Intervention endurance participant E2) and only eating certain foods such as grains and cereals when they craved them "I think your body tries to tell you…like I really want carbs and then I might eat some bread" (Intervention endurance participant E8). The endurance sport control group athletes seemed to include grain and cereal foods more freely compared to their intervention group counterparts and made food choices based upon other factors such as family, rather than just their sport, "I often figure what the kids will like and what they'll eat – so that's why we eat a lot of pasta" (Control endurance participant E9).

The aesthetic sport intervention group did not meet the daily grain and cereal intake recommendations (4.6 ± 1.8 serves.dy^{-1}), but the single participant in the aesthetic sport control group did meet requirements for this food group (7.2 serves.dy^{-1}) (Table 9). However, statistical analysis of the food group intake differences between the aesthetic sport groups was not possible due to insufficient representation (n=1) in the control group for this sport. Nonetheless, the aesthetic sport intervention group athletes spoke about including these foods in their diet, "breakfast is like weet-bix because it is easy or maybe a bit of toast and vegemite" (Intervention aesthetic participant A2), and "we eat similar meals each week – we always have pasta on Mondays" (Intervention aesthetic participant A1). The athlete representing the aesthetic sport control group included more grain and cereal foods in both her meals and snacks, "I'll make muffins which will last me the week so I might have one of them or saladas with pesto and tomato", "last night I really felt like pasta, so I made pasta" (Control aesthetic participant A3).

Neither the team sport intervention (4.8 ± 1.6 serves.dy^{-1}) nor control group (5.3 ± 0.6 serves.dy^{-1}) met grain and cereal food group recommendations (6 serves.dy^{-1}) at baseline (Table 9). One of the team sport intervention group athletes spoke about avoiding these foods, "just the occasional time that I think about pasta or a burger, and then I think nah you can't have a burger you can do something better than that" (Intervention team participant T10). Similar to athletes from the other sports, the team sport athletes discussed eating grain and cereal foods before games "I like to fuel up on carbs before games and stuff, I like to have pasta before a game" (Control team participant T9). However, they were more relaxed before training and varied what they ate, "before training it is more varied, depending on what is there that I feel like" (Control team participant T2).

Fruit

Baseline statistical analyses found the mean daily intake of fruit among the endurance sport intervention group was significantly lower than the team sport control group ($p = 0.018$) (Table 9). Data from the aesthetic sport control group could not be included in comparative analyses due to the inadequate number of participants in this group. There were no other significant differences in daily fruit serves intakes between other groups (Table 9).

The recommended number of daily fruit servings (2 serves.dy^{-1}) was not met by the endurance sport intervention group (1.2 ± 1.0 serves.dy^{-1}), while the control group (2.4 ± 0.4 serves.dy^{-1}) did meet this recommended intake at baseline (Table 9). Despite this, the athletes from the endurance sport intervention group discussed enjoying fruit and including it in their diet, "I get a fruit and vegie box delivered every week" (Intervention endurance participant E3).

Both the aesthetic sport intervention group (1.4 ± 1.0 serves.dy^{-1}) and single control group athlete (1.2 serves.dy^{-1}) did not meet the recommended 6 fruit serves per day at baseline (Table 9). One of the aesthetic sport intervention group athletes specifically mentioned not eating enough fruit, "I don't eat enough fruit cause I'm not too good at eating through the day" and she also discussed disliking bananas "I don't like bananas, but I'll eat them" (Intervention aesthetic participant A4).

The team sport intervention (1.0 ± 0.8 serves.dy^{-1}) and control (0.4 ± 0.3 servrs.dy^{-1}) groups did not meet their recommended 6 fruit serves per day at baseline (Table 9). One of the team sport intervention group athletes mentioned having fruit before a game or training "a sandwich and fruit, I'll have that at least 3 hours before we're supposed to start" (Intervention team participant T8). Team sport control group athletes spoke about fruit being a convenient snack option, "A snack is usually just fruit, depends on what is in the house", and "I'd grab like an apple or that sort of thing that is ready to eat straight away" (Control team participant T7).

Vegetables

At the baseline data collection point, there were no significant differences between any of the sports for vegetable food group intakes (Table 9). Statistical analyses for the aesthetic sport control group could not be included due to an inadequate number of participants in this group.

The mean number of daily vegetables serves for the endurance sport intervention group (4.6 ± 2.2 serves.dy^{-1}) did not quite meet the required 5 serves of vegetables per day, while the control group sport counterpart (6.2 ± 3.7 serves.dy^{-1}) did meet this requirement (Table 9). Two of the endurance sport intervention athletes were self-reported vegetarian, stating "I eat mainly plant-based" (Intervention endurance participant E10). Other athletes in this group also spoke about enjoying vegetables and including "lots" in their diet "I love avocado, I really do love a variety of veggies together with yummy cashew dressing. I really enjoy healthy food" (Intervention endurance participant E8), "I have plenty of vegies" (Intervention endurance participant E3). The endurance sport control group athletes also discussed including vegetables in their diet, "at the greengrocer I buy the vegetables that I like to eat, I'm not overly adventurous" (Control endurance participant E9).

Neither the aesthetic sport intervention group (3.1 ± 2.1 serves.dy^{-1}) nor the single control group athlete (4.4 serves.dy^{-1}) met the recommended daily vegetable serves (Table 9), which was also reflected in the reported intakes by the team sport intervention (4.2 ± 2.3 serves.dy^{-1}) and control groups (3.4 ± 2.1 serves.dy^{-1}). Despite this, team sport athletes from both the intervention and control groups discussed including vegetables in their diet. One of the intervention group athletes was a vegetarian, "I'm vegetarian, I make sure that I'm eating foods so my diet is balanced" (Intervention team participant T8). One of the non-vegetarian control group athletes spoke about having a "well-rounded diet" and adding vegetables if she thought they were lacking "I've got a well-rounded diet. If I'm feeling like I'm missing something, I'll like eat more red meat, broccoli or spinach that sort of thing" (Control team participantT5).

Lean Protein

There were no significant differences between sports groups at baseline for lean protein food group intakes (Table 9). Statistical analyses that included the aesthetic sport control group were not performed due to an inadequate number of participants (n=1) in this group (Table 9).

Among the endurance sport intervention group, the mean daily intake of lean protein foods (1.9 ± 1.0 serves.dy^{-1}) did not meet lean protein daily recommendation of at least 2.5 serves per day (Table 9). However, the endurance sport control group did meet this food group recommendation (3.2 ± 2.2 serves.dy^{-1}). Despite not meeting lean protein recommendations, the endurance sport intervention group athletes spoke about including lean protein in their meals, "I have got some meat out for tonight but I have to decide what I want to do with it. It's nice lean beef and I have plenty of vegies" (Intervention endurance participant E3). However, another athlete from this group spoke about omitting meat before a race "if I am leading up to a race, I cut meat out the week before", when asked *"why is that?"* the participant replied, "umm I just find it sits heavy in my stomach" (Intervention endurance participant E10). One athlete from the endurance sport control group spoke of including lean protein in their diet, "I do try to have red meat to have the iron but also the higher protein" (Control endurance participant E5).

Neither the aesthetic sport intervention group (1.9 ± 0.4 serves.dy^{-1}) nor control group athlete (1.5 serves.dy^{-1}) met the daily recommended serves of lean protein. One of the aesthetic sport intervention group athletes discussed not enjoying meat, but still eating it because she felt "…that it is good – my parents tell me I need to eat it for training – protein" (Intervention aesthetic participant A2). Another athlete from this group stated, "Sometimes we have different things, my dad and my brother might be having steak and I'll have like salmon, Mum and I don't like meat as much" (Intervention aesthetic participant A4). Despite an inadequate daily lean protein foods intake, the aesthetic sport control group athlete spoke about including lean protein in her diet "Yeah the other night it was chicken schnitzels, but I had that the day before, so I had an omelette instead" (Control aesthetic participant A3).

Mean daily lean protein food intakes for the team sport intervention (1.8 ± 0.7 serves.dy^{-1}) and control groups (1.5 ± 1.1 serves.dy^{-1}) showed neither group met the lean protein recommended 2.5 serves daily (Table 9). This was supported by very few of the team sport groups athletes mentioning during interviews the regular inclusion of lean protein in their diets. General comments were made such as "I basically think meat and vegetable and then what I can add" (Intervention team participant T2), but another intervention group team sport athlete mentioned avoiding lean meats, "I like all types of food except meat because I'm a vegetarian" (Intervention team participant T8) The following comment about lean protein foods was from a team spirt athlete in the control group, "I don't like barbeque meats like steak, I don't want to eat any of that" (Control team participant T3).

Dairy

Statistical analyses of inter-sport dairy food intakes at baseline found the endurance sport intervention group (1.5 ± 0.4 serves.dy^{-1}) had a significantly lower (p=0.045) dairy foods intake compared to their control group counterparts (2.3 ± 0.4 serves.dy^{-1}), but a significantly higher (p=0.020) dairy intake than the team sport intervention group (0.8 ± 0.1 serves.dy^{-1}) (Table 9). Among the control groups, the mean number of dairy foods serves for the endurance sport athletes (2.3 ± 0.4 serves.dy^{-1}) was significantly higher (p=0.037) than the team sport group (0.9 ± 0.2 serves.dy^{-1}) (Table 9).

Daily recommended dairy food servings (2.5 serves.dy^{-1}) were not met by the endurance sport intervention (1.5 ± 0.4 serves.dy^{-1}) or control groups (2.3 ± 0.4 serves.dy^{-1}) (Table 9). The low dairy food intakes of this endurance sport intervention group was supported by one of the athletes in this group speaking about restricting her cheese intake, “cheese, I love cheese but I try to limit it – that would be the big one… um just cause the way it makes me feel, I find my skin flares up if I eat too much. Yep, that would be the one thing that I love but I avoid” (Intervention endurance participant E10). One athlete from the endurance sport control group reportedly included dairy foods daily, “To start the normal day, if we have yoghurt and muesli, I’ll have that” (Control endurance participant E5).

In the aesthetic sports, neither the intervention group (1.3 ± 0.4 serves.dy^{-1}) nor the control group athlete (1.6 serves.dy^{-1}) met the recommended daily dairy servings. Interview responses about dairy foods were limited to the intervention group in this sport category and included, “snack is just like whatever is there – maybe crackers and cheese or seaweed snacks” (Intervention aesthetic participant A7) and “If I have something on in the morning like gym, I’ll have a yoghurt or something to fuel myself (Intervention aesthetic participant A2).

Both the team sport intervention (0.8 ± 0.1 serves.dy^{-1}) and control group counterparts (0.9 ± 0.2 serves.dy^{-1}) did not meet the recommended number of daily dairy servings. During the semi-structured interviews, the team sport athletes mentioned including dairy in their diet as follows, “Before games I have banana and milo & peanut butter on toast” (Control team sport participant T2), “if it is a bigger snack, like a sandwich, I’ll eat it 2 hours before training and then an Up & Go like an hour before” (Control team sport participant AG).

Discretionary Foods

In the discretionary foods category, the notable results from the baseline data included a significantly higher mean oil equivalents intake for the endurance sport intervention group compared to the aesthetic sport intervention group (p=0.020) (Table 9). Conversely, this same endurance sport intervention group had a mean solid fat intake significantly lower than their control group counterparts (p=0.026) (Table 9).

Comparisons between the endurance sport control groups and the team sport control groups for baseline mean discretionary food intakes suggested the endurance sport group consumed higher numbers of daily serves for oil equivalents, solid fat, and sugars (Table 9). However, the variability in individual intakes for these discretionary foods, particularly among the endurance sport control group athletes, precluded any statistically significant differences. As for other food group categories, mean intake data for the aesthetic sport control group was not statistically tested due to the inadequate number of participants in this control group.

The endurance sport control group exceeded the recommended intake of discretionary foods (0-10 $tsp.dy^{-1}$) at baseline, including oil equivalents (10.2 ± 3.5 $tsp.dy^{-1}$), solid fats (12.9 ± 7.0 $tsp.dy^{-1}$) and added sugar (19.7 ± 21.2 $tsp.dy^{-1}$) (Table 9). Despite the high intakes, discretionary foods intakes were acknowledged in the following way by endurance sport control group athletes during interviews, “I eat too much sugar and too much coffee” (Control endurance participant E5). The endurance sport intervention group maintained their mean daily intakes of all discretionary foods below the recommended maximum daily intake (Table 9), which seemed consistent with a comment from one of the participants about restricting some foods in this category, “I guess chocolate – I don’t have an adult relationship with it!” (Intervention endurance participant E8).

The aesthetic sport intervention and control groups maintained their mean daily discretionary food intakes at baseline below the recommended maximum of 10 teaspoons per day, and their interview comments reflected these intakes (Table 9). When probed about why they restricted intakes of some discretionary foods, the aesthetic sport athletes made comments such as “just because I know that they aren’t good for you” (Intervention aesthetic participant A1) and “because it is classified as an unhealthy food” (Intervention aesthetic participant A2). Being athletes also informed their restricted intakes of perceived ‘unhealthy’ foods, with comments like “particularly around comp season having to be a certain leanness and I feel like it affects the way I train if I have too much sugar” (Intervention aesthetic participant A5).

Similarly at the baseline data collection point, results showed the team sport intervention and control groups also maintained mean discretionary food intakes below the recommended maximum 10 teaspoons per day (Table 9). These results were supported by interview responses such as, “cause you know you are always taught ‘eat everything in moderation’ not to eat too much sweets” (Control team sport participant T3). Awareness of recommendations to restrict intakes of discretionary foods was illustrated by the following comment relating to energy intake and expenditure, “[If stopped soccer] I’d have to eat less, like dessert I still probably have more of that kind of thing than I should because I know that I can because I’m not going to get fat” (Control team sport participant T9).

Food Groups upon Study Completion

Table 12 Distribution of number of serves from each Food Group upon study completion

Food groups (serves.dy^{-1})	AGHE* serves/day Females 19-50yrs	Intervention			Control		
		Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Grains/ Cereals	6	6.4 ± 2.2	5.7 ± 2.0	6.2 ± 2.4	4.0 ± 2.2	10.9	5.5 ± 1.2
Fruit	2	0.9 ± 0.5[1]	0.9 ± 0.6	0.8 ± 1.2	2.4 ± 1.0[1]	1.8	0.7 ± 0.4
Vegetables	5	4.5 ± 1.9	4.0 ± 2.1	2.5 ± 0.8	4.6 ± 1.0	4.3	2.4 ± 0.9
Lean Protein	2.5	1.9 ± 0.7	1.9 ± 0.8	2.0 ± 0.9	2.3 ± 1.3	2.0	2.1 ± 0.3
Dairy	2.5	1.7 ± 0.7	1.1 ± 0.6	1.5 ± 0.2[2]	1.5 ± 0.2	2.1	0.8 ± 0.4[2]
Discretionary Foods							
Oil Equivalents (tsp)	0 – 10 tsp.dy^{-1}	8.2 ± 1.5[3]	6.0 ± 2.2	4.3 ± 2.5[3]	6.6 ± 2.0	6.6	5.3 ± 0.6
Solid Fat (tsp)		6.4 ± 2.8	6.7 ± 2.2	5.3 ± 1.9	8.3 ± 1.9	9	5.1 ± 1.6
Added Sugar (tsp)		6.3 ± 2.6	5.2 ± 6.0	1.8 ± 1.2	11.9 ± 10.0	9.2	3.2 ± 2.0

[1]*Mean fruit intake for the endurance intervention group significantly lower than the endurance control group (p = 0.017).*
[2]*Mean dairy intake for the team sport intervention group significantly higher than the team sport control group (p = 0.042).*
[3]*Mean oil equivalents intake for the endurance sport intervention group significantly higher than team sport intervention group (p = 0.030).*
**AGHE: Australian Guide to Healthy Eating (National Health and Medical Research Council, 2013)*

Upon completion of the study, data for the aesthetic sport control group was not included in analyses, due to the inadequate number of participants in this group (n=1). Other analyses of inter-sport food group intake data (Table 10) showed the mean fruit food group intake for the endurance intervention group (0.9 ± 0.5 serves.dy^{-1}) was significantly lower (p=0.017) than that of their control group counterparts (2.4 ± 1.0 serves.dy^{-1}).

The dairy food group study completion data shows the team sport intervention group (1.5 ± 0.2 serves.dy^{-1}) had a significantly higher (p= 0.042) intake than their control group counterparts (0.8 ± 0.4 serves.dy^{-1}) (Table 10).

Among the discretionary food group, the only notable inter-sport difference is a significantly higher (p=0.030) mean oil equivalents intake for the endurance sport intervention group (8.2 ± 1.5 tsp.dy^{-1}) compared to the team sport intervention group (4.3 ± 2.5 tsp.dy^{-1}) (Table 10).

At study completion there were no significant differences in food group intakes between sports groups within or between the intervention and control groups (Table 10).

Food Groups at Baseline vs. Study Completion – Summary Table

Table 13 Distribution of number of serves from each Food Group – Intervention and control groups Baseline vs Study Completion.

	Intervention						Control					
	Endurance (n=7)		Aesthetic (n=5)		Team (n=3)		Endurance (n=2)		Aesthetic (n=1)		Team (n=3)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Grains/cereals	4.8 ± 1.8[1]	6.4 ± 2.2[1]	4.6 ± 1.8	5.7 ± 2.0	4.8 ± 1.6	6.2 ± 2.4	5.3 ± 2.5	4.0 ± 2.2	7.2	10.9	5.3 ± 0.6	5.5 ± 1.2
Fruit	1.2 ± 2.0	0.9 ± 0.5	1.4 ± 1.0	0.9 ± 0.6	1.0 ± 0.8	0.8 ± 1.2	2.4 ± 0.4	2.4 ± 1.0	1.2	1.8	0.4 ± 0.3	0.7 ± 0.4
Vegetables	4.6 ± 2.2	4.5 ± 1.9	3.1 ± 2.1	4.0 ± 2.1	4.2 ± 2.3	2.5 ± 0.8	6.2 ± 3.7	4.6 ± 1.0	4.4	4.3	3.4 ± 2.1	2.4 ± 0.9
Lean Protein	1.9 ± 1.0	1.9 ± 0.7	1.9 ± 0.4	1.9 ± 0.8	1.8 ± 0.7	2.0 ± 0.9	3.2 ± 2.2	2.3 ± 1.3	1.5	2.0	1.5 ± 1.1	2.1 ± 0.3
Dairy	1.5 ± 0.4	1.7 ± 0.7	1.3 ± 0.4	1.1 ± 0.6	0.8 ± 0.1[2]	1.5 ± 0.2[2]	2.3 ± 0.4	1.5 ± 0.2	1.6	2.1	0.9 ± 0.2	0.8 ± 0.4
Oil Equivalent	8.4 ± 2.5	8.2 ± 1.5	4.2 ± 1.8	6.0 ± 2.2	6.1 ± 1.8	4.3 ± 2.5	10.2 ± 3.5	6.6 ± 2.0	5.4	6.6	5.6 ± 2.0	5.3 ± 0.6
Solid Fat	6.0 ± 1.5	6.4 ± 2.8	5.7 ± 2.7	6.7 ± 2.2	5.9 ± 2.9	5.3 ± 1.9	12.9 ± 7.0	8.3 ± 1.9	8.2	9.0	4.2 ± 1.0	5.1 ± 1.6
Added Sugar	4.4 ± 3.0	6.3 ± 2.6	6.3 ± 7.6	5.2 ± 6.0	3.5 ± 2.0	1.8 ± 1.2	19.7 ± 21.2	11.9 ± 10.0	6.7	9.2	4.4 ± 3.7	3.2 ± 2.0

[1]*Mean grain/cereals intake for the endurance sport intervention group significantly higher than baseline ($p = 0.039$).*

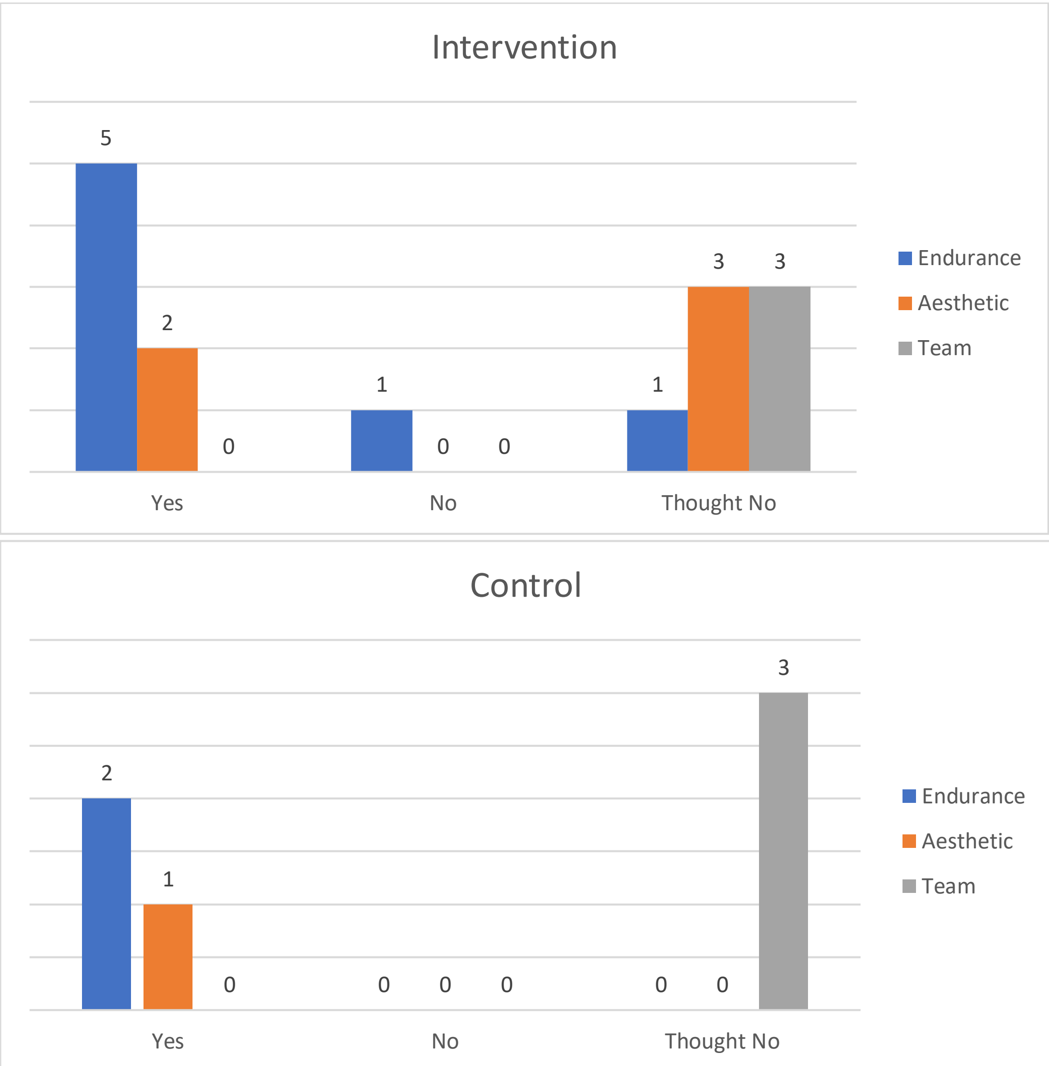
[2]*Mean dairy intake for the team sport intervention group significantly higher than baseline ($p = 0.047$).*

Table 11 shows the intra-sport results (pre vs. post) for the intervention and control groups. At study completion, following individualised ‘Food First’ counselling, the endurance sport intervention group showed a significant increase in their grain/cereals food group intake (*p* = 0.037) compared to baseline. The team sport intervention group showed a significant increase in their dairy intake (*p* = 0.014) between baseline and study completion. There were no other statistically significant results in intakes of the five food groups when comparing baseline and study completion data.

5.3.5 Dietary Supplements Intakes

Prevalence of Supplement Use

Figure 15 Dietary supplements intake reports by number of participants.



Participant responses to the dietary supplements intake questionnaire were a binary ‘yes’ or ‘no’, but an equivalent ‘don’t know/can’t recall’ category, represented in Figures 1 and 2 as ‘thought no’ was added following the questionnaire validation study presented in Chapter 3.

Figure 1 shows five of the seven endurance sport athletes (71.4%) from the intervention group reported taking dietary supplements overall, whereas only two of the five aesthetic sport intervention group athletes (40%) reported dietary supplement intakes. None of the team sport intervention group athletes reported supplement use, although all three participants in this group were not sure according to their supplements questionnaire responses. Their confusion was indicated by their responses to types of supplements later in the questionnaire, for which each of these team sport intervention group athletes provided brand, dose and frequency information for specific supplements intakes, suggesting they did take dietary supplements.

Among the sports in the control group, all endurance sport athletes (n=2; 100%) reported taking dietary supplements, while the single aesthetic sport participant also reported supplement use (Figure 1). None of the team sport control group participants reported supplement use, but they seemed unsure as all participants in this group (n=3) recorded a 'thought no' response (Figure 1).

The frequency of reported supplement use was highest among the sports in the intervention group with seven participants recording 'yes' to supplement use, whereas only three participants from the control sports recorded a positive response (Figure 1). However, the total number of participants in the intervention and control groups differed markedly.

Table 14 Reasons for taking dietary supplements.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
High Nutrient requirements	1	0	0	0	0	0
Instructed by a Health Professional	1	1	0	1	0	0
Following a restrictive Diet	0	0	0	0	0	0
Diet inadequate in certain nutrients	0	0	0	0	1	0
Other	3	1	0	1	0	0
NA	2	3	3	0	0	3

Within the questionnaire, participants responded to a question about reasons for choosing to take dietary supplements. Table 12 shows the number of participants from each sport in both the intervention and control groups that chose each available reason for supplement use. For those who reported taking supplements, the most common answers from the specific categories provided in the questionnaire were that they were instructed by a health professional, with 3 responses recorded. However, the highest response rate was for the category 'other' (Table 12), for which five athletes responded. This category included personal reasons besides those listed in the questionnaire as possible reasons for supplement use. The category 'NA' reflected no supplement use by responding participants.

The highest response rate was from the intervention group of sports, with the endurance sport participants providing the highest number of responses (Table 12). In the control group, the highest response rate was also from the endurance sport participants.

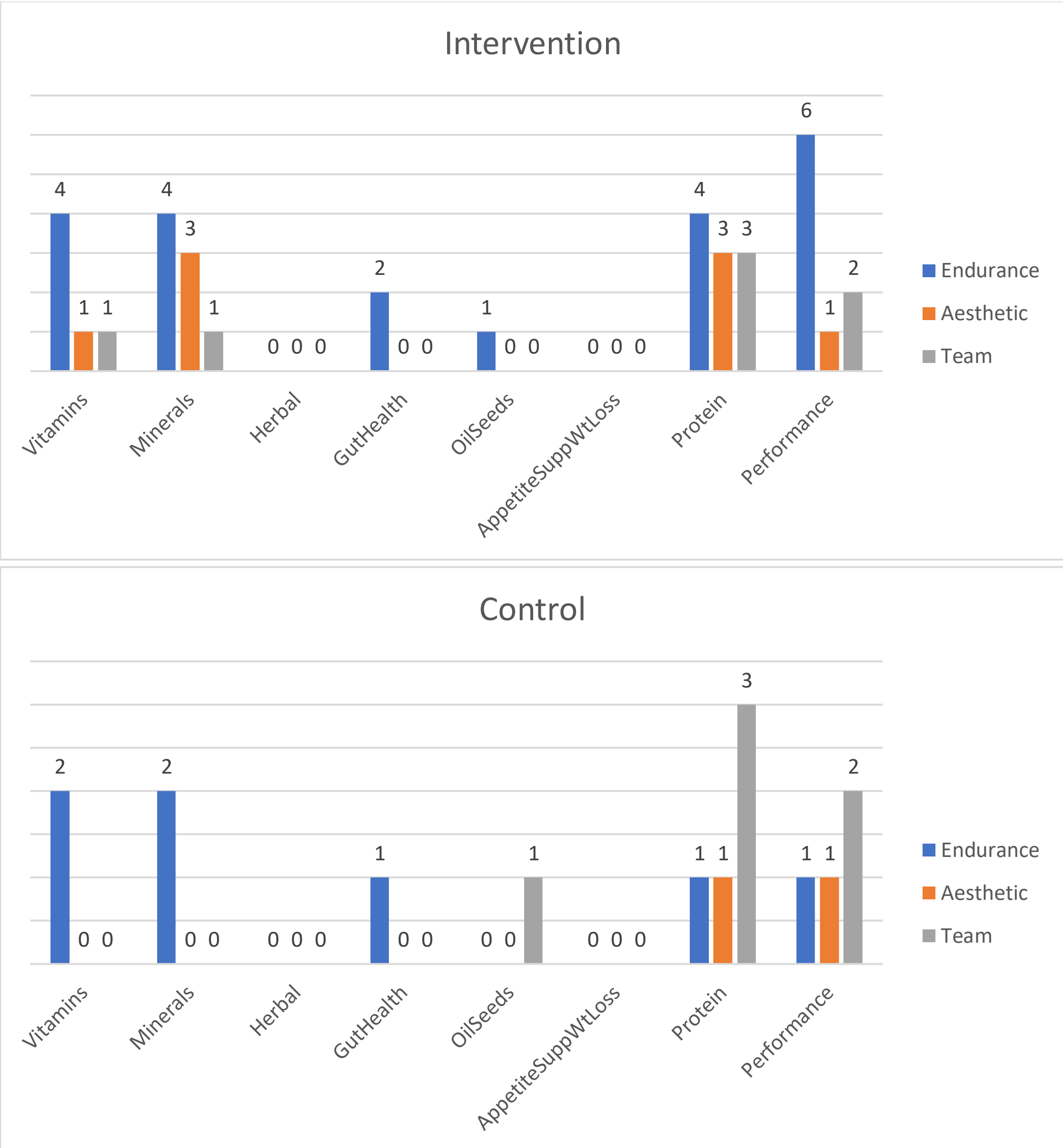
Table 15 Reasons for not taking dietary supplements.

	Intervention			Control		
	Endurance (n=7)	Aesthetic (n=5)	Team (n=3)	Endurance (n=2)	Aesthetic (n=1)	Team (n=3)
Adequate nutrition from diet	0	1	1	0	0	2
Don't want to	0	0	0	0	0	0
Too costly	0	0	0	0	0	0
Unsure whether beneficial	3	1	2	1	0	1
Other	0	1	0	0	0	0
NA	4	2	0	1	1	0

The questionnaire also investigated the reasons some participants did not take supplements, and responses from each sport in the intervention and control groups are shown in Table 13. The most common options selected by both the intervention and control group athletes were that they gain adequate nutrition from their diet (3 respondents) and that they were unsure whether beneficial (8 respondents). Among the sports participants, the highest response rate was from the endurance sport intervention group, with three responding to the 'unsure whether beneficial' reason (Table 13).

Dietary Supplements Intakes at Baseline

Figure 16 Dietary supplement categories and frequency of intakes at baseline.



Endurance sport athletes in both the intervention and control groups recorded supplement intakes from a variety of supplement categories, including vitamins, minerals, gut health, oils and seeds, protein, and performance (Figure 2). Four athletes in the endurance sport intervention group reported taking vitamins and minerals supplements, whereas two of the endurance sport control group reported these same supplements, representing all participants in the endurance sport control group. Gut health supplements were reported by two of the seven athletes in the endurance sport intervention group, and by one of the two athletes in the same sport control group. Oil and seed supplements were reported by one endurance sport intervention group athlete, but no control athletes. Four of the endurance sport intervention group reported protein supplement intakes, compared to only one from the endurance sport control group. Performance supplements were the most widely used choice by endurance sport athletes. Among the intervention group, six of the seven athletes reported taking performance supplements, while one of the two athletes in the endurance sport control group reported this supplement intake.

Recorded supplement intakes by the aesthetic sport intervention group were from the vitamin, minerals, gut health, oils and seeds, protein, and performance categories (Figure 2). However, vitamin supplements were reported by only one aesthetic sport intervention group athlete, while three athletes in this intervention group reported mineral supplement intakes, and three reported protein supplement intakes. Two athletes from the aesthetic sport intervention group recorded performance supplement intakes.

The single aesthetic sport control group athlete reportedly did not take either vitamin or mineral supplements but did report protein as well as performance supplement intakes (Figure 2).

Supplement intake patterns for the team sport intervention group included vitamin, mineral, protein, and performance categories (Figure 2). Vitamin and mineral supplements were both taken by one team sport athlete from the intervention group, but protein supplements were taken by all of the team sport athletes in this group, and performance supplement intakes were recorded by two team sport athletes in the intervention group (Figure 2).

Among the team sport control group oil and seed supplements were only taken by one athlete and two of these athletes recorded performance supplement intakes (Figure 2).

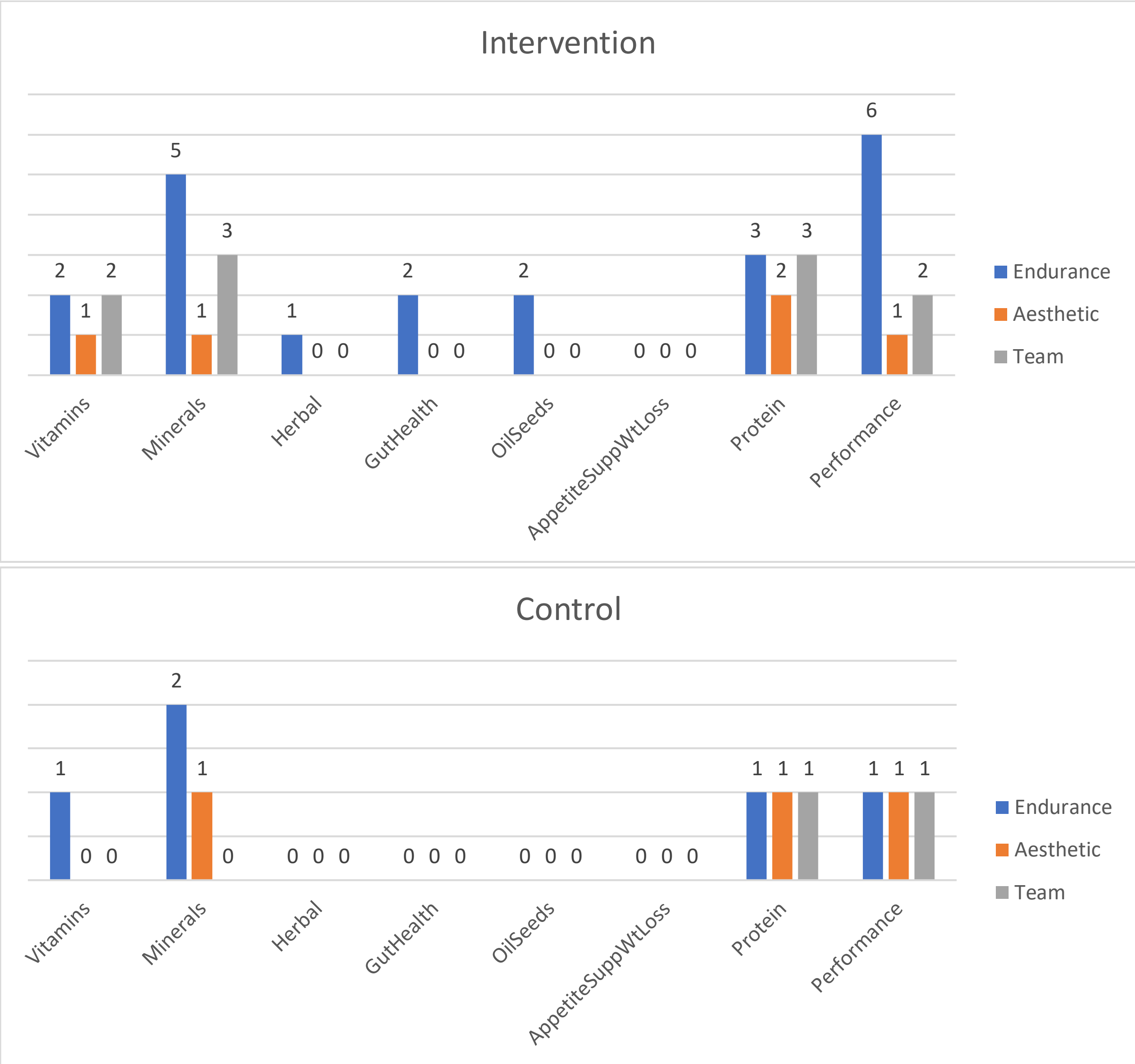
During the semi-structured interviews, endurance sport athletes spoke of taking supplements for health and performance reasons. Although some athletes seemed indifferent to supplements with perceptions that their diet provided adequate nutrients, “I’m quite indifferent. If I could see a difference in me, it is probably something that I would continue doing – It’s just something that I haven’t spent enough time considering, I guess I’m trying to get nutrients in my diet” (Intervention endurance sport participant E2). The cost of supplements was mentioned by participant in the endurance sport control group, “Supplements can be a waste of money if you’re not deficient in it and I guess I’m conscious of that as well – everything costs so much each month and I’m not going to throw it away for no reason. If there is no proven benefit, there is no point in taking it” (Control endurance sport participant E5).

Many of the aesthetic sport athletes from both the intervention and control group did not feel the need to take supplements, “I guess I never really felt the need to, I mean I train a bit but I don’t train a lot, I never really felt the need to, I guess that I eat enough. What I do is not that high intensity” (Intervention aesthetic sport participant A4). It was also highlighted by two of the aesthetic sport athletes from the intervention group that they avoided supplements due to drug testing and the risk of contamination from supplements, “I would take more supplements if I wasn’t in competitive sport. Like it is just an unknown with drug testing, we get told unless it is really something vital, just try and get the nutrition from food rather than tablets, just ‘cause you don’t know what is in them” (Intervention aesthetic sport participant A5). Drug testing was not a factor mentioned by athletes from the other sport groups.

The consensus among the team sport athletes was that they preferred getting nutrients from food rather than supplements but would take them if required. The main reason for supplement use for the team sport intervention group was the occurrence of a deficiency that had been medically identified, “I only take Vit D because I’m deficient – from the blood test result” (Intervention team sport participant T8).

Dietary Supplements Intakes upon Study Completion

Figure 17 Number of participants taking dietary supplements at study completion.



The dietary supplements questionnaire was repeated at study completion. Figure 3 shows the endurance sport athletes in the intervention group recorded supplement intakes in all but the weight loss categories. Minerals and performance supplements were the most popular in this sport group, with five athletes from the endurance sport intervention group reporting mineral supplement intakes and six recording performance supplements. Among the control group endurance sport participants, only four supplement categories were reported, including vitamins, minerals, protein, and performance supplements (Figure 3). Two participants from this control group recorded mineral supplement intakes while only one participant recorded intakes from each of the other three categories (Figure 3).

Aesthetic sport athletes from the intervention group recorded supplement intakes from vitamin, mineral, protein, and performance categories, with two athletes ticking the protein supplement box and one athlete for each of the three supplement categories (Figure 3). The dietary supplement intake pattern was similar for the aesthetic sport control group, although vitamin supplements were not reported by this group. Each of the minerals, protein and performance supplement categories had one athlete reporting intakes per category (Figure 3).

The highest supplement intakes reported by the team sport intervention group were three participants taking mineral supplements and three reporting protein supplements (Figure 3). The only other supplement categories included two participants recording vitamin intakes and two recording performance supplements (Figure 3). The team sport control group results showed supplement intakes limited to one athlete recording protein intakes and one ticking the performance supplement category box (Figure 3).

A comparison of supplement intakes at baseline with study completion showed endurance athletes took a similar number of supplements at completion and baseline. The most notable changes included both endurance sport intervention and control group athletes taking fewer vitamin supplements on completion of the study (Figure 3) compared to baseline(Figure 2). The endurance sport intervention group decreased from four to two athletes reporting vitamin supplements and the control group decreased from two to one between baseline (Figure 2) and study completion (Figure 3). Mineral intakes among the endurance intervention group increased from four to five athletes recording these supplement intakes by study completion and the control group remained consistent at two athlete reports for supplemental mineral intakes (Figures 2 and 3). One of the endurance sport intervention athletes started taking herbal supplements by the end of the study (Figure 3), after reportedly no intake of herbal supplements at baseline (Figure 2). Gut health supplement intakes remained consistent for the endurance sport intervention group with two of the seven athletes in this group reporting this supplement category at baseline (Figure 2) and at the end of the study (Figure 3). Oils and seed supplement use had increased by the end of the study among the endurance sport intervention group from one participant recording intake of this supplement at baseline (Figure 2) to two reports at study completion (Figure 3). Protein supplement intakes decreased from four endurance sport intervention group athletes at baseline (Figure 2) to three at study completion (Figure 3) and the use of performance supplements remained consistent for the endurance sport athletes, with six athletes from the intervention group recording performance supplements at both baseline (Figure 2) and completion (Figure 3).

Among the endurance sport control group, there was a decrease in vitamin intakes from two reports at baseline (Figure 2) to none by the end of the study (Figure 3). Mineral intakes remained the same in the endurance sport control group, with two athletes reporting this supplement category at baseline (Figure 2) and at study completion (Figure 3). There was a decrease in the pattern of gut health supplement intakes over the course of the study, with one athlete recording this supplement at baseline (Figure 2) while no intakes were recorded at study completion (Figure 3). Protein and performance supplement intakes did not change among the endurance sport control group, with 1 athlete recording intakes in each of these supplement categories at baseline (Figure 2) and upon study completion (Figure 3).

Vitamin intakes did not change for the aesthetic sport intervention group, with one athlete recording intakes in this supplement category at baseline (Figure 2) and at the end of the study (Figure 3). Mineral intakes in this control group decreased from three athletes recording intakes at baseline (Figure 2) down to one athlete at study completion (Figure 3). The pattern of protein and performance supplement intakes remained the same in this aesthetic sport control group, with one athlete record for each supplement category at baseline (Figure 2) and at study end (Figure 3).

The pattern of dietary supplement intakes among the team sport control group at study completion showed a consistent decrease in reported intakes in the following supplement categories, when baseline data were compared to study completion. The oils and seeds supplement intakes decreased from one athlete report at baseline (Figure 2) to none at study completion (Figure 3), while protein supplement intakes decreased in the team sport control group from three athlete records at baseline (Figure 2) to one by the end of the study (Figure 3). Similarly, results for the performance supplement category showed a decreased intake from two reports at baseline (Figure 2) to one upon completion of the study (Figure 3).

5.4 Discussion

There is limited published evidence that compares the prevalence of low energy availability (LEA) between different sports, as the assumption has been that LEA is more likely to be reported among elite female athletes in aesthetic (leanness) sports compared to sports that do not have a focus on a lean body composition (Melin et al., 2015; Civil et al., 2019).

Comparisons between three different types of sports is a novel focus in this PhD project, which also includes investigations of the manifestation of LEA through food choices. In addition, dietary supplements use among elite female athletes was investigated, to determine whether intakes are more likely to contribute to a perceived lack of nutrient intakes in athletes with and without LEA. Dietary remediation with athletes identified with LEA was also addressed through personalised motivational interviews (MI), conducted between the baseline and study completion data collection periods.

Among the leanness sports, represented by trampoline and tumbling sports in this study, female athletes may face added pressure to maintain a lean body composition that is considered advantageous to their sport performance. This may lead to restrictive eating behaviours and poor food choices (Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019). The restriction of certain food groups to manipulate body composition may lead to nutrient deficiencies, particularly micronutrient deficiencies which can have negative effects on health and sports performance (Vicente et al., 2023). Endurance sport athletes such as distance runners may favour a lean body composition to increase their power-to-weight ratio (Melin et al., 2015; Melin et al., 2016; McCormack et al., 2019) with the intention to maximise their performance, while aesthetic sport athletes such as gymnasts may favour a slim figure for artistic expression and advantage when performing certain movements (Silva & Paiva, 2015; Schaal et al., 2017; Costa et al., 2019). Evidence suggests athletes from traditionally non-leanness sports such as team sports receive less scrutiny of their body composition and are therefore believed to be at a lower risk of LEA (Wright et al., 2014; Braun et al., 2018; Zanders et al., 2018; Zabriskie et al., 2019).

5.4.1 Low energy availability and dietary intakes at baseline

Surprisingly, at baseline a high prevalence of low energy availability (LEA) was discovered across all sport groups (endurance, aesthetic, and team sports), not just in lean body composition or ‘leanness’ sports such as endurance and aesthetic sports (Table 3). The prevalence of LEA in endurance sport athletes at baseline in this study (77.7%) was similar to a small number of published reports (Day et al., 2015; Melin et al., 2016), while predictably the prevalence of LEA in aesthetic sport athletes in this study (86%) was similar to others (Civil et al., 2019; Torres-McGehee et al., 2021). The true prevalence of LEA in the team sport group at baseline in this study is unknown due to accelerometer malfunctions at baseline (7 of 12 participants). The five accelerometers that functioned correctly all measured exercise energy expenditure (EEE) correctly, facilitating identification of LEA in 42% of the athletes in this team sport group. This prevalence was similar to other studies which reported that LEA prevalence ranged from 23-67% (Magee et al., 2020; Moss et al., 2021) in similar female team sport athletes.

The high prevalence of LEA across endurance, aesthetic and team sports was not expected due to the traditional body composition differences between leanness and non-leanness sports. It was expected sports that place value on leanness from an aesthetic, acrobatic perspective (aesthetic sports) or a weight-bearing, power-to-weight ratio perspective (endurance sports) would have a greater prevalence of LEA due to the use of dietary restriction to maintain a lean body composition (Melin et al., 2016; Schaal et al., 2017; McCormack et al., 2019; Jagim et al., 2022). The emphasis these sports place on maintaining a lean body composition can lead to anxiety and preoccupation with body fatness, leading to restrictive dietary practices (Civil et al., 2019; Costa et al., 2019).

In a novel part of this PhD study, the manifestation of LEA in these leanness-focussed sports was investigated through food group intakes. Surprisingly, the non-leanness team sport participants had a significantly lower (p=0.020) intake of dairy foods among the intervention (LEA) group at baseline compared to the aesthetic sports (Table 9). Restricted dairy food intakes are often the focus for athletes striving to achieve a lean body composition, as these foods are perceived as being fatty and therefore counter-productive in maintaining low body fat (Bisogni et al., 2012; Eck & Byrd-Bredbenner, 2019; Villa et al., 2021), despite the availability of low fat dairy food options. An endurance intervention athlete described restricting dairy. "I try to limit it… just cause the way it makes me feel, I find my skin flares up if I eat too much" (Intervention E10). The discovery of the lowest mean intakes of dairy foods among the team sport athletes at baseline (Table 9) may be due to the young age in this (soccer) team sport (23 years) (Table 1), as a lean body composition can be a focus among adolescents and young adult women, irrespective of their sport participation (Bisogni et al., 2012; Eck & Byrd-Bredbenner, 2019). However, as none of the participants from each sport in both the intervention and control groups met the dairy food recommended daily serves at baseline (Table 9), this age-related proposition could explain the prevalence of energy restriction through this food group in at least the aesthetic and team sports in both the LEA (intervention) and non-LEA groups. Indeed, the highest intake of daily dairy foods serves was recorded by the endurance sport athletes in both the intervention and control groups. The mean age of participants in these groups was 35.4 and 34.5 years respectively, who were significantly older (p=0.005) than their aesthetic and team sport counterparts (Table 1). It could be argued that the older endurance sport athletes may have been less age-related conscious of body composition, although the mean number of daily dairy food serves was still lower than the recommendations for this food group. Nonetheless, the endurance sport athletes identified with LEA did have a significantly lower (p=0.045) dairy food intake compared to the same-sport control group (non-

LEA) (Table 9), suggesting some influence in their dairy food restriction from their sport participation.

Restricted intakes from the dairy food group can compromise dietary calcium intakes, leading to an acute risk of stress fractures through low bone mineral density (Goodwin et al., 2014; Heikura et al., 2018; Mountjoy et al., 2018a; McCormack et al., 2019) which is likely to negatively impact on sports performance, and a longer-term increased risk of osteopaenia and osteoporosis (Melin et al., 2015; McCormack et al., 2019). As inadequate mean dietary calcium intakes were observed among LEA-identified participants in the intervention group sports at baseline (Table 6), the risks of low bone mineral density and the negative health and sport performance sequelae are high. These risks are also likely among the non-LEA (control) team sport group, whose mean daily dietary calcium intakes were also inadequate (Table 6).

A seeming anomaly to lean body composition-associated restrictive dietary practices were the relatively high mean dietary fat intakes observed at baseline among the endurance and aesthetic sports in the intervention (LEA) group (Table 6). The mean dietary fat intakes recorded in each of these sport groups exceeded their sport-specific recommendations (Table 6). These results are inconsistent with energy restriction from fat, traditionally attributed to athletes identified with LEA (Bisogni et al., 2012; Eck & Byrd-Bredbenner, 2019). However, the team sport athletes in the intervention (LEA) and control (non-LEA) groups maintained mean daily dietary fat intakes within the recommended range, although this result was not significantly different to their respective endurance and aesthetic sport participants in the intervention and control groups. Similar results were observed for mean dietary fat intakes among the endurance and aesthetic sport participants in the control group (Table 6), suggesting specific dietary fat restriction was not a consideration among these non-LEA athletes, consistent with evidence supporting less concern about body fatness among female team sport athletes (Wright et al., 2014).

Further evidence for energy restriction though specific food groups was shown by the inadequate intakes of grains and cereal foods at baseline across all sports except the aesthetic sport control group athlete (Table 9) whose data was excluded from statistical analysis due to the inadequate number of representatives in this sport group. These grains/cereals results were consistent with inadequate carbohydrate intakes among participants in each sport in the intervention group (LEA-identified athletes) (Table 6), although the non-LEA (control group) endurance and aesthetic sport participants did meet their daily carbohydrate recommendations. An intervention group soccer athlete described “I’ll go a bit lower calories and lower carbs because I’m not as tired or as hungry”

(Intervention T8). These comments from the participants reinforce the consistent promotion from popular media that carbohydrate foods and sugars are 'fattening' (Logue et al., 2018; Eck & Byrd-Bredbenner, 2019), suggesting athletes are not immune to these popular media messages. However, this nutrient is the main energy source for elite athletes (McCubbin et al., 2020; Moore et al., 2021), and the inadequate carbohydrate intakes demonstrated by athletes in each of the intervention (LEA) group sports also suggests their dietary restriction was focussed on messages from popular media instead of nutrition experts. However, as there were no significant differences in grains/cereal food intakes between sports in either the intervention or control groups, the assertion that energy restriction through carbohydrate intake manipulation is limited to body-composition aware endurance & aesthetic sports was refuted by these results.

Investigation of the dietary manifestation of LEA was a novel primary aim in this PhD study. To investigate this aim, patterns of food group intakes were observed. Typically, high fibre foods are used as 'fillers' to provide bulk and satiation to meals and snacks, which also lowers the energy density of food intakes (Barron et al., 2016; Melin et al., 2016).

Dietary fibre intakes at presentation for the study (baseline) among the intervention group (LEA) of sports did not show excessive intakes for any of the sports participants (Table 6). In fact, neither the aesthetic (nor team sports participants met their recommended dietary fibre intake of 25g.dy^{-1} at baseline, while the endurance sport intervention group had a mean daily fibre intake just above the recommendation (Table 6), but not excessive. A comparison of this nutrient intake with high-fibre food groups (Table 9), typically fruit, vegetables, and possibly grains/cereals, supported the findings for dietary fibre intake in Table 6. None of the sports groups from the intervention group exceeded the recommended number of daily serves for these dietary fibre food sources at baseline (Table 9), and neither did they meet the recommended intakes for each of the relevant food groups (Table 9). These results suggest that use of low energy density foods such as dietary fibre to reduce total energy intakes was not a factor in dietary manipulation among the female athletes with LEA. Rather, the results show that restrictive intakes across most of the food groups was the dietary approach to limit total energy intakes in their goal to achieve or maintain a lean body composition, leading to LEA.

Inadequate carbohydrate intakes are often associated with high protein intakes (Masson & Lamarche, 2016). Although there were no significant differences between all sports across the intervention (LEA) and control (non-LEA) groups, athletes in the endurance sport intervention and control groups were the only participants who met their sport-specific recommended dietary protein intakes at baseline (Table 6). However, other than the endurance control (non-LEA) participants, none of the other sports groups met the recommended number of daily lean protein serves (Table 6). A team sport athlete reported during the interviews that they were vegetarian. This may explain the inadequate dietary protein intakes among some of the athletes, but not all reported following a vegetarian diet. Omission of beef is a popular dietary choice among some women, particularly those in the adolescent and young adult age group (Condo et al., 2019; Eck & Byrd-Bredbenner, 2019), regardless of athlete status. Comments from some athletes reflect this distaste, with a focus on dislike of the taste but also a perception that beef/red meat is unhealthy, "I don't like barbeque meats like steak, I don't want to eat any of that" (Control T3). As lean protein foods are a good source of dietary iron, inadequate protein intakes from lean protein foods reflected the inadequate dietary iron intakes found in each of the sports in both the intervention (LEA) and control (non-LEA) groups (Table 6). Dietary iron has an important role in sports performance as well as health, with a high risk of iron deficiency anaemia frequently reported among female athletes (Robertson et al., 2014; Melin et al., 2016). In addition, protein is a secondary energy source for endurance athletes (Tarnopolsky, 2004), and only the endurance sport control group of participants met their dietary protein (Table 6) and lean protein food group requirements (Table 9). Whether this was by design based on nutrition knowledge or by chance, remains unknown, although comments from some of these athletes support their observed intakes, "after I'll have something protein like a protein shake" (Intervention E10). Although others have also reported inadequate protein intakes among female basketball and soccer athletes (Zanders et al., 2018; Magee et al., 2020), this study adds to the knowledge gap about inadequate intakes of lean protein foods (Table 9), particularly among aesthetics sport athletes, but also surprisingly among team sport athletes in both the intervention and control groups (Table 9). It has been generally accepted that female team sport athletes focus more on strength and fitness than necessarily a lean body composition (Reed et al., 2014; Wright et al., 2014; Jenner et al., 2019), suggesting they would be more aware of meeting protein requirements. However, this accepted knowledge was challenged by the results in this study.

Energy availability and dietary results for the intervention (LEA) sports groups indicated nutrition education was needed, to assist these athletes to reverse their LEA status. A novel aspect of this PhD project was to test the effectiveness of individualised dietary counselling using a motivational interview (MI) technique. Within the counselling sessions, a 'Food First' approach was used to dissuade participants from using dietary supplements and obtain their macro- and micro-nutrients from food. Of course, where a medical condition requiring short-term nutrient supplementation was indicated, affected athletes were not dissuaded from following the supplement intake guidelines. However, in most cases across the intervention and control groups, dietary supplement intakes observed at baseline were haphazard (Table 6), and although macro- and micro-nutrient deficiencies were observed (Table 6), the MI counselling technique emphasized the reasons why nutrient intakes from food were more beneficial than supplement intakes.

5.4.2 Low energy availability and dietary intakes at study completion

The intervention group of sports (endurance, aesthetic, and team) comprised female athletes whose mean energy availability met the criteria for low energy availability (LEA) (EA <30 kCal.kg FFM.dy^{-1}). The prevalence of LEA in traditionally non-aesthetic sports (team sport) (Table 3) was a surprising result, and although some of the literature have reported this (Devlin et al., 2017; Braun et al., 2018; Zanders et al., 2018; Condo et al., 2019; Jenner et al., 2019; Zabriskie et al., 2019; Magee et al., 2020), none have compared the within sport dietary intakes across different sports. In addition, the novel inclusion of individualised motivational interview (MI) counselling as an intervention to assist with remediation of LEA was tested against a group of matching sports comprising female athletes who did not meet the LEA criteria (non-LEA). The study completion data discuss the effectiveness of this MI counselling compared to a standard nutrition education infographic provided to each participant in the control group sports.

Comparisons between baseline and study completion data found that each sport in the intervention group increased their energy availability (EA) from baseline, with a significant difference between the pre- and post-intervention EA for the endurance (p=0.039) and team sports (p=0.036) (Table 5). Encouragingly, the team sport participants in the intervention group increased their mean EA above the LEA threshold (30 kcal.kg FFM.dy^{-1}), suggesting an overall positive effect of the individualised MI. However, although the endurance and aesthetic sports in the intervention group increased their EA compared to their baseline data (Table 5) this was not sufficient to meet the LEA cut-off threshold (30 kcal.kg FFM.dy^{-1}). As both these sports are considered leanness sports whose athletes are at risk of LEA and associated nutrient deficiencies (Melin et al., 2015; Melin et al., 2016; Civil et al., 2019; McCormack et al., 2019), further investigations of more effective dietary counselling techniques are indicated for these at risk sports.

By comparison, the control groups who received a general nutrition education infographic rather than MI counselling, showed minimal changes in EA from baseline to completion (Table 4).

However, as these sports participants who by definition comprised the control group as they were not energy deficient and therefore did not qualify as LEA candidates, the need to change their energy intakes was not considered necessary. However, it was disappointing to note that the endurance sport control group showed a decrease in mean EA between baseline and completion of the study (Table 5), placing athletes from this sport in the at-risk region for LEA (<45 kcal.kg FFM.dy^{-1}). For the single athletes in the aesthetic sport control group, there was no change to the mean EA which remained above the LEA threshold, although statistical analysis was not possible due to the inadequate number of participants (n=1) in this sport group. Unfortunately, pre- versus post-study comparison for EA in the team sport control group are unknown due to accelerometer malfunctions, causing missing baseline EA data (Table 5). However, the at completion it was disappointing to find the stand-alone EA data indicated LEA (Table 5). As the lack of baseline EA data for this group, and the finding that at study completion the group mean EA suggested LEA, this group cannot strictly be considered a control group according to the criteria described in the Methods section and above, for allocation to an intervention or control group. Nonetheless, results from the other sports in the control group suggest the generalised nutrition education infographic was not as effective as the MI tool to encourage positive changes to energy intakes and thereby EA.

Macronutrient intakes analysed at baseline and at study completion showed no significant differences for dietary protein, carbohydrate, and fat within either the intervention or control groups (Table 8). Despite the significant improvements in mean EA following the individualised MI among the endurance and team sport intervention group participants (Table 5), the energy macronutrients did not show the same pattern of significant increases. Nonetheless, mean daily increases in protein and carbohydrate intakes were observed for the endurance and aesthetics sports in the intervention group (Table 8), while mean daily contribution from dietary fat showed desirable decreases across each sport. Although not significant for each individual macronutrient, the cumulative effect of increases in both the protein and carbohydrate mean daily intakes were sufficient to contribute to the observed significant increase in EA (Table 5) which was sufficient to remediate LEA in these at risk athletes. Matching the increased post-intervention mean intakes of carbohydrate among the endurance sport athletes in intervention group (Table 8) was the significant increase in mean grains/cereals food group serves following the MI counselling sessions at the post-intervention data collection point (Table 11). Similar but not significant increases in the number of daily serves from this food group were observed in the aesthetic and team sport groups at study completion, which was an encouraging outcome supporting use of the individualised MI counselling sessions. These increased intakes of the grains/cereals food group at study completion were also encouraging, as athletes can be indoctrinated by social media and other sources about the false role of carbohydrates in gaining body fat weight (Silva & Paiva, 2015; Schaal et al., 2017; Costa et al., 2019).

In contrast, decreased intakes for protein and carbohydrate intakes in the control group of sports was discouraging (Table 8) and may have been partly due to the ineffectiveness of the general nutrition education infographic received by the control group participants. Indeed, the lack of effectiveness of this type of nutrition education tool has been extensively demonstrated by others (Valliant et al., 2012; Day et al., 2015; Nascimento et al., 2016; Laramée et al., 2017; Rossi et al., 2017).

These results suggest there was at least some positive effect from the MI counselling among the intervention group of sports compared to the general nutrition education infographic provided to the control group participants.

While manifestations of LEA through excess intakes of low energy density fibre foods at the expense of more energy dense carbohydrate and protein foods was not evident from the baseline dietary observations, post-intervention data showed increases in dietary fibre (Table 8) intakes for each of the intervention group sports, albeit not significant, but not the representative fruit and vegetable food groups in which the mean daily number of serves had decreased upon study completion (Tables 10, 11). However, it could be argued that the modest dietary fibre increases may have been due to an increased selection of wholemeal and wholegrain grains/cereal choices from this food group.

Given the moderately positive remediation effect of the MI intervention elevating LEA to non-LEA status in the team sport intervention group (Tables 4, 5), and increasing EA above baseline results in the endurance and aesthetic sports in the intervention group (Tables 4, 5), it was encouraging to observe increases in mean dietary calcium intakes across each sport in the intervention group (Table 8). Although these post-intervention increases were not significantly different compared to baseline data (Table 8), nor significantly different from their respective sports in the control group at study completion (Table 7), they reflected a positive change in dietary choices. However, it was still insufficient to meet the dietary calcium recommended intake (Table 7), even when the mean calcium supplement intake was added (Table 7). The increases in dietary calcium intakes following the MI intervention did not seem to come exclusively from increased dairy food intakes, except for the team sport intervention group whose number of daily dairy food intakes were only just significantly higher (p=0.047) than baseline intakes (Table 11). Nonetheless, among the endurance and aesthetic sport participants in the intervention group, the observed increases at study completion in dietary carbohydrate (Table 8) and the grains/cereals food group (Table 11) may have assisted with these increased post-intervention dietary calcium intakes, as pasta and some breads can contribute to dietary calcium intakes.

Mean dietary calcium intakes had decreased at study completion among the endurance and team sports participants in the control group, although this change was not statistically significant (Table 8), suggesting the general nutrition education infographic was not as effective as the MI intervention to effect positive changes to dietary calcium intakes. There was an observed increase in dietary calcium intake in the aesthetic sport control group, but as the number of participants in this sport was insufficient, these data were not included in statistical analyses. The decreased dietary calcium intakes among the endurance and team sport control group participants is of concern, as calcium is an integral nutrient in bone health (Robertson et al., 2014; Silva & Paiva, 2015), regardless of their non-LEA status

An observed increases in mean dietary iron intakes following the MI intervention for each of the sports groups (Table 8) were encouraging, although pre- versus post-differences were not significant. Nonetheless, these small increases suggest the individualised MI counselling sessions were somewhat effective in encouraging positive dietary change among the LEA athletes. However, the mean dietary iron intakes in each of the intervention group sports did not reach the recommended intake (Table 7), even with the additional contribution from iron supplements to dietary intakes (Table 7). Of course, iron losses cannot be ignored when assessing body iron balance, with endurance sport athletes at particular risk of iron losses through excessive sweating (Beermann et al., 2020), and most female athletes at risk of substantial iron losses if they experience heavy menstrual blood loss on a regular basis (Beermann et al., 2020). It can be a delicate balancing act for elite female athletes whose iron losses may be high while their dietary intakes are inadequate. Therefore, although post-intervention improvements in dietary iron intakes among the intervention group of sports was encouraging, their inability to meet dietary iron requirements and maintain body iron balance if iron losses are greater than intakes, may still put them at risk of iron deficiency or manifest iron deficiency anaemia, with adverse effects on their health and sports performance (Robertson et al., 2014). The largest increase in dietary iron intakes measured post-intervention were observed among the aesthetic and team sport participants (Table 8), although mean lean protein and alternatives food group that contributes the most to dietary iron did not change (Table 11) between pre-and post-intervention data collection in these sports. It is difficult to discern from which foods the modest increases in dietary iron came if there were no changes to their main food group source, unless there were increased intakes from iron-fortified carbohydrate foods within the increased intakes in the gains/cereals food group observed among the intervention sports (Table 11).

The observed decrease in dietary iron intakes among the control group sports (Table 8) suggested again that the general nutrition infographic did not have a positive influence on dietary change for dietary iron intakes. Despite these athletes being classified as non-LEA, their decreased dietary iron intakes by the end of the study suggests more focussed remedial action is required among this group of female athletes.

Overall, there was some supporting evidence to promote the use of the MI counselling technique among female athletes to remediate their LEA status through dietary change. In addition, the lack of positive effect of the general nutrition infographic on dietary change for the non-LEA female athletes (control group) suggests all female athletes may benefit from individualised MI dietary counselling to improve their nutrition status to maximise the benefits from their intensive training regimens.

5.4.3 Dietary supplement intake patterns and the Effect of the 'Food First' Motivational Interviews on supplement intakes.

Among the primary aims of this PhD study were investigations of dietary supplement intake patterns, and the effect of a 'Food First' approach to dietary counselling within the scope of the motivational interview methodology, to promote whole foods as the best source of macro-and micro-nutrients instead of dietary supplements. It is preferable that nutrient intakes are from food to ensure appropriate physiological doses rather than an imbalance in nutrient intakes or specific supplement intakes at high doses for extended periods, which may be harmful to health and sports performance (Robertson et al., 2014). Indeed, intakes of various types of dietary supplement are well documented among female athletes (Benardot et al., 2014; Robertson & Mountjoy, 2018; McCubbin et al., 2020), with some evidence of high-dose dietary supplements as a part of their daily nutrition routine (Benardot et al., 2014; Knapik et al., 2015).

In general, the semi-structured interviews with athletes revealed they took supplements mainly when they felt they needed them, and that their intakes were not regular. This was shown by the small and inconsistent contribution of dietary supplements to key nutrient intakes at baseline (Table 6; Figure 1) and at study completion (Table 7; Figure 2) across each representative sport.

Nonetheless, in this study Vitamin supplements were the most popular among the endurance sport participants in the intervention group at baseline, followed by performance and protein supplements (Figure 2). Similarly, among the control group participants vitamin and mineral supplements were the most popular of all dietary supplements listed in the dietary supplements questionnaire (Figure 2). Despite having the highest supplement intakes of the athlete groups in this study, endurance sport athletes in both the intervention and control groups spoke during interviews about being indifferent towards supplement use. They were open to taking supplements if they could see a difference to their performance, or were required for a diagnosed nutrient deficiency, but were wary of "wasting money" on supplements. When asked in the questionnaire about reasons for not taking dietary supplements (Table 13), several of the endurance sport intervention group responded that they were unsure if supplements were beneficial. Further investigation during interviews about the discrepancy between reported intakes and their attitudes towards supplement use may have provided some further explanations. However, interviews were conducted prior to analyses of the first (Q1) dietary supplements questionnaire.

Nonetheless, some insight into reasons for supplement intakes were provided in Table 12, which showed some of the athletes stated (perceived) high nutrient requirements and instructed by a health professional were their supplement intake reasons. However, a category labelled 'other' was included in the questionnaire, which was the most popular answer recorded. Had the qualitative interviews been conducted after implementation of the first dietary supplements questionnaire (Q1), exploration of these 'other' reasons during the interviews may have provided further insight into the discrepancy between actual dietary supplement intakes and the attitudes towards supplement intakes by these athletes.

Iron was another of the micronutrient supplements that most endurance sport participants had reported as previously, if not currently consuming. Iron supplements in particular are commonly used by endurance and marathon runners as acute treatment for diagnosed iron deficiency, but also perceived to prevent future iron deficiency (Beermann et al., 2020), regardless of whether dietary analysis was performed. As these endurance sport athletes were distance runners, their susceptibility to high iron losses through high impact footstrike placed them at risk of iron deficiency, particularly as baseline (Table 7) and post-intervention dietary iron intakes (Table 8) in the endurance sport intervention group, and lean protein food group intakes were inadequate at baseline (Table 9) and post-intervention (Table 10). During interviews, both the intervention and control groups of endurance athletes spoke of being aware of the importance of iron and reportedly took iron supplements if they felt their energy levels were getting low, perceiving this as a symptom of iron deficiency, rather than necessarily in response to diagnosed iron deficiency.

Calcium supplements were only reported by the aesthetic sport intervention group, and this was upon study completion (Table 8). This uptake of calcium supplement post intervention may have been due to the positive effects of the MI counselling session, particularly as dietary calcium n at baseline in this athlete group were inadequate, but as interviews were not conducted at the end of the study, reasons for sudden inclusion of this supplement at study completion were not available. None of the other sports groups in either the intervention or control groups reported calcium supplement intakes, despite no improvements to inadequate dietary calcium intakes following the MI counselling interventions (Table 11).

The effects of a 'Food First' approach to MI dietary counselling sessions was of particular interest as this novel methodology has not been reported elsewhere. Although patterns of dietary supplement intakes were inconsistent among all participants, the goal of the 'food first' approach was to reduce reliance on supplements and improve nutrient intakes from foods, particularly where micronutrient inadequacies were identified.

The most notable changes in supplement intakes between baseline and completion of the study were among the intervention group of sports, suggesting a positive effect of the 'Food First' approach. Decreased vitamin supplement intakes among the endurance sport participants, and decreased mineral supplement intakes among the aesthetic sport participants were observed (Figure 3), but there was an increase in mineral intakes among the team sport intervention group (Figure 3). By comparison, the general sports nutrition infographic seemed to have little effect in control group sports, with the exception of a decrease in the number of athletes consuming protein supplements across all sports in this group (Figure 3). However, as both the team sport intervention and control groups were from the same squad (elite women's soccer) the opportunity for information exchange between individuals from each group may have occurred after the MI intervention, with the unintended outcome of specific nutrition education about supplement intakes being passed from the intervention group participants to the control group participants. In addition, the infographic provided for the control group sports participants did not specifically address dietary supplement use. Data from the aesthetic sport control group were not analysed due to only a single athlete representing that group.

Although investigation of the effectiveness of a 'Food First' approach was directed at a reduction in reliance on dietary supplement intakes, some supplements could not be discouraged during as they had been prescribed by health professionals. However, these supplements were of less concern to the athlete's health as they were being used under supervision and presumably consumed in specifically prescribed doses. It must also be noted that supplements may be necessary in the recovery from LEA to help correct nutrient deficiencies in the short term, of which there were several identified and shown in Table 11. Others have also addressed the need for dietary supplement recommendations during remediation of athletes identified with LEA (Robertson et al., 2014; Casazza et al., 2018; Robertson & Mountjoy, 2018; Holtzman & Ackerman, 2021).

Findings from this study also highlighted the inconsistent use of supplements by athletes from all participating sports in both the intervention and control groups (endurance, aesthetic, and team sports). This inconsistent supplement use reported by participants may have weakened the potential positive effect of the 'Food First' approach to dietary counselling during the motivational interviews.

5.4.4 Limitations

Over the duration of the study many limitations emerged that may have affected study outcomes. Despite the homogeneity of the athletes in each sport represented in this study, one of the main limitations were the small sample sizes that were related to recruitment difficulties, which may have created a bias towards higher prevalence of LEA participants in the sample populations than reported in the whole sport populations. In addition, the relatively high prevalence of LEA found in each of the sports limited the number of control group participants, given the sample size limitations for each sporting group.

There were a limited number of female athletes in each of the sports groups training and competing locally at an elite level, as many had moved interstate or overseas just prior to the study commencement, to pursue greater opportunities. Interstate or external athletes could not be included as participants were required to have their body composition measured and accelerometers fitted in person.

The study also took place during the COVID-19 pandemic, further decreasing the number of athletes available or willing to participate. Many athletes were not training due to COVID lockdown restrictions and therefore did not meet the inclusion criteria. Athletes were also stuck interstate or overseas due to border restrictions and upon return had to spend time in quarantine, by which time the data collection period had expired.

Over the duration of the study there were delays that lengthened the study. Some participants caught COVID-19 or were required to self-isolate during the data collection periods and had to repeat data collection. The first data collection period was drawn out due to the COVID-19 pandemic commencing just after recruitment had begun, which pushed back the intervention and completion data collection dates. This led to increased attrition due to participants relocating interstate or overseas to compete in other sport leagues, or loss of interest resulting in dropouts.

Adaptations were made to suit COVID-19 restrictions, and these changed over the duration of the study. Parts of the study were changed from face-to-face to virtual interactions, conducted via Zoom or other online platforms that the athletes were familiar with. This included the semi-structured interviews and MI intervention sessions. The parts of the study that were required to be in-person such as body composition measurements and accelerometer fitting, were done where possible in open areas to allow ventilation while wearing face masks.

Another limitation was the malfunction of several accelerometers during the baseline data collection period. This resulted in missing exercise energy expenditure (EEE) data for many team sport athletes and one endurance sport athlete. Consequently, these athletes were allocated to the control groups as energy availability (EA) could not be calculated. The true prevalence of LEA in the participating sports groups may have been higher, depending upon the EA of these athletes. As all the team sport athletes with functioning accelerometers were identified to have LEA, there were no EEE or EA data for team sport athletes at baseline. This may have skewed results as by possibly including athletes with LEA in the control group due to no EA data, when they should have been allocated to the intervention.

Due to limited participant numbers and the relatively small sample sizes, the study only compared two groups for each sport, the intervention (LEA) and control (non-LEA) groups. Ideally if a larger sample size had been achieved the LEA groups would have been split into two groups, some participants with LEA receiving the MI ‘food first’ intervention and others the control infographic. This would have provided a LEA control group rather than comparing to a control group of athletes without LEA. However even if more athletes were recruited there was no guarantee of how many would meet the LEA diagnostic criterion.

If time allowed athletes would have been followed up over a longer period to determine if the dietary changes for the intervention were sustained long term. This was not within the scope of the study, especially considering the disruptions to the timeline caused by the COVID-19 pandemic.

5.5 Conclusions

Low energy availability (LEA) was found to be prevalent among female athletes from leanness (endurance and aesthetic sports) and non-leanness sports. Among the leanness sports, there was a 78% prevalence of LEA in the endurance sport group and 86% among the aesthetic sport group. These results were not surprising, given the body of evidence showing these sports place a high priority on a lean body composition, which is directly associated with LEA. However, the surprising finding was that LEA was prevalent among 42% of the team sport group, which is not traditionally considered to be leanness sport, highlighting that there are other causes of LEA. More recent evidence is gradually emerging about some team sports identifying athletes with LEA, but a comparison with other sports within the one study has not been identified in the literature to date. This novel approach shows the benefits of standardised measurement tools used across all participating sports in the study reported here, to ensure variability in the measurement parameters between sports is captured as accurately as possible.

Assessment of dietary intakes at baseline revealed inadequate carbohydrate intakes across all sports and dietary fibre intakes in excess of the recommended intake among the groups identified with LEA, which are findings consistent with dietary manipulations reported among female athletes with LEA (Reed et al., 2014; Robertson et al., 2014; Masson & Lamarche, 2016; Melin et al., 2016; Moore et al., 2021; McHaffie et al., 2022). It was disappointing to see that these elite female athletes did not regard carbohydrate as a nutrient essential to their sports performance. The pressure within these LEA groups to conform to a lean body composition seemed to outweigh their dietary considerations for performance. Their nutrition knowledge about the roles of nutrients in sports performance was also poor and may have contributed to inadequate intakes. Evidence from the semi-structured interviews with participants revealed attitudes and knowledge towards carbohydrate foods were consistent with mainstream views promoting carbohydrate as a 'fattening' macronutrient, and thus were minimised in the habitual diets of these athletes. This was reinforced by the food group data, which highlighted the manifestation of LEA among the intervention groups athletes across each of the sports, showing inadequate numbers of daily serves of grain (cereal) foods at baseline.

Nonetheless, knowledge among athletes with LEA about the role of dietary fibre promoting satiety, seemed inconsistent among the leanness sport groups. The endurance sport intervention group met but did not exceed the recommended daily dietary fibre intake, while the aesthetic and team sport intervention groups did not meet their recommended daily intake of fibre. These results were not indicative of purposeful dietary manipulation using high fibre foods to decrease the energy density of the diet. Baseline food group data also showed inadequate numbers of daily serves of fibre-rich fruit and vegetable foods for all intervention groups, suggesting bulking of food intake with high fibre foods was not a dietary strategy that has been observed among other athletes with LEA. Moderate increased intakes of dietary fibre and fruit and vegetable food groups were observed for all sports intervention groups, but these increases were not significant when compared with baseline data or the respective sport control groups. Nonetheless the small increases suggested the novel approach of including personalised MI counselling to the intervention groups was encouraging.

Dietary fat intakes were in excess of their sport-specific recommendations among all but the team sport control (non-LEA) groups, which is a dietary intake counterproductive to lean body composition goals. The excess dietary fat intake results further reinforced the lack of nutrition knowledge among these elite female athletes, and the inclusion of personalised motivational interviews (MI) in dietary counseling sessions with the intervention (LEA) groups were intended to address both the harmful dietary manipulations and poor nutrition knowledge among these athletes. Results at study completion showed small decreases in mean daily fat intakes in the intervention groups when compared to the baseline data, but these changes did not reach statistical significance. Intakes of dairy foods at baseline were inconsistent with the dietary fat intake data, with inadequate daily intakes of dairy foods for all groups, across all sports. However, intakes of oils and solid fats in the discretionary food groups were in excess of recommendations for each of the sport intervention and control groups, with this food group the major contributor of dietary fat rather than calcium-rich dairy foods. There was no effect of the MI nor infographic on changes to discretionary food (oils and solid fat) intakes, suggesting further qualitative investigation of the influences on these particular food choices would be useful, particularly in the intervention groups, to understand the lack of change despite personalised MI counselling sessions.

Dietary restriction inevitably translates to inadequate micronutrient intakes. While mean daily calcium intakes did not meet requirements in the intervention groups for each sport at baseline, post-study results showed some promising effects of the MI, with increased intakes in the intervention groups for each sport, although none of the increases reached dietary requirements. This result is of concern as female athletes with LEA are at high risk of low BMD and associated stress fractures, which is exacerbated by inadequate dietary calcium and dairy food intakes. However, equally poor dietary calcium intakes were observed among the team sport control group, suggesting the MI did not adequately address dairy food intakes or non-dairy calcium alternatives. A high mean calcium supplement intake in the endurance sport intervention group resulted in adequate calcium intakes at study completion for this group, but as one of the aims of this study was to provide 'Food First' counselling with the motivational interviews, this proved to be a disappointing result.

Overall, given the baseline findings of their likely purposeful dietary restriction or lack of nutrition knowledge, it was disappointing to find only minimal positive effects of the MI in the intervention groups compared to the general sports nutrition education infographic provided to the control (non-LEA) groups. While some nutrient changes were positive after the personalised sport-specific MI interventions, many remained unchanged. These results suggest modifications to delivery of the MI counselling sessions are required for future studies of this type, with the possible addition of more frequent sessions than the two provided in this study, to improve the effectiveness of MI counselling in providing nutrition education and bringing about beneficial dietary change. Further investigation through qualitative interviews in future studies with at risk female athletes may more clearly identify the effects of social media and non-evidence-based nutrition information on individual dietary attitudes and intakes, to inform nutrition professionals about more effective counselling strategies.

CHAPTER 6 RESEARCH SUMMARY

The chapters of this PhD thesis have combined to address the following research aims:

10. To determine the prevalence of LEA among elite female athletes from sports with different body composition requirements
11. To determine how LEA manifests through dietary manipulation among elite female athletes identified with LEA
12. To explore the determinants of food choice among elite female athletes with and without LEA
13. To evaluate the effectiveness of 'Food First' personalised motivational interview counselling to remediate nutrient deficiencies associated with LEA in elite female athletes.

These aims answer the following research questions:

1. Is LEA more prevalent among elite female athletes from lean body-composition sports than female athletes from team sports?
2. Are there demonstrated improvements in dietary risk factors for LEA following 'Food First' motivational interview counselling in participants identified with LEA?

This chapter summarises the findings of the studies that were included in this PhD to answer the research questions and aims.

6.1 LEA Prevalence

It was hypothesised that low energy availability (LEA) would be more prevalent among leanness sports such as endurance and aesthetic sports that focus on maintaining a lean body composition and low body mass to enhance performance. The current evidence suggests that traditionally non-leanness sports such as team sports are at lower risk of LEA due to less pressure on attaining a lean body composition.

Baseline measurements shown in Chapter 5 found LEA was prevalent among 78% of endurance athletes, 86% of aesthetic athletes and 42% of team sport athletes. However the true prevalence of LEA in the team sport group was unknown as seven of the twelve accelerometers malfunctioned, therefore it was not possible to calculate EA for these seven participants.

It was found that leanness sport athletes (endurance and aesthetic sports) had similar energy availability (EA) values to non-leanness sport athletes (team sport). The research concludes that LEA exists in both leanness and non-leanness athlete populations to a similar degree, which is contrary to most of the research evidence in which the prevalence of LEA is reportedly restricted to leanness sports. Further research is required to make more direct comparisons between different sport populations, with larger sample sizes.

6.2 Manifestation

The manifestation of LEA was investigated through the collection of nutrient and food group intake data. The key macronutrient intake that was inadequate compared to current guidelines across all sports intervention (LEA) groups was carbohydrate similar to studies with leanness-sport athletes which found restricted carbohydrate intakes. Protein was lower than recommendations for aesthetic and team sport groups and fat intake was either adequate or excessive for all groups. Low carbohydrate intakes were further supported by low intakes of carbohydrate-rich food groups such as grains and cereal foods, and fruit. This is concerning as carbohydrate is the primary fuel for physical activity and brain function and improves performance by maintaining training intensity and volume.

As well as macronutrient intakes, food group intakes were also analysed based upon recommendations for the general population using the Australian Guide to Healthy Eating. The main food group of concern was dairy, with the recommended number of daily dairy serves (2.5/day) not met by any of the intervention (LEA) groups. This resulted in low dietary calcium intakes that were also recorded in these groups, none of which met the recommended intake of 1,000 mg per day. These low dairy and calcium intakes present a health concern as calcium is an important micronutrient that has a role in bone health, improving bone mineral density and decreasing the risk of injures such as stress fractures.

This was the first study to our knowledge to investigate the manifestation of LEA among female athletes from different sports. This information can help plan effective dietary interventions by knowing the areas of inadequacy to focus on. Both intentional and unintentional inadequate intakes of carbohydrate and dairy foods could be addressed through athlete education. Athletes intentionally restricting these foods may need to be educated on the importance of the nutrients provided and the consequences of inadequate intakes to performance and health if they do not meet recommendations. Athletes unintentionally restricting intakes of these foods in their diet may need encouragement to periodise nutrition intake to match energy expenditure and adequate portion sizes if these foods.

6.3 Determinants of Food Choice

There were many determinants of food choice that affected the athletes' dietary habits and nutrition intakes, both around training and competition and day-to-day.

Athletes from all sports groups (endurance, aesthetic, and team sport) were affected by external factors such as feeling the need to eat foods that were perceived as 'good' or 'healthy' and restricting foods that they perceived as 'bad'. The endurance and aesthetic sport athletes were more restrictive than the team sport athletes who more commonly included these foods in their diet "in moderation".

Another prominent external determinant of food choice was family, friends and teammates or fellow competitors. These results indicated that family and friends may need to be involved in interventions to address LEA in the affected athletes as their involvement could make a difference to whether or not recommended dietary changes are successful.

Internal determinants of food choice also had an impact on nutrition intakes. For example, athletes avoided foods that they did not like or they perceived to made them feel unwell. These determinants may not necessarily be able to be changed, although food and nutrition awareness is important so that changes can be made around them. For example, athletes that avoid meat could be educated about appropriate protein alternatives that they can include instead to avoid inadequate protein intakes.

Sport and exercise had a large impact on food choices. Athletes from all sports groups spoke about eating enough to fuel themselves for training and competition. For endurance athletes, nutrition was a priority around training and competition, but not at other times. Aesthetic sport athletes had mixed views of nutrition around training, with some understanding the importance of adequately fuelling for training sessions, while others did not think they expended enough energy to warrant extra energy from food. Team sport athletes understood the value of adequately fuelling for training or competition, although many did not have the knowledge to tailor dietary intakes to the changes in energy expenditure across the week. These findings indicated a lack of sports nutrition knowledge among athletes from all sports groups. Athletes need to be educated on the importance of adequate nutrition throughout the day and on days that they have not exercised, and how to adjust food intake on days when they have extra training sessions or do more exercise than usual.

6.4 Effectiveness of a 'Food First' Motivational Interviewing Intervention

Upon completion of the study, it was found that there were statistically significant increases in energy availability for all groups (endurance, aesthetic, and team sport intervention groups) indicating that the intervention was a moderately effective tool to address LEA, but improvements are still required, particularly among the leanness sports. The team sport intervention group increased their mean EA enough to be above the LEA threshold of 30 $kcal.kgFFM.d^{-1}$, although the leanness sports (endurance and aesthetic sports) most at risk of LEA did not increase their EA sufficiently to break out of the LEA category. Increases in key nutrient and food group intakes were not statistically significant between baseline and study completion, but the small increases among the intervention groups were clearly sufficient to improve their EA.

Analysis of macro- and micronutrient intakes found that the aesthetic sport intervention group also significantly increased their mean carbohydrate and iron intakes upon study completion. However, neither increase was sufficient to meet the recommended nutrient intakes.

Food group intake analyses found that the endurance intervention group increased mean grains and cereal intake, meeting this food group recommendation following MI counselling. The team sport group also significantly increased dairy food intake, although not enough to meet current recommendations. Nonetheless any positive changes to dietary intakes are encouraging, particularly among the at risk sports groups.

These significant results demonstrate that the 'food first' motivational interviewing intervention had some positive effect in improving nutrient intakes, particularly energy availability. Further research is required on this approach to nutrition counselling, such as extending the number of sessions to allow for more education and follow-up with participants to address barriers to change to improve the effectiveness of the MI intervention. Future studies should also use larger sample sizes, as the sample-sizes for each group in this study were unfortunately lower than the calculated required minimum, although each sport group representative population was homogeneous, thereby minimising statistical error from inter-individual variability. A longer follow-up period may be useful to better investigate the effectiveness of the intervention in a larger population long term.

6.5 Recommendations for practice

Results from the study presented here indicate that sports nutrition practitioners now need to be aware of the prevalence of LEA among non-leanness sports such as team sports, as well as the traditional leanness sports which have a lean body composition focus. As the competitive edge is continually sought among elite female athletes, the pressure to conform to a lean body composition in the belief this will directly translate to improved sports performance is now emerging among sports other than endurance and aesthetic sports. The debilitating effects of LEA among elite female athletes can be career-ending and have harmful long-term effects on their health. Therefore, awareness of the prevalence of LEA in all female sports must be highlighted, along with useful dietary counselling strategies to address the dietary restrictions used by these athletes to achieve their body composition goals which are aligned to performance outcomes.

Adoption of personalised motivational interviews (MI) in dietary counselling sessions have been demonstrated in this study to be of some value to improve EA status. With modifications to address barriers to change, this strategy can be invaluable to sports nutrition practitioners in remediating LEA cases among female athletes.

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APPENDICES

Appendix 1: Literature Review, Article Summary Tables

Table 1.a Identification of LEA within Endurance sports

Author, Year	Sample Size	Sport	Age Range, Mean Age	Energy Intake Method	Exercise Energy Expenditure	Body Composition	Mean +/- SD EA (kcal.kgFFM.d^{-1})	Subjects with LEA (%)
(Beermann et al., 2020)	n = 20	Collegiate Distance Runners	20.2 ± 1.7	Food frequency questionnaire	Activity Log	DXA	32.8±16.1	41% (<30)
(Day et al., 2015)	n = 25	Distance runners, sprinters, hurdlers and jumpers	19.5 ± 1.8	3x 24hr recall	Accelerometer	3- site skinfold measurement	30.7	92% (<45) 52% (<30)
(Fahrenholtz et al., 2018)	n = 25	Endurance athletes	26.6 ± 5.6	Prospective dietary record	Accelerometer and activity log	DXA	35.6 ± 11.6 (participants with MD), 41.3 ± 12.7 (participants with eumenorrhea)	-

(Goodwin et al., 2014)	n = 25	Endurance runners	25 ± 3.2	Prospective weighed dietary record	Accelerometer	DXA	28.1 ± 11.5	92% (<45) 56% (<30)
(Heikura et al., 2018)	n = 35	Middle- and long-distance runners and race walkers	26	Prospective dietary record	Activity Log	DXA	24 ± 6 (participants with LEA <30) 38 ± 8 (participants without LEA >30)	31% (<30)
(Kettunen et al., 2021)	n = 19	Cross-Country Skiers	16.7 ± 0.7	Weighed food diaries	HR monitor and activity log	Bio-impedance	Home 33.7 ± 9.6; Camp 40.3 ± 17.3	89% Home 58% Camp (<45) 26% Home 37% Camp (<30)
(Kinoshita et al., 2021)	n = 18	Endurance Runners	16.8 ± 0.9	Dietary record and photos	Running speed and HR monitor	DXA	All 35.0 ± 15.0; <30 16.5 ± 7.5; >30 44.3 ± 6.6	33% (<30)
(Matt et al., 2022)	n = 60	Endurance Runners	Cohort 1 15.7 ± 1.1; Cohort 2 15.8 ± 1.2	Food frequency questionnaire	Accelerometer	DXA	29.6 ± 17.4	60% (<30)
(McCormack et al., 2019)	n = 33	Cross-country runners	20.3 ± 1.8	Food frequency questionnaire	Activity log	DXA	36.9 ± 21.3	28.6% (<30)
(Melin et al., 2015)	n = 40	Endurance athletes	26.3 ± 5.7	Prospective weighed dietary record	HR monitor and activity log	DXA	39.6 (35.3–43.9) Mean (95% CI)	42.5% (<45) 20% (<30)

(Melin et al., 2016)	n = 25	Endurance athletes	26.6 ± 5.6	Prospective weighed dietary record	HR monitor and activity log	DXA	42.5 ± 12.1	56% (<45) 12% (<30)
(Muia et al., 2016)	n = 61	Middle and long-distance runners	median age of 16 (interquartile range = 16–17)	Prospective weighed dietary record	Activity Log	Skinfold model of Warner and colleagues	36.5 ± 4.5	69.6% (<45) 17.9% (<30)
(Viner et al., 2015)	n = 4	Cyclists	38.4 ± 10.3	Dietary Record App	HR monitor and activity log	DXA	Pre season 26.2 ± 14.1; Competition 25.5 ± 3.1; Off-season 23.8 ± 8.9	-

Table 1.b Identification of LEA within Aesthetic sports

Author, Year	**Sample Size**	**Sport**	**Age Range, Mean Age**	**Energy Intake Method**	**Exercise Energy Expenditure**	**Body Composition**	**Mean +/- SD EA (kcal.kgFFM.d^{-1})**	**Subjects with LEA (%)**
(Civil et al., 2019)	n = 20	Ballet Dancers	18.1 ± 1.1	Prospective weighed dietary record	Accelerometer	DXA	39.5 ± 10.8	66% (<45) 22% (<30)
(Costa et al., 2019)	n = 21	Synchronised Swimmers	20.4 ± 1.6	Prospective dietary record	Activity Log	4- & 7- site skinfold measurements, DXA	30.3 ±12.6 (using EEE = 400), 26.1 ±12.5 (using EEE = 600)	90% (<45) 52% (<30)

(Prus et al., 2022)	n = 50	Competitive Dancers	19.8 ± 4.1	Dietary Record App	Accelerometer	Bio-impedance	31.39 ± 9.77	28% (<30) 68% (30–45) 4% (>45).
(Schaal et al., 2017)	n = 11	Synchronised Swimmers	20.4 ± 0.4	Prospective weighed dietary record	HR monitor	7- site skinfold measurements	Baseline: 25.0 ± 3.2 Wk 2: 22.3 ± 1.9 Wk 4: 18.0 ± 2.8	-
(Silva & Paiva, 2015)	n = 67	Gymnasts	18.7 ± 2.9	24 hr recall	Activity Log	Bio-impedance	31.5 ± 11.9	82.1% (<45) 44.8% (<30)
(Villa et al., 2021)	Pre-teen (n = 17) Teen (n = 13)	Gymnasts	Pre-teen 10.51 ± 1.07; Teen 15.87 ± 1.43	7-day food records	Accelerometer	Bio-impedance	Pre-teen 69.38 ± 14.47, Teen 34.7 ± 7.5	Pre-teens 70.6% (<45) 29.4% (<30) Teens 100% (<30)

Table 1.c Identification of LEA within Team sports

Author, Year	Sample Size	Sport	Age Range, Mean Age	Energy Intake Method	Exercise Energy Expenditure	Body Composition	Mean +/- SD EA (kcal.kgFFM.d^{-1})	Subjects with LEA (%)
(Braun et al., 2018)	n = 56	Soccer Players	14.8 ± 0.7	Prospective weighed dietary record	Activity log	Bio-impedance	30.0 ± 7.3 Range: 20.3 – 51.0	53% (<30)
(Magee et al., 2020)	n = 18	Collegiate Soccer Players	19.2 ± 1.1	Dietary Record App	Accelerometer	Air displacement plethysmography	All 27.5 ± 8.9, LEA 23.0 ± 5.7, Non-LEA 36.4 ± 7.3	67% (<30)
(Moss et al., 2021)	n = 13	Soccer Players	23.7 ± 3.4	5-day weighed food diary	Activity log	DXA	Mean all days 35 ± 10;	62% (<45) 23% (<30)

							Rest days 42 ± 7; Light training 35 ± 11; Heavy training 29 ± 10; Match day 29 ± 16	
(Reed et al., 2014)	n = 19	Soccer Players	19 ± 1	Prospective dietary record	HR monitor and activity log	DXA	Pre season: 19.7 ± 4.3 (EA <30); 52.3 ± 5.0 (EA >30); Mid season: 19.5 ± 2.1 (EA <30); 43.0 ± 3.2 (EA >30)	Pre season: 26% (<30) Mid season: 33% (<30) Post Season: 12% (<30)
(Wright et al., 2014)	n = 22 Hockey n = 9 Netball n = 13	Field Hockey and netball players	19.5	Prospective dietary record	Activity Log	DXA	24 ± 12	59% (<30)
(Zabriskie et al., 2019)	n = 20	Lacrosse athletes	20.4 ± 1.8	Prospective dietary record	Accelerometer	DXA	Off season 30 ±11; Off season 26 ±11; Pre-season 23 ± 9; In season 29 ± 10; In season 29 ± 9	-

(Zanders et al., 2018)	n = 13	Basketball Players	19.8 ± 1.3	Prospective weighed dietary record	HR Monitor and Accelerometer	DXA	1. 47.6 ± 5.2; 2. 45.1 ± 11.8; 3. 44.6 ± 10.6; 4. 47.7 ± 4.7; 5. 46.2 ± 6.7	-

Appendix 2: Validation of a Supplement Intake Questionnaire, Information Sheet

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INFORMATION SHEET
(for *'Validation of a Supplement Intake Questionnaire in athletes and non-athlete controls'*)

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Description of the study

This project will be the validation of a Supplements Intake Questionnaire among elite female athletes and age-matched non-athlete controls. The project is supported by Flinders University, College of Nursing and Health Sciences.

Purpose of the study

The aim of the project is to validate a previously developed questionnaire that measures supplement intakes. Validity of the questionnaire will be determined by comparing supplement intakes collected by the questionnaire to a 8-day food intake diary method, recording 8 days of dietary intake including supplements over the period of a month. It has been shown in the literature that a 8-day food diary is adequate to obtain as close as possible to a 'true' representation of participants' dietary intake.

Validation of the supplements intake questionnaire is required to determine if it is a suitable and robust supplements intake data collection tool for future sports nutrition research. Athletes are among the highest users of supplements, and accurate and reliable measurement of supplement intakes is important in assessment of nutritional status in athletes.

inspiring achievement

What will I be asked to do?

To participate you will be required to complete and submit the Supplement Intake Questionnaire, before completing a 8-days food diary over 4 weeks. The supplement questionnaire will be repeated again after the food diary has been completed. The supplement intake questionnaire will be emailed to you, along with instructions. You will have the option of printing a hard copy and complete with pen & paper, or complete electronically as Word documents. If you choose to print a hard copy a reply paid envelope will be provided with the return address, electronic copies can be sent to the researcher via email.

The 8-day food intake diary will be emailed to you, along with instructions. You will have the option of printing hard copies and completing with pen & paper, or completing the food intake diaries electronically as Word documents and emailing them back to the student researcher. If you choose the former (print a hard copy), you will be provided with reply paid envelopes in which to return your food intake diaries.

Participation is entirely voluntary. Participation in the study will remain confidential. Completion of the questionnaire should take approximately 15 minutes. The food diary entries will take approximately 15-30 minutes at the end of each of the 8 days recorded.

What benefit will I gain from being involved in this study?

The dietary intake data obtained from your food diary will be analysed. This will be used to provide you with personalised dietary feedback, to assist you with making dietary changes to improve your overall health (where relevant).

Will I be identifiable by being involved in this study?

You will only be identifiable to the study researchers. All supplement intake and dietary data collected from you will be de-identified when it comes to reporting the results in the scientific literature.

Your supplement intake questionnaire, 8-day food diary and other personal information (age, gender) will be stored electronically in password-protected files on the Supervisor's password-protected computer, with a back-up copy stored in the Flinders University secure and password-protected cloud (Flinders OneDrive). Hard copies mailed back to the researchers will be electronically scanned and stored with the other electronic files. Hard copies will then be destroyed in an onsite confidential documents shredder. Researchers named in this Information sheet will be the only people to have access to the data files. Electronic files containing data collected and assessments made will be kept for 5 years, after which they will be permanently deleted.

Are there any risks or discomforts if I am involved?

The researchers anticipate few risks from your involvement in this study. All information provided by you in your supplement intake questionnaire and 8-day food diary will be kept completely confidential, and you are encouraged to be honest in reporting your supplement & dietary intakes. As researchers, we are not judgemental about supplement & dietary choices.

The most likely burden for you during the study is remembering to complete the 8-day food diary on the days chosen to record, and spreading these out across a 4-week period.

How do I agree to participate?

Participation is voluntary and you are free to withdraw from the study at any time without penalty or consequences. A Consent form accompanies this Information document. If you agree to participate, please read and sign the Consent form and send it back to Clare at clare.flower@flinders.edu.au for electronic copies, or to Clare via *Dr Kathryn Jackson, Flinders University, College of Nursing & Health Sciences, GPO Box 2100, Adelaide, 5001* for posted hard copies. Please also request in advance a reply-paid envelope to be sent to your postal address if you choose postal return of your food intake diaries.

How will I receive feedback?

Following assessment of your 8-day food diary, you will be emailed or posted personalised dietary feedback and recommendations. On project completion, outcomes of the project will be available to all participants in the form of a research journal article, in which individual participants will not be identifiable.

Thank you for taking the time to read this information sheet, and we hope that you will accept our invitation to be involved.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number: 8426).
For more information regarding ethical approval of the project only, the Executive Officer of the Committee can be contacted by telephone on (08) 8201 3116, by fax on (08) 8201 2035, or by email to human.researchethics@flinders.edu.au

Appendix 3: Validation of a Supplement Intake Questionnaire, Consent Form

Flinders
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CONSENT FORM FOR PARTICIPATION IN RESEARCH

(by dietary intake record and interview/feedback)

'Validation of a Supplement Intake Questionnaire among female athletes and non-athlete controls.'

I …...

being over the age of 18 years hereby consent to participate as requested in the Letter of introduction and Information Sheet for the research project on *'Validation of a Supplement Intake Questionnaire among female athletes and non-athlete controls.'*

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
4. I understand that:
   - I may not directly benefit from taking part in this research.
   - I am free to withdraw from the project at any time and am free to decline to answer particular questions, without disadvantage.
   - While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.
5. I have had the opportunity to discuss taking part in this research with a family member or friend.
6. I understand that only the researchers on this project will have access to my research data and raw results; unless I explicitly provide consent for it to be shared with other parties. Should we need to seek your consent to share your research data with other parties, you will be contacted via email or via mail.

Participant's signature……………………………………Date…………………..

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name…………………………….……………………….................

Researcher's signature…………………………………..Date…………………….

Appendix 4: Supplement Intake Questionnaire

Research Project: 'Validation of a dietary supplements questionnaire.'

Dietary Supplements Questionnaire

Thank you for taking the time to answer the following questions. This questionnaire aims to investigate (non-prescription) supplement use among elite athletes and the general population. The information you provide will be used to determine individual nutrient intakes from supplements.

All information provided in this questionnaire will remain confidential as stipulated by the Flinders University Social & Behavioural Research Ethics Committee (Project No. 8426). If you would like more information about this project, please refer to the Participant Information document.

It would be beneficial to have access to your supplements when completing this questionnaire. It will take approximately 5 - 20 mins to complete, depending on the number of supplements you take.

Section A: Participant information

Date of birth ______ / ______ /______

Height:__________cm **Weight:_________kg**

Type of living situation (Please select most relevant)

- ☐ Living with parents
- ☐ Shared housing
- ☐ University housing
- ☐ Renting
- ☐ Home owner
- ☐ Other (please specify): ____________

What is the highest Year level of schooling you have completed?

- ☐ Primary school [Year 7 or less]
- ☐ Year 8
- ☐ Year 9
- ☐ Year 10
- ☐ Year 11
- ☐ Year 12
- ☐ Don't know

What is the highest qualification/level of education you have completed since leaving school?

- ☐ University degree or diploma
- ☐ University Masters degree or PhD
- ☐ CAE or Teacher's College or Nursing or Trade Certificate/ apprenticeship/ vocational (e.g. TAFE 1–2 year course, Hairdressing Certificate or Diploma course)
- ☐ Other
- ☐ Don't know
- ☐ I have not completed any further qualifications / education since school
- ☐ Other (please write here) ………………………………………………

Section B: Supplement use and information

Question 1.

Do you currently take any supplements? (Please tick)

- ☐ **YES**
  - ➢ Please indicate why you use supplements
    - ☐ I have high nutrition requirements
    - ☐ I have been instructed to take supplements by my Doctor/Dietitian/Naturopath/other health professional.

      Please specify which health professional: ____________________
    - ☐ I am on a restrictive diet
    - ☐ My diet is inadequate of certain nutrients
    - ☐ Other (please specify): ______________________________

- ☐ **NO**
  - ➢ Please indicate why you do not use supplements
    - ☐ I do not need them as I gain adequate nutrition from my diet
    - ☐ I do not want to take supplements
    - ☐ Supplements are too costly
    - ☐ I am unsure whether supplements would be beneficial to my health
    - ☐ Other (please specify): ______________________

Question 2.

Do you believe you need dietary supplements (please circle): **YES** **or** **NO**

Please explain why you do / do not believe you need supplements:

Question 3.

Please look over the Tables on the next few pages, and complete the supplement information relevant to you

(**Please do not fill out tables that are not relevant to your consumption)**

3.1. Vitamins

Supplement	Brand: e.g. Nature's Own, Cenovis. Ethical Nutrients, Swisse, etc.	Frequency: e.g. twice daily, daily, once weekly, 2-3 times weekly, 4-5 times weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Multi Vitamin				
Vitamin A				
Vitamin C				
Vitamin D				
Vitamin E				
Vitamin K				
Thiamine (B1)				
Riboflavin (B2)				

Supplement	Brand: e.g. Nature's Own, Cenovis. Ethical Nutrients, Swisse, etc.	Frequency: e.g. twice daily, daily, once weekly, 2-3 times weekly, 4-5 times weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Niacin (B3)				
Biotin (B7)				
Vitamin B6				
Vitamin B12				
Vitamin B-Complex				
Beta-Carotene				
Coenzyme Q10				
Folic Acid/ Folate				
Other:				

3.2 Minerals

Supplement	Brand: e.g. BioCeuticals, Cenovis. Ethical Nutrients, Swisse, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Multi Mineral				
Chromium				
Calcium				
FeFol				
Folate				
Iodine				
Iron				
Magnesium				

Supplement	Brand: e.g. BioCeuticals, Cenovis. Ethical Nutrients, Swisse, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Potassium				
Selenium				
Zinc				
Other:				

3.3 Herbals

Supplement	Brand: e.g. Blackmores, Healtheries, Nature's Own, Cenovis, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Bilberry				
Capsaicin				
Curcumin				
Echinacea				
Fenugreek				
Garlic				
Ginger				
Ginkgo Biloba				

Supplement	Brand: e.g. Blackmores, Healtheries, Nature's Own, Cenovis, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Ginseng				
Kava Kava				
St Johns Wort				
Tribulus Terrestris				
Other:				

3.4 Gut Health

Supplement	Brand: e.g. Ethical Nutrients, Lifespace, Faulding, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Prebiotics				
Probiotics				
Synbiotics				
Other:				

3.5 Oil and Seed Supplements

Supplement	Brand: e.g. Blackmores, BioCeuticals, Nature's Own, Swisse, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Cod Liver Oil				
Evening Primrose Oil				
Krill Oil				
Salmon Oil				
Omega 3				
Chia Seeds				
Flaxseed				
Hemp Seeds				

Supplement	Brand: e.g. Blackmores, BioCeuticals, Nature's Own, Swisse, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Lecithin				
Linseed				
LSA				
Psyllium				
Other:				

3.6 Appetite Suppressants/Weight Loss

Supplement	Brand: e.g. OptiFast, Fat Blaster, Atkins, Osmolax, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Weight Loss Shake				
Detox Shakes				
Carcinia Cambogia				
Super CitriMax				
CarnoSyn				
Calcium Pyruvate				
Svelte				

Supplement	Brand: e.g. Osmolax, Ducolax, Coloxyl, Fat Blaster Diuret, Absolute Nutrition Water Shed, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Diuretics				
Laxatives				
Cascara				
Senna				
Other:				

3.7 Protein supplements

Supplement	Brand: e.g. Optimum Nutrition, True, Musashi, Body Science, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder
Whey Protein				
Casein/Milk Protein				
Egg White Powder/ Liquid				
Weight/Mass Gainer				
Soy Protein Powder				
Hemp Protein Powder				
Brown Rice Protein Powder				
Pea Protein Powder				

Supplement	Brand: e.g. Optimum Nutrition, True, Musashi, Body Science, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, teaspoons or Tablespoons of liquid or powder, weight (grams) of bar/cookie
Rice & Pea Combination Powder				
Ready to Drink **Protein Shakes**				
Protein Bars/Cookies				
Other:				

3.8 Performance Supplements

Supplement	Brand: e.g. SIS, Musashi Sustagen, ETIXX, True, Optimum Nutrition, No Doz, Shotz, Beet It, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, ml of liquid, grams (g) of powder, teaspoons, Tablespoons or scoops of liquid or powder
Pre-Workout				
Pre-Workout Caffeinated				
Caffeine Tablets				
Beetroot Juice				
Branched Chain Amino Acids (BCAA)				
Creatinine				

Supplement	Brand: e.g. SIS, Musashi Sustagen, ETIXX, True, Optimum Nutrition, No Doz, Shotz, Beet It, etc.	Frequency: e.g. 2 daily, daily, 1 weekly, 2-3 weekly, 4-5 weekly	Form: e.g. tablets/ liquid/ powder	Dosage: e.g. number of tablets, ml of liquid, grams (g) of powder, teaspoons, Tablespoons or scoops of liquid or powder
Glucosamine				
Pickle Juice				
Carbohydrate powders				
Carbohydrate Gels				
Sports Drink				
Other:				

Please answer the following questions to provide feedback on the questionnaire.

1. **How easy was it to fill out the questionnaire?**
   - ☐ Extremely easy
   - ☐ Slightly easy
   - ☐ Neither easy nor difficult
   - ☐ Slightly difficult
   - ☐ Extremely difficult
2. **Was there any part of the questionnaire that you didn't understand?**
   - ☐ The wording was difficult to understand
   - ☐ The long list of supplements was overwhelming
   - ☐ I couldn't find the supplements that I take listed
   - ☐ I was unable to recall some of the information asked
   - ☐ Other ______________________________
3. **Do you have any other comments about your experience with this survey?**

____

____

____

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Thank you for participating

Appendix 5: Determinants of Food Choice: Qualitative Study, Information Sheet

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Dr Kathryn Jackson
College of Nursing & Health Sciences

Sturt Road
Bedford Park SA 5042

GPO Box 2100
Adelaide SA 5001

Tel: +61 7221 8852
E: kathryn.jackson@flinders.edu.au

Web:
http://www.flinders.edu.au/people/kathryn.jackson
CRICOS Provider No. 00114A

INFORMATION SHEET

(for *'Determinants of food choice, Pilot Study'*)

Researcher(s)
Ms Clare Flower
College of Nursing & Health Sciences
Flinders University
Tel: 7221 8852

Supervisor(s)
Dr Kathryn Jackson
College of Nursing & Health Sciences
Flinders University
Tel: 7221 8852

Dr Deb Agnew
College of Education, Psychology and Social Work
Flinders University
Tel: 8201 3456

Description of the study

This project will be a Pilot Study investigating athletes' food choices by interviewing male and female football players. The project is supported by Flinders University, College of Nursing and Health Sciences and the Social & Behavioural Research Ethics Committee.

Purpose of the study

The aim of the project is to investigate factors that affect food choice in male and female football players.

Knowing and understanding the factors that affect food choice is important when working with athletes to assist them in making positive dietary changes to achieve optimal nutrition for sports performance. In this research project we want to find out which factors influence athletes' food choices the most, so we can incorporate the common factors into a future research project with elite athletes.

What will I be asked to do?

Participation will involve being interviewed by the primary researcher (Clare Flower). The interview taking around 45 – 60 minutes and will take place at your football club. Questions will be asked about your food choices and dietary habits, and the different influences that affect the choices you make. The interview will be recorded on an

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electronic device and later transcribed. After the interview you will be given a copy of the transcript, allowing you to review and edit your answers if necessary. Everything said during the interview will remain anonymous.

Participation is entirely voluntary. Participation in the study will not be made public to your club, coaches and teammates.

Will I be identifiable by being involved in this study?

Comments made during the interview will only be identifiable to the study primary researcher. Although your participation will not be revealed to your club, coaches or teammates, confidentiality cannot be guaranteed as the interviews will be held at your football club, and other players may witness you attending an interview with Clare.

Your interview recording, transcript and other personal information (age, gender) will be stored electronically in password-protected files on the Supervisor's password-protected computer, with a back-up copy stored in the Flinders University secure and password-protected server. Researchers named in this Information sheet will be the only people to have access to the data files. Electronic files containing data collected and any analyses will be kept for 5 years, after which they will be permanently deleted.

Are there any risks or discomforts if I am involved?

The researchers anticipate few risks from your involvement in this study. All information provided by you in your interview will be kept completely confidential, and you are encouraged to be honest in the answers you provide during the interview.

How do I agree to participate?

Participation is voluntary and you are free to withdraw from the study at any time without penalty or consequences. A Consent form accompanies this Information document. If you agree to participate, please read and sign the Consent form and send it back to Clare at clare.flower@flinders.edu.au for electronic copies, or for posted hard copies to Clare via *Dr Kathryn Jackson, Flinders University, College of Nursing & Health Sciences, GPO Box 2100, Adelaide, 5001*.

How will I receive feedback?

On project completion, outcomes of the project will be available to all participants in the form of a summary. The summary will outline common themes found during the interviews and how this may be used by Sports Dietitians. This summary will be emailed to all sports clubs involved in the project and will be available to participants upon request. Individual participants will not be identifiable in the summary.

Thank you for taking the time to read this information sheet, and we hope that you will accept our invitation to be involved.

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (Project number: 8552).
For more information regarding ethical approval of the project only, the Executive Officer of the Committee can be contacted by telephone on (08) 8201 3116, by fax on (08) 8201 2035, or by email to human.researchethics@flinders.edu.au

Appendix 6: Determinants of Food Choice: Qualitative Study, Consent Form

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CONSENT FORM FOR PARTICIPATION IN RESEARCH
(by interview)

'Determinants of Food Choice among elite sports people: A Pilot Study'

I ....

being over the age of 18 years hereby consent to participate as requested in the Letter of introduction and Information Sheet for the research project on '*Determinants of Food Choice among elite sports people: A Pilot Study'*.

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I agree to audio recording of my information and participation.
4. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
5. I understand that:
   - I may not directly benefit from taking part in this research.
   - I am free to withdraw from the project at any time and am free to decline to answer particular questions, without disadvantage.
   - While the information gained in this study will be published as explained, I will not be identified, and individual information will remain confidential.
   - Whether I participate or not, or withdraw after participating, will have no effect on my participation in training or team selection.
   - I may ask that the audio recording be stopped at any time, and that I may withdraw at any time from the session or the research without disadvantage.
6. I understand that <u>only</u> the researchers on this project will have access to my research data and raw results; unless I explicitly provide consent for it to be shared with other parties
7. I have had the opportunity to discuss taking part in this research with a family member or friend.

Participant's signature...Date.......................

Participant's email address...

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name…………………………………………………………………..............

Researcher's signature…………………………………..**Date**…………………….

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee in South Australia (Project number 8552). For queries regarding the ethics approval of this project, or to discuss any concerns or complaints, please contact the Executive Officer of the committee via telephone on +61 8 8201 3116 or email human.researchethics@flinders.edu.au

Appendix 7: Determinants of Food Choice: Qualitative Study, Interview Guide

Suggested Interview Questions with elite athletes:

1. What foods do you like to eat?
2. Are there any foods you don't eat? Why?
3. Are there any foods you eat but don't like? Why?
4. Are there any foods you like but don't eat? Why?
5. What influences your food choices?
    a. What helps you make decisions about what foods you buy?
    b. What do you think about when you go to the fridge/pantry to choose something to eat?
6. Who is responsible for meal times/choices in your household?
    a. How much control do you have over the food served to you?
7. How do you decide what/when to eat?
8. Who do you go to for advice on nutrition or supplements?
    a. Is there someone at the club?
    b. Is there anyone outside the club you go to?
    c. Do you do your own research?
        i. How do you decide what information is reliable?
        ii. Do you get it checked?
        iii. How do you decide whether to follow advice/information?
9. Do you take supplements?
    a. How do you feel about taking supplements?
    b. Why do they are/aren't necessary?
    c. What would influence your choice to take supplements or not?
10. Do you include anything in your diet that is specifically related to your sport?
    a. Is there anything in your diet that you think helps your performance?
    b. Is there anything you are instructed to take to help your performance/recovery?
        i. Who instructs you to take these?
11. Would your diet change if you stopped playing sport? How?
    a. Are there any restrictions on your diet?
    b. Is there anything you include that you would stop eating?
12. Do you ever restrict your food intake?
13. Have you ever tried to lose weight or change body composition?
    a. Why did you decide to do this? Was it related to sports performance?
    b. Was this within season?
    c. How did you do this? Restricting food intake? More exercise?
14. Do you ever notice that you eat more than friends/family who don't play sport/exercise?

Appendix 8: Prevalence of LEA, Information Sheet and Consent Form

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PARTICIPANT INFORMATION SHEET AND CONSENT FORM

Title: 'Energy Intake in Female Athletes'

Chief Investigator
Ms Clare Flower
College of Nursing & Health Sciences
Flinders University
Tel: 7221 8852

Supervisor
Dr Kathryn Jackson
College of Nursing & Health Sciences
Flinders University
Tel: 7221 8852

Description of the study
This project will investigate energy intake among elite female aesthetic, endurance and team sport athletes. This project is supported by Flinders University, College of Nursing & Health Sciences and has been approved by the Flinders University Human Research Ethics Committee (Project number 4785).

Purpose of the study
This project aims to find out whether there is a difference in energy intake in female athletes from different sports (aesthetic, endurance and team) compared to energy expenditure. We call this energy availability. This difference between different sports may be due to the pressures on athletes and emphasis on body composition that varies between sports. The study will also investigate how athletes make food choices, identifying which factors have the most impact upon the choices made.
Energy intake, energy expenditure and non-invasive body composition data will be collected and used to determine if the energy intake and energy expenditure match. Those athletes who show a mis-match between energy intake and energy expenditure will be offered 1:1 nutrition sessions with an accredited Sports Dietitian, to help you fuel for your sports performance. The same data will again be collected after the nutrition sessions to identify whether the information provided had an impact upon your energy availability.

Benefits of the study
Your participation in this study will help explore energy availability in female athletes from aesthetic, endurance and team sports. By also investigating factors that impact the food choices made by individuals from these athlete groups, this information can help to provide an understanding of why female athletes are making particular food choices that may be affecting their health and sports performance.

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As well as helping to gain these research findings you will also receive dietary advice (in the form of nutrition sessions or written advice) from an accredited Sports Dietitian which will help optimise your sports performance as well as general health.

Participant involvement and potential risks
If you agree to participate in the research study, you will be asked to:

- Record a 4-day food diary twice during the project
- Have energy expenditure measured over 4 days using an accelerometer twice during the project
- Have your body composition measured by bio-electrical impedance analysis (BIA)
- Fill out online dietary supplement intake questionnaire twice (2x 15 mins) and menstrual history questionnaire (10 mins) once during the project
- Attend a one-on-one interview (30-40 mins) with the researcher (an accredited Sports Dietitian) that will be audio recorded
- Attend 1-2 nutrition sessions (30-40 mins) with a dietitian

Participation in the project is entirely voluntary.

The researchers do not expect the questions to cause any harm or discomfort to you. However, if you experience feelings of distress as a result of participation in this study, please let the research team know immediately. You can also contact the following services for support:

- Lifeline – 13 11 14, www.lifeline.org.au
- Beyond Blue – 1300 22 4636, www.beyondblue.org.au
- Butterfly Foundation – 1800 334673 butterfly.org.au/

Withdrawal Rights
You may, without any penalty, decline to take part in this research study. If you decide to take part and later change your mind, you may, without any penalty, withdraw at any time without providing an explanation. To withdraw at any time, please contact Clare Flower (clare.flower@flinders.edu.au) to notify her that you do not want to answer questions or participate in the research activities. Any data collected up to the point of your withdrawal will be securely destroyed.

Confidentiality and Privacy
Only researchers listed on this form have access to the individual information provided by you. Privacy and confidentiality will be assured at all times. The research outcomes may be presented at conferences or written up for publication. However, the privacy and confidentiality of individuals will be protected at all times. You will not be named, and your individual information will not be identifiable in any research reports without your explicit consent.

No data, including identifiable, non-identifiable and de-identified datasets, will be shared or used in future research projects without your explicit consent.

Data Storage
The information collected will be stored securely on a password protected computer and/or Flinders University server throughout the study. Any identifiable data will be de-identified for data storage purposes unless indicated otherwise. All data will be securely transferred to and stored at Flinders University for five years after publication of the results. Following the required data storage period, all data will be securely destroyed according to University protocols.

How will I receive feedback?
On project completion, a short summary of the outcomes will be provided to all participants via email.

Ethics Committee Approval
The project has been approved by Flinders University's Human Research Ethics Committee (Project number 4785).

Queries and Concerns
Any queries or concerns regarding the research can be directed to the research team. If you have any complaints or reservations about the ethical conduct of this study, you may contact the Flinders University's Research Ethics & Compliance Office team via telephone 08 8201 2543 or email human.researchethics@flinders.edu.au.

Thank you for taking the time to read this information sheet which is yours to keep. If you accept our invitation to be involved, please sign the enclosed Consent Form.

CONSENT FORM

Consent Statement

☐ I have read and understood the information about the research, and I understand I am being asked to provide informed consent to participate in this research study. I understand that I can contact the research team if I have further questions about this research study.

☐ I am not aware of any condition that would prevent my participation, and I agree to participate in this project.

☐ I understand that I am free to withdraw at any time during the study.

☐ I understand that I can contact Flinders University's Research Ethics & Compliance Office if I have any complaints or reservations about the ethical conduct of this study.

☐ I understand that my involvement is confidential, and that the information collected may be published. I understand that I will not be identified in any research products.

I further consent to:

☐ recording my food and drinks intake

☐ completing a questionnaire

☐ participating in an interview

☐ having my interview audio recorded

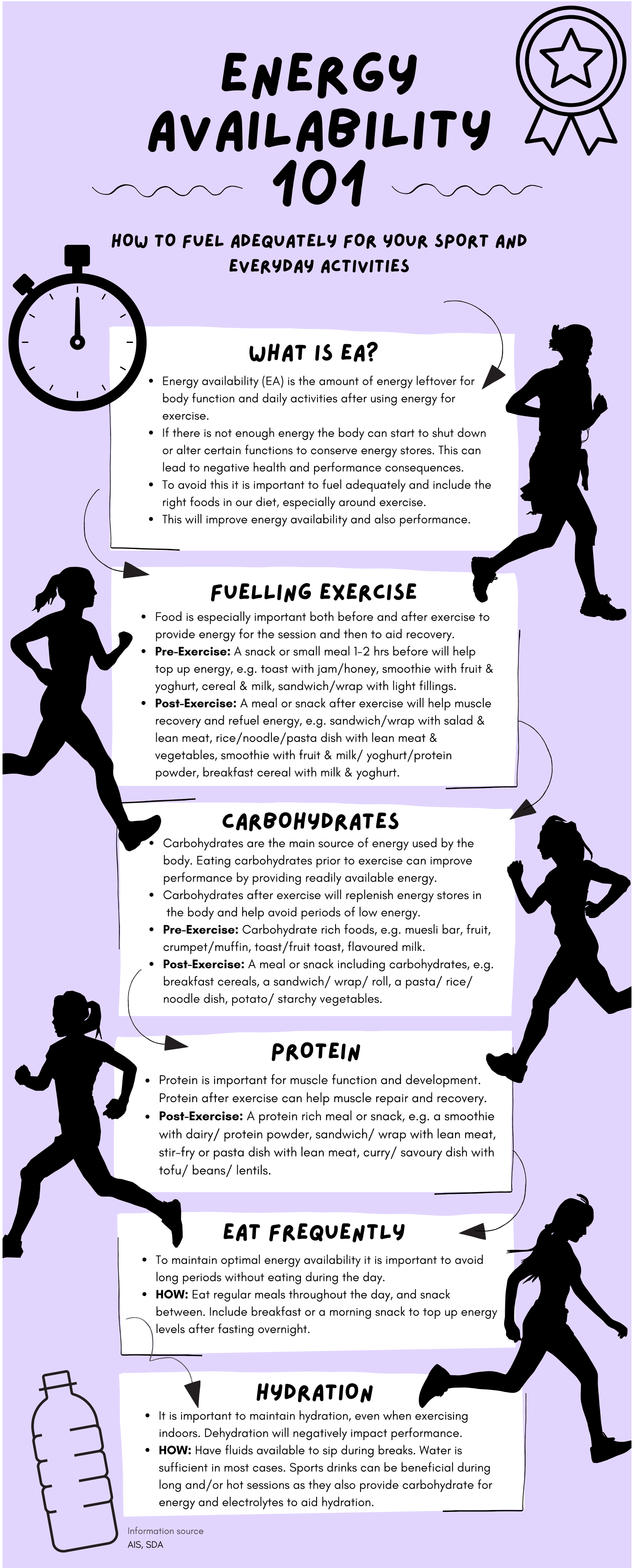
☐ having my information audio recorded

Signed:

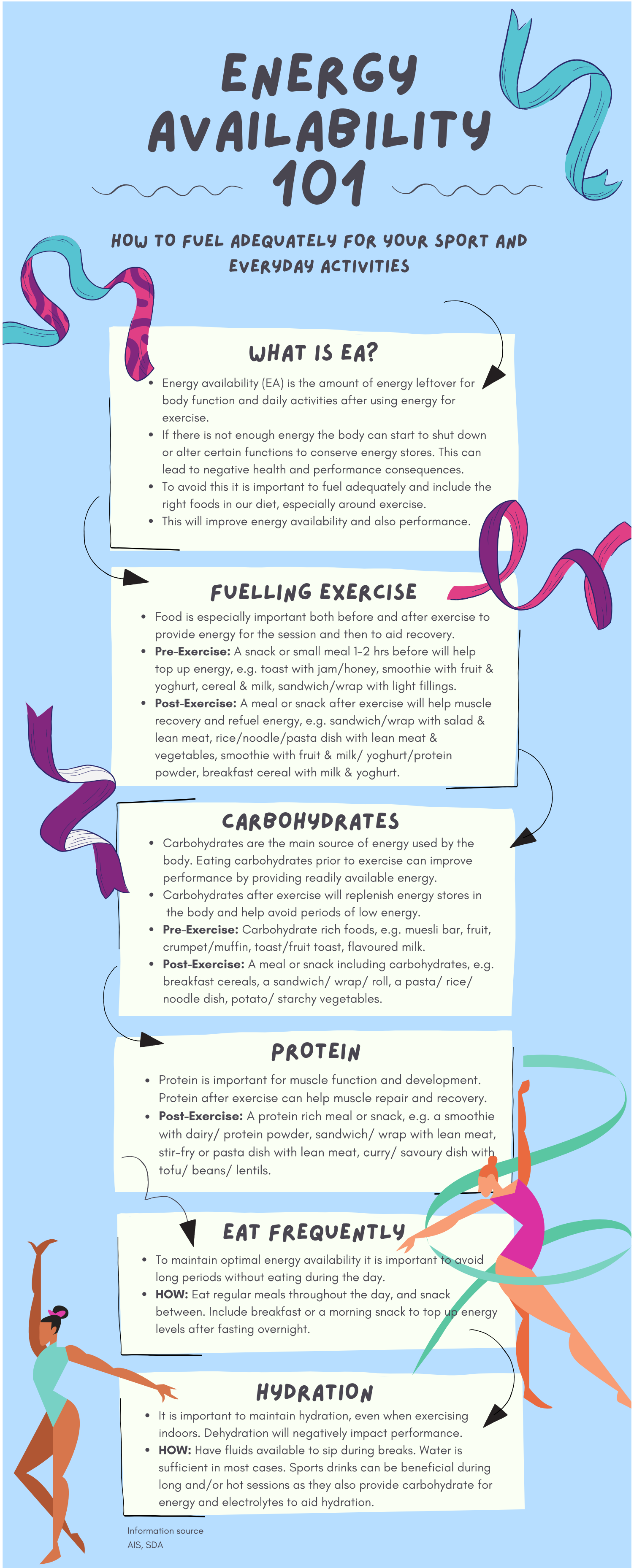
Name:

Date:

Appendix 9: Prevalence of LEA, Endurance Sport Control Group Infographic



Appendix 10: Prevalence of LEA, Aesthetic Sport Control Group Infographic



Appendix 11: Prevalence of LEA, Team Sport Control Group Infographic

ENERGY AVAILABILITY 101

HOW TO FUEL ADEQUATELY FOR YOUR SPORT AND EVERYDAY ACTIVITIES

WHAT IS EA?

- Energy availability (EA) is the amount of energy leftover for body function and daily activities after using energy for exercise.
- If there is not enough energy the body can start to shut down or alter certain functions to conserve energy stores. This can lead to negative health and performance consequences.
- To avoid this it is important to fuel adequately and include the right foods in our diet, especially around exercise.
- This will improve energy availability and also performance.

FUELLING EXERCISE

- Food is especially important both before and after exercise to provide energy for the session and then to aid recovery.
- **Pre-Exercise:** A snack or small meal 1-2 hrs before will help top up energy, e.g. toast with jam/honey, smoothie with fruit & yoghurt, cereal & milk, sandwich/wrap with light fillings.
- **Post-Exercise:** A meal or snack after exercise will help muscle recovery and refuel energy, e.g. sandwich/wrap with salad & lean meat, rice/noodle/pasta dish with lean meat & vegetables, smoothie with fruit & milk/ yoghurt/protein powder, breakfast cereal with milk & yoghurt.

CARBOHYDRATES

- Carbohydrates are the main source of energy used by the body. Eating carbohydrates prior to exercise can improve performance by providing readily available energy.
- Carbohydrates after exercise will replenish energy stores in the body and help avoid periods of low energy.
- **Pre-Exercise:** Carbohydrate rich foods, e.g. muesli bar, fruit, crumpet/muffin, toast/fruit toast, flavoured milk.
- **Post-Exercise:** A meal or snack including carbohydrates, e.g. breakfast cereals, a sandwich/ wrap/ roll, a pasta/ rice/ noodle dish, potato/ starchy vegetables.

PROTEIN

- Protein is important for muscle function and development. Protein after exercise can help muscle repair and recovery.
- **Post-Exercise:** A protein rich meal or snack, e.g. a smoothie with dairy/ protein powder, sandwich/ wrap with lean meat, stir-fry or pasta dish with lean meat, curry/ savoury dish with tofu/ beans/ lentils.

EAT FREQUENTLY

- To maintain optimal energy availability it is important to avoid long periods without eating during the day.
- **HOW:** Eat regular meals throughout the day, and snack between. Include breakfast or a morning snack to top up energy levels after fasting overnight.

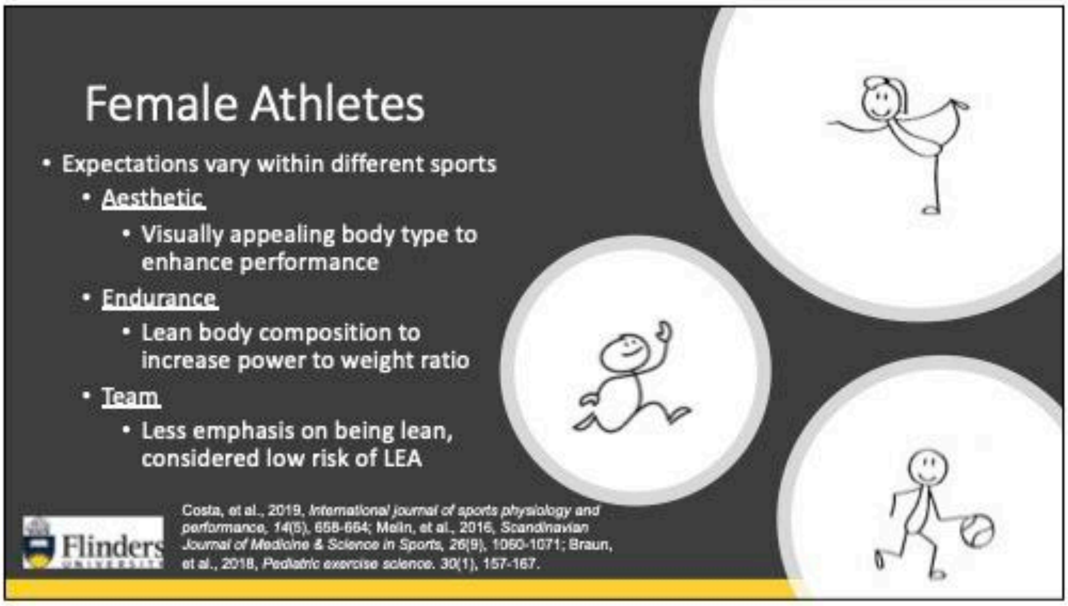
HYDRATION

- It is important to maintain hydration, even when exercising indoors. Dehydration will negatively impact performance.
- **HOW:** Have fluids available to sip during breaks. Water is sufficient in most cases. Sports drinks can be beneficial during long and/or hot sessions as they also provide carbohydrate for energy and electrolytes to aid hydration.

Information source
AIS, SDA

Appendix 12: Sports Dietitians Australia Female Athlete Symposium Presentation 2020

1



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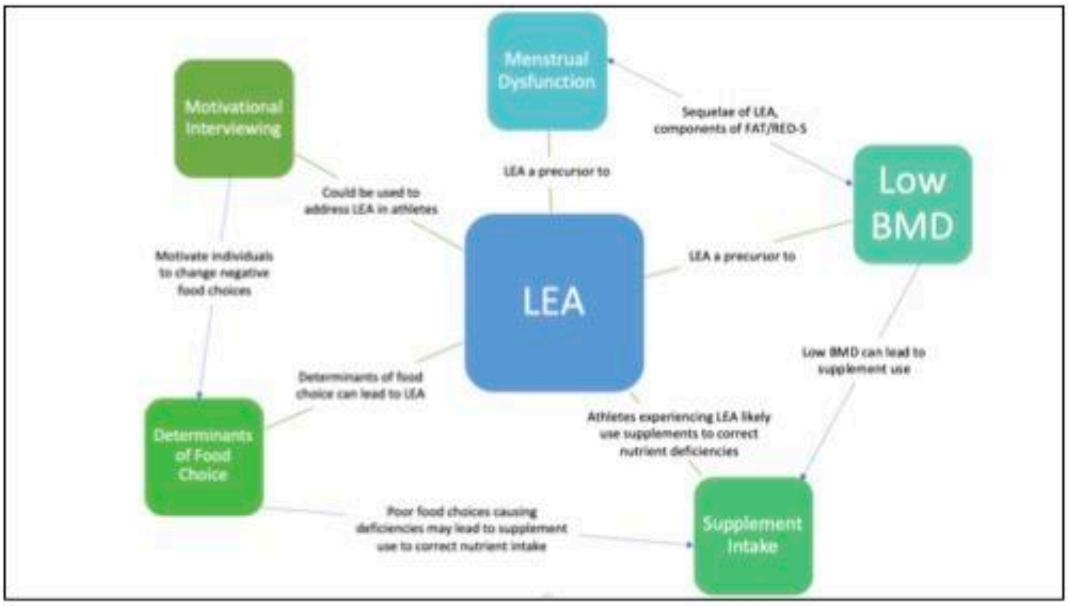

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Research Questions

1. Are elite female athletes from lean body-composition sports at a higher risk of LEA than female athletes from other sports?
2. Do elite female athletes with LEA demonstrate higher risk of ill-health sequelae than those without LEA?
3. Are there demonstrated improvements in dietary risk factors following 'Food First' nutrition counselling in participants diagnosed with LEA?

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Aims of my research

1. To determine the prevalence and manifestations of LEA among elite female athletes from sports with different body composition requirements
2. To explore the determinants of food choice among participants with and without LEA
3. To investigate the relationship between LEA and ill-health sequelae
4. To evaluate the nutritional effectiveness of a 'Food First' motivational interview approach to alleviate diagnosed LEA in elite female athletes

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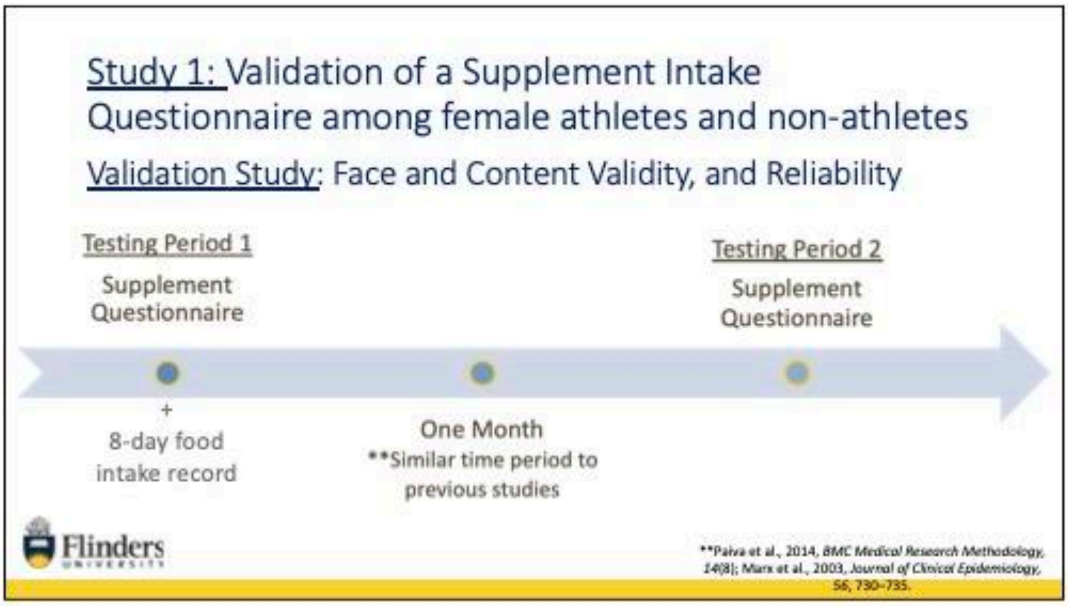
5

Study 1: Validation of a Supplement Intake Questionnaire among female athletes and non-athletes

- Validation of a supplement intake questionnaire
  - A tool to assess whether nutrient adequacy is being met through supplements rather than food
- Method
  - Self-Administered questionnaire
    - National level Australian Rules Football (AFL) Women's squad
    - Elite female Endurance runners
    - Non-athlete control group (University Students)
- Questionnaire completed on two separate occasions, one month apart
- 8-day food and supplement intake diary also completed

6


Study 1: Validation of a Supplement Intake Questionnaire among female athletes and non-athletes
Validation Study: Face and Content Validity, and Reliability
Testing Period 1
Supplement Questionnaire
+
8-day food intake record
One Month
**Similar time period to previous studies
Testing Period 2
Supplement Questionnaire
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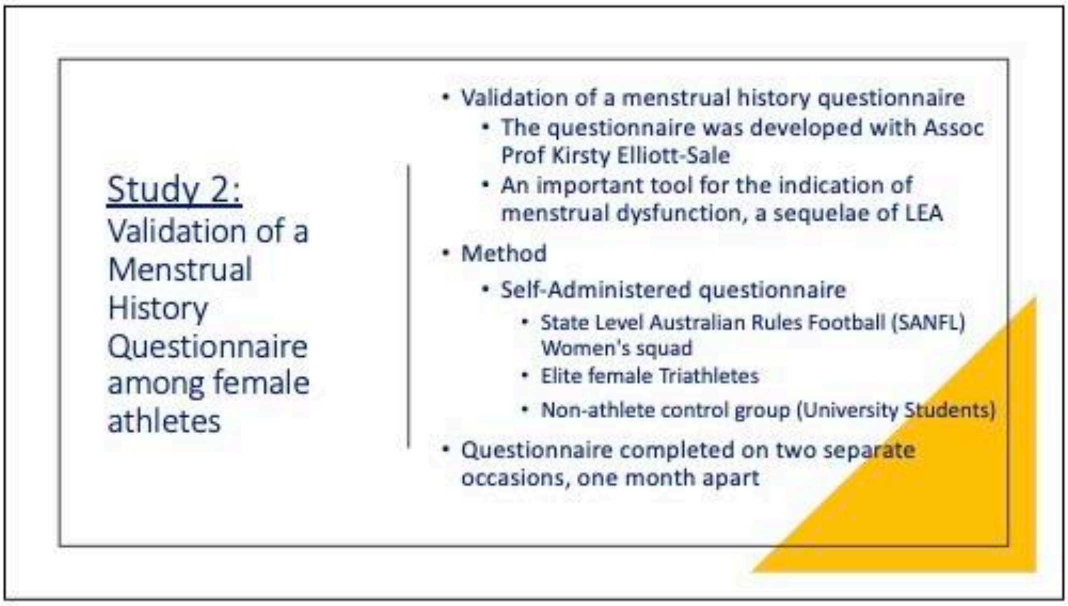
**Paiva et al., 2014, BMC Medical Research Methodology, 14(8); Marx et al., 2003, Journal of Clinical Epidemiology, 56, 730–735.

7


Study 2: Validation of a Menstrual History Questionnaire among female athletes
Validation of a menstrual history questionnaire
The questionnaire was developed with Assoc Prof Kirsty Elliott-Sale
An important tool for the indication of menstrual dysfunction, a sequelae of LEA
Method
Self-Administered questionnaire
State Level Australian Rules Football (SANFL) Women's squad
Elite female Triathletes
Non-athlete control group (University Students)
Questionnaire completed on two separate occasions, one month apart

8

Study 2: Validation of a Menstrual History Questionnaire among female athletes

Validation Study : Face and Content Validity, and Reliability

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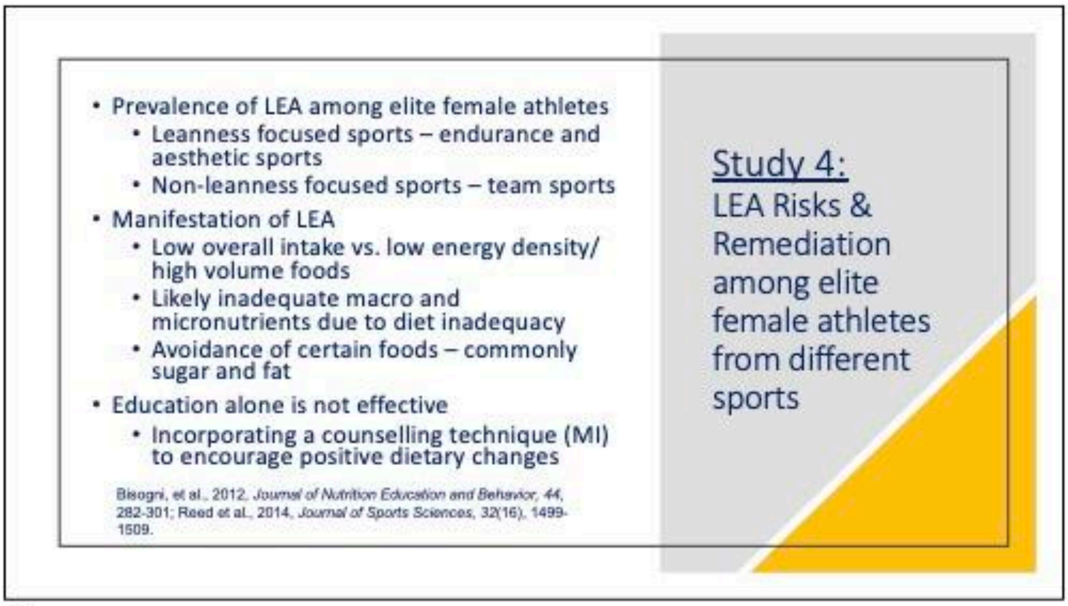
**Paiva et al., 2014, *BMC Medical Research Methodology*, 14(8); Marx et al., 2003, *Journal of Clinical Epidemiology*, *56*, 730–735.

9

Study 3: Determinants of Food Choice among elite sports people: A qualitative Pilot Study

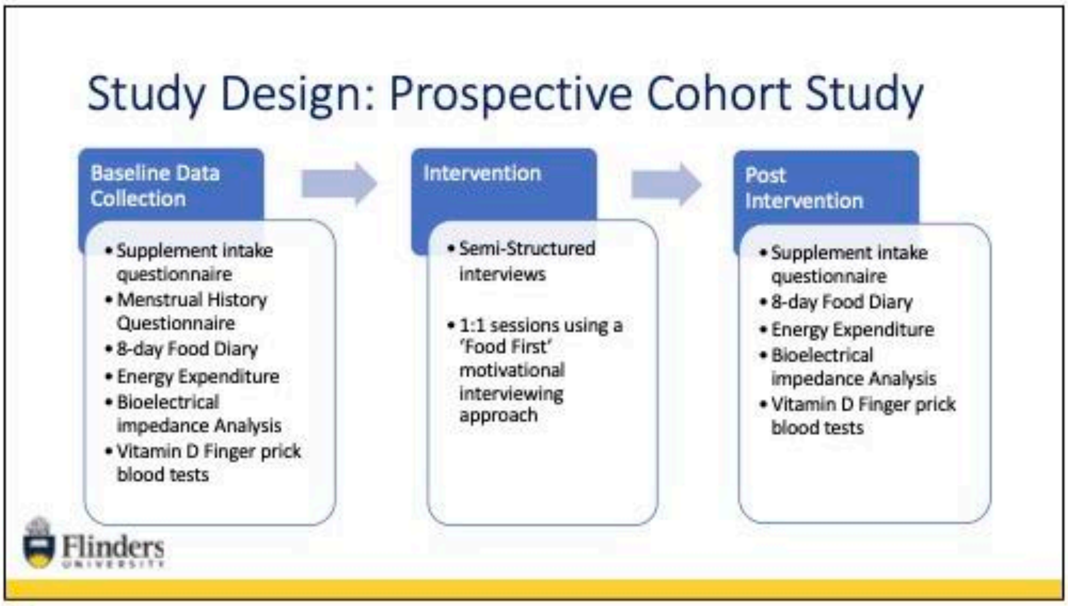
- Qualitative Pilot study
  - Investigate what influences athletes' food choices
  - Interviews via video call
  - A list of pre-planned questions, not strictly followed
- Participants
  - State Level Australian Rules Football (SANFLW) Women's squad
  - Ballroom Dancers (National level)
- Topics to be discussed
  - Food preferences, nutrition knowledge, lifestyle, time constraints, cooking abilities, support with food preparation

10



• Prevalence of LEA among elite female athletes
• Leanness focused sports – endurance and aesthetic sports
• Non-leanness focused sports – team sports
• Manifestation of LEA
• Low overall intake vs. low energy density/ high volume foods
• Likely inadequate macro and micronutrients due to diet inadequacy
• Avoidance of certain foods – commonly sugar and fat
• Education alone is not effective
• Incorporating a counselling technique (MI) to encourage positive dietary changes
Bisogni, et al., 2012, Journal of Nutrition Education and Behavior, 44, 282-301; Reed et al., 2014, Journal of Sports Sciences, 32(16), 1499-1509.
Study 4:
LEA Risks & Remediation among elite female athletes from different sports

11



Study Design: Prospective Cohort Study
Baseline Data Collection
• Supplement intake questionnaire
• Menstrual History Questionnaire
• 8-day Food Diary
• Energy Expenditure
• Bioelectrical impedance Analysis
• Vitamin D Finger prick blood tests
Intervention
• Semi-Structured interviews
• 1:1 sessions using a 'Food First' motivational interviewing approach
Post Intervention
• Supplement intake questionnaire
• 8-day Food Diary
• Energy Expenditure
• Bioelectrical impedance Analysis
• Vitamin D Finger prick blood tests
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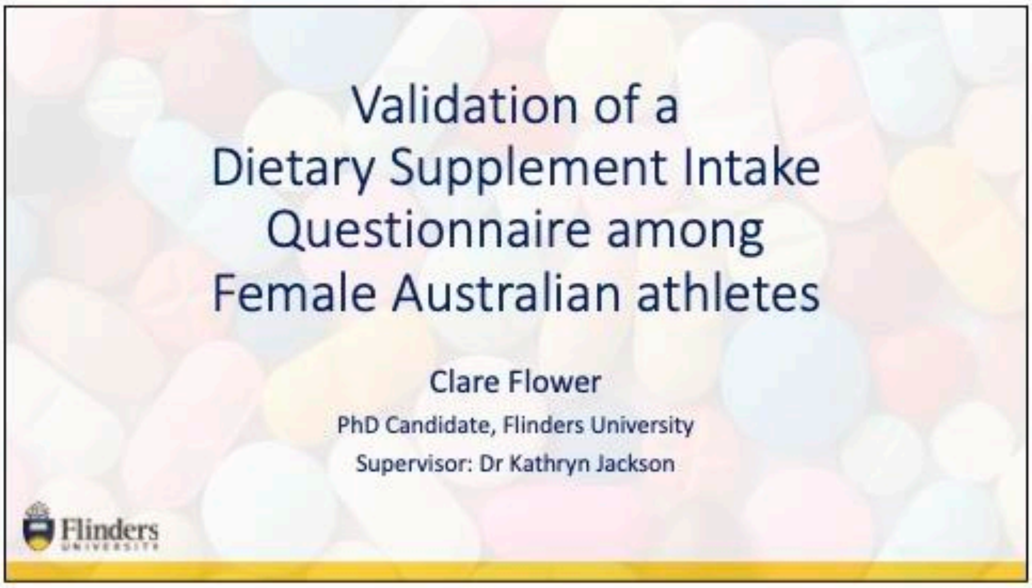
12

Appendix 13: Sports Dietitians Australia Conference Oral Presentation 2021



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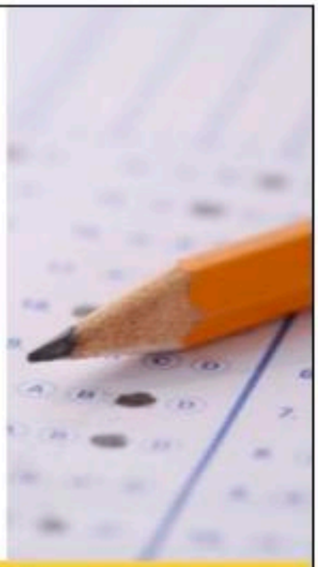
Methods

- Questionnaire
  - Categories included:
    - Vitamin, Mineral, Herbal, Gut Health, Oil & Seed, Weight Loss, Protein, and Performance Supplements
  - Completed twice, one month apart
  - An 8-day food and supplement intake diary
- Participants - female athletes aged 18 to 25 years
  - Endurance Runners
  - Australian Rules Football Players (AFLW)



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3

Methods

- Face Validity
  - Measures the subject of interest, and is relevant
  - Test: Fleiss' Kappa
- Construct Validity
  - Measures the correct construct accurately
  - Test: Linear Regression, Bland Altman Plots
- Reliability / Test-Retest Repeatability
  - Measures stable and consistent results
  - Test: Linear Regression

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Results & Discussion

- Face Validity
  - Poor inter-rater agreement
    - Only the demographic questions
- Construct Validity
  - General agreement ($R^2 > 0.8$)
    - Herbal, Gut Health, Oil & Seed supplements
- Reliability
  - General agreement ($R > 0.8$)
    - Mineral, Herbal, Gut Health, Oil & Seed supplements

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Conclusion

- **Modifications required** to improve the representation of supplements taken **infrequently around training and exercise**
- Once altered the questionnaire will be a **useful instrument** to assist with nutrition assessment among **female athletes**

- Future research:
  - The questionnaire will be used in a future study to investigate the supplement intakes of elite **female athletes** with **low energy availability**

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Appendix 14: Dietitians Australia Conference Oral Presentation 2022

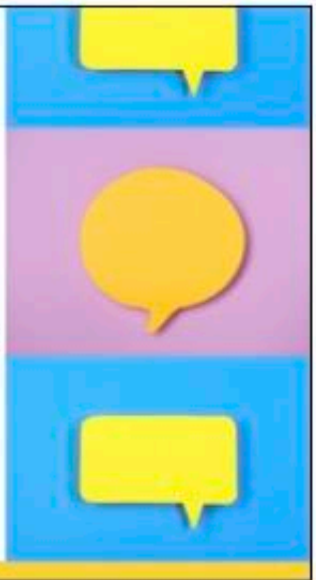
1

2

Methods

- Semi-Structured Interviews
  - Investigate what influences athletes' food choices
  - Interviews via video call
- Topics discussed
  - food preferences, lifestyle, routine, influence of family / partner / friends, nutrition knowledge / education and sport

Participants
  - Team Sport Athletes: Australian Rules Football Players (South Australian National Football League)
  - Aesthetic Sport Athletes: DanceSport competitors



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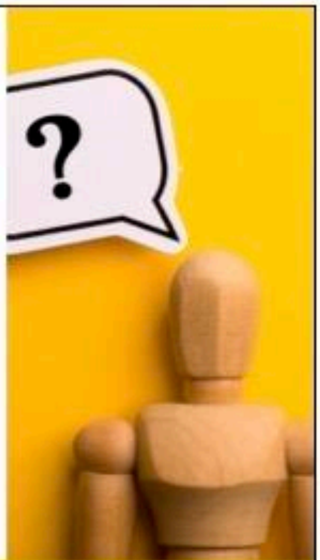
Data Analysis

- Theory
  - Social Constructionism (Burr, 1995)

- Thematic analysis (Braun & Clarke, 2006)
  - Transcription of data
  - Coding of data (by 2 separate reviewers)
  - Identification of themes
  - Review themes
  - Define and name themes
  - Report findings



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Themes

Good / Bad foods
Family / Partner / Friends
Body cues / Knowing own body
Dieting / Restrictive eating

Social Constructs of Food Choice

Nutrition Knowledge/ Education

Previous Nutrition Knowledge & Experience
Internet / Apps / Social Media

Eating patterns in season & prior to competition
Game / competition day routine
Coaches / teammates

Sport

Environment/ Routine

Work / Uni / Training / Routine
Organisation / Meal Preparation

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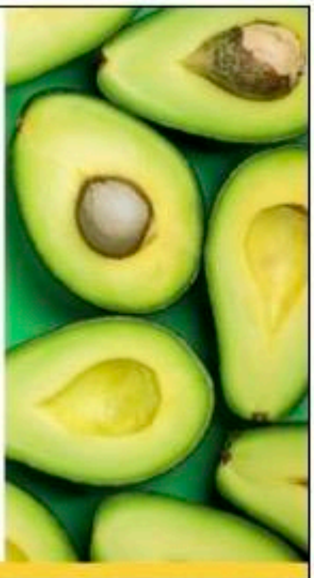
Social Constructs of Food Choice

- Good foods
  'I don't really enjoy Brussels sprouts but if they're there I'll eat them, I know that they're good for me' (Footballer)
- Bad foods
  'it's more about not eating things than eating things' (Footballer)
- Family / Partner / Friends
  'sugar melts the skin off your face' (Dancer)
- Body cues / Knowing own body
  - 'if my body reacts to something well then I know not to eat it' (Dancer)
- Dieting / Restrictive eating
  - 'cheat days', 'intermittent fasting' (Dancers)



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Nutrition Knowledge / Education

- Previous Nutrition Knowledge / Experience
  'I did nutrition high school, I know that's not the same as a dietitian, but I have a pretty good idea of what I should be eating' (Footballer)
- Internet / Apps / Social Media
  'Women's Health and that kind of thing, like even though they're not necessarily scientific as such, but I don't think that they could publish stuff which was a lie' (Footballer)

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Environment / Routine

- Work / Uni / Training / Routine
  'training is literally like from 6:00 to 8:30, sometimes then I don't get home till 9:30 and then like I'm eating dinner at 9:30' (Footballer)
- Organisation / Meal Preparation
  'I really dislike cooking, so I will do a mass cook up like once a week and have it all sort of in the freezer or in the fridge ready to go' (Dancer)

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Sport

- Eating patterns in season / prior to competition
  'Like the pressure in football is that I don't want to get dropped, so therefore you're doing everything you can' (Footballer)
  'if I cut down my carbs then it's easier for me to lean down if I need to for dancing' (Dancer)
- Game / competition day routine
  'probably about 8 weeks before a comp, I would pretty much just live on my veggie soup' (Dancer)
- Coaches / teammates
  'not heaps it's more just we find it interesting to find out what things work best for teammates' (Footballer)
  'I'm influenced easily, not easily but if some people tell me that something is really working for them then I just give it a go I guess' (Dancer)

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9

Conclusion

- Social Constructs of Food Choice
  - Most participants chose 'good' or 'healthy' foods and avoided 'bad' foods, were influenced by friends/family, and susceptible to dieting
- Nutrition Knowledge / Education
  - The footballers had greater nutrition knowledge
  - Most participants did not know how to identify reliable information
- Environment / Routine
  - All participants were influenced by time availability around commitments
- **SPORT**
  - **The footballers made food choices that would improve sport performance**
  - **The dancers valued leanness and were likely to restrict food to maintain body composition**

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10