LOW ENERGY AVAILABILITY IN FEMALES: RISK, KNOWLEDGE, AND EDUCATION

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Abstract

This dissertation consists of three major studies:

Study I

Background: Assessing knowledge on the signs and symptoms of Relative Energy Deficiency in Sport (RED-S) among athletes and healthcare professionals can aid in developing targeted education and training for the sports medicine team. However, there is no consensus on a valid tool for evaluating RED-S knowledge.

Aim: The aim of this study was to develop and validate a questionnaire which assesses knowledge on signs and symptoms of RED-S among healthcare professionals and physically active individuals.

Methods: The questionnaire was created in two phases: item development and item validation. Item development was established through literature review, expert review (n=4) and pre-testing (n=35). Item validation was demonstrated by administrating the developed questionnaire among healthcare professionals (n=97) and physically active individuals (n=77) for item analysis, internal reliability, and construct validity. The questionnaire was re-administered in the same groups (n=88) for test-retest reliability.

Results: The final questionnaire has 18 items. The expert responses showed >80% acceptability, and good content and face validity. Item response analysis resulted in removal of six items due to low discrimination ability. Construct validity was confirmed with significantly higher knowledge scores in healthcare professionals compared with non-health professionals (mean difference (95% CI) = 2.8 (1.9, 3.7)). Internal consistency, assessed using Cronbach's alpha (α =0.79), and test-retest reliability using intra-class correlation coefficients (ICC=0.80; Spearman's correlation = 0.84, $p<0.001$), were good.

Conclusion: This questionnaire provides a valid and reliable tool to assess knowledge on signs and symptoms of RED-S among female healthcare professionals and physically active individuals. This information will provide valuable data to develop targeted education material.

Study II

Background: Nutrition knowledge is potentially both a barrier to and a facilitator of adequate dietary intakes amongst athletes. Inadequate dietary intakes can result in Low Energy Availability (LEA) which can lead to serious health outcomes – a cascade is known as RED-S. To date, there is very little information on the relationship between nutrition knowledge and risk of LEA amongst female team sport athletes.

Aim: This study aims to determine whether general and sports nutrition knowledge is associated with the risk of LEA amongst female team sport athletes.

Methods: Using a cross-sectional study design, female athletes (>16 years old) who participated in team sports in New Zealand completed an online questionnaire. The questionnaire included the LEA in Female Questionnaire (LEAF-Q) to determine LEA risk, and the Abridged Sport Nutrition Knowledge Questionnaire (ANSK-Q) to assess general nutrition, and sports nutrition knowledge. The relationship between LEA risk and knowledge, as well as other factors like age and BMI, was analysed using the Kruskal-Wallis test of independent variables and Chi-square tests.

Results: Among the 100 female athletes (mean (±sd) age: 21.9 (± 6.09) years; BMI: 25.1 kg/m^2 (±3.29) who completed the questionnaire, 53% were at-risk for LEA, and 70% (n=67) had poor general and sports nutrition knowledge. Female athletes who were 'at-risk' for LEA and those who were 'not at-risk' for LEA did not differ statistically in terms of age (p=0.350) or BMI (p=0.576). 54% of the participants who were 'not at risk' for LEA had an A-NSK score between 50 and 60% (i.e., average knowledge), whereas 54% of the athletes who were 'at risk' for LEA had poor nutrition knowledge. However, there was no statistical difference between the groups (p=0.273).

Conclusion: More than half of the athletes were 'at-risk' for LEA, which is similar to the prevalence rates amongst other athletic populations in New Zealand. The knowledge scores of the athletes who were 'at risk' of LEA and those who were 'not at risk' of LEA were not statistically significantly or practically different. Additionally, the overall findings of poor nutrition knowledge among team sports athletes implies the need for nutrition education.

Study III

Background: Social media platforms such as Instagram have the potential to reach a large audience and may be well-suited for promoting RED-S related education. Thus, it is timely to consider Instagram's role in education and awareness, with a special focus on RED- S knowledge and awareness, including its benefits and limitations.

Aim: The aim of pilot study was to assess the reliability, accuracy, clarity, and level of engagement of existing Instagram posts on the definition of RED-S.

Methods: We systematically searched for publicly available Instagram accounts that provided information on RED-S related photos, infographics, and videos over a 3-week period using three hashtags: #relativeenergydeficiencyinsports, #relativeenergydeficiency and #lowenergyavailability. The post URL, caption text, the account holder's qualification, the image posted, the number of followers and likes, and the hashtags for the post were recorded for each post. Posts not in English, relating to food, eating disorders, and mental health were excluded. Two experts evaluated the quality of the content based on four criteria: accuracy (‘not accurate’ (=1) to ‘extremely accurate (=5)), clarity (‘not clear’ (=1) to ‘extremely clear’ (=5)), understandability (‘not easy to understand’ (=1) to ‘extremely easy to understand (=5)) and engagement (‘not engaging’(=1) to ‘extremely engaging (=5)). The like-to-follower ratio, which reflects the percentage of followers who react by “liking” the post was calculated. The Kruskal-Wallis rank test was used to compare the number of likes, followers, and total quality score for posts with infographics or written content images. The association between total quality score, likes, followers, and like-to-follower ratio were examined using Spearman's rank correlation test.

Results: 4,632 posts with RED-S related hashtags were identified, of these 34 RED-S definitions-related posts were eligible and used for final review. The posts had a median of 29 likes (25th/ 75th percentile:11, 137) and a median of 1,714 followers (25th/ 75th percentile: 454, 10,800). Based on expert review, 52% (n=18) were rated high for accuracy, 58%(n=20) for clarity, 50%(n=17) for level of understanding, and 36% (n=12) for level of engagement. Based on their Instagram profile 80% of account holders had formal academic or professional qualifications, with 30% being identified as dietitians and nutritionists. Total quality score of each post ranged from 7-16 (out of 20) with a mean (SD) of 13.3. (4.1); non-profit organizations received the highest mean score (16). There were no statistically significant differences between the number of likes, followers, and total quality score received by the two types of posts (i.e., posts with and without infographics) (all $p>0.05$). The like-to-follower

ratio was non-significantly negatively correlated with the total quality score of Instagram posts (i.e., accuracy, clarity, understanding, and interesting) (rs=-0.216, p=0.220).

Conclusion: Our findings suggest that physically active people and athletes should be encouraged to follow specific Instagram accounts such as IOC and Athlete Triad Coalition to obtain accurate (i.e., evidence-based information which was simple to understand) and clear information on the definition of RED-S. Overall, among 48% of the posts shared by account holders with a professional qualification, 12% (n=4) contained inaccurate or misleading information, and 36% (n=14) provided an incomplete picture of the definition of RED-S reflecting that there is limited understanding on RED-S condition.

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Chapter/ Append.	Paper title	Authors	Contribution of candidate and co-authors – please detail the nature and extent (%)	Journal	Status (e.g., under review, forthcoming, published)
Chapter 3	Original paper – The development and validation of questionnaire to	Namratha Pai Rachel C.	Candidate led data analysis and wrote the first draft of manuscript (75%)	*Journal of Science and Medicine*	Published

	assess relative energy deficiency is sports (RED-S) knowledge	Brown Katherine E. Black	Supervisor (s) led advice, mentor and review (25%)	*in Sport*	
Chapter 3	Abstract – Knowledge on signs and symptoms of relative energy deficiency in sports among healthcare professionals and physically active individuals	Namratha Pai Rachel C. Brown Jillian J. Hazard Katherine E. Black	Candidate wrote, designed and presented the work (75%) Supervisor (s) led advice, mentor, and review (25%)	*MDPI- Medical Sciences Forum*	Presented at the Nutrition Society of New Zealand Annual Conference, Online,2-2 December 2021
Chapter 5	Abstract – Risk of Low Energy Availability and nutrition knowledge among female team sport athletes.	Namratha Pai Rachel C. Brown Katherine E Black	Candidate led data analysis and writing of the abstract (75%) Supervisor (s) led advice, mentor, and review (25%)	*American College of Sports Medicine's Annual Meeting and World Congresses May 2023*	Under review

Certification by Primary Supervisor:

The undersigned certifies that the above table correctly reflects the nature and extent of the candidate's contribution to this co-authored work

Name: Associate Professor Katherine Black

Signature:

Date: 21st, January, 2023

Preface

This thesis has been prepared in fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Human Nutrition at the University of Otago. My thesis supervisors were Associate Professor Katherine E. Black and Professor Rachel C. Brown.

The research in this thesis included three research projects and the aims of the research projects were: (i) to develop and validate a questionnaire which assesses knowledge of signs and symptoms of RED-S among healthcare professionals and physically active individuals. (ii) to assess the relationship between the risk of LEA and nutrition knowledge among team sports athletes. (iii) to systematically review the accuracy of the definition of RED-S on RED-S related posts on Instagram.

Chapter 1 Introduction: This section provides information on the importance of identifying current knowledge on the signs and symptoms of RED-S/LEA using validated questionnaires and highlights the limited information on the relationship between nutrition knowledge and risk of RED-S/LEA among team sports, and the gaps in the literature on the use of social media platform for promoting RED-S related education.

Chapter 2 Literature review: This chapter discusses the background and aetiology of RED-S, methods to measure energy availability, the potential health and performances of RED-S, the prevalence of LEA among participants in different sports, the assessment methods used to assess prevalence, the screening tools used to measure the risk of LEA, the knowledge gaps and the various tools used to assess the RED-S/LEA knowledge, the current literature on general nutrition and sports nutrition knowledge among athletes and the different validated screen tool to assess the knowledge, role of social media among young athletes, and finally the education interventions using social media.

Chapter 3: The development and validation of a questionnaire on RED-S. Associate Professor Katherine E. Black and Professor Rachel C. Brown were integral to the design of the study. Dr Jillian J. Hazard provided statistical guidance to the candidate. The candidate was responsible for the following:

- Obtained data from Redcap
- Developed steps to systematically validate the items in the questionnaire.
- Performed the data analysis on Stata 13.

- Wrote the chapter

The results of this chapter were presented at the 2021 Annual Scientific Meeting of the Nutrition Society of New Zealand: Tūhono – Reconnecting.

Pai, N.N., Brown, R.C., Haszard, J.J., Black, K.E. (2022). Knowledge on Signs and Symptoms of Relative Energy Deficiency in Sports among Healthcare Professionals and Physically Active Individuals. *Medical Sciences Forum*, 9(1):17. DOI: 10.3390/msf2022009017

This chapter is also published in the *Journal of Science and Medicine in Sports*

Pai, N.N., Brown, R.C., Black, K.E. (2022). "The development and validation of a questionnaire to assess Relative Energy Deficiency in Sport (RED-S) knowledge". *Journal of Science and Medicine in Sports, 25*(10), 794-799. DOI: 10.1016/j.jsams.2022.07.004

Chapter 4: Assessing the risk of LEA and nutritional knowledge among New Zealand athletes. This study was affected by the COVID-19 pandemic lockdown, during which clubs and sports organisations were unable to operate normally, thereby affecting the data collection process. Associate Professor Katherine E. Black and Professor Rachel C. Brown were integral to the design of the study. The candidate was responsible for the following:

- Designed the study analysis
- Prepared study documents (e.g., data collection sheet, posters, protocol)
- Collected data between Feb 2020-September 2022
- Performed calculations and statistical analysis on Stata 13.
- Wrote the chapter

The result of this work is submitted to the annual meeting and world congresses of the American College of Sports Medicine (March 2023).

Chapter 5: Systematically reviewing the Instagram post on RED-S related definition. Associate Professor Katherine E. Black and Professor Rachel C. Brown were integral to the design of the study. The candidate was responsible for the following:

- Designed the study
- Developed steps of systematically review the posts on Instagram
- Collected the data from Instagram February 15, 2022, to March 7, 2022

- Conducted the data analysis on Stata.
- Wrote the chapter

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A big thank you to my friends from India and the new ones I made in New Zealand. I'm grateful for their constant help and how comfortable they've made me feel here in Dunedin.

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The University of Otago is the last one, but not the least. From the bottom of my heart, thank you. I am getting the chance to get a doctorate has been a huge blessing.

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List of Abbreviations

ACTH	Adrenocorticotrophic Hormone
AM	Amenorrhoeic
A-NSKQ	Abridge Nutrition for Sports Knowledge Questionnaire
ATP	Adenosine triphosphate
BMD	Bone Mineral Density
BMR	Basal Metabolic Rate
BEDA-Q	Brief Eating Disorder in Athlete's Questionnaire
CRH	Corticotropin-Releasing Hormone
CVD	Cardiovascular disease
DE	Disorder Eating
DT	Drive to Thinness
DXA	Dual-energy X-ray absorptiometry
E2 level	Oestradiol
EA	Energy Availability
ED	Eating Disorder
EDE-Q	Eating Disorder Examination Questionnaire
EDI	Eating Disorder Inventory
EEE	Exercise Energy Expenditure
EI	Energy Intake
EU	Eumenorrheic
FAST	Female Athlete Screening Tool
FFM	Fat-Free Mass
FSH	Follicle Stimulating Hormone

GH	Growth Hormone
GNKQ	General Nutrition Knowledge Questionnaire
GnRH	Gonadotrophic Releasing Hormone
GPS	Global Positioning System
HDL-C	High-density Lipoprotein Cholesterol
HPA	Hypothalamic-Pituitary-Adrenal
HPO	Hypothalamic-Pituitary-Ovarian
ICC	Item Characteristic Curves
IgA	Immunoglobulin A
IGF-1	Insulin-like Growth Factor
IL-6	Interleukin-6
IOC	International Olympic Committee
IRT	Item Response Theory
kcal/kg	Kilo calories per Kilogram
LBM	Lean Body Mass
LDL-C	Low-Density Lipoprotein Cholesterol
LEA	Low Energy Availability
LEAF-Q	Low Energy Availability in Females Questionnaire
LH	Luteinizing Hormone
MD	Menstrual Dysfunction
NCAA	National Collegiate Athletic Association
NZ	New Zealand
RED-S	Relative Energy Deficiency in Sport
RED-S CAT	RED-S Clinical Assessment Tool
REE	Resting Energy Expenditure
RMR	Resting Metabolic Rate

T3	Triiodothyronine
T4	Thyroxine
TC	Total Cholesterol
The Triad	The Female Athlete Triad
TRH	Thyrotropin Releasing Hormone
TSH	Thyroid Stimulating Hormone
URS	Upper Respiratory Symptoms

Glossary

Account holders/ Users	Those who have registered for a social media account to create, share, and/or receive updates. People/organizations who create the account may choose to create interactive platforms so that people, groups, and organisations can share, collaborate on, discuss, and edit user-generated or self-curated content that is posted online.
Followers	Those who view, like, comment, or share any post uploaded by another Instagram account holder/user by choosing to follow that account holder. To follow an account, a followers must tap the "follow" button on its profile.
Instagram	A social media site where users can publish both photos and videos with written descriptions.
Like	Followers can acknowledge their support/appreciation for a post by clicking the heart symbol on Instagram.
Post	Content uploaded on Instagram and shared by the account holder. It can consist of written text, images, videos, or links to other pieces of content.
Social media	Refers to websites and applications that make it simpler for people to share information, concepts, and ideas through online networks and communities, for example: WhatsApp, Twitter, Facebook, Instagram, and YouTube.

Chapter 1: Introduction

1.1. INTRODUCTION

Dietary intakes play an important role in the health and performance of athletes; one area which has gained interest for its impacts on health and performance outcomes is Energy Availability (EA) (Loucks & Thuma, 2003). EA is defined as dietary energy intake (EI) minus exercise energy expenditure (EEE) divided by fat-free mass (FFM), and it particularly refers to the energy remaining to support other bodily processes after exercise (Nattiv et al., 2007; Mountjoy et al., 2014). Low energy availability (LEA) causes the body to downregulate and store energy for survival, which has been linked to adverse health and performance outcomes (De Souza et al., 2014; Nattiv et al., 2007). The effects of LEA are typically illustrated by the female athlete triad (the Triad) and Relative energy deficiency in sports (RED-S), especially in athletes (Matzkin et al., 2015; Mountjoy et al., 2014; Mountjoy et al., 2018; Nattiv et al., 2007).

In RED-S, LEA has a detrimental effect on health, including metabolic and endocrine changes, impaired bone mineral density, and performance issues (Mountjoy et al., 2014; Mountjoy et al., 2018). Given the wide-ranging effects of RED-S on athletes' health and wellbeing, it is crucial that risk of LEA be identified early to provide intervention before long-term harm occurs (Mountjoy et al., 2018). To lower the risk of RED-S, athletes and their support staff must be able to identify its signs and symptoms and understand the health and performance consequences of this syndrome (Tornberg et al., 2017). Questionnaires are the easiest and most cost-effective way to assess this type of knowledge, and the information derived can help develop targeted education material (Sim & Burns, 2021). However, there is currently no validated questionnaire to assess the knowledge on RED-S among athletes and their supporting staff, making it challenging to develop targeted education.

The risk of LEA in female team sports has not been as widely explored compared to endurance sports (Sharps et al., 2022). The few studies that have investigated the risk of LEA in athletes who play team sports, have found reasonably high rates of LEA present (30-66%) (Christensen, 2019; Condo et al., 2019; Groom, 2019; Kumar, 2019; Łuszczki et al., 2021). It is believed that one potential contributing factor to LEA is inadequate nutrition knowledge (Logue et al., 2018). Good nutritional understanding can be one contributor to healthy dietary intake that maximises health, well-being, and sports performance (Miller & Cassady, 2015;

Quaidoo et al., 2018). Yet studies demonstrate that there is insufficient knowledge among athletes and coaches, including knowledge on the general and sports nutrition (Condo et al., 2019; Rash et al., 2008; Rosenbloom et al., 2002; Zawila et al., 2003), triad/RED-S, LEA, and its related short- and long-term health effects (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015). The risk of developing LEA could be reduced among athletes by having a good depth of knowledge about nutrition, LEA, and RED-S. But limited studies have assessed this relationship between risk of LEA and nutrition knowledge. This assessment can aid in the development of nutrition education with targeted interventions.

Furthermore, studies have shown that social media is a popular source of information for athletes and physically active individuals (Bourke et al., 2019). Given the popularity of social media, practitioners have recognised its potential to be used as an educational platform (Callan & Johnston, 2017). There has been an increase in the number of young adults using Instagram as their preferred channel for educational information (Border et al., 2019). However, numerous questions have been raised regarding the appropriateness and accuracy of some educational resources shared on social media (Carpenter et al., 2020). Because they do not have an editorial board, screening procedures, or quality control, these social media platforms have the potential to publish misleading information (Carpenter et al., 2020). However, to the author's knowledge, no studies have been conducted to evaluate whether Instagram posts about RED-S could be a reliable source of knowledge and information for their followers.

Therefore, the three overall aims of this thesis were:

1. To develop and validate a questionnaire which assesses knowledge of signs and symptoms of RED-S among healthcare professionals and physically active individuals.
2. To assess the relationship between risk of LEA and nutrition knowledge among team sports athletes.
3. To systematically review the accuracy of the definition of RED-S on RED-S related posts on Instagram.

2. Literature Review

2.1. INTRODUCTION

The female athlete triad (the Triad) and RED-S generally describe the consequences of LEA, specifically in athletes (Matzkin et al., 2015; Mountjoy et al., 2014; Mountjoy et al., 2018; Nattiv et al., 2007). EA is defined as dietary energy intake minus exercise energy expenditure divided by fat-free mass, and it specifically refers to the amount of dietary energy remaining for other body functions after accounting for the energy required for exercise training (Loucks & Thuma, 2003; Melin et al., 2014; Melin et al., 2015). While the Triad is a syndrome involving LEA, menstrual dysfunction, and decreased bone density primarily seen in female athletes. RED-S is a broader concept that encompasses both male and female athletes, emphasising the range of physiological consequences resulting from prolonged low energy availability. Therefore, LEA/RED-S is a condition in which an individual lacks the energy to support and maintain their normal physiological functions. For some athletes, this can have negative short- and long-term health and performance- related effects (Mountjoy et al., 2018).

2.2. BACKGROUND OF RED-S

In 2005 the International Olympic Committee (IOC) developed a Consensus Statement on the Triad. The Triad is a continuum that starts with ideal EA, eumenorrhea, and normal bone health and ends with LEA, severe menstrual irregularities, and osteoporosis. It explains the relationship underlying EA, menstrual function, and bone health (Barrack et al., 2013; Feldmann et al., 2011; Hausswirth & Le Meur, 2011; Mountjoy et al., 2018; Nattiv et al., 2007; Nichols et al., 2007; Stickler et al., 2015).

In 2014, the IOC experts created a RED-S Consensus Statement to replace the 2005 Female Athlete Triad Consensus Statement in light of new and ongoing research on the subject that has recently changed. (Mountjoy et al., 2014). RED-S broadens the Triad concept and acknowledges that both men and women can experience impaired physiological function due to an inappropriate energy intake. Additionally, RED-S details the complexity of the situation and how more physiological functions, as well as health and performance, are impacted. Furthermore, when the amount of energy available is low, the body compensates by impacting physiological mechanisms, which impairs cellular maintenance, thermoregulation, development, and reproduction (Mountjoy et al., 2018). This compensation aids in restoring energy balance and supports survival but effects the health of an individual (Logue et al., 2018). As a result, RED-S occurs when an athlete experiences prolonged LEA. It has been proposed that health problems arise when EA falls below a particular threshold that has been estimated at 30 kcal/kg of fat free mass (FFM) per day (Loucks, 2004).

The syndrome of RED-S is the result of LEA and impairs health and performance and include, but is not limited to, alterations of BMD, reproductive function, metabolism, immunological, haematological, musculoskeletal and gastrointestinal function, and mental health, with or without DE/ED (Mountjoy et al., 2014). It should be noted that the expansion to the RED-S model from the Triad does not diminish the importance of the Triad and its related consequences, as the RED-S model is inclusive of the issues regarding the Triad (Mountjoy et al., 2014). In summary, while both the Female Athlete Triad and RED-S are related to low energy availability and its health consequences, the triad specifically focuses on female athletes and encompasses low energy availability, menstrual dysfunction, and decreased bone mineral density. RED-S is a broader concept that includes the triad but also extends to male athletes and includes a wider range of health consequences beyond the triad's components.

In 2018, the IOC made recommendations for RED-S prevention and treatment (Mountjoy et al., 2018). It emphasised that, RED-S knowledge education needs to be expanded as part of a more thorough strategy for achieving an all-encompassing approach to athletes' health, with education programmes as a key tool. In the study conclusion, the authors argued that RED-S should be more widely acknowledged as the cause for decline in performance and health and that maintaining athletes' general health requires education and awareness of this condition (Mountjoy et al., 2018). Designing RED-S education programmes, providing evidence-based research sources, encouraging, and supporting athletes, and using a multidisciplinary team (sports general practitioner, dietitian, counsellor, and physiotherapists) are among the main recommendations. Policies for coaches dealing with athlete cases are also recommended (Mountjoy et al., 2018).

2.3. AETIOLOGY

Most studies identify LEA as the primary aetiology of RED-S. LEA can be intentional due to clinical eating disorders (ED) or disordered eating (DE) behaviour. It can also occur unintentionally as a result of inadequate knowledge of the proper fuelling or refuelling requirements specific to a given sport (Mountjoy et al., 2014; Nattiv et al., 2007). ED is a clinical mental illness described by unusual eating habits, a fear of gaining weight, and false ideas about what constitutes a healthy diet, weight, and body shape (Svenaeus, 2014). DE behaviours may include fasting, skipping meals, limiting what you eat, and utilising pills/laxatives (Svenaeus, 2014). Additional factors linked to LEA include intense exercise, losing/gaining weight before a competition, or unintended mismatches between EI and expenditure, for instance, a decreased appetite, inadequate knowledge of nutrition, or insufficient time to plan and prepare food (Gibbs et al., 2013; Nattiv et al., 2007; Tenforde et al., 2016). Other common contributing reasons include excessive exercise habits among athletes and ignorance of the high energy cost of exercise (Burke et al., 2018), or a lack of energy intake necessary to meet the high cost of exercise (Burke, 2001), such as a lack of appetite (Larson-Meyer et al., 2012), or the consumption of bulky, low-energy-density foods high in fibre (Melin et al., 2015; Reed et al., 2013).

Research suggests that some healthcare professionals, coaches, and athletes might not be aware that rapidly changing body weight or body composition or managing it improperly can have negative effects on an athlete’s health and performance (Garthe et al., 2013; Stellingwerff, 2018; Tipton, 2015). Also, people who engage in excessive exercise or restrict certain foods or food groups are more likely to experience nutrient deficiencies (Lis et al., 2015; Peñas-Lledó et al., 2002). Therefore, it is becoming more widely acknowledged that identifying LEA is important for preserving athletes' health and performance, regardless of ED or DE behaviours (Folscher et al., 2015; Slater et al., 2016).

2.4. ENERGY AVAILABILITY

The root cause of RED-S, which results in physiological impairment is LEA. It is necessary to define the term EA in order to fully understand this. EA is the difference between the amount of energy consumed in the diet and the amount used for exercise relative to an individual’s FFM (Loucks et al., 2011). According to (Mountjoy et al., 2018) and (Loucks & Thuma, 2003), EA is defined as follows:

$$\frac{\text{daily energy intake(EI; kilocalories)} - \text{daily exercise energy expenditure(EEE; kilocalories)}}{\text{Fat} - \text{free mass (FFM; kg)}}$$

The overall result is expressed relative to FFM, reflecting the body's most metabolically active tissues. Exercise energy expenditure (EEE) is calculated as the additional energy expended above that required for daily living during bouts of exercise (Loucks et al., 2011; Melin et al., 2015). The range of 30-45 kcal/kg of FFM/day is seen as suboptimal, while less than 30 kcal/kg of FFM/day is regarded as LEA and may lead to RED-S conditions. EA of 45 kcal/kg of FFM/day is suggested for adequate physiological functioning (Logue et al., 2019). In response to LEA, the body slows down essential bodily functions and switches to "energy-saving mode," which lowers basal metabolic rate (BMR) (Keay & Rankin, 2019).

There are many drawbacks to gathering LEA data, including the lack of a uniform procedure, the cost of the tools and personnel required to compute each component, and the random and systematic errors associated with the estimation of each component (Burke et al., 2018; Fahrenholtz et al., 2018; Koehler et al., 2017). The most challenging tasks are obtaining a precise record of typical Energy Intake (EI) from self-reported sources and monitoring EEE throughout several training and competitive activities carried out by athletes, as well as their additional leisure activity (Burke et al., 2018; Cialdella-Kam et al., 2014). Through the use of various dietary assessment techniques, several authors have tried to assess athletes' food intake (Ono et al., 2012; Zapolska et al., 2014; Mielgo-Ayuso et al., 2015). The aforementioned studies used a variety of techniques, including 24-hour recall, qualitative interviews, dietary records, and Food Frequency Questionnaire (FFQ). The results of these studies showed inadequate energy intake, which called for the implementation of a nutrition education intervention. However, the occurrence of under-reporting was never taken into consideration (Ferraris et al., 2019). Under-recording, generally refers to the purposeful or unintentional omission of reporting specific foods consumed, and under-eating, which refers to the purposeful or unintentional reduction of food intake during the study period, are the two main causes of the phenomenon of under-reporting dietary intake (Ferraris et al., 2019).

All techniques used to measure dietary intake are challenged by errors in precision (repeatability, reliability), validity (accuracy), and reproducibility (Black, 2001). EI misreporting is a phenomenon that occurs when athletes report their dietary habits incorrectly, particularly when it comes to their energy consumption. This inaccurate reporting may take two forms: Providing implausibly low estimates of energy intake is known as underreporting (UR), and providing implausibly high estimates is known as overreporting (OV). Depending on the methodology used and the characteristics of the subjects involved, underestimation and overestimation can both happen (Mendez, 2015). The accuracy of reported energy intake could potentially be impacted by a number of factors. Age, sex, body fat percentage, body mass index (BMI), education level, social desirability, and income level are some of these variables (Scagliusi et al., 2009; McGowan et al., 2012; Poslusna et al., 2009). Athletes frequently underestimate how much energy they use on a daily basis, which points to an underestimation bias (Black et al., 1991). There is little to no research addressing the under-or over-reporting tendencies of these athletes regarding their dietary intake with regard to athletes with RED-S. However, a review of the literature revealed that a significant portion of total energy expenditure—between 10% and 50%—is underestimated among athletes based on self-reported energy intake (Capling et al., 2017). Instead of insufficient food consumption, this underestimation is primarily attributed to poor recording practises (Hill & Davies, 2001). It is important to not undervalue the potential effects of systematic bias and various types of misreporting in dietary intake assessments on the relationships found in research studies (Lioret et al., 2011). This problem might lead to an over-estimation of the prevalence of low energy availability. In studies that evaluate athletes' dietary intake and/or investigate the link between diet and performance, deliberate misreporting of dietary intake is a significant problem (Nielson & Adair, 2007; Ferraris et al., 2019). To better understand the reporting patterns of athletes with RED-S, further research is needed.

Table 2.1: *Energy availability thresholds for physically active individuals*

Category	Range	Effects
Adequate EA	>45 kcal/kg fat-free mass/day	Sufficient energy for all physiological processes
Reduced or sub-clinical EA	30-45 kcal/kg fat-free mass/day	Acceptable range for athletes looking to lose weight over a short period of time as part of a well-planned dietary and exercise regimen.
LEA	<30 kcal/kg fat-free mass/day	Insufficient energy for safe bodily function, which can have negative effects on health and athletic performance.

(Source: Mountjoy et al., 2014; Nattiv et al., 2007).

Additionally, there are many drawbacks to gathering LEA data, including the lack of a uniform procedure, the cost of the tools and personnel required to compute each component, and the possibility of estimating errors (Burke et al., 2018; Fahrenholtz et al., 2018; Koehler et al., 2017). The most challenging task is obtaining a precise record of typical Energy Intake (EI) from self-reported sources and monitoring EEE throughout several training and competitive activities carried out by athletes, as well as their additional leisure activity (Burke et al., 2018; Cialdella-Kam et al., 2014).

Estimates from activity logs, heart rate monitoring, and/or accelerometery have all frequently been used to calculate EEE (Brown et al., 2017; Łagowska & Kapczuk, 2016;

Lagowska et al., 2014; Melin et al., 2015; Schaal et al., 2017; Woodruff & Meloche, 2013; Cialdella-Kam et al., 2014; Burke et al., 2018). Despite the fact that Global Positioning System (GPS) devices, heart-rate monitors, and power meters may provide individualised feedback on the amount of energy used during simple exercise routines (such jogging or cycling), information on more challenging or field-based exercise activities is lacking (e.g., resistance training, team sport, swimming). Other studies have utilised accelerometers to monitor movement of the body (Reed et al., 2013). Another common technique used in studies to calculate EEE is from activity records using the Metabolic Equivalent of Task or by referring to tables estimating the energy expenditure of exercise. (Black et al., 2018; Heikura et al., 2018; Koehler et al., 2013; VanHeest et al., 2014).

Skinfold measurement, bioelectrical impedance analysis, and dual-energy x-ray absorptiometry (DXA) are a few examples that are frequently used methods to assess FFM (Fosbøl & Zerahn, 2015). The most accurate measurement of body composition in athletes seems to be DXA (Nana et al., 2015). However, compared to the EI and EEE components, FFM inaccuracies bring less noise while calculating EA (Burke et al., 2018).

2.5. HEALTH CONSEQUENCES OF RED-S

The IOC Consensus Statement from 2014 presented potential RED-S health effects, and the 2018 version elaborates on these each component (Mountjoy et al., 2014; Mountjoy et al., 2018). The information that is now available on each health consequence is restricted to a few of the initial Consensus Statement's recommended systems. Studies are required, for instance, to look at how athletes with RED-S may be affected by metabolic, haematological, continued growth, cardiovascular, gastrointestinal, immunologic, and psychological factors. The effects of RED-S on the physiological systems now known to be impacted will be described in detail below, including how LEA causes the disruption of each body system or function. Unintentional RED-S can be challenging to recognise because its signs and symptoms are difficult to recognise. Utilising biomarkers connected to RED-S may offer a quick way to monitor energy status and spot athletes who may be "at risk" of energy deficiency (Burke et al., 2018).

2.5.1. Endocrine and Menstrual Function

LEA suppresses reproductive function, redistributing energy for essential functions like growth and reproduction to thermoregulation, locomotion, and cellular maintenance (Wade et al., 1996). Specific endocrine markers of interest have been researched in relation to LEA.

Included in these are the hypothalamic releasing hormones, corticotrophin releasing hormone (CRH), gonadotrophic releasing hormone (GnRH), and thyrotropin releasing hormone (TRH). Thyroid stimulating hormone (TSH), adrenocorticotrophic hormone (ACTH), follicle stimulating hormone (FSH), luteinizing hormone (LH), and growth hormone (GH) are examples of pituitary trophic hormones. Oestradiol from the ovaries and testes, as well as the thyroid hormones T3 and T4, are among the hormones produced by target organs of endocrine system (Keay & Francis, 2019; Keay & Rankin, 2019).

2.5.1.1. Luteal Hormone (LH) and Gonadotrophic releasing hormone (GnRH)

In women, disruption of the pulsatile secretion of LH by the pituitary and the disruption of the pulsatile secretion of GnRH by the hypothalamus are the primary causes of menstruation and ovarian dysfunction (Loucks et al., 1989). In athletes, GnRH and LH pulsatility appear to be disrupted either by the stress of exercise or by LEA (Knobil, 1993). The pulsatile release of LH was slowed by short-term (5 days) reductions in EA below 30 kcal/kg of FFM/day with diet and exercise (Loucks & Thuma, 2003). The slower LH pulse shortens the second half of the menstrual cycle, known as the luteal phase, which also delays folliculogenesis (i.e., process of female germ cell developing within the ovary's somatic cells into a fertile egg) (Lieberman et al., 2017). Additionally, LH and FSH are two hormones that may influence the ovarian synthesis of oestrogen and progesterone (Allaway et al., 2016). Changes in synthesis of these hormones lead to interruptions in the menstrual cycle (Clarke & Khosla, 2010).

Therefore, collectively, endocrine disruption that is linked with LEA may upset the hypothalamic-pituitary-ovarian (HPO) axis, which can lead to a wide range of menstruation problems. For instance, primary amenorrhea (delayed menarche; no periods by age 16) and secondary amenorrhea (three consecutive months without periods) (Master-Hunter & Heiman, 2006). Menstrual irregularities such as oligomenorrhea (irregular, lengthy cycle lasting more than 45 days) and anovulation (short luteal phase of 10 days) can also occur (Ackerman & Misra, 2018). These prospective studies show that abnormalities may appear over a few menstrual cycles and, if not detected early, can become chronic conditions. Possible consequences include weak bones, recurrent illness, and poor growth (Lieberman et al., 2017; Williams et al., 2015).

2.5.1.2. Cortisol

Menstrual dysfunction with subsequent LEA causes higher cortisol levels than seen among eumenorrheic athletes (Ackerman et al., 2013). Higher cortisol levels and perceived fatigue were positively correlated among elite synchronised swimmers during a 4-week intensive training period (Schaal et al., 2017). Similar associations were seen among elite endurance athletes irrespective of their EA status (optimal, sub-optimal, LEA) (Melin et al., 2015). Additionally, high cortisol levels indicate increased physiological stress during intensive training, especially in women with menstrual irregularities (Logue, et al., 2018). Ovarian suppression occurs when the body is in energy conservation mode, leading to poor performance (VanHeest et al., 2014). Long-term reproductive health in the endocrine system is understudied (Mountjoy et al., 2014).

2.5.2. Metabolic function

RED-S reduces glucose utilisation, mobilisation of stored fat, slows metabolism, and reduces growth hormone production, impairing metabolic function (Loucks & Thuma, 2003; Mountjoy et al., 2014). The 2018 IOC Consensus Statement update included possible reductions in Resting metabolic rate (RMR), leptin, T3, Insulin-like growth factor (IGF-1), and an increase of ghrelin concentrations (Mountjoy et al., 2018). Currently, there are no published guidelines for testing biomarkers or metabolic function in athletes suspected of RED-S.

2.5.2.1. Resting metabolic rate (RMR)

RMR is largely driven by lean mass and is the amount of energy the body requires at rest to carry out its essential functions. RMR can be utilised as a measure of EA, or the amount of energy still available for use in metabolic processes after accounting for exercise and dietary intake (Schofield et al., 2019). RMR is centrally controlled and connected to energy intake and appetite (Blundell et al., 2015). Suboptimal EA and a reduced RMR are caused by insufficient energy intake to support an increased training load. EA has been estimated using RMR to identify people with LEA (De Souza et al., 2007; De Souza et al., 2007; Melin et al., 2015; Woods et al., 2017). In a study on EA in female endurance athletes, Melin et al. (2015) found that LEA was associated with reduced RMR compared to optimum EA and that menstrual dysfunction was associated with a lower RMR and lower work efficiency (Melin et al., 2015).

2.5.2.2. Appetite Hormones

Leptin and Ghrelin: Leptin, an appetite-suppressing hormone, is produced by adipocytes and regulates energy homoeostasis. Leptin production by adipocytes changes in response to feeding and fasting (Koehler et al., 2016). Leptin decreases quickly when EA is low, possibly indicating inadequate exercise recovery and energy deficiency (Koehler et al., 2016; Rayner & Trayhurn, 2001). A study on healthy exercising women found that leptin levels depend on energy availability, not intake, and exercise has no effect on leptin's diurnal rhythm beyond its impact on energy availability (Hilton & Loucks, 2000). Due to energy restriction, gastric mucosa produces more ghrelin, appetite-stimulating hormone, which increases appetite and feeding behaviour (Koral & Dosseville, 2009). A decrease in EA was accompanied by an increase in ghrelin in a study of elite synchronised swimmers, reflecting a decrease in energy stores (Schaal et al., 2017). According to a study on healthy females who underwent dietary and activity modifications, fasting ghrelin concentrations rise when body weight is reduced in response to the changes in energy availability (Scheid et al., 2011).

2.5.2.3. Triiodothyronine (T3)

T3 is a component of the Hypothalamic-pituitary-ovarian (HPO) axis and is responsible for controlling metabolism based on the availability of glucose in the brain. Additionally, low T3 levels could be a biomarker for EA because hypothyroidism, one of the symptoms of LEA, is a sign of low T3 levels (Logue et al., 2018). A study showed that lower T3 levels are related to within-day energy deficiency (WDED) in athletes with eumenorrhea and menstrual dysfunction (Fahrenholtz et al., 2018). Reduced REE (Resting energy expenditure) and hormonal response during LEA may be a physiological response to conserve energy (De Souza et al., 2007; Melin et al., 2015; Mountjoy et al., 2018). In addition, when compared to sedentary and regularly menstruating athletes, recreational and competitive athletes with menstrual abnormalities exhibited lower T3 and REE (relative to FFM) (De Souza et al., 2007). Elite endurance athletes with menstrual dysfunction had a lower RMR and T3 than those with optimal EA (>45 kcal/kg FFM/day) (Melin et al., 2015). Decreased RMR and T3, which can cause menstrual irregularities, is a plausible response to reduced EA or LEA in female athletes (McClung et al., 2009).

2.5.2.4. Insulin-like Growth factor (IGF-1)

IGF-1 plays a role in growth and development of human body, including bones and muscles. In athletes, IGF-1 has beneficial effects as it improves muscle protein synthesis and glycogen storage, which could improve performance (Guha et al., 2013). Female swimmers whose ovarian hormone production was suppressed showed a decline in performance over the course of a 12-week training camp and had lower levels of IGF-1. IGF-1 declined even in those with normal menstrual function over a 12-week training camp, although to a lesser extent (VanHeest et al., 2014), demonstrating a relationship between training stress and IGF- 1 levels. Additionally, healthy females with a regular menstrual cycle had lower IGF-1 responses when

EA was < 20 kcal/kg LBM$^{-1\cdot}$ d^{-1} (Loucks & Thuma, 2003). This suggests a connection between low IGF-1 and the EA status of female athletes.

2.5.2.5. Insulin and Glucose

In energy deficiency, insulin and glucagon levels drop, glycerol and free-fatty acids rise, and fasting glucose levels fall (Logue et al., 2018). In a fasting state, the body relies on stored energy, requiring gluconeogenesis and glycogenolysis to produce glucose from non-carbohydrate sources (Rui, 2014). EA below 30 kcal kg^{-1} fat-free mass day^{-1} has been linked to the suppression of insulin, according to laboratory tests (Hilton & Loucks, 2000; Loucks & Thuma, 2003; Loucks et al., 1998). Exercise-induced changes in glycerol and free fatty acid concentrations were seen in men (Koehler et al., 2016) and women (15 kcal/kg FFM/day) with LEA (Loucks et al., 1998). Reductions in insulin (by 34%–38%) and fasting glucose (by 8%–12%) were also noted (Loucks et al., 1998). Additionally, athletes with menstrual dysfunction had lower fasting glucose levels than eumenorrheic athletes (Melin et al., 2015).

2.5.3. Cardiovascular Health

LEA may accelerate changes in cholesterol synthesis. Among endurance amenorrhoeic athletes who had a lower fat intake and engaged in greater amounts of endurance exercise it was observed that they had elevated triglycerides, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) (Melin et al., 2015). A previous study on amenorrhoeic females showed a rise in LDL oxidation susceptibility, (i.e., oxidized LDL formed due to chemical reaction and may build up on the artery walls) following vigorous, prolonged aerobic exercise (Sánchez-Quesada et al., 1995). In amenorrhoeic athletes compared with oligomenorrhea and regular cycle, unfavourable lipid profiles [higher TC and LDL-C] have been reported (Rickenlund et al., 2005). The type of sport practiced—weight class may have more effects than endurance—and the length of time spent in a LEA state are potential influences on lipid levels. Additionally, to fully understand LEA and its effects on CVD risk, more research with comprehensive plasma lipid and lipoprotein concentrations is needed.

2.5.4. Bone Mineral Density (BMD)

The highly specialised framework of bones is known for its hardness, rigidity, and capacity for self-regeneration (Kini & Nandeesh, 2012). Under normal circumstances the body adjusts to the changes in the biomechanical pressures it encounters to maintain bone strength via osteoclasts (i.e., aged bone resorption) and osteoblasts (i.e., new bone formation), which continuously remodel bones throughout the life (Kini & Nandeesh, 2012). Exercise and growth hormones are all crucial osteoblastic stimulants that increase bone remodelling and have a knock-on effect on the bones (Kini & Nandeesh, 2012; Kohrt, 2004). Adolescence is the period of maximum bone formation, which facilitates and increases BMD, increasing bone strength (Kini & Nandeesh, 2012; Kohrt, 2004). According to Whiting et al. (2004), peak bone density is reached between the ages of 25 and 35 years, and for girls, bone mineral accrual peak rate occurs between age 12 to 15 years (during the adolescent growth spurt) (Whiting et al., 2004). According to Nattiv et al. (2021), bone protein quality, BMD, and bone structures all play a significant role in bone strength and fracture risk. These factors may help us understand why some athletes experience a higher incidence of fractures while others do not, despite having similar BMD (Nattiv et al., 2021).

Dual-energy X-ray absorptiometry (DXA) measures BMD. Risk of osteoporosis can be assessed using DXA z-scores (Joy et al., 2014). It has been suggested that a z-score less than –1.0 could be an indicator of sub-optimum bone mineral density for athletes due to the need for stronger bones to manage activities with repeated or high impact (Hind & Hamer, 2021). Adolescent athletes who have a BMD z-score less than –1.0 are regarded to be "at risk" for having poor bone mass (Barrack et al., 2010). The presence of LEA and RED-S may not be detected prior to an injury, such a stress fracture. Additionally, assessment should be done about athlete's prior history of vitamin D deficiency.

It is widely documented that LEA has been associated with decreased bone health in female athletes, notably in the anatomical regions of the lumbar spine, femur neck, and hips (Ackerman & Misra, 2011; Ackerman et al., 2013; Barrack et al., 2010; De Souza et al., 2014; Mountjoy et al., 2014; Mountjoy et al., 2018; Nattiv et al., 2007). LEA may lead to unfavourable bone outcomes, such as a reduction in bone formation, an increase in bone resorption, or combination of the two (Papageorgiou et al., 2018). Even the presence to LEA for a very short period of time in females who engage in recreational activity can have a negative influence on bone turnover markers (Ihle & Loucks, 2004; Papageorgiou et al., 2018).

Oestrogen is essential to bone remodelling (Krassas & Papadopoulou, 2001). Menstrual dysfunction decreases oestrogen, which increases bone demineralisation and decreases bone mineral density, reducing fracture resistance (Lambrinoudaki & Papadimitriou, 2010). Compared to eumenorrheic athletes, 13 of 35 (37%) elite female athletes who were amenorrhoeic (age 23.8 ±4.4), were twice as likely to have two or more stress fractures, and lost five times as many training days to bone injuries (age 26.7± 2.9) (Heikura et al., 2018).

Athletes who have oligomenorrhoea/amenorrhoea or LEA have low BMD, altered bone fragility, and bone turnover markers, reduced bone strength, and a higher risk for bone stress injuries when compared to athletes with optimal EA (Papageorgiou et al., 2018). However, changes in BMD may not be identified over a short amount of time. Also, earlier treatments in the form of exercise (especially weight-bearing exercises) and dietary changes (such as vitamin D and calcium supplementation) may promote bone mineralisation sufficiently to maintain BMD during the period of LEA (Papageorgiou et al., 2018).

2.5.5. Haematological Changes

The IOC 2014 Consensus Statement discusses the relationship between LEA and iron deficiency, however there are several gaps in the research in this area (Mountjoy et al., 2014). RED-S may impair iron regulation in athletes, according to a review of iron considerations for athletes. This could be due to LEA, inadequate dietary intakes, or iron absorption (Sim et al., 2019).

Numerous possible mechanisms have been investigated over the years, but more recently activity of a group of proteins made by the white blood cells called the interleukin-6 (IL-6) and the hormone that controls how the body uses iron called the hepcidin have been studied (Clénin et al., 2015; Peeling et al., 2017). It appears that IL-6 peaks right after exercise, with hepcidin elevations peaking three hours later. Hepcidin, a hormone made and released by the liver, binds to and breaks down ferroprotein, the channel in the liver, spleen, and enterocytes that allows iron to leave the cell (Pantopoulos et al., 2012). As a result, iron is temporarily unavailable for use in bone marrow to synthesise haemoglobin and in muscle for oxidative phosphorylation. Hepcidin production appears to increase by four main variables, which include baseline serum ferritin (i.e., iron stores), baseline serum iron, post- exercise IL-6, and exercise duration (Peeling et al., 2017). It has been reported that LEA may result in iron deficiency via its impact on oestrogen. It is believed that hypoestrogenism causes an increase in the hormone hepcidin, which causes ferroprotein (an iron transporter) to degrade and, as a consequence, reduces iron absorption (Ganz.,2006; Frazer et al., 2002; Yang et al., 2012). Notably, it is yet unknown if iron deficiency is seen in amenorrheic females since the absence of menstrual loss may reduce this impact (Petkus et al.,2017).

2.5.6. Growth and Development

It is crucial to take into account how RED-S may influence athletes of all ages;Younger athletes and adolescents who have been diagnosed with eating disorders such anorexia may have alterations in GH and IGF-1 levels as well as reduced linear growth, which may affect their growth and development (Loucks & Heath, 1994; Loucks & Thuma, 2003; Loucks et al., 1998). Additionally, athletes who have LEA are more likely to have inadequate intakes of macro- and micronutrients, particularly if they engage in practises that involve restricting their diet (Beals & Manore, 1998; Manore, 1999). In addition, intestinal structure is likely to be compromised in athletes who are severely malnourished, and as a result, decreased absorptive function is likely in individuals who have LEA (Ferraris & Carey, 2000; Monteleone et al., 2004). Because of this, the availability of nutrients for physiological processes may be reduced. During the adolescent years, when growth and development are at their peak, some of the nutrients of concerns are vitamins A, D, B12, and C, as well as iron, zinc, calcium, and protein (Spear, 2002). It's possible that developmental delays and stunted growth could occur if you were missing one or more of these nutrients. It should be noted that it is unclear how athletes with RED-S may have negative health effects from altered growth and development (Mountjoy et al., 2018). To conclude, further study is required to completely understand if RED-S slows or harms growth and development, and whether recovery from these potential effects is possible.

2.5.7. Psychological Health

In RED-S, psychological issues may precede, produce, or result from LEA in both male and female athletes (Mountjoy et al., 2014; Mountjoy et al., 2018). Adolescent female athletes with menstrual dysfunction are more likely to struggle with stress management, moderate depressive symptoms, and psychosomatic symptoms (Bomba et al., 2007; Marcus et al., 2001).

Research studies have used the Drive for Thinness (DT) score as a proximal predictor of LEA. (De Souza et al., 2007; Garner, 1991). Researchers discovered that both sedentary females and physically active females with higher DT scores also had higher ineffectiveness, asceticism, bulimic tendencies, and cognitive restraint., they also had low RMR, low level of T3, and high levels of ghrelin, suggestive of LEA (De Souza et al., 2007).

Another study showed that elite female athletes with menstrual irregularities had a higher DT than eumenorrheic athletes (Melin et al., 2016). Well-trained endurance athletes with higher ED scores with lower the energy balance, ($p=0.008$) (Torstveit et al., 2019). In a qualitative study of the psychological effects of RED-S, Langbein et al. (2021) discovered that athletes with RED-S suffered from both physiological impairments and psychological distress, including irritability, vulnerability, weakness, anxiety, fear, and helplessness (Langbein et al., 2021). Therefore, when investigating athletes suspected of having RED-S, examining implications of psychological health, mental well-being, and detected psychological problems is necessary.

2.5.8. Immunological Health

The cause of illness in athletes is often multifactorial because normal immune function may be inhibited by a variety of factors, including, but not limited to, inadequate nutrient intake, poor sleep, environmental and psychological stress, and extensive periods of high- intensity activity (Gleeson, 2016; Gleeson & Pyne, 2016; Mountjoy et al., 2018; Walsh et al., 2011). However, there is little study on the relationship between RED-S and impaired immunological function.

Despite the lack of clear evidence, some studies have shown that mucosal immunity seems to be affected in weight category sports, where athletes occasionally use fast and rapid weight reduction techniques in conjunction with intense exercise (Abedelmalek et al., 2015; Imai et al., 2002; Shimizu et al., 2011). These athletes may be more vulnerable to infectious diseases as a result of the immunoglobulin changes and rapid weight loss. Additionally, it appears that frequent weight cycling (. i.e., the fluctuating increases and decreases in bodyweight) affect salivary immunoglobulin A (IgA) levels during practice, competition, and resting periods (Tsai et al., 2012). Salivary IgA plays a crucial role in mucosal immunity by inhibiting the attachment of foreign pathogens and toxic molecules to mucosal surfaces (Marcotte & Lavoie, 1998). Taekwondo athletes with low salivary IgA had a significantly higher incidence of upper respiratory tract infection following competition (Tsai et al., 2012). Japanese elite collegiate runners who experienced menstrual dysfunction had higher rates of upper respiratory symptoms (URS) and lower rates of IgA secretion (Beals & Manore, 1998). Recently, two hundred and six athletes from sports including equestrian, soccer, boxing, hockey, gymnastics, rowing, rugby sevens, triathlon, sailing, and water polo completed the LEAF-Q survey (males, n=47, age 25.8±4.1 years; females, n=85, age 24.3±3.9 years). On the Low Energy Availability in Females Questionnaire (LEAF-Q), 40% of females were at risk of LEA. Upper respiratory tract infections, body pains, headache symptoms, and digestive problems were more likely to be reported in those who were at risk of LEA (Drew et al., 2018). However, due to the complexity of the immune system, RED-S-related illness and infection risk may be difficult to assess.

2.5.9. Gastrointestinal Health

Delays in gastric emptying, longer transit times, altered sphincter function, and constipation are examples of modifications to typical gastrointestinal function seen amongst those with RED-S (Norris et al., 2016). Constipation is a common symptom of eating disorders in people with slowed colonic transit time. However, once a diet with enough caloric intake is resumed, function can return to normal (Chun et al., 1997). It is observed that low levels of thyroid hormones caused by LEA are a contributing factor in gastrointestinal issues such as constipation, nausea, vomiting, and gastrointestinal discomfort (Ebert, 2010). Both the structure and function of the gastrointestinal tract, including the small intestine, are at risk of being impaired due to fasting (Monteleone et al., 2004). Alterations in the function of the small intestine can lead to a reduction in the amount of nutrients absorbed by the body (Monteleone et al., 2004).

The frequency and consistency of bowel movements as well as gastrointestinal symptoms like pain, cramping, bloating, and pain were assessed among endurance athlete using the LEAF-Q screening tool, which consists of questions about gastrointestinal function. It was observed that there was a negative correlation between EA and digestive system symptoms ($p=0.023$) (Melin et al., 2015). Ackerman et al. (2018) assessed athletes general health, athletic performance, disease, injuries, and Triad and RED-S risk factors (Ackerman & Misra, 2018). Participants were required to complete the LEAF-Q and the Faecal Incontinence Questionnaire to evaluate gastrointestinal disturbances (Reilly et al., 2000). Those with LEA were 1.5 times more likely to have digestive symptoms than those with adequate EA. These two studies highlight the relationship between LEA and gastrointestinal symptoms. However, there is still a gap in our understanding of how to adequately test, assess, and treat individuals suspected of having RED-S who have such adverse health effects.

2.6. PERFORMANCE CONSEQUENCES OF RED-S

Although the consequences of prolonged LEA on athletic performance in both genders are still not well understood, it is generally observed that LEA can reduce glycogen stores, inhibit protein synthesis, and increase risk of injury and illness in both professional and recreational athletes (Areta et al., 2014; Drew, Raysmith, et al., 2017; Drew, Vlahovich, et al., 2017; Logue et al., 2019). Important hormones needed for muscle development include insulin, testosterone, IGF-1, and growth hormone (Roemmich & Sinning, 1997). T3 is necessary for the synthesis of muscle protein and the generation of ATP (Harper & Seifert, 2008). Decreases in T3 and T4 hormone levels have been linked to impaired skeletal muscle aerobic metabolism (Harper & Seifert, 2008). It has been shown that LEA reduces aerobic capacity via its impact on thyroid and oestrogen levels (Loucks, 2004). Vasodilation may be reduced when there is decreased oestrogen production. And reduced muscle oxygen and nutrient absorption caused by a reduction in vasodilation may affect aerobic performance (Loucks, 2004). Additionally, the decreased oestrogen as a result of RED-S may have an impact on memory and cognition due to its effects on dopamine and serotonin. It is advised to consume enough macronutrients, such as carbohydrates, to enhance glycogen stores, which are crucial for recovery and performance (Burke et al., 2011). Additionally, female athletes' glycogen levels only rise when they have enough energy (Tarnopolsky et al., 2001).

Vanheest et al. (2014) found that after a twelve-week training period, among athletes with LEA and menstrual irregularities, performance declined (i.e., 10% slower 400-meter swimming speed), while performance improved by 8.2% among those with regular menstruation with optimal EA (VanHeest et al., 2014). Silva and Paiva (2016) found that among female elite rhythmic gymnasts, LEA was negatively correlated with competition rankings, and that most gymnasts in general displayed poor sleep quality, which had an impact on daytime sleepiness (Silva & Paiva, 2016). Ackerman et al. (2019) recently reported that female athletes competing in a variety of sports had a reduction in performance due to LEA. These effects were self-reported and included consequences such as decreased strength and conditioning response, poor judgment, poor coordination and focus, depression, and decreased endurance performance (Ackerman et al., 2019).

Woods et al. (2017) examined the impact of an intensified training load without an increase in energy intake on performance as well as the impact on exercise regulation and RMR among professional rowers. Seventeen (10 male 7 female) elite rowers trained for six days per week over a period of four weeks. The resultant participants ranged in age from 21 to 30 years; there were 10 men and 7 women. The intensity and duration of training load, which leads to increased energy expenditure and LEA, was linked to lower RMR, lower body mass and fat mass, increased fatigue, and mood disturbances. The lack of change in energy intake and change in body composition was likely responsible for the declining RMR (Woods et al., 2017). In general, failing to increase energy intake in response to an increase in the intensity of training load may have a negative effect on performance which leads to changes in mood and a reduction in RMR.

Tornberg et al. (2017) examined whether there was a connection between neuromuscular performance, metabolic and endocrine changes, and reproductive function. The study included 30 professional female endurance athletes (aged 18 to 39 years). Among the 30 participants, 12 used hormonal contraceptives, 5 had secondary amenorrhea and 7 were eumenorrheic.

To allow for a washout period, these participants who used contraceptives were instructed to stop using them six weeks before the study's start date. Participants filled out a LEAF-Q and completed a three-month menstrual bleeding diary that allowed researchers to identify whether they had polycystic ovarian syndrome, secondary amenorrhea, oligomenorrhea, or eumenorrhea. Participants were fasting, and body composition was evaluated using a DXA scan. The blood samples were drawn to determine the levels of oestradiol, androstenedione, total testosterone, progesterone, serum T3, cortisol, TSH, insulin, and capillary blood glucose. In comparison to athletes who had eumenorrhea, those who had secondary amenorrhea weighed less, had lower BMIs, and had both a lower percentage of body fat and a lower percentage of fat-free body mass, glucose, oestrogen, T3 and elevated cortisol levels (Tornberg et al., 2017). There were no significant differences in the number of calories consumed, the amount of energy spent, or the amount of endurance training performed by athletes who had secondary amenorrhea or eumenorrhea. They concluded that the endurance athletes with secondary amenorrhea endurance had lower neuromuscular performance than that of eumenorrhea endurance athletes (Tornberg et al., 2017). Additionally, athletes who had secondary amenorrhea engaged in resistance training on a more regular basis and had higher levels of cortisol, lower RMR levels, lower levels of T3 and blood glucose, and lower levels of work efficiency (Tornberg et al., 2017). When compared to healthy athletes, those with amenorrhea had significantly lower oestrogen-to- cortisol ratios and significantly higher cortisol-to-insulin ratios. Researchers found that a quicker reaction time was linked with higher level of blood glucose, T3, and oestrogen levels, as well as lower cortisol levels. Compared to those with amenorrhea, athletes who had eumenorrhea had a faster reaction time by 7%, increased knee muscle strength by 11%, and increased endurance by 20%. In conclusion, athletes who experienced secondary amenorrhea had poorer performance on neuromuscular tests compared to eumenorrheic athletes. (Tornberg et al., 2017).

2.6.1. Injury

Low BMD and a high incidence of stress fractures are linked to athletes who are in a state of LEA, as was discussed in section 2.5.4. Due to their training loads and the nature of several sports, athletes often sustain injuries; nevertheless, there are presently few research examining soft tissue injuries in relation to LEA.

Physically active females (n=1,000) who were categorised as having low or adequate EA completed a 113-item questionnaire (adapted from the (IOC) position on RED-S

(Mountjoy et al., 2018) to assess potential negative effects of LEA (Ackerman et al., 2019). This research found that people classified as having LEA were more likely to suffer from performance-decreasing consequences. Athletes with LEA had a 1.1 times higher risk of injury, a 2.1 times higher risk of having a reduced training response, and a 1.5 times higher risk of having a lower endurance performance, in addition to the psychological disadvantages previously indicated in section 2.5.7 (Ackerman et al., 2019). Additionally, LEA may increase the risk of sickness; in fact, women who were identified as being at risk for LEA were more likely to suffer from bouts of sickness that interfered with training three times more often than women who were not at risk (Logue et al., 2019).

Summary

To summarize, RED-S and its hormonal effects are mostly caused by LEA. When the body's energy availability is low, there is less EA for normal physiological processes. As a result, physiological functions slow down to make up for this energy deficit it. Every demographic of athletes is at risk from LEA. LEA promotes detrimental outcomes in several areas of health in the active individuals, including menstruation dysfunction, various eating disorders, elevated stress hormone levels, altered HPA axis activity, low BMD, RMR, and increased risk of psychological disturbances. Athletes' perceptions of and propensity for injury, as well as their reaction to training and endurance performance, are all impacted by LEA.

2.7. PREVALENCE OF LOW ENERGY AVAILABILITY

The health and performance consequences of triad and RED-S in athletes is difficult to interpret due to significant variations in measuring and defining LEA, menstrual disturbance, and low BMD.

The prevalence of LEA is more common among female than male athletes (Koehler et al., 2016). . Table 2.2 summarises the prevalence of LEA in various sports which vary from low to high (12-100%). Of note, LEA is observed in a variety of sports, not simply those that place a focus on leanness (Gibbs et al., 2013; Reed et al., 2013; Woodruff & Meloche, 2013). However, owing to variation in the sports and categories of athletes (such as performance level and age) examined, as well as limited research sample numbers (range 9–833), precise estimations of prevalence are difficult to ascertain. The diverse range of methodologies, markers, and predictors utilised to evaluate LEA prevalence in published research and athlete 339recruitment in sport-specific groups may also explain the variance in LEA prevalence (Black et al., 2020).

In general, LEA is prevalent in 2.2% of non-athletes (Muia et al., 2016), and depending on the sport and stage of the season, up to 67% of female collegiate athletes have the condition (Jagim et al., 2022). Sports that require large amounts of endurance training and high levels of aerobic activity, appear to put athletes at higher risk. Calculating EA from dietary intakes and energy expenditure 41% of cross-country runners and 51% of track and field athletes had LEA (Beermann et al., 2020; Day et al., 2014; Folscher et al., 2015). LEA rates are reported to be even higher in athletes who participate in weight-sensitive sports like ballet, weightlifting, wrestling, or figure skating (Logue et al., 2018). According to one study, 100% of synchronised swimmers and 96.2% of female ballet dancers met the clinical criteria for LEA (Schaal et al., 2017; Torres-McGehee et al., 2020). The high prevalence of LEA can be attributed to multiple factors. One obvious factor is disordered eating to optimise physique or physical performance (Mountjoy et al., 2014; Nattiv et al., 2007b). However, LEA may also occur unintentionally due to lack of appetite or poor nutritional knowledge (Melin et al., 2019).

Table 2.2: *Estimated prevalence of LEA in various sport groups.*

Author	Sex	Sample size	Study population	Mean age (y) ± SD	Mean ± SD EA (kcal/kg FFM/Day) [a]	Subjects with LEA (%)	Comments
(Day et al., 2014)	F	25	Division 1 track/field collegiate athletes	Athletes: 19.5	23.0 ± 5.7	52	92% (n=23) of the participants had FFM/day intakes below 45 kcal/kg/day, and 52% (n=13) had FFM intakes below 30 kcal/kg/day.
(Viner et al., 2015)	M/F	10 [6(M), 4 (F)]	Endurance cyclists	M:42 F: 38.4	(M) Pre-session:18.8±12.1 (F) Pre-session: 26.2 ±14.1 (M) Competition:19.5 ± 8.5 (F) Competition: 25.5 ±3.1 (M) Off-season: 21.7 ± 9.2 (F) Off-season: 23.8 ± 8.9	Pre-season: 70 Competition: 90 Off-season: 80	EA did not change throughout the season
(Melin et al., 2015)	F	40 [24(MD), 16 (EU)]	Elite endurance athletes	26.3	19.1 (range 11.6 - 22.6)	63	Elite athletes had 25% ED, 60% MD, 45% impaired bone health, and 23% all three Triad conditions.
(Silva & Paiva, 2015)	F	67	Rhythmic gymnasts	18.7	29.8 ± 10.8	44.8	Athletes with LEA had low intakes of minerals such calcium, iron, and magnesium as well as folate, D, E, and K vitamins.
(Lagowska & Kapczuk, 2016)	F	52 (31 athletes 21 ballet dancer)	Athletes and Ballet dancer with MD	Athletes: 18.1 Ballet dancers: 17.1	Athletes: 28 ± 9.2 Ballet dance: 21.7 ± 7.2	Ballet dancers: 100	Higher EA in athletes vs. ballet dancers $p < 0.05$.
(Melin et al., 2016)	F	25	Elite endurance athletes	26.6	42.5 ± 12.1	12	There was no evidence of a difference in EA between athletes with FHA and EU.

(Muia et al., 2016)	F	110 [61 athletes, 49 non-athlete controls]	Middle /long-distance athletes	Athletes: 16 non-athletes: 17	Athletes: 36.5 ± 4.5. Non-athletes: 39.5 ± 5.7	Athletes: 17.9 non-athletes: 2.2	Athletes had subclinical-EA compared to non-athletes (p <0.005)
(Brown et al., 2017)	F	25	Pre-professional contemporary dancers	21	7-day EA: 26 ± 13 Week EA: 24 ± 10 Weekend EA: 36 ± 21	N/A	Weekends and weekdays had similar energy expenditure (p=0.297). However, weekday EI, EA, and energy balance were lower than weekend values (p=0.002; p=0.003; p=0.004, respectively).
(Ong & Brownlee, 2017)	F	9	Dragon boat athletes	23	23.7 ± 13	66	Six of nine athletes had EA < 30 kcal/kg FFM/day.
(Schaal et al., 2017)	F	11	Synchronized swimmers	20.4	Baseline: 25± 3.2 Intensive training week 2: 22.3 ± 1.9 and week 4: 18.0 ± 2.8	Baseline: 100 Intensive training week 2: 100 and week 4: 100	EA was significantly decreased at week 4 compared to baseline; p <0.05
(Heikura et al., 2018)	M/F	59	Elite distance athletes	M: 27 F: 26	N/A	M: 25 F: 31	Athletes with MD had ~4.5 times more bone injuries and low testosterone levels.
(Clark et al., 2018)	F	15	Collegiate endurance runner	19 to 22	28.7 ± 7.5	40	60% of the athletes had optimal or subclinical energy status. Athletes with clinical MD who were at risk for LEA were successfully identified by LEAF-Q.
(Civil et al., 2019)	F	20	Ballet dancers	18	Weekday: 38 ± 13 Weekend: 44 ± 13	22	EA <30 kcal/kg FFM/day: 22%. No correlation between EA and

							MD (p = 0.17) or LEAF-Q score (p = 0.11).
(Costa et al., 2019)	F	21	Collegiate synchronized swimmers	20	26 ± 13 to 30 ± 13	N/A	Estimated EA positively correlated with measured RMR (p = 0.045).
(Heikkilä et al., 2019)	M/F	48 [21 (M),27 (F)]	Elite distance athletes	M: 27 F:26	M:36 ± 6 F:33 ± 7	N/A	Self-reported iron consumption, sex hormones, or EA did not significantly affect Hb mass results. There was a tendency for a negative correlation between LEAFQ score and %Hb mass. (r = -0.353, p = 0.07).
(Meng et al., 2020)	F	114	Elite athletes (ELA) Recreational athletes (REA)	20 ± 2	N/A	55.8 ELA, 35.1 REA. LEA determined using LEAF-Q	LEA participants show higher incidence of amenorrhea, lower E2 levels (p<0.05), and decreased BMD in the arms, legs, and total body (p<0.05).

Abbreviation: AM=amenorrhoeic, EI= energy intake, EEE=exercise energy expenditure, EU=eumenorrheic, E2 level= oestradiol levels, FFM=fat-free mass, F=female, FHA=Functional hypothalamic oligomenorrhea/amenorrhea, Hb mass= haemoglobin mass, %Hb mass= percentage haemoglobin mass, LEAF-Q Low Energy Availability in Female Questionnaire M=Male, SD=standard deviation, LEA=Low energy availability, Mixed sports = individual and team sports athletes, Mixed level= athletes in recreational, competitive, and/or professional level, MD=menstrual dysfunction, N/A=not available, NCAA=National Collegiate Athletic Association. a EA measured using the energy availability formula ((Energy availability = (Energy intake (kJ) − Energy expenditure during exercise (kJ))/fatfree mass (kg))] and categorised as: Optimal energy availability (>45 kcal/kg FFM/day), Sub-clinical energy availability (30–45 kcal/kg FFM/day), Low Energy availability (<30 kcal/kg FFM/day).

2.8. PREVALENCE OF LEA WITHIN TEAM SPORTS (EA<30 KCAL/KGFFM)

The prevalence of LEA in female team sports has not been as widely explored compared to endurance sports (Sharps et al., 2022). Reed et.al (2013) performed one of the earliest investigations examining the prevalence of LEA in a sample of football players (n=19). According to the threshold of EA (<30kcal/kgFFM/day), 12% of athletes had LEA during the offseason, up from 26% during preseason, 33% at the middle of the season, and 26% towards the end of the season (Reed et al., 2013). In later research on football players (n=56), 53% had LEA (<30 kcal/kgFFM/day) (Braun et al.,2018) and among dragon boat athletes, 66% had LEA (<30 kcal/kgFFM/day) (Ong & Brownlee, 2017). Additionally, Dobrowolski et al. (2020) most recently investigated 30 footballers and indicated a concerning 64.1% of footballers had an EA of ≤30kcal/kgFFM/day (Dobrowolski & Wlodarek, 2020). Differences in the prevalence of LEA among these studies may reflect differences in training regimens and dietary influences such as food and health awareness, nutritional attributes of the food, off-season, and weight changes before and between events during competition (Thurecht & Pelly, 2020).

Collectively, these studies suggest that team sports players and players of individual sports experience a similar prevalence of LEA

2.9. PREVALENCE OF RISK OF LEA WITHIN TEAM SPORTS ACCORDING TO LEAF-Q

As discussed in a previous section there is still a sizable gap in our understanding of how to measure energy availability precisely and accurately. The LEAF-Q (Melin et al., 2014) is the most widely used validated screening tool that has been shown to accurately identify the risk of LEA in females. The most recent studystudies on LEA in team sport athletes using the LEAF-Q show that LEA is common in team sport athletes (approximately 30-55%) (see Table 2.3).

In a recent study, 40% of 833 physically active female athletes in team or individual sports who completed the LEAF-Q were found to be at risk of LEA (Logue et al., 2019). The study had a slightly lower prevalence of athletes at risk compared to other studies (Christensen, 2019) (Renard et al., 2021). This could be due to the variety of athletes included in the study which spanned a range of competition levels and covered both individual and team sports categories. Sharps et al. (2022) also used LEAF-Q to evaluate the risk of LEA among recreational, competitive, and professional female athletes (team or individual sports) and found overall, 53% of 112 female athletes to be at risk despite the level of sport (Sharps et al., 2022).

In a group of 24 elite rugby 7's players, just over 50% were classed as at-risk of LEA based on their LEAF-Q responses (Christensen, 2019; Groom, 2019; Kumar, 2019). Conversely, only 30% of elite-level professionals football players (n=30) were classed as at risk of LEA using LEAF-Q during preseason (Condo et al., 2019). Differences in risk of LEA may be due to increased knowledge (or educational programmes) made by the sport organisation (Kroshus et al., 2018; Warrick et al., 2020).

Table 2.3: *Prevalence of LEA within team sport athletes assessed using LEAF-Q.*

Study	Sex, Age	Sample size (n)	Athletes	Measure of LEA	Subjects with LEA (%)
(Groom, 2019)	F, 16-40 y	24	Elite rugby 7s players	LEAF-Q	50
(Christensen, 2019)	F, Not reported	20	Elite rugby 7s players	LEAF-Q	55
(Kumar, 2019)	F,> 16 y	23	Elite rugby 7s players	LEAF-Q	52
(Lohman et al., 2019)	F, 18-35 y	27	Elite Football players	LEAF-Q	30
(Logue et al., 2019) [a]	F, 18-44 y	833	Individual sports (n=268) Team sports (n=330) Recreational sports (n=235)	LEAF-Q	40
(Sharps et al., 2022) [a]	F, 18-40 y	112	Recreational= 69 Competitive= 34 Professional= 9	LEAF-Q	53 Recreational: 45 Competitive: 65 Professional: 67

Abbreviation: F= females, y= age in years, n=number of participants, LEAF-Q= Low Energy Availability in Female Questionnaire, %= percentage.

[a] Participants in the study included from both team and individual sports. Examples of team sports include football, hockey, rugby, netball, volleyball, cricket, and softball. And in the category of individual sports, there are gymnastics, boxing, swimming, cycling, powerlifting, running, cycling, Olympic weightlifting, etc.

2.10. KNOWLEDGE GAPS

The detrimental effects of RED-S on numerous biological functions emphasise how crucial it is to avoid LEA. Increasing education and awareness among all athletes, coaches, support personnel, and sports federations is essential (Mountjoy et al., 2018). Although early screening and LEA education have been implemented in sports organisations (Mountjoy et al., 2018), there are some important knowledge gaps that need to be addressed. Despite knowing that menstrual irregularities are associated with low BMD, research indicated that 33% of exercising women believed irregular menstrual cycle were normal among active women (Miller et al., 2012). According to numerous studies, less than 50% of the support team, which includes coaches, sports instructors, doctors, and physiotherapists, can identify the Triad components (Brown et al., 2014; Curry et al., 2015; Feldmann et al., 2011; Kroshus et al., 2015; Kroshus et al., 2014; Pantano, 2006; Troy et al., 2006). Recent research Lodge et al. (2021) found female cross-country runners had the lowest knowledge, confidence, and educational impact score (scores comparing those with and without education) on the Triad and RED-S while athletic trainers had the best scores (Lodge et al., 2022). These finding support the necessity for education. Additionally, Mountjoy et al. (2018) discovered that just 7% (i.e., 2 out 28) of the observed Olympic federations had education initiatives on RED-S (Mountjoy et al., 2018a). To reduce the risk of RED-S, athletes, coaches, and healthcare support staff should be engaged in the education programmes on LEA (Becker et al., 2012).

Although increasing nutrition knowledge is a crucial step, it does not alone result in behaviour change (Worsley, 2002; Zinn et al., 2005; Heaney et al., 2011; Spronk et al., 2015; Teo et al.,2023). It is important to recognise that the association between knowledge of nutrition and dietary behaviour is influenced by various factors. For example, the translation of knowledge into behaviour can be influenced by factors such as socioeconomic status (Owen et al., 2000), cultural background, and age (Spronk et al., 2014). The association can also be influenced by factors such as self-efficacy, motivation, and environmental facilitators or barriers (Sterdt et al.,2014; Carddock et al., 2016; Martins et al., 2021). The behaviour of individuals can also be influenced by their beliefs, values, and attitudes towards food and nutrition (Birkenhead et al., 2015; Manore et al., 2017). In conclusion, effective education interventions should go beyond the provision of knowledge and address the multifaceted nature of behaviour change. This requires an understanding of the complex interaction between individual, social, and environmental factors. However, understanding athletes' baseline knowledge levels can help targeted interventions to address their specific needs and promote positive dietary practices (Abood et al., 2004; Patton-Lopez et al., 2018; Heikkilä et al.,2019; Sánchez-Díaz et al., 2020; Solly et al., 2023).

2.11. SCREENING

Identification of athletes at risk for LEA is crucial from a short- and long-term health perspective, as well as for maintaining or improving sports performance (Mountjoy et al., 2014; Nattiv et al., 2007). There is currently no consensus on the best tool to screen for LEA. Many tools were solely intended for men or women and do not focus on college athletes or team sports. However, most research that aims to assess athletes at risk for LEA use one of three tools. These include the RED-S clinical assessment tool (RED-S CAT) (Mountjoy et al., 2015), LEAF-Q (Melin et al., 2014), and the Female Athlete Screening Tool (FAST) (McNulty et al., 2001). Other tools, such as the eating disorder examination questionnaire (EDE-Q) (Mond et al., 2004) and Brief Eating Disorder in Athlete's Questionnaire (BEDA-Q) (Martinsen et al., 2014) are also sometimes used individually or in conjunction with another screening measures (Sim & Burns, 2021).

2.11.1. The Low Energy Availability in Females Questionnaire (LEAF-Q)

The LEAF-Q was created by Melin et al. (2014) as a screening method based on self-reported physiological symptoms to identify females who were more likely to develop the Triad (Melin et al., 2014). The survey was created using information from women who worked out five or more days per week and were between the ages of 18 and 39 years. The initial study included 29 total items and focused on the symptoms of LEA that are most often experienced, including dizziness, injury, cold sensitivity, GI function, and menstrual function, along with the use of oral contraceptives. To account for test-retest reliability, the survey was then repeated a second time within a two-week period. After a two-week gap between tests, it was found that the test-retest reliability was 0.79. To confirm the symptoms that survey respondents had self-reported, 47 participants volunteered for further testing. In this research, energy availability and exercise energy expenditure were examined using 7-day food diaries and laboratory based maximal treadmill tests, respectively. Accelerometer and heart rate monitor data were also collected during this time. To determine if an ED or DE behaviour was present, the Eating Disorder Inventory and Eating Disorder Examination were employed. Reproductive function was assessed by a gynaecological exam. DXA was used to measure fat-free mass and fat bone mass). After a supine to standing blood pressure assessment, blood was collected to measure the blood hormone concentrations. According to the results of the physiological studies, the LEAF-Q has a sensitivity of 83% and a specificity of 90% to correctly detect females with LEA and/or reproductive function and/or bone health (Melin et al., 2014). This confirmed the questionnaire offers an inexpensive, useful, and effective technique to assess the availability of energy without tests or quantitative measures.

Recently, the LEAF-Q was used among team sports to determine which of its players exhibited Triad/RED-S risk factors (Łuszczki et al., 2021). The author investigated 34 female players between the ages of 13 and 18 years, who played football for at least two years, trained three days/week, and currently participated in one game/week. Indirect calorimetry was used to determine REE, BMD and body composition were measured using DXA, and a 24-hour diet recall was used to assess energy consumption. Of the athletes, 64.7% were recognised as being at risk for the triad and RED-S based on LEAF-Q (Łuszczki et al., 2021). Additionally, it was discovered that 76.5% of the athletes did not reach their energy requirements, and those who did not satisfy the requirements had a tenfold increased chance of developing Triad and RED-S compared to those who did. There was no statistically significant difference in REE between the at-risk and not at risk of LEA. The author's state that physiological developmental changes take time to appear, and the mean age was 15.41 years, the significant changes in BMD, BMI, and REE reported in athletes with RED-S may not have occurred yet. The substantial number of athletes who were classified as ‘at-risk’ by the LEAF-Q, however, implies that LEA was a common problem among the participants (Łuszczki et al., 2021). Additionally, the study findings indicate that LEAF-Q is good tool to identify LEA in team sports.

2.11.2. Female Athlete Screening Tool (FAST)

The FAST, which can detect subclinical ED in female athletes, has been validated (Knapp et al., 2014; McNulty et al., 2001). The 33-question FAST questionnaire was validated by three groups of female college athletes and non-athletes. The three cross- sectional groups were: female athletes with ED; female athletes without eating pathology; college women who did not engage in sports but had eating disorder. In comparison to athletes without ED and non-athletes with ED, athletes with ED scored considerably higher on the FAST ($p<0.001$). It shows that FAST could distinguish between people who engage in pathological eating behaviours and those who do not, whether they are athletes or not (McNulty et al., 2001). The reliability analysis showed that it has a high degree of internal consistency (Cronbach's alpha =.87). Both the Eating Disorder Inventory (EDI; r =0.89) and the Eating Disorder Examination-Questionnaire (EDE-Q; r =0.60) exhibited a positive correlation with the FAST. FAST, however, was not a good indicator other the aspects of the Triad such as menstrual and bone health. This tool may be helpful as a rapid and inexpensive diagnostic tool for evaluating EDs. This is crucial given athletes' recovery from the triad depends on early detection and rapid treatment (Hinken, 2018).

2.11.3. Brief Eating Disorders in Athletes Questionnaire (BEDA-Q)

Elite female adolescent athletes filled out the BEDA-Q questionnaire (Martinsen et al., 2014). The questionnaire was constructed in two different forms, one with seven questions (sensitivity: 85.7%; specificity: 78.8%), and the other with nine questions (sensitivity: 82.1%; specificity: 84.6%). The capacity to identify between female athletes with and without ED was shown in both surveys. However, version 2 of the BEDA-Q, which comprises nine questions, has a diagnostic predictive accuracy of 0.86 (95% confidence interval (CI), 0.78-0.93) compared to version 1 with a value of 0.83 (95% CI, 0.74-0.92) (Martinsen et al., 2014). However, BEDA-Q was validated exclusively among elite athletes, and it is unclear if this can be used among other athletic groups. It is also unknown if the interviewers for the Eating Disorder Examination (EDE) were screened, and it doesn't appear that logistic regression was carried out for each of the health history and Eating Disorder Inventory (EDI-2) items, both of which are crucial for obtaining reliable results and useful for clinical implications (Knapp et al., 2014).

2.11.4. RED-S clinical assessment tool (RED-S CAT)

The RED-S clinical assessment tool is designed to help medical experts analyse athletes (both genders) with RED-S. The risk assessment chart divides risk into three categories using a traffic light metaphor). The tool also includes a sample RED-S treatment contract and a return-to-play evaluation (Mountjoy et al., 2015). Red indicates high risk, no play or practice, and the participant should sign a written contract for treatment and recovery. Eating disorders, psychological and physical illnesses, bradycardia, and adoption of extreme weight reduction methods are examples of symptoms in the red group. Yellow indicates a moderate risk level After receiving a medical clearance, the athlete may train and compete if they are adhering to the treatment plan. Inhibited growth or development, prolonged LEA, irregular menstruation (>3 months), poor BMD, or stress fractures associated to hormonal abnormalities or LEA are all indications of intermediate risk; 5% to 10% weight loss in a month is also a warning sign. The athlete may participate fully in all aspects of the sport if they fall into the green group. Athletes in the green group maintain a suitable body by wholesome eating and exercise routines, adequate EA, and are in good physical and mental health (Karpinski & Rosenbloom, 2017). By providing nutritional therapy and rehabilitation and using counselling and coaching approaches throughout the nutrition care process, dietitians and nutritionists are in a position to help patients and athletes throughout return to play (Karpinski & Rosenbloom, 2017).

Although both male and female individuals can use the RED-S CAT, additional validation is required (Sim & Burns, 2021). It is known that LEA and RED-S affect several physical processes, including but not limited to the criteria's assessed in this tool, such as low body fat, irregular menstruation, recurrent illness and injury, and psychological characteristics (Mountjoy et al., 2018b), making the RED-S CAT difficult to represent as an efficient screening tool. Thus RED-S CAT may be the standard assessment tool for athletes at overall risk, while LEAF-Q is likely the best indicator of sign and symptoms of LEA in female athletes and indicate athletes' risk of developing RED-S.

2.12. KNOWLEDGE ON LEA AMONG ATHLETES AND HEALTHCARE PROFESSIONALS

The concept of nutrition knowledge can be explained as having an awareness of practices and concepts of nutrition, diet, and health (Miller & Cassady, 2015; Quaidoo et al., 2018). One of the fundamental components of health literacy that affects dietary intake, the onset of chronic diseases, and related health costs is the capacity to understand the impact of diet choices on one's health (Spronk et al., 2014). Knowledge of sports nutrition can be thought of as the basis for understanding dietary strategies to enhance and optimise athletic performance (Jagim et al., 2021). Thus, nutrition knowledge is a modifiable determinant of dietary behaviour (Birkenhead & Slater, 2015) However, it is important to keep in mind that despite athletes having some understanding of the nutritional needs for sports performance, athletes' dietary knowledge does not always translate into dietary habits that consistently applied to best practises (Jagim et al. (2021), Magee et al. (2021).

Athletes need to have some understanding of nutrition to know the significance of daily dietary preferences and subsequently food consumption for sports performance, recovery, and overall wellbeing (Birkenhead & Slater, 2015; Torres-McGehee et al., 2012). Unfortunately, there is often a lack of knowledge among athletes and their coaches (Grete R et al., 2011; Hoogenboom et al., 2009; Spendlove et al., 2012; Torres-McGehee et al., 2012). This in turn can hinder the full performance potential of athletes.

Most athletes recognise that optimal nutrition is an important and integral part of training and performance (Rosenbloom et al., 2002). Some athletes, however, remain poorly informed on good dietary habits and do not always have the knowledge and skills to make effective everyday food choices (Grete R et al., 2011). The nutritional practices identified in some endurance female athletes indicate deficiencies in calorie, vitamin, and mineral intake (Hoogenboom et al., 2009; Rosenbloom et al., 2002). The majority of research indicates that the nutritional quality of food choices improves as athletes' knowledge increases (Martinsen et al., 2014). Thus, there exists a link between nutrition knowledge and positive outcomes. For example, better nutrition knowledge was associated with a positive attitude toward dietary restraint among athletes (Bond et al., 2001). In addition, athletes with a greater knowledge of nutrition were more likely to consume fruits, vegetables, and carbohydrate-rich foods than those with poor nutritional understanding (Alaunyte et al., 2015). Moreover, studies have argued that nutritional knowledge is closely linked to healthy eating and better food choices, independent of demographic variables (Wardle et al., 2000).

Table 2.4: *General/Sports specific nutritional Knowledge Score assessed using different questionnaires in athlete populations.*

Reference	N (gender)	Sport, Type	Age (y) ± SD	Tool design	No. of items, question type	Validation	Reliability	Scores[a] (%)	Findings
(Rosenbloom et al., 2002)	91 (F), 237 (M)	Mixed sports, mixed levels	19 ± 1.3 (F) 19 ± 2.7 (M)	Self-developed questionnaire by the author	19 Multiple Choice, General Nutrition, Sports Specific	Pre-tested, content validated by panel including dietitian	Not reported	31	Athletes have misconceptions about the role of nutrients in sports performance, resulting in early fatigue and declines in performance.
(Zawila et al., 2003)	60 (F)	Collegiate runners	19.8 ± 1.04	Modified Questionnaire (Barr, 1986; Werblow et al., 1978)	76 Likert scale, True/False, 7 open ended questions.	Construct validity for the questionnaire by (Barr, 1986), additional questions by research committee, university faculty members, physician.	r=0.82	35	Lack essential knowledge to prevent nutrition-related health issues. However, those with nutrition education scored significantly higher.
(Rash et al., 2008)	52 (F), 61 (M)	Track Athletes	19.3 ± 1.2 (M), 19.1 ± 1.1 (F)	Existing questionnaire by (Jonnalagadda et al., 2001; Zawila et al., 2003)	True/False, General Nutrition, Sports specific.	Pre-tested, content validated by a panel including dietitians	Not reported	59 (M), 58 (F)	80% of athletes thought vegetarian athletes required protein supplements; 40% thought that the body depends on protein for immediate energy.
(Hoogenboom et al., 2009)	85 (F)	collegiate swimmers,	19.26 1.16	Modified questionnaire from (Zawila et al., 2003) and modified to its current form by (Bailey, 2004).	76 True/ False	Face validity and construct validity for the survey was conducted.	Not reported	55	Athletes lacked knowledge of nutrition, healthy eating, a balanced diet, and its effects on performance.
(Raymond-Barker et al., 2007)	91 (F)	endurance athlete (i.e., runner, cyclist) or gymnast	>18	Existing GNKQ by Parmenter & Wardle, 2000.	110 Yes/No, Multiple Choice, in 4 sections	GNKQ: Good construct validity by nutrition vs computer expert (p<0.001). content validity by physician,	Test-retest reliability > 0.7 Internal reliability A:(r=.893)	78	The absence of difference in nutrition knowledge between athletes who are at risk and those who are not implies that lack of

						gynaecologist, sports dietician and physiologist.	C: (r=.887)		knowledge is not to account for the restrictive eating patterns linked to the Triad.
(Spendlove et al., 2012)	99 (F) 76 (M)	elite Australian athletes	18·9 ± 4·9	Modified GNKQ (Hamilton et al., 1994; Parmenter & Wardle, 2000) to develop R-GNKQ	Multiple choice, yes/no or agree/ disagree items, open ended questions.	Content validity by Dietitians and nutrition scientists. Dietitians scored higher than Athletes and Community in all sub-sections and overall (p<0·005)	test–retest reliability (r= 0.94)	59	The level of nutrition knowledge among athletes was high for dietary recommendations but low for the relationship between diet and illness, including understanding the sources of nutrients in food and making food choices.
(Buffington et al., 2016)	153 (F)	Mixed sports, mixed levels	18-27 (SD NR)	Self-developed Energy balance knowledge test	30 Multiple choices, True/False	Validated as a pilot research project where 20 female athletes scored 62%.	Not reported	60	After a 10-week intervention on education on energy balancing and the development of cognitive-behavioural abilities, athletes showed improvements in their health, lifestyle choices, and performance
(Trakman et al., 2017)	181 (F)	Australian football athletes and netball club.	>17	Modified NSKQ (Trakman et al., 2017) to develop 37 items A-NSKQ.	Likert scale: 17 GNK; 20 SNK.	Good construct validity was demonstrated (GNK: 77% vs 60 % & SNK: 60% VS 40% in nutrition vs non-nutrition P < 0.001, respectively)	Test-retest reliability (r = 0.8, P < 0.001 [GNKl] and r = 0.7, P < 0.001 [SNK]).	47	NK scores on the A-NSKQ (46%) are comparable to NSKQ results (49%).

(Karpinski et al., 2019)	202 (F)	Collegiate, competitive and non-competitive athletes	26.3 ± 11.2	Self-developed SNK questionnaire by the author	49 (49-SNKI) Y/N/don't know	Content and construct validity (38.5 ± 5.3 versus 15.9 ± 9.2; P <.001), internal consistency (0.843)	reliability (*r* = 0.951; *P* < .001)	55	Knowledge questions on fat (61%) and hydration (58%) were the most accurately answered.
Heikkila et al. (2018)	156 (M) 156 (F) 94 (C)	Endurance athletes, high school and their coaches	17.9±1.2	Existing questionnaire Heikkilä et al. (2018)	true/false	Construct validity: Nutrition students scored significantly higher knowledge scores than humanities students (p <0 .001)	All knowledge sections had 0.85 test-retest reliability between those groups.	73 (M & F) 81 (C)	Athletes scored lower on "dietary supplements" and "nutrition guidelines " subcategories, whereas the coaches had greater nutrition knowledge in all five subcategories (p <0.001).
(Heikkilä et al., 2019)	35 (F), 44 (M)	Biathlon, orienteering, endurance running, race-walking, triathlon	18 (SD NR)	Existing questionnaire Heikkilä et al. (2018)	true/false	Construct validity: Nutrition students scored significantly higher knowledge scores than humanities students (p < 0.001)	All knowledge sections had 0.85 test-retest reliability between those groups.	78	Education intervention group scored 78% (week 0), 85% (week 5), and 84% (week 17) on nutrition knowledge.
(Condo et al., 2019)	30 (F)	Football League players	24.15 ±4.1	Existing SNKQ by Zinn et al. (2005)	88 Likert scale	Content & construct validity: Sports dietitians, group of academics & nutrition students (p<0.001)	Test-retest Reliability (r=0.74–0.93), aside from the fluid sub-category (r=0.52)	55	Knowledge on supplements section received the lowest scores (18%)

(Challis et al., 2020)	5 (M) 30 (F)	Professional dancers	21.5 ± 2.7	SNKQ from Zinn et al. (2005).	True/false	Content & construct validity: Sports dietitians, group of academics & nutrition students ($p<0.001$)	Not reported	47	Body composition and nutrition knowledge was negatively correlated ($r = -.663$, $p <0.001$).

Abbreviation: % =percentage, A-NSKQ= Abridge Nutrition for Sports Knowledge Questionnaire, EAT-26= Eating attitude Test-26 items, F= Female, GNK=General Nutrition Knowledge, GNKQ= General Nutrition Knowledge Questionnaire, ICC= intra-class correlation, M=Male, Mixed sports = individual and team sports athletes, Mixed level= athletes in recreational, competitive, and/or professional level, N=Number of participants, NSKQ=Nutrition for Sports Knowledge Questionnaire, NZ= New Zealand, PCC= Pearson's correlation coefficient, R-NKQ= Revised General Nutrition Knowledge Questionnaire, SD= Standard deviation, SN=Sports Nutritionists, SNK=Sports Nutrition Knowledge, y= age in years.

[a] Score= The value represents the participants' average percentage score, which was determined by dividing the number of right answers by the total number of possible responses.

2.12.1. General and sports Nutrition Knowledge

To study the nutrition knowledge of recreational and elite female athletes, and coaches, a search was conducted across databases from February to September 2020 using terms including 'nutrition knowledge' or 'nutrition assessment' or 'knowledge assessment') and ('athlete' or 'sport') and ('questionnaire' or 'tool' or 'instrument') to assess the general and sports nutrition knowledge among athletes and their support staffs. This search indicated that general and/or sports specific nutrition knowledge was poor to average, with mean scores of approximately 31%–77% (Table 2.4).

Studies showed that athletes have some understanding in terms of how to lose weight safely and effectively. For instance, 100% swimmers believed that skipping meals was not a suitable method of weight loss (Hoogenboom et al., 2009) and 75% of college athletes were aware that eating carbohydrates did not "make them fat" (Rosenbloom et al., 2002). Additionally, according to Harrison et al. (1991), 84% of elite athletes and 63% of non-elite athletes disagreed to the true statement which stated, "you may lose weight by limiting your intake" (Harrison et al., 1991).

While some studies have shown that athletes have some understanding of nutrition (Harrison et al., 1991; Hoogenboom et al., 2009; Rosenbloom et al., 2002), many more have found that this is not the case. Previous research has shown that most athletes are unable to accurately assess the importance of certain nutrients or the suggested proportions of macronutrient towards energy intake. According to one survey, just 22% of collegiate swimmers, 28% of athletes, and 18% of coaches knew that protein and carbohydrates supplied the same amount of energy per gram (Collison, 1996; Corley et al., 1990; Hoogenboom et al., 2009). Additionally, 46% and 40% of collegiate athletes believed that protein was an excellent source of "immediate" energy or that protein was a source of fuel for the muscles, respectively (Rosenbloom et al., 2002). Only 42% of professional athletes properly responded to questions on the sources of saturated and unsaturated fat (Hamilton et al., 1994). Similarly, over 60% of female athletes believed that the daily need for calcium could be satisfied by only two glasses of milk (Zawila et al., 2003). Furthermore, athletes often hold the misconceptions that vitamin and mineral supplements provide energy and that vegetarian athletes cannot perform as well as non-vegetarian athletes (Condo et al., 2019; Rash et al., 2008; Rosenbloom et al., 2002; Zawila et al., 2003).

When dietary intake was measured using food-group portions or sport-specific dietary practise questionnaires, two studies found a positive association between nutrition knowledge and intake (Hamilton et al., 1994; Harrison et al., 1991). Other studies have shown significant, positive, but weak associations between knowledge of nutrition and some dietary components, with higher intakes of fruits and vegetables being the most frequently reported (Alaunyte et al., 2015; Condo et al., 2019; Day et al., 2014; Rash et al., 2008). Thus, better understanding of nutritional requirements may benefit athletes and their performance. However, more research is needed to understand the current general and sports nutrition knowledge among athletes.

Most studies showed no significant differences in nutrition knowledge scores between sport type or between team or individual athletes (Condon, Duke, & Herbold, 2007; Nichols et al., 2005; Spendlove et al., 2012; Heydenreich et al., 2014; Heikkilä et al., 2019; Saribay & Kirbas, 2019). However, a few studies have indicated that athletes who compete in endurance sports have a greater understanding of nutrition than athletes who compete in team sports (Magee et al., 2017; Nazni & Vimala, 2010). Weeden et al. (2014) also found that individual sports participants scored significantly higher than team sports participants (85% vs. 72%, respectively). Due to the different physical demands of team sports and individual sports, it is still unclear whether there is a difference in knowledge between athletes who participate in each type of sport. The accuracy of nutrition knowledge research is also compromised by studies using a variation of questionnaires, the frequent use of non-validated questionnaires, and other factors like variations in participant literacy, socioeconomic status, and education (Axelson & Brinberg, 1992; Spronk et al., 2014; Trakman et al., 2016). Therefore, more research is needed to understand whether the type of sport and its associated training and education programmes influence nutrition knowledge.

Despite these problems, exploring nutritional knowledge as a potential strategy for enhancing individual’s food quality may be crucial (Axelson & Brinberg, 1992; Spronk et al., 2014). The same rationale holds true for sports nutrition knowledge, a modifiable factor that affects food choices. Given many athletes do not adhere to sports nutrition recommendations (Jenner et al., 2021; Jenner et al., 2020; Tam et al., 2019), influencing dietary habits has the potential to enhance their athletic performance (Trakman et al., 2016). Overall, the literature emphasises that improving nutrition knowledge among athletes may improve dietary intakes and potentially performance.

2.13. KNOWLEDGE SCREENING TOOLS

To assess athletes' nutritional knowledge, a variety of questionnaires have been developed. To promote better food choices and increase appropriate nutritional knowledge, it is crucial to use a valid and reliable technique for assessing general and sport nutritional knowledge in an athletic population. Questionnaires testing female athletes' and coaches' general or sports nutrition knowledge are described below.

2.13.1. General Nutritional Knowledge Questionnaire (GNKQ)

This questionnaire is divided into four sections: i) nutritional guidelines; ii) food and nutrient sources; iii) everyday food choices; and iv) relationships between nutrition and disease. Additionally, it inquiries about respondents' degree in nutrition or other similar topics (Parmenter & Wardle, 2000). There is a total of 110 Yes/No and multiple-choice questions in the survey. Each piece of information is worth one point when the response is correct. The GNKQ has been well validated and used to assess general nutrition knowledge in athletes from the UK, USA, and Australia (Hendrie et al., 2008; Raymond-Barker et al., 2007). When given to groups with diverse levels of nutritional knowledge, the questionnaire produced significantly different results (construct validity), demonstrating that it was effective in assessing a continuum of nutritional knowledge. Additionally, internal consistency was good (Cronbach's alpha = 0.70-0.97) and the test-retest reliability was greater than the required threshold of 0.7 (Parmenter & Wardle, 2000). With the assistance of dietitians and nutritionists, Spendlove et al. (2012) re-examined the GNKQ for content validity (n=53), who reviewed each item of the GNKQ using a specially designed evaluation form that asked for feedback on whether the item should be kept, changed, or eliminated as well as an optional open-ended answer, which led to a modification of the questionnaire (R-GNKQ; 96 items) (Spendlove et al., 2012). The GNKQ and R-GNKQ both had strong test-retest correlation values for general nutritional knowledge ($r=0.92$, $p<0.001$), demonstrating robust instrument reliability. Due to the content validity by expert panel that the R-GNKQ underwent, which was not done for the GNKQ, it proved to be more effective at detecting knowledge. Additionally, R-GNKQ assessing known potential confounders of nutrition knowledge, such as living circumstances, amount of physical activity, and ethnicity.

2.13.2. Sports Nutrition Knowledge Questionnaire

This survey was designed to assess knowledge and perceptions amongst coaches, athletic trainers, and strength and conditioning specialists (SCSs) (Torres-McGehee et al., 2012). A 10-

point Likert scale (1 = not at all, 5 = well, 10 = extremely well) was used to evaluate answers to questions about nutrition programmes participated, nutritional resources, perceived nutritional knowledge and habits, and their top three nutritional information choices and top three recommended athlete resources. Twenty multiple-choice questions on knowledge of sports nutrition were included in the survey. Four categories were used to group the questions, including hydration, weight management and ED, supplements and performance, and micronutrients and macronutrients. Following each question, participants were invited to indicate their degree of confidence in the accuracy of their responses by picking it from a 4-point Likert scale (1= being not at all confident; 4 = being extremely confident). Confidence ratings were assigned to survey questions after they had been scored, and they were then split into two categories: confidence scores for the right and wrong answers. Twelve professionals who closely worked with athletes: sports dietitians (n = 2), athletic training (n = 5), exercise physiology (n = 2), SCSs (n = 2), and sports medicine (physician = 1) were involved in developing construct validity. Additionally, a pilot study was conducted on athletes, coaches, athletic trainers and SCSs. The expert's recommendations and participant input were considered, and the necessary modifications were implemented. This questionnaire on sports nutrition knowledge has been a useful instrument for evaluating knowledge in coaches and trainers. However, it has the drawback that it takes relatively longer to complete than other questionnaires since each question requires respondents to rank their level of confidence (Torres-McGehee et al., 2012).

2.13.3. General and Sport nutrition Knowledge (GeSNK)

The development of this questionnaire was divided into six stages: (1) item creation and selection of experts; (2) item analysis and item discrimination; (3) internal accuracy measurement; (4) reliability evaluation with a 2-week test-retest analysis; (5) simultaneous validity testing with two similar tools; and (6) validity (Calella et al., 2017). There were 62 questions on the GeSNK, with 29 items on general nutrition, while 33 items addressed on nutrition and sports. Some questions could be responded as True, False, or I don't know. The first eight questions ask about the major macro- and micronutrient components of specific foods and had three possible answers: High, Low, or Absent. The reliability for the GeNSK on General Nutrition section was 0.82, the reliability for the GeNSK on Nutrition and Sport was 0.83, and the overall reliability was 0.85. Dietetics, Nutrition, and Movement Science groups consistently outperformed the Economics group on both portions of the GeSNK, which was used to evaluate the construct validity ($p < 0.001$). As a result, GeSNK was shown to be a reliable, valid, and efficient questionnaire, making it a tool that has promise for examining the connection between nutritional awareness, demographic factors, and dietary behaviour in adolescents and young adults. It may also be used to examine the connections between nutrition knowledge and participation in sports, as well as the differences in nutrition knowledge across different sports and levels of competition (Calella et al., 2017).

2.13.4. The Nutrition Knowledge Questionnaire for Athletes (NKQA)

This questionnaire by Furber et al. (2017) was psychometrically validated and shown to have high reliability. The NKQA was developed using track and field athletes' knowledge related to sport nutrition. It covers a wide range of general and sports nutrition topics with 62 questions. The outcomes suggest face and construct validity through the development of the question pool, content validity (the nutrition educated group scored 30% higher than the non-nutrition educated group), reliability (test-retest correlation of 0.98, $p<0.05$), and internal consistency (Chronbach's alpha > 0.7). A pilot test was conducted on track and field athletes ($n = 59$) who completed the validated questionnaire. The entire questionnaire resulted in considerably higher scores for the nutrition educated group than the non-nutrition educated group (80.4 vs. 49.6%); these significant differences in the two groups' scores indicates good content validity ($p<0.05$). Additionally, the correlation between test-retest ($r=0.98$, $p<0.05$) shows acceptable internal reliability. Each sub-internal section's consistency was good (α = 0.78–0.92). Thus, questionnaire satisfied all psychometric requirements and provided an accurate, and objective way to assess track and field athletes' general and sports nutrition knowledge (Furber et al., 2017).

2.13.5. A 49-Item Sports Nutrition Knowledge Instrument (49-SNKI)

Created in 2019, this recent instrument is designed for adult athletes. The outcomes of the pilot instrument assessment were used to create a final questionnaire with 49 items. A total score was calculated to measure nutrition knowledge, with a potential range of overall scores from -49 to 49 (right answers earned 1-point, wrong answers earned -1 point, and 'Don't Know' responses received 0 points). Additionally, the scores for each of the six issue categories (carbohydrates, protein, fat, hydration, energy balance/weight control, and micronutrients) provided individual segment scores. Internal consistency (0.843), reliability ($r = 0.951$; $p<0.001$), and construct validity (mean total score for licenced dietitians compared to athletes 38.5 ±5.3 vs. 15.9 ±9.2; $p<0.001$) were all evaluated (Karpinski et al., 2019). Thus, the 49-SNKI has good face validity, content validity, internal consistency, reliability for test-retests, and (construct) criteria validity.

2.13.6. Nutrition for Sport Knowledge Questionnaire (NSKQ)

Created by Trakman et al. (2017), the NSKQ, which included 89 questions across six sub-sections of nutrition (weight management, macronutrients, micronutrients, vitamins, sports nutrition, and alcohol), was based on current recommendations for sports nutrition (Kreider et al., 2010; Potgieter, 2013). It was further developed in collaboration with a group of dietitians and was validated using an approach that included both Rasch analysis and the Classical Test Theory (CTT) (Parmenter & Wardle, 2000). To the author's knowledge, no other sports nutrition questionnaire has undergone Rasch analysis. Although the goal of Rasch analysis is to create a unidimensional questionnaire, different sections will measure different concepts in measuring nutrition knowledge, so each subsection should be unidimensional while the entire questionnaire will be multidimensional. All subsections for internal and test- retest reliability achieved or approached adequate values. However, this questionnaire was considered to have flaws due to poor response and completion rates, which were found in research among Australian footballers (Jenner et al., 2021). This was partly due to the NSKQ's average completion time of 25 minutes. According to several studies, a questionnaire should be completed in 13 minutes or less to get the most responses (Calella et al., 2017). The NSKQ was re-evaluated in response to the low completion rates with the goal of developing a more effective and efficient instrument, which resulted in the development of the Abridged Nutrition for Sport Knowledge Questionnaire (A-NSKQ) (Trakman et al., 2018).

The A-NSKQ is a multidimensional instrument containing two sub-sections (general nutrition knowledge and sports nutrition knowledge) with a total of 35 questions, which takes approximately 12 minutes to complete (Trakman et al., 2018). The general knowledge section covered knowledge of nutrients and energy density. The sports nutrition section covered hydration, supplements, and nutrient requirements in the 35-item A-NSKQ. Additionally, the questionnaire demonstrates excellent test-retest reliability ($r = 0.7–0.8$), and participant scores correlate strongly with the complete NSKQ ($r = 0.9$). The A-NSKQ has been verified against the Rasch model (Trakman et al., 2018).

Furthermore, the A-NSKQ has been considered a reliable assessment tool in several studies examining the nutrition knowledge of athletes (Jagim et al., 2021; Magee et al., 2020; Mitchell et al., 2022; Renard et al., 2021). In team sports, studies using A-NSKQ have reported mean scores between 40-50%, indicating poor nutrition knowledge. Football Division III female student-athletes reported an average score of 44.7% (n=18) (Magee et al., 2020). Similarly, Division III male and female student-athletes (n=67) received a mean score of

47.9±11.3% (Jagim et al., 2021). Additionally, a recent study used the A-NSKQ to test knowledge and found that individual-sport athletes scored higher (47 ± 12% vs. 40 ± 13%, p = .001), than team-sport athletes (Szczepańska. et al., 2021). Overall, the A-NSKQ appears to be a valid and reliable tool for assessing knowledge among athletes participating in various sports.

2.14. THE TRIAD/RED-S KNOWLEDGE AMONG ATHLETES AND HEALTHCARE PROFESSIONALS

As discussed in previous sections, the Triad/RED-S is becoming increasingly recognised as being harmful to the health and overall performance of female athletes. Despite this, few studies have investigated knowledge of RED-S/the triad among coaches and athletes (Lodge et al., 2022). Some of the methods used to evaluate the knowledge of athletes include questioning participants about their perceptions of knowledge, with few questions about the syndrome, or concentrating on one of the components (LEA, menstrual dysfunction, or low BMD) or aspects of the syndrome (effects, signs, or recognition) (Frideres et al., 2015). Studies which have evaluated knowledge of nutrition and the Triad/RED-S among coaches, and athletes in mixed sports over a range of competitive levels ranged from low to average, with mean scores of around 32% to 64% (Table 2.5).

Although 64% of the 91 coaches reported they had heard of the "female athlete triad," only 43% (n=25) of them were able to name its three components (Pantano, 2006). Additionally, this study showed that 24% of coaches believed menstruation abnormalities were normal among active women. In a study by Miller et al. (2012) only 10% of the 180 female athletes could identify all three components of the triad (Miller et al., 2012). Additionally, only 54% were aware of the connection between amenorrhea and LEA. Furthermore, only 54% of respondents were aware that menstruation dysfunction raises the chance of having weak bones (Miller et al., 2012). This study's findings also showed that 35% of female athletes believed that irregular periods were normal among physically active women without knowing it is an alarming sign of developing the triad (Miller et al., 2012). These findings showed that a high percentage of women who exercise have a lack of understanding about the relationship between the three components of the triad.

Likewise, most female athletes and their coaches received a mean score of approximately 30-35% on correctly identifying all components of triad and its health effects (Brown et al., 2014; Day et al., 2017; Tabone, 2013). Additionally, a recent study among athletes who were at risk of the Triad, 65.2% said they were concerned about their weight and 59.4% said they were restricting their dietary intake, 42% expressed dissatisfaction with their looks. Of the at-risk individuals, 42% responded "no" when asked whether missing your period was harmful (Day et al., 2017). Thus, the literature indicates that athletes, coaches and supporting staff have limited understanding and awareness of all the components of the triad and its effect on health and performance.

Limited research has examined athletes' and healthcare professionals' knowledge and awareness of RED-S since it is a relatively new topic. About 33% of athletic trainers had heard of the RED-S concept, compared to 98.6% who had heard of the Triad (Kroshus et al., 2018). However, more research is needed to evaluate the knowledge of RED-S among athletes.

Lack of mandatory guidelines for screening, prevention, and education of the triad/RED-S is problematic (Mountjoy et al., 2014). Regular seminars and workshops regarding energy availability and nutrition for enhancing health and performance should be offered to athletes and coaches, and they should include a section that discusses the health effect of the triad/RED-S (Mountjoy et al., 2018). Coaches claim to have seen the triad risk indicators, but they had little awareness of the adverse health consequences (Brown et al., 2014; Javed et al., 2013). Javed et al. (2013) highlighted several knowledge gaps among doctors, physical therapists, coaches, and trainers. While menstrual function and stress fracture history are likely to be evaluated on physical forms for pre-season physical examinations, awareness of the triad/RED-S and LEA are less likely to be evaluated (Javed et al., 2013). According to Brown et al. (2014), coaches had little awareness of the triad, although most coaches felt comfortable talking to athletes about their periods. According to coaches, their teams received little dietary knowledge and the triad was not addressed.

Overall, previous studies demonstrate that there is insufficient awareness among athletes and coaches regarding knowledge on the triad/RED-S, LEA, and its related short- and long-term health effects. To promote early identification of athletes at risk of LEA, it is vital to also assess the baseline knowledge on LEA and RED-S among athletes and their support team. This assessment can help in the development of nutrition education with targeted interventions.

Table 2.5: *Knowledge of LEA among athletes and healthcare professionals*

Reference	N (gender)	Sport, Type	Age (y)	Tool design	No. of items, question type	Validation	Reliability	Scores[a] (%)	Findings
(Tabone, 2013)	45(F)	Track and Field and Cross-Country	18-22	Self-developed questionnaire from De Souza et al., (2014)	12 Multiple choices, True. False emphasising triad knowledge	Not reported	Not reported	31%	Participants were unable to accurately identify components the Triad, the recommended daily calcium intake, the proportion of female athletes with disordered eating patterns, or the prevalence of amenorrhea.
(Brown et al., 2014)	240 (F) Athletes 10 (C)	Mixed sports, mixed levels and their coaches	14-18	Modified questionnaire from Feldmann et al., (2011); Pantano, (2006) including 3 energy availability questions.	True/False/I don't know	Not reported	Not reported	64% (F), Did not report the score for coaches.	The health effects of the Triad were less known to coaches, although most (9/10) athletes were comfortable discussing menstruation with athletes.
(Day et al., 2015)	25 (F)	Distance runners, sprinters, hurdlers, and jumpers	19.5 ± 1.8	Modified questionnaire from Beals & Hill, (2006); Pantano, (2006)	True/False, 3 questions specific to EA, Sports Specific	Content validity by experts (Beals & Hill, 2006).	Not Reported	64%	Prior to nutrition education, only 8% could identify all three Triad components.
(Day et al., 2017)	99 (F)	Mixed sports, mixed levels	18-29	Self-developed questionnaire by the author	Yes/No	Not reported	Not reported	43%	41.4% reported that it is normal to skip periods, showing that female athletes have misconception about the importance of regular menstruation.
(Kroshus et al., 2018)	285 ATs (M & F)	ATs at all NCAA member	Certified as an AT for 18.31	Self-developed questionnaire	Yes/No/don't know; Open ended	Not reported	Not reported	32.98% had heard of RED-S	On average, participants could correctly identify two components of the Triad.

		institutions	± 9.02 years		Question				
(Krick et al., 2019)	89 (F)	Mixed sports, mixed levels	15.9 ± 1.2	Existing questionnaire from Feldmann et al., (2011) and energy availability-related questions by Brown et al., (2014)	7 Likert scale	Not reported	Not reported	35.7%	Female high school athletes answered <50% of triad knowledge questions correctly.

Abbreviation: %=percentage, ATs = Athletic Trainers, C=Coach, EA= Energy available, F= Female, M=Male, Mixed sports = individual and team sports athletes, Mixed level= athletes in recreational, competitive, and/or professional level, N=Number of participants, NCAA= National Collegiate Athletic Association, RED-S=Relative Energy Deficiency in Sports, y= age in years.

[a] Score = The value represents the participants' average percentage score, which was determined by dividing the number of right answers by the total number of available responses.

2.15. SCREENING TOOL TO ASSESS TRIAD AND RED-S KNOWLEDGE

To the best of the author's knowledge, there is no validated questionnaire for assessing the knowledge of the signs and symptoms associated with RED-S among athletes and healthcare professionals. Most of the existing tool assess the knowledge of the Triad among athletes, coaches, and health care professionals.

A questionnaire was developed by Pantano (2006) containing 36 questions in two parts. This questionnaire aimed to assess the knowledge, perceptions, and behaviours of coaches on the triad. The first part consisted of demographic and general information, and an assessment of the knowledge and perceptions of the coach regarding the triad. The purpose of the second section was to evaluate existing approaches to the Triad's treatment and prevention. A panel of 20 experts received a prototype questionnaire to examine for construct and content validity (90% response rate) (Pantano, 2006). Based on the expert panel's suggestions, changes were made to the survey. Numerous studies have utilised and modified this questionnaire to evaluate athletes and coaches' knowledge of the triad (Brown et al., 2014; Day et al., 2015).

Another commonly used instrument in research is a questionnaire created by Feldmann et al. (2011) that assessed participants' knowledge of and attitudes regarding menstruation health. It has some limitations including that it was designed to assess the knowledge of high school track athletes but was not validated prior to use on these athletes. Given that the questionnaire was administered to high school track athletes, it may not be appropriate to assess attitudes and knowledge about menstruation among older athletes as attitudes and knowledge may change with age.

A cross-sectional survey by Brown et al., (2014) used 34-questions to evaluate the Triad knowledge and self-reported prevalence of Triad risk factors. Three additional questions were added to the questions developed by Pantano et al., (2006) and Feldmann et al. (2011) to measure triad knowledge and awareness. The questionnaire was divided into the following sections: demographics (4 items); triad knowledge (11 items, including 3 on EA); nutrition knowledge (4 items); and triad risk factors, including eating habits (2 items), body image beliefs (3 items), menstrual history (8 items), and stress fracture history (2 items). There was no evidence of further validity and reliability testing of the questionnaire, likely because it was created from a previously validated questionnaire. This questionnaire was completed by 170 female athletes aged 14-18 years from a wide range of sports and their coaches (Brown et al., 2014). Only half (n = 83) of respondents correctly responded to the statement, "Not eating enough might lead me to miss my period". Of the 59 who answered the question on “How much I eat does not affect bone health”, 81% correctly answered. The high correct response indicated the question was easy and did not differentiate knowledge accurately, and so the sentence was changed to “Not eating enough calories could cause me to have brittle bones”. After question revision, 71 (64%) of the 111 participants answered the question correctly. The participants' responses to those questions may have been influenced by their general awareness of calcium and its effect on bones, which may have caused them to focus on the quality of their food rather than their calorie intake. As a result, it's possible that these questions did not accurately reflect participants' understanding of the connection between caloric consumption and menstruation and bone health. The best way to frame the questions for assessing understanding of these links will need more investigation.

Another study by Day et al., (2017) evaluated knowledge and encouraged female athletes who were at risk for the triad to increase their calorie intake by employing text message reminders (Day et al., 2017). A questionnaire with 16 items was used to examine participants' understanding of the Triad, their dietary practises, their attitudes about addressing coaches and trainers about Triad-related topics, their engagement in sports, and their general knowledge of nutrition. However, there was no information on questionnaire development, and measures of accuracy and reliability.

Kroshus et al. (2018) assessed the general knowledge about the Triad and RED-S in athletic trainers. With the answer choices of ‘yes,’ ‘no,’ and ‘I don't know,’ participants indicated whether they had heard of the words the Triad and RED-S. Those who had heard of the Triad were asked to list, in an open-ended response, what they believed to be its three components. Additionally, those who had heard of RED-S were asked to identify the condition's cause, symptoms, performance and health consequences, and risk factors. The accuracy of these replies was determined by whether they correctly identified or defined each of the three conditions: (1) menstruation irregularities; (2) bone density; and (3) DE, nutrition, or energy imbalance. To reflect the revised RED-S conceptualisation, a fourth grouping for responses that particularly mentioned energy imbalance and not DE or nutrition was included. Responses (such as burnout) that did not fit one of these categories were classified as wrong. However, it is unclear if the validity and reliability of the questionnaire was undertaken (Kroshus et al., 2018).

In a recent study, Krick et al. (2019) created a triad knowledge questionnaire with modifications of the questions from Feldmann et al., (2011) and the questions on energy availability from Brown et al., (2014). They used a Likert scale with options from ‘strongly agreeing’ to ‘strongly disagreeing,’ with ‘don't know’. Each statement had two acceptable responses: for a true statement, "strongly agree" and "agree" would both be accepted, while for a false statement, "strongly disagree" and "disagree" would both be accepted. One point was awarded for each correct response, for a total of seven (Krick et al., 2019). This research, like many others in this area, did not discuss the reliability and validity of the items developed.

Therefore, there is a need to develop a valid and reliable tool to assess current knowledge on RED-S in both athletes and health professionals. Such a questionnaire will provide valuable and meaningful information on whether there is a lack of knowledge on RED-S that needs to be addressed by an education intervention.

2.16. SOCIAL MEDIA

Social media usage is rapidly growing among young adults (aged 16 to 30 years) (Pollard et al., 2015). Sites such as Facebook, Instagram, and Twitter allow followers to consume a constant flow of information from family, friends, teammates, sports stars, health professionals, and celebrities. Account holders on social media may upload links, videos, and photos to graphically present their content (McCully et al., 2013). Increased connection, access to information, peer-to-peer support, real-time communication, and cost effectiveness are all significant advantages of using social media for nutrition education, awareness, and preventive programmes (Ventola, 2014). However, these advantages can also prove problematic. For example, account holders may readily and rapidly share information online without checking the authenticity of the provided material (Gallup, 2018). Unlike the circulation of print sources, which often requires publishing companies, editors, and proof- readers, internet information does not require such gatekeepers (Wood, 2016).

Studies have shown that social media is a popular source of information for athletes and physically active individuals (Bourke et al., 2019). In New Zealand, 306 athletes from elite to recreational level were surveyed about their use of social media. Of the 306 athletes surveyed (females (n=180), males (n=126)), 65% reported that they had used social media to gain nutrition information in the last 12 months (Bourke et al., 2019). Female athletes (74%) were more likely than male athletes (51%) to use social media to seek nutrition information. Elite athletes (i.e., 32 out of 87, 37%) were less likely than recreational athletes (i.e., 121 out of 219, 55%) to use social media for nutrition, which may reflect differences in access to sports nutritionists/dietitians. Athletes who reported using social media for nutrition information used it for recipes, restaurant reviews, and weight management (Bourke et al., 2019).

Given the popularity of social media, practitioners have recognised its potential to be used as an educational platform (Callan & Johnston, 2017). For example, sports dietitians reported they see value in using social media to communicate with their athletes. A recent study reported 89% of the 44 sports dietitians surveyed used social media in their practice, of which 97% thought it was beneficial (Dunne et al., 2019). Sports dietitians communicated with athletes via WhatsApp in a variety of settings, contexts, and times of day. These interactions allowed for smaller, more frequent bits of communication. They were considered briefer compared to phone calls, voicemails, and emails. (Dunne et al., 2019).

2.16.1. Instagram

Instagram is a free photo and video sharing app (Instagram, 2019) and has over one billion monthly active users and more than 500 million daily active users (Marocolo et al., 2021). Account holders may make quizzes and surveys, tag followers in public postings, and send private messages (Tulloch, 2014). Instagram users can tag photos and videos with captions, hashtags, location tags, and other Instagram accounts (e.g., #lifestyle, #healthydiet, #fitness, etc. are common hashtags used in captions). When followers tap or click a hashtag, they are shown other photos and videos with the same hashtag. Instagram's engagement per post is ten times greater than that of Facebook and thirty times that of Twitter (Wong et al., 2019). Recently, there has been an increase in the number of young adults using Instagram as their preferred channel for educational information (Border et al., 2019). According to Pew Research Centre, 76% of adults aged 18 to 29 years used Instagram at least daily, with 60% saying they use it many times in a day (Perrin & Anderson, 2019). A growing number of Instagram accounts related to sports nutrition for both athletes and physically active individuals are emerging and gaining popularity (Levenson et al., 2016). Thus, it is timely to consider Instagram's role in education and awareness, with a special focus on RED-S knowledge and awareness, including its benefits and limitations.

Numerous questions have been raised regarding the appropriateness and accuracy of some educational resources shared on social media (Carpenter et al., 2020). Particularly, there are concerns about the legitimacy of the qualifications people use in their Instagram account profiles, such as "personal trainers," "educators," and "nutritionists". Despite the fact that there is a process for accounts to become "verified" (a verified badge appears next to an

Instagram account's name in search results and on the profile), anyone can create an account (Instagram, 2021). Verification on Instagram means an account represents the public figure, celebrity, or global brand it claims to represent. However, this does not stop unlicensed professionals from posting content on Instagram without being verified; in other words, there are many accounts without the badge that share nutrition and health information. Because they do not have an editorial board, screening procedures, or quality control, these social media platforms have the potential to publish misleading information (Carpenter et al., 2020).

2.17. LITERATURE ON SOCIAL MEDIA (INSTAGRAM) AS AN EDUCATIONAL TOOL

Recent studies have examined the existing content and quality of posts on social media platforms like Instagram in areas such as dental anatomy (Douglas et al., 2019), eating disorders (Goh et al., 2021), Marijuana (Cavazos-Rehg et al., 2016), and nutrition and dietetics (Kabata et al., 2022). Douglas et al. (2019) study on dental anatomy, a subject that heavily relies on visual resources to support learning, assessed 80 Instagram accounts, and found that accounts had a variety of effective teaching methods, including clinical photos, educational videos, multiple-choice questions, and cartoons. Most educational material included a photo of a clinical case, typically taken in an operating room, with a summary of the patient's treatment and outcomes. Some accounts specified whether the account holders were students, professionals, or others, but this was not always specified. Additionally, the authors noted that using social media to create the material would be cost- and time-efficient, while also allowing students to expand their knowledge through the posts' design. However, they noted Instagram lacks quality control and patient privacy measures, and the study further suggested to modify Instagram’s terms and conditions to incorporate a review process by the Instagram authorities before posting online (Douglas et al., 2019). Since social networking is the main focus of these platforms, a review process seems unrealistic.

Only two studies, to the author's knowledge, have investigated the use of Instagram as a nutrition educational tool (Alssafi & Coccia, 2019; Peters, 2021). Alssafi and Coccia (2019) examined the viability of a 6-week weight-loss intervention programme delivered via Instagram amongst undergraduate students (n=103) in the Kingdom of Saudi Arabia. The authors found that the number of likes on Instagram posts decreased (likes range between 13-35) over the course of six weeks. However, the findings from a post-intervention questionnaire reported that 100% of participants considered the postings fascinating and motivational, and 95% said the Instagram posts inspired them to eat healthier (Alssafi & Coccia, 2019). It is worth noting that this study is only accessible as an abstract and there is no information on the frequency of Instagram posts or total number of likes received or whether nutritional intake or body weight changes were measured. As a result, determining how this decrease in likes translates into dietary intakes and body weight management among students is unknown.

Another recent study investigated the food and drink choices of National Collegiate Athletic Association (NCAA) Division I students from a Fuelling Station (Peters, 2021). The station was near the athletic facility and provided a variety of snacks for the athletes. The purpose of the study was to evaluate a Nutrition Education Intervention, which consisted of interactive educational posters on Instagram, posters on the wall, and a continuous informative PowerPoint on the Fueling Station screen. A survey at baseline and after three weeks of the social media intervention collected information on food selected, time and purpose of eating, using a 14-item electronic questionnaire. After the Fuelling Station Education (FSE), the number of athletes who had acceptable carbohydrate choice improved by eight (pre-intervention $n = 20$ (26 %), post-intervention $n = 28$ (37 %)) ($p =0.169$). Among the 371 NCAA Division I student-athletes, 77 participated in the pre- and post-intervention survey and were included in the analysis; 77 (93%) stated being aware of the education and 34 (44%) stated they modified their diet as a result of what they learned from tabletop posters, food posters on walls, and Instagram posts and stories (Peters, 2021). This study demonstrated high levels of engagement and an increase in the number of athletes who made acceptable carbohydrate choices following intervention. However, there was no statistically and practically significant change in this behaviour. Also, it is difficult to assess the independent effects of Instagram, given other educational tools were also used.

So, while there is evidence to support the notion that students/athletes prefer using a social media platform to seek nutrition knowledge (Bourke et al., 2019), only two studies have previously focused on developing social media posts to influence students'/athletes' general nutritional intakes, food choices, and weight management. Neither of these studies found significant behavioural changes (Alssafi & Coccia, 2019) (Peters, 2021).

Another study aimed to assess existing posts related to ED on Instagram (Goh et al., 2021). The study focused on posts which provided information on seeking help, persistent ED warning signals, and recovery, by using the hashtags #EDrecovery and #EatingDisorderRecovery (Goh et al., 2021). A qualitative thematic analysis was conducted to evaluate the themes posted on recovery hashtags. Behavioural and psychological signs suggestive of EDs based on the Mental Health First Aid Eating Disorders Guidelines (Hart et al., 2012) showed that a large percentage of followers have persistent behavioural and/or psychological issues. However, only 9.4% of Instagram users discuss or encourage others to get professional assistance. The development of a supportive community, increased awareness and reduced stigma of EDs, and the recovery journey were among the significant themes that emerged from the qualitative analysis. This suggests that Instagram may facilitate recovery from EDs by encouraging good peer support, reducing stigma, and providing information about eating disorders and treatment. Therefore, social media platforms could be used to improve help-seeking and recovery for people with EDs (Goh et al., 2021).

A recent study looking into the authenticity of information on Instagram aimed to determine whether Instagram posts could serve as trustworthy sources of knowledge and information about dietetics and nutrition (Kabata et al., 2022). The research was conducted using a built-in website search engine to sift through posts on a random basis to find ones that dealt with nutrition. The top 250 posts using each of the five trending hashtags (#nutrition, #nutritionist, #instadiet, #diet, and #dietitian) were recorded and evaluated. Posts (n=61) that used multiple hashtags in a row, contained abusive or potentially dangerous content, and contained advertisements and commercial offers were deleted. The quality of the nutrition information provided for each eligible post was then evaluated using a 5-point Likert scale ranging from poor to good quality, and its popularity was determined by the number of followers, likes, and comments on each chosen post. The engagement level was determined by the likes, comment, and engagement ratio (i.e., based on the percentage of like-to-follower ratio and comment-to-like ratio). A total of 1189 posts were reviewed. Even after being broken down into categories, the overall quality of nutritional knowledge was very poor (i.e., 93.9% of all posts were rated poor). The posts classified as "dietetics" had the highest level of engagement (32.7%), the most likes (mean n = 116), and had the highest quality scores. The posts with cooking instructions received the most comments. The authors concluded that viewers cannot receive useful nutrition information from random post searches, and that it is best to conduct a focused search for high-quality professional profiles to find reliable information (Kabata et al., 2022).

As discussed in the previous literature review section (2.15), there is a lack of knowledge regarding RED-S and its associated short- and long-term effects on health and performance. According to a study by Kroshus, most athletes and healthcare professionals are not familiar with the terms or concept of RED-S (Kroshus et al., 2018). Additionally, to the author's knowledge, no studies have been conducted to evaluate whether Instagram posts about RED-S could be a trustworthy source of knowledge and information for their followers. As a result, it's crucial to evaluate the quality of the Instagram posts about the RED-S, paying close attention to the definition since studies have shown that athletes are not familiar with the term. This will illustrate whether there are reliable resources on Instagram that healthcare professionals can suggest athletes and other active individuals to follow to learn more about RED-S.

3. The development and validation of a questionnaire to determine RED-S knowledge

3.1. INTRODUCTION

Over the last 60 years, considerable research has been undertaken to understand the underlying cause(s) of menstrual irregularity and low BMD, both of which are seen in a concerning proportion of female athletes (Melin et al., 2014). It is generally accepted LEA is the key factor underlying these unfavourable health outcomes (Melin et al., 2014). The effects of LEA on the endocrine system have largely been reported in female athletes, and only recently in male athletes (Mountjoy et al., 2018). Low energy intakes (with or without an eating disorder) in association with menstrual disorders and altered bone mineral density has been termed as the female athlete triad, with the new term RED-S now replacing the Triad and reflecting the wider issues that have subsequently been found to be associated with LEA (Mountjoy et al., 2018; Stickler et al., 2015; Nazem & Ackerman, 2012; Barrack et al.,2013; Hausswirth & Meur, 2011;Feldmann et al., 2011; Nattiv et al., 2007; Nichols et al.,2007). While the Triad emphasises the connection between EA, female reproductive function, and bone health, RED-S broadens the idea and acknowledges the effects of energy deficit in both men and women. The intricacy of the problem is described by RED-S, which also recognises that additional physiological functions, health, and performance are impacted. In addition, the Triad is defined by clinical endpoints, and these symptoms may not appear until severe adverse effects have occurred, whereas RED-S symptoms such as decreased energy metabolism, impaired glucose homoeostasis, dyslipidaemia, GI problems, and injuries may allow for early detection and put the athlete's health at lower risk (Mountjoy et al., 2014).

When compared to athletes with sufficient EA, athletes with LEA/RED-S are at higher risk of having a lower training response, poor judgement, reduced coordination, reduced focus, increased irritability, depression, and reduced endurance performance (Mountjoy, et al., 2014; Ackerman et al., 2018). Therefore, it is important to identify risk factors and detect symptoms of RED-S early in the process in order to protect the health and performance of female athletes (Folscher, Grant, Fletcher, & Rensberg, 2015; Slater et al., 2016).

To lower the risk of RED-S, athletes and their support teams must first be well aware of the signs, symptoms, and effects of LEA on sports performance, recovery, and general health (Birkenhead & Slater, 2015; Torres-McGehee et al., 2012). Unfortunately, some previous studies suggest knowledge of the Triad (LEA, low BMD, and menstrual dysfunction) and its health consequences are limited among athletes (Day, Wengreen et al., 2015; Brown, Wengreen, & Beals, 2014; Zawila, Steib, & Hoogenboom, 2003). Healthcare professionals such as dietitians, nutritionists, physiotherapists, physicians, and personal trainers are uniquely positioned to prevent, identify, and educate female athletes at risk of LEA (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015). However, research conducted in healthcare professionals showed that they have limited awareness and knowledge about the Triad, (Curry et al., 2015; Kroshus et al., 2015), and even less knowledge of LEA and RED-S (Kroshus et al., 2018).

Of the few studies examining the knowledge of the Triad and LEA amongst healthcare professionals and athletes, different questionnaires have been used, making it difficult to compare findings (Tam et al., 2019; Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015; Troy et al., 2006). Moreover, RED-S is a relatively new concept, and so very few studies have explored the knowledge and awareness of this concept amongst healthcare professionals and athletes (Curry et al., 2015). A recently published study by Kroshus et al., (2018) found that 33% of athletic trainers had heard of the RED-S concept in comparison to 98.6% who had heard of the Triad. To the best of our knowledge, there is no validated questionnaire for assessing the knowledge of the signs and symptoms associated with RED-S among healthcare professionals and athletes within the New Zealand context. Such a questionnaire could provide valuable information on current knowledge and help determine what further education is required to help ensure healthcare professionals are well equipped for the identification, treatment, and prevention of RED-S. Therefore, this study aims to develop and validate a reliable questionnaire to determine knowledge on signs and symptoms of RED-S among a group of health professionals and a group of physically active individuals. To achieve this aim, this study uses following objectives:

1. Develop a knowledge questionnaire on the risks and symptoms of RED-S and LEA for content validity using expert review.

2. Evaluate a knowledge questionnaire on RED-S for face validity among a group of healthcare professionals and physically active individuals.

3. Assess the construct validity of a knowledge questionnaire on RED-S by comparing knowledge scores of healthcare professionals with the physically active individuals.

4. Evaluate test re-test reliability and internal reliability of a knowledge questionnaire on RED-S among health professionals and a physically active population.

3.2. METHODS

Ethical approval for this study was obtained from the Department of Human Nutrition, University of Otago reference D18/068. The initial step was development of a questionnaire on the signs and symptoms of RED-S based upon the components of RED-S identified in a review of the literature. This questionnaire was then evaluated in two separate phases. Phase 1 involved expert review and refinement of the questionnaire to achieve content validity. The questionnaire was also pre-tested in a small group of nutritionists and dietitians to assess face validity and to ensure items were interpreted correctly. Phase 2 involved administrating the questionnaire (Test 1) in Healthcare Professionals including dietitians, nutritionists, physiotherapists, physicians and personal trainers working with or without female athletes, those training to become healthcare professionals, and members of the general population who were physically active. These data were used to undertake item response analysis and assess internal consistency. The questionnaire (Test 2) was then re-administered in a sub-sample to assess reliability, where further refinement and assessment of validation was undertaken. The questionnaire was hosted on REDCap™ (Vanderbilt University, United States).

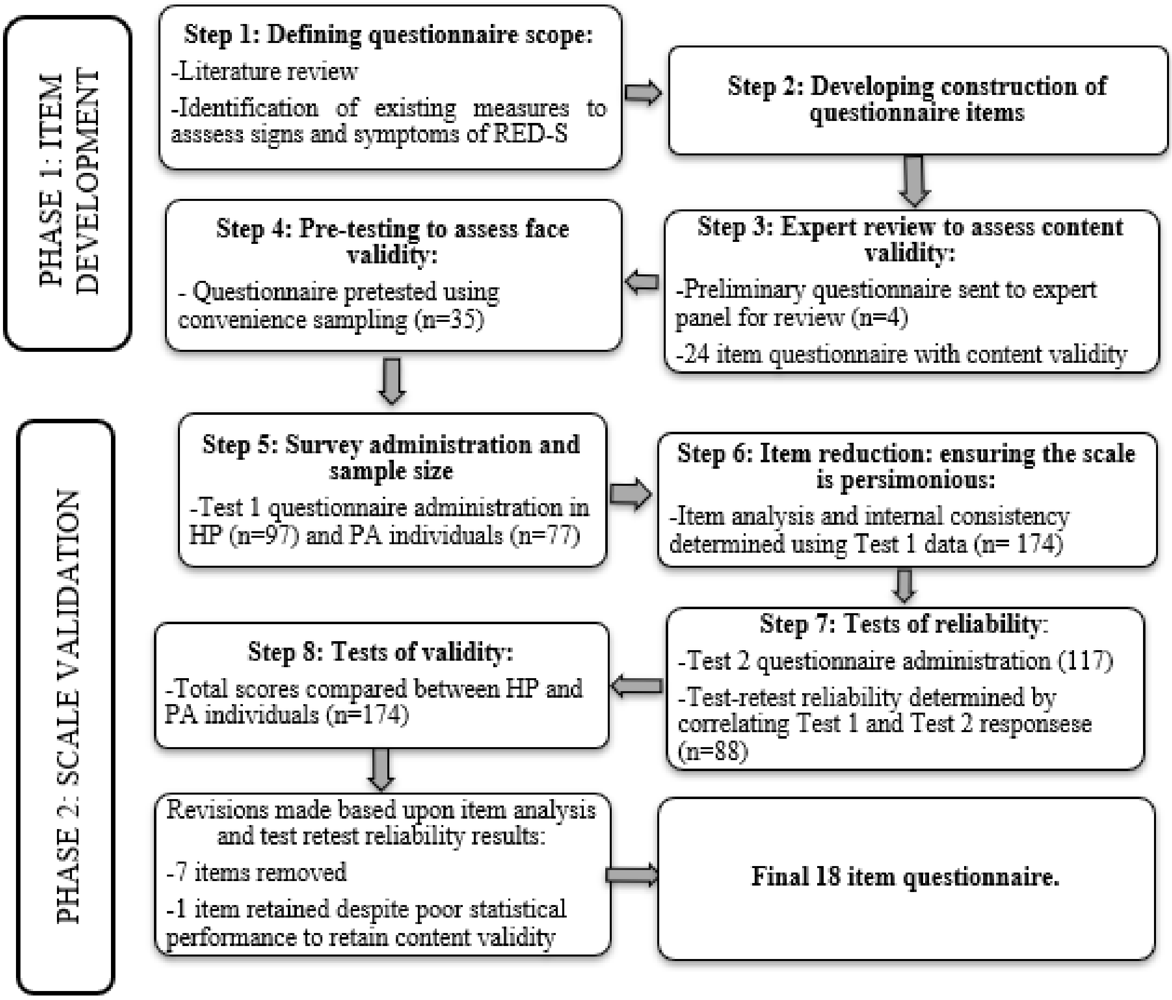


Figure 3.1: *An overview of the three phases and eight steps of scale development and validation. RED-S Relative Energy Deficiency in Sport, HP Health Professionals, PA Physically active Individuals.*

3.2.1. Phase 1: Item development

Step 1: Defining questionnaire scope:

The first step in developing the questionnaire was clearly defining what the questionnaire needed to measure. Knowledge of RED-S in females can be measured by assessing the theoretical or practical understanding of the consequences including menstrual irregularities, poor bone health, gastrointestinal disturbances, impaired immunity, mental health problems, increased cardiovascular disease risk (CVD), and decreased neuromuscular performance. Thus, the questionnaire was developed to measure existing knowledge and beliefs that healthcare professionals and physically active individuals have about menstrual irregularities, osteoporosis, disordered eating (DE), Low Energy Availability (LEA), the Female Athlete Triad (Triad) and Relative Energy Deficiency in Sport (RED-S). The measurable components of knowledge were identified and modified to ensure they were appropriate for healthcare professionals and physically active individuals in a questionnaire format. The domains that assessed knowledge were identified and have been labelled as: 1) Awareness and definition of LEA, Triad, RED-S; 2) knowledge of RED-S signs & symptoms; and 3) knowledge of disordered eating, menstruation, bone health and RED- S/inadequate energy intake and performance consequences.

Step 2: Development and construction of questionnaire items

Existing questionnaires from relevant publications (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015; Troy et al., 2006) and resources were identified, and relevant items were included in the questionnaire. Current literature was evaluated to ensure the questionnaire was evidence-based. The questionnaire contained a mixture of open, closed, partially closed-ended questions and 100 mm visual analogues scales (VAS) (Table 3.1).

Step 3: Expert review to assess content validity

Content validity refers to the extent to which a questionnaire measures the defined construct or idea. To assess content validity, a group of three to ten experts review the questionnaire for the comprehensiveness and relevance to the research objectives. (Litwin, 1995; Rattray & Jones, 2007). In this study, four health professionals who specialise in RED-S were identified and invited to the review the questionnaire. Each expert was asked to rate the items using a 4-point Likert scale on the following two dimensions: clarity and relevance (DiIorio, 2006). Clarity refers to how understandable the item is; whereas relevance allows experts to judge how pertinent the item is to the goals of the survey, i.e., assessing knowledge pertaining to the relationship between RED-S and its signs and symptoms, and performance consequences (Davis, 1992). The index used was based on four criteria, relevance ('not relevant'(=1) to 'very relevant'(=4)), clarity ('not clear'(=1) to 'very clear'(=4)), simplicity ('not simple' (=1) to 'very simple' (=4)) and ambiguity ('doubtful'(=1) to 'meaning is clear' (=4)). The responses were converted to a percentage and the acceptably level was set as >80 % as this is generally considered to be the minimum value for adequate content validity (Litwin, 1995; Rattray & Jones, 2007). In addition to the quantitative feedback, the experts also provided written feedback for each of the items at their discretion. The instruments were distributed via the email with an introductory cover letter (DiIorio, 2006). Refer Appendix A1 to see the list of question used in expert review interview.

Step 4: Pre-testing to assess face validity

Face validity refers to whether a questionnaire actually measures what it is designed to measure. The best way to achieve face validity is by pre-testing the questionnaire in a sample of the target group with the aim to determine the relevance and clarity of questionnaire items to the potential participants. (Parmenter & Wardle, 2000). The ideal number of participants for face validity is six to ten (Krueger, 2014).

The main purpose of pretesting in this study was to assess the clarity, readability, and interpretation of individual items, thereby contributing to face validity. A preliminary version of questionnaire was pre-tested on a convenience sample of (n=35) nutritionists and dietitians to help assess ease of readability. Based on the feedback, additional participant characteristic questions and branching logic were added. Branching logic takes into consideration previous reported responses and skips irrelevant questions, to ensure appropriate questions are displayed.

At the end of Phase 1, the 24-item questionnaire consisted of questions on 1) Knowledge of LEA, the Triad and RED-s (3 items); and 2) Attitudes and awareness towards LEA and the health of female athletes (21 items).

3.2.2. Phase 2: Assessment of Construct Validity

Construct validity is the highest level of validity, requiring experimental evidence that a questionnaire correctly evaluates the construct it aims to measure (Kimberlin & Winterstein, 2008; McKelvie, 2005; Parmenter & Wardle, 2000). To experimentally demonstrate construct validity, several methods exist; the simplest approach is to show that the questionnaire can differentiate between two groups that are known to differ in the construct of interest (Smith, 2005). Construct validity in the present study was determined using two relevant indicators. The first one was "differentiation by known groups", where we compared total scores between health professionals and physically active individuals using unpaired sample t-tests (two-tailed), where the former group are expected to score significantly higher. The second assessment was by correlation analysis, in which associations between the total score and other variables (listed in Table 3.2) were determined by Spearman Correlation Coefficients (r). (Parmenter & Wardle, 2000)

To assess the validity of the questionnaire a sample of the population was recruited. A convenience sampling distribution method was employed. Healthcare professionals, those training to become healthcare professionals and physically active individuals were recruited (details to follow). Prior to the commencement of the completion of the questionnaire, participants provided informed consent via an online question.

The survey comprised of the 24-item questionnaire which was used to assess the knowledge of RED-S, as well as questions on the demographic characteristics of the participants and questions to measure the level of confidence, comfort in discussing about disorder eating, weight management and menstruation and knowledge of nutrition. In total, the survey contained 36 items. The survey was designed and hosted on REDCapTM (Vanderbilt University, United States).

Step 5: Survey administration and sample:

The questionnaire was administered to assess the knowledge and awareness of signs and symptoms of Relative Energy Deficiency in Sport (RED-S) among two groups: 1) healthcare professionals such as dietitians, nutritionists, physiotherapists, physicians and personal trainers working with or without female athletes; and 2) physically active individuals. Respondents over the age of 18 years were recruited via social media advertising and personal communications, where study details and a link to the REDCap™ questionnaire were provided. Additionally, the email addresses of 481 medical centres, 52 dietetic/nutrition clinics, 499 physiotherapy clinics, 177 gyms and fitness centres across New Zealand (NZ) were obtained from multiple online directories. Invitation emails were sent to these health practices, which included a copy of the study information and a link to the online survey. Posters informing articipants of the study were also distributed around the University of Otago campus, including the Unipol Fitness and Recreation Centre, where those interested were encouraged to email the research team for detailed information and access to the online questionnaire.

Despite contacting 1209 healthcare clinics initial response rates were low; as the aim was to recruit at least 240 participants to have 10 participants per item (Rosi et al., 2020). Therefore, healthcare professionals were further recruited by contacting physiotherapy, nutrition, dietetic and medical associations. This resulted in Physiotherapy NZ and the Nutrition Society of NZ advertising the study on their website and Facebook pages. An email with the questionnaire link and study information was also sent to members of Dietetics New Zealand Sports Nutrition Special Interest Group. All participants who completed the study were entered into a draw to win one of four $50 gift vouchers. The winning participants were contacted via the email provided.

For comparison of demographic characteristics between healthcare professionals and physically active individuals, $\chi 2$ tests were used unless >20 % of cells had expected counts below 5, in which case Fisher's exact test was used. Independent t-tests were used to assess differences between groups for ratings of the importance of athlete health, and the importance of leanness and weight for performance.

Step 6: Test-retest reliability

Although validity ensures that a questionnaire offers accurate results, reliability ensures that the questionnaire offers a reliable form of assessment (Rattray & Jones, 2007). In the present study two primary forms of reliability assessment were undertaken: test-retest reliability and internal reliability (McKelvie, 2005; Rattray & Jones, 2007). Internal reliability or internal consistency examines the extent to which all items in a questionnaire are correlated with one another and whether they are assessing the same concept. (Rattray & Jones, 2007). Cronbach's alpha coefficient (Cronbach's) was used to evaluate internal reliability (Kimberlin & Winterstein, 2008; McKelvie, 2005; Parmenter & Wardle, 2000). The acceptable coefficients for internal reliability for questionnaire range from 0.7 and above. (Kimberlin & Winterstein, 2008; McKelvie, 2005; Parmenter & Wardle, 2000)

Test-retest reliability was performed to evaluate the stability of questionnaire scores over time, which was measured by administering the questionnaire to the same sample at two different time points and correlating the scores. (Kimberlin & Winterstein, 2008; McKelvie, 2005). To assess correlation of the scores over time, Spearman's correlation coefficients and Intra Class Correlation coefficients (ICC) were calculated (Weir, 2005). Spearman's correlation coefficient method does not measure the 'true" agreement between the test 1 and test 2, and only measures the degree of association. High correlations, therefore, do not necessarily guarantee good agreement between the test-retest. While intra-class correlation reflects both the level of correlation and agreement between Test-retest. The minimal cut-off for correlation coefficient for Spearman's correlation coefficients and Intra Class Correlation coefficients is 0.70 and has been widely accepted by authors when developing nutrition knowledge questionnaires. (McKelvie, 2005; Parmenter & Wardle, 2000). As recommended, the second test was conducted two weeks after the first test, which allows the answers to be forgotten while minimising true change in the measured construct (McKelvie, 2005).

Test-retest reliability was also assessed with a Bland-Altman plot, along with a paired t-test to assess potential bias (Bland & Altman, 2010; Ludbrook, 1997). The agreement for total score between the Tests 1 and 2 is shown visually by the Bland Altman analysis. The scatter plots show the average difference between each score and the average combined score from the two tests. Examining notable outliers and patterns for score change is simple (Bland and Altman, 1999). By calculating the limits of agreement (LOA) between the difference and mean of the total score, the Bland-Altman approach may be used to gauge the degree of possible bias. The mean difference in the overall score minus 1.96 standard deviation is used to compute the LOA (Bland and Altman, 1999). The LOA's width illustrates that the stronger the agreement is with a smaller LOA (Bland & Altman, 2010; Ludbrook, 1997).

To assess test-retest reliability, the questionnaire was administered twice amongst the same sample, although not all participants chose to repeat the test. The second test was administered by sending a reminder email to all the participants to complete within 2 weeks of completing the first. Once respondents moved on to different sections, they were unable to return to previous pages which prevented them from reviewing previous answers.

3.2.2.1. Questionnaire scoring

Table 1 describes the questionnaire items, reasoning for the inclusion of each item, and the scoring protocol. To calculate overall knowledge scores all items were equally weighted, each worth a maximum total score of +1 and minimum score of zero. Multiple- choice items with a single correct response were scored as +1 for a correct answer and zero for incorrect answers. Items 10 to 12 in Table 3.1, where there was more than one correct response option, each correct response was considered as +1 score. Respondents who selected the "unsure" response for a question scored zero.

For the open-ended question, "Indicate the approximate age that peak bone mineral density is reached in women?", all responses given by participants were recorded. The candidate received a score of +1 for any age range that included 18 to 29 years and zero for any age range that does not include 18 to 29. (Appendix A2).

Table 3.1: *Questionnaire items and scoring protocol***.**

Item	Question	Reason for question	Response options	Scores
1	Have you ever heard of Low Energy Availability (LEA) ?	LEA is less well known within the healthcare community (Kroshus et al., 2018; Kroshus et al., 2015)	Yes No	1 0
2	Have you ever heard of Relative Energy Deficiency in Sports (RED-S)?	Limited studies have explored the knowledge and awareness of the RED-S concept. A newly published study found only 33% of athletic trainers had heard of the RED-S. (Kroshus et al., 2018)	Yes No	1 0
3	Have you ever heard of Female Athlete Triad (Triad)?	The majority of healthcare professionals are slightly more aware of the term the Female Athlete Triad when compared to LEA and RED-S. (Curry et al., 2015; Kroshus et al., 2015)	Yes No	1 0
4	Having an irregular menstrual cycle is often a sign that female athletes/active individuals are in peak competitive shape	Kroshus et al reported that close to 70% of nurses disagreed to some extent that irregular menstrual cycles were an indication of peak performance and were unaware of the consequences associated with irregular menstrual cycles. (Kroshus et al., 2015)	True False Unsure	0 1 0
5	Indicate the approximate age that peak bone mineral density is reached in women? (The age at which maximum strength and density of bones is reached)	Knowledge deficits existed regarding the approximate age that peak bone density is reached in women; moreover, less than 30% of coaches could correctly identify this. (Brown et	any age range that does not include 18 to 29	0

		al., 2014)	any age range that includes 18 to 29 years	1
6	Do you think it is normal for female athletes/active individuals to miss their periods? (Excluding pregnancy or purposely skipping periods by contraception)?	Many athletes believe that menstrual irregularities are normal, especially during intense periods of training and competition (Brown et al., 2014; Miller et al., 2012). Further exploration is needed on the knowledge and beliefs surrounding menstrual irregularities among healthcare professionals. (Pantano, 2017)	Yes No Depends on the situation Unsure	0 1 0 0
7	Do you think that not consuming enough energy could result in the absence of periods?	Previous study did not measure participants' true knowledge of the relationship between energy intake and menstruation. (Brown et al., 2014)	Yes No Unsure	1 0 0
8	Do you think fractures (very small cracks or breaks) occur more often in girls/women who miss their period for 3 or more months than in girls/women who have regular periods? (Excluding pregnancy or purposely skipping periods by contraception)	Less than half of nurses were aware of the association between menstrual irregularities and low BMD. (Brown et al., 2014)	Yes No Unsure	1 0 0
9	Do you think irregular, or the absence of periods is associated with developing weaker bones?	Healthcare professionals, especially physicians, believed that osteoporosis screening/prevention should occur when certain risk factors are present (Fleming & Patrick, 2002; Otmar et al., 2012; Suarez-Almazor et al., 1997). These risk factors included recent diagnosis of ED (Fleming & Patrick, 2002), family history of osteoporosis, steroid use (Fleming & Patrick, 2002; Suarez-Almazor et al., 1997) and recent fractures. Unfortunately, risk factors of LEA such as menstrual irregularities received less attention (Brown et al., 2014; Fleming & Patrick, 2002)	Yes No Unsure	1 0 0

10-12	Which of the following can increase an athlete's risk of infections such as cold and flu? (please tick all that apply)	Immunity can be compromised due to the stress caused by large amounts of intense exercise (overtraining) and energy restrictions (Drew et al., 2017)	Intensive training with inadequate rest Insufficient intake of fluids' (2) Insufficient energy intake' (3) Don't know' (treat as three items)	1 0 1 0
13	For the following statement please answer true or false. Inadequate energy intake affects concentration	Low oestrogen caused by LEA may affect cognition and memory through its effects on neurotransmitters such as serotonin and dopamine. (Fink et al., 1996). Thus, low levels of thyroid hormones resulting from LEA are associated with impaired memory and cognitive decline (Hage & Azar, 2012).	True False Unsure	1 0 0
14	For the following statement please answer true or false. Inadequate energy intake affects coordination	LEA is difficult to directly assess, hence it is important to identifiy its signs and symptoms to prevent long-term health consequences. (Melin et al., 2014) Neuromuscular performance such as strength and muscular endurance of the knee decreased in female athletes with amenorrhea, possibly caused by increased cortisol and decreased glucose, oestrogen and FFM. (Tornberg et al., 2017). Additionally, decreases in knee and elbow strength were observed male wrestlers with LEA (James & Wayne, 1997).	True False Unsure	1 0 0
15 –	Which of the following do you think could result from	While direct research on the performance effects	Treat as eleven different	

25	chronic insufficient energy? (Please tick all that apply)	of RED-S is limited, adequate energy availability is necessary to improve athletic performance. (Saris, 2001)	items – this means that those who don't tick the false items, get a point for that too. 1= ticked 0= non-ticked	
15	Improved endurance performance	LEA is associated with impaired performance (Ackerman et al., 2019; VanHeest et al., 2014; Woods et al., 2017).	1 0	0 1
16	Decreased (short term) performance	LEA is thought to decrease aerobic performance via its effects on oestrogen and thyroid hormones. Hypoestrogenism can decrease vasodilation. Basically, decreases in vasodilation can impair aerobic performance by reducing muscular uptake of oxygen and nutrients (Loucks et al., 2011).	0 1	0 1
17	Increased sprint performance	Muscular protein synthesis is affected by lower anabolic hormones and possibly higher cortisol in severe or prolonged LEA.	1 0	0 1
18	Decreased sprint performance	Female runners with secondary functional hypothalamic amenorrhea (FHA) had longer manual response times and lower muscle strength and endurance than eumenorrheic athletes (Tornberg et al., 2017).	0 1	0 1
19	Weight changes		0 1	0 1
20	Body composition changes	Glycogen stores, exhaustion, stress, and vigour may also decrease physical performance.(Degoutte et al., 2006; Stellingwerff et al., 2011).	0 1	0 1
21	Increased bone mass		1 0	0 1
22	Decreased muscle strength	LEA alters muscular adaptations needed by endurance and resistance athletes.	0	0

		Body weight may mask LEA's effects or even improve or stay stagnant performance (Wasserfurth et al., 2020).	1	1
23	Increased muscle strength		1	0
			0	1
24	Decreased muscle mass	Weight loss plateaus after prolonged low energy intake (Trexler et al., 2014). This is a natural physiological change, but some athletes will reduce energy intake to keep losing weight (Wasserfurth et al., 2020).	0	0
			1	1
25	Increased injuries		0	0
		LEA lowers BMD in female athletes(Jens et al., 2005) Low oestrogen causes connective tissue stiffness, which affects jump height and higher risk of ligament injury and power performance (Chidi-Ogbolu & Baar, 2018).	1	1
Total score possible				**25**

3.2.3. Statistical analysis

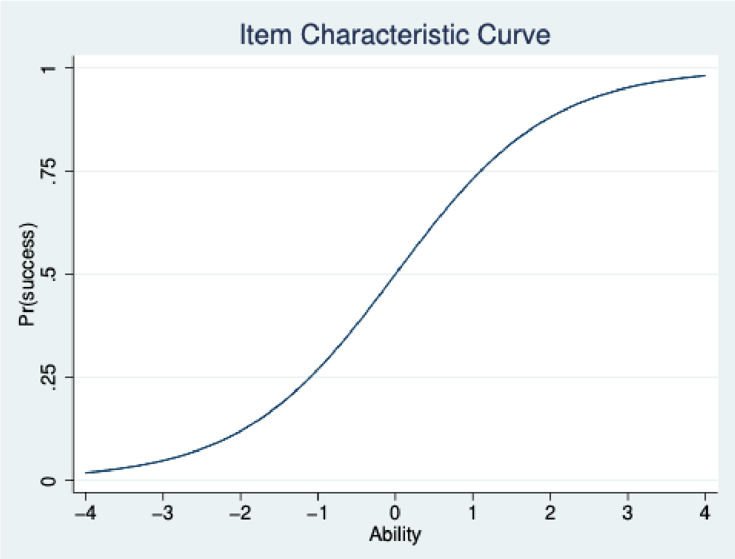
Item response analysis and internal consistency were conducted using Test 1 data. Test-retest reliability was assessed by using data from participants that completed the questionnaire at both Test 1 and Test 2 measurement occasions. From these analyses, decisions were made on which questions to keep in the revised final version of the questionnaire. Analyses were undertaken using Stata version 16.1(StataCorp, TX).

3.2.3.1. Item response theory (IRT)

Item response theory (IRT) is used to provide information about how survey items perform to measure an underlying construct (Embretson, 2000). The basic assumption is that any response to an instrument item gives some indication of an individual's level of latent trait or ability. As a result, the greater an individual's ability, the greater the likelihood of a correct answer. The relationship between ability (i.e., total score) and likelihood of getting the item correct is estimated using a logistic model (Boeck & Wilson, 2004). The parameters for the logistic model are estimated using the available data and can be used to describe concepts such as ‘difficulty’ and ‘discrimination’.

The difficulty of an item is assessed by the level of the underlying attribute (e.g., knowledge of RED-S) when the probability of getting the item correct is 50%. For example, if the difficulty of an item is assessed to be -2 using the available data, then this item is considered to be easy. This is because to have 50% probability of getting the item correct, a total survey score of 2 standard deviations less than the mean (i.e., very low ability) is needed. A good survey will have items with a range of difficulties – some easy and some hard (Boeck & Wilson, 2004).

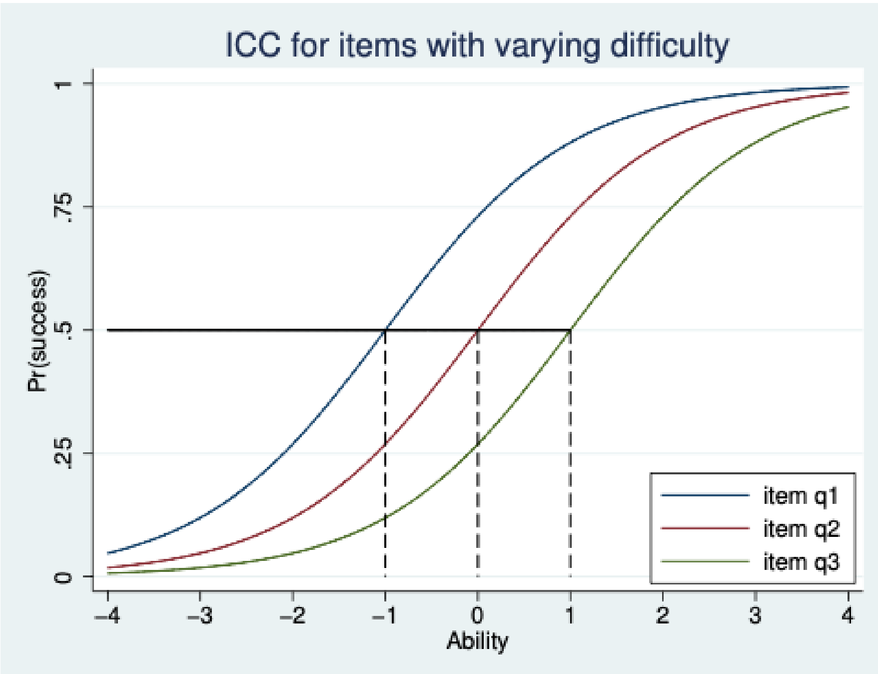
The discrimination of an item determines the rate at which the probability of getting the item correct changes with the level of ability (i.e., how they answer questions about knowledge of RED-S). In other words, high item discrimination indicates that the item can distinguish better between low and high levels of ability (e.g., knowledge of RED-S). The item discrimination index is “calculated by subtracting the proportion on participants in the lower group (lower %) from the proportion of participants in the upper group (upper %) who got the item correct. (Boeck & Wilson, 2004). For example, if the discrimination of an item is estimated to be close to 0 using the available data, this indicates that scores for this item do not distinguish well between those of low and high ability. Conversely, a discrimination of closer to 2 indicates that this item distinguishes between those of high and low ability well. A good survey will have items that discriminate well between those with low and high abilities (i.e., that have high discrimination values)



(Source: Boeck & Wilson, 2004)

Figure 3.2: *The Item Characteristic Curve (ICC) is a graphical representation of the relationship between ability and probability of getting the item right*.

The curve is S-shaped, as seen in Figure above, and represents a logistic model where the parameters that define the model are estimated by the data provided about item responses and the total score (which approximates ability).



(Source: Boeck & Wilson, 2004)

Figure 3.3: *Illustrates the ICC of three items of varying difficulty*.

The least difficult item is q1, while the most difficult is q3. At any ability level, the chance of success on item q1 is greater than the probabilities of success on the other two items.

indicating that as the difficulty of an item increases, so does the ability level that the examinee will need to correctly respond to the item (Boeck & Wilson, 2004).

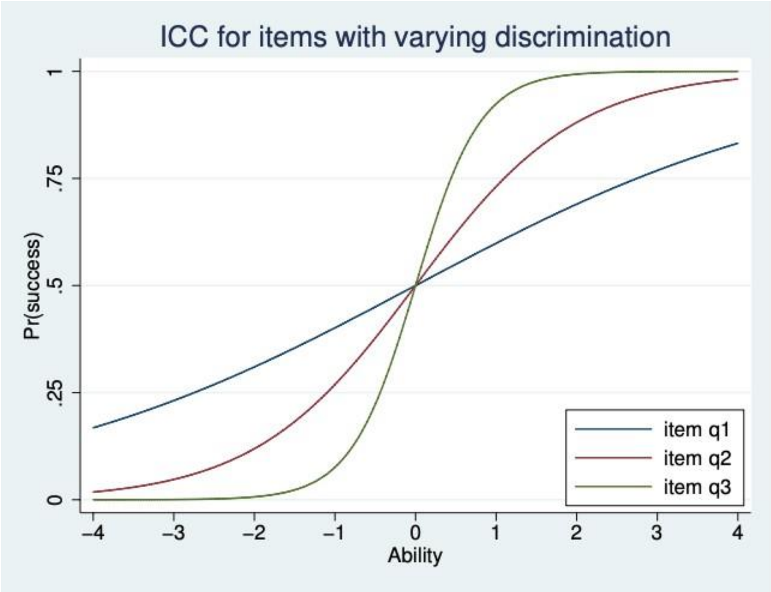


Figure 3.4: *illustrates the ICC of three items of varying discrimination.*

In figure 3.3, all the three items have the same discrimination, whereas, in Figure 3.4, all three items have same difficulty, but different discrimination values. Item q1 does not distinguish clearly between those of high and low ability, whereas item q3 has a higher discrimination value (or higher rate of change), where those of higher ability have a substantially higher probability of success, compared to those of lower ability (Boeck & Wilson, 2004). While q2 moderately discriminates between higher and lower abilities.

Specifically, both discrimination and difficulty parameters are estimated and combined to create Item Characteristic Curves (ICCs) for each response option included in the questionnaire. Overall, the discrimination parameter provides information about the slope of the ICC; whereas, a difficulty parameter provides information related to the particular level of ability, or specific location on the sequence of knowledge levels upon which an individual would fall if he or she endorsed a particular response option (Embretson, 2000).

The main purpose of using IRT in the present study was to describe two distinguishing characteristics of each item, which are identified as discrimination (the ability of the item to discriminate between those of good and poor knowledge) and difficulty (how hard or easy the item is). Questionnaires ideally contain items with good discrimination and a mix of difficulties. IRT was administered on Stata software version 16.1 (StataCorp, TX), providing numerical output, as well as a graphical representation of estimates (Boeck & Wilson, 2004). IRT analysis contributed to the refinement of items in the questionnaire to ensure a parsimonious scale.

Table 3.2: *Variables to use for correlation analysis.*

Variable name	Question	Response Options
No. of healthcare professionals	Do you currently, or have you previously, worked as a health professional?	1. Currently work as a healthcare professional 2. I have previously worked as a healthcare professional. 3. I have never worked as a healthcare professional
Worked with female athletes (work/volunteer with athletes/active individuals)	Do you work/volunteer with female athletes/active individuals?	1. Yes 2. No
Years of experience in current role. (work/volunteer with athletes/active individuals)	How many years have you worked in this role? If you have worked less than a year in this role, please state '< 1 year'	Open ended question.
Nutrition education	Have you ever completed a nutrition course or paper e.g., at University, Polytech, or short course (online)?	1. Yes 2. No
Confidence in giving advice (Currently/previously worked as a Healthcare Professionals or work/volunteer with athletes/active individuals)	How confident are you about giving advice about nutrition to athletes?	1= not confident at all 10= very confident
Self-rate knowledge	How would you rate your own knowledge of sports nutrition?	1.Poor 1. Average 3. Good 4. Excellent
Comfortable talking about disordered eating (Currently/previously worked as a Healthcare Professionals or work/volunteer with athletes/active individuals)	How comfortable would/do you feel talking about disordered eating/eating disorders with female athletes/active individuals?	1= not confident at all 10= very confident
Comfortable discussing weight management (Currently/previously worked as a Healthcare	How comfortable would/do you feel talking about weight management and/or body composition with female	1= not comfortable at all 10= very comfortable

Professionals or work/volunteer with athletes/active individuals)	athletes/active individuals?	
Opinion on athletes' health	In your opinion, how important is an athlete's health?	1= not important at all 10= very important
Comfortable talking about periods (Currently/previously worked as a Healthcare Professionals or work/volunteer with athletes/active individuals)	How comfortable would/do you feel talking about menstruation (periods) with female athletes/active individuals?	1= not comfortable at all 10= very comfortable
Opinion on athletes' weight	In your opinion, how important is an athlete's/active individual's weight for performance?	1= important at all 10= very important
Opinion on athletes' leanness	In your opinion, how important is an athlete's/active individual's leanness for performance?	1= not important at all 10= very important

3.3. RESULTS

Table 3.3: *Demographic data and other characteristics of participant (n=174).*

Characteristics	Total population		Physically Active Individuals (n=77)		Healthcare Professionals (Total no. of participants=97)	
	n	(%)[a]	N	(%)[a]	N	(%)[a]
Age (Mean ± SD) years	164	33.3 ±12.4	74	31.5 ± 12.5	90	34.8 ± 12.2
Gender (n (%))	166		75		91	
Female	146	(88.0)	66	(88.0)	80	(87.9)
Male	19	(11.4)	8	(10.7)	11	(12.1)
Not specified	1	(0.6)	1	(1.3)	0	
Ethnicity, n (%)	174		77		97	
NZEO[b]	147	(84.5)	66	(85.7)	81	(83.5)
Māori	13	(7.5)	6	(7.8)	7	(7.2)
Pacific	5	(2.9)	2	(2.6)	3	(3.1)
Asian[c]	9	(5.2)	3	(3.9)	6	(6.2)
Education, n (%)	174		77		97	
Secondary	29	(16.7)	25	(32.5)	4	(4.1)
Tertiary	131	(75.3)	42	(54.5)	89	(91.8)
Others	14	(8.0)	10	(13.0)	4	(4.1)
Ever completed a nutrition course or paper e.g., at University, Polytech or short course (online) n (%)	174		77		97	
Yes	68	(39.1%)	20	(26.0)	48	(49.5)
No	106	(60.9%)	57	(74.0)	49	(50.5)
Self-rating the level of knowledge on sports nutrition? n (%)	174		77		97	
Poor	28	(16.1%)	12	(15.6)	16	(16.5)
Average	82	(47.1%)	40	(51.9)	42	(43.3)
Good	58	(33.3%)	23	(29.9)	35	(36.1)
Excellent	6	(3.4%)	2	(2.6)	4	(4.1)
Rating of importance of an athlete's health? Median (25th, 75th percentile)[d]	174	99 (96,100)	77	99 (95,100)	97	100 (96,100)
Rating of importance an athlete's/active individual's weight is for performance. [d] Median (25th, 75th percentile)	172	66 (51, 80)	76	69 (56,80)	96	64 (50,78)
Rating of importance an athlete's/active individual's leanness is for performance Median.[d] (25th, 75th percentile)	172	62 (50, 75)	76	65 (51,78)	96	56 (50,72)

Abbreviations: n=number, NZEO: New Zealand European and others, SD= Standard Deviation, %= percentage, median (25,75) = 25th & 75th percentile.
Percentage calculated from those that completed the question (n=174).
[a] Unless otherwise specified
[b] NZEO ethnicity comprises: New Zealand European, Other European, MELAA (Middle Eastern, Latin American, African), also those who preferred not to answer.
[c] Asian ethnicity comprises: Southeast Asian, Chinese, Indian, Other Asian

[d] Level of confidence, comfort and importance was measured on a 100 mm VAS scale from 0 to 100. The direction of scale was orientated towards the right, indicating a higher score reflected a positive perception on health.

Respondent characteristics are reported in Table 3.3. A total of 257 people showed an interest and were provided with a link to the questionnaire; however, only 174 participants completed it to a standard deemed acceptable for statistical analysis. Therefore, the results are based on 174 participants of which 97 were Healthcare professionals i.e., physiotherapists, dietitians, general practitioners (GPs), personal trainers, nurses etc.; and 77 participants were physically active individuals (Table 3.3). The mean age of the sample was 33.3 (SD 12.4) years, ranging from 18 to 70 years. Most of the sample (88%) were female, with a tertiary education qualification (75%), and identified as New Zealand European ethnicity (85%). The majority of participants who were currently working as healthcare professionals had worked with female athletes/active individuals and had a median of 16 years of experience in their profession (25th/ 75th percentile: 2, 33). On average, 53% of healthcare professionals were confident about giving advice on nutrition to athletes (range 22.5, 71.5) and had undertaken some form of nutrition education. Most of healthcare professionals self- rated their level of knowledge on sports nutrition as good or excellent, while physically active individuals self-rated this as poor or average.

Healthcare respondents were moderately comfortable in discussing DE/ED with female athletes/active individuals, as the median (on a 100mm VAS scale from 0 to 100) was 58 mm (Table 3.3). Healthcare professionals who have worked with female athletes, however, were more comfortable than Healthcare professionals who did not work with female athletes in discussing weight/body composition and menstruation, as the median of comfortability score was 61mm and 80mm, respectively. Similarly, healthcare professionals considered an athlete's/active individual's weight and leanness during performance as important, although not as much as respondents considered an athlete's health as the most important factor.

Table 3.4: Characteristics *of participant (n=174).*

Characteristics	**n**	**(%)[a]**
Worked/ volunteered with female athletes/ active individuals	52[b]	
Yes	49	(94.2)
No	3	(5.8)
Number of years in the role to work/volunteer with athletes/ active individuals. Median (25th, 75th percentile)	52[b]	16 (2, 33)

[a] Unless otherwise specified

[b] Observation includes only those healthcare professionals who work/volunteer with athletes/active individuals (n=52).

The majority of health professionals who have worked with athletes/active individuals were females with a median of 16 years of work experience (25th and 75th percentiles: 2 and 33 years) (Table 3.4).

Table 3.5: *Describing the level of confidence and comfort on various topic of nutrition among healthcare professionals (n=97)[a].*

	Median (25th, 75th percentile)
Level of confidence about giving advice on nutrition to athletes. [b]	53 (22,70)
Level of comfort while talking about disordered eating/eating disorders with female athletes/active individuals. [b]	58 (36,74)
Level of comfort talking about weight management and/or body composition with female athletes/active individuals? [b]	61 (39.5,74.5)
Level of comfort talking about menstruation (periods) with female athletes/active individuals? [b]	80 (61,98)

[a] Level of confidence/comfortability to discuss was considered in participants who were healthcare professionals or previously worked as healthcare professional (n=97)
[b] Level of confidence and comfort was measured on a 100 mm VAS scale from 0 to 100. The direction of scale was orientated towards the right, indicating a higher score reflected a positive perception on health.

The mean (IQR) comfort rating for providing menstruation advice was high among healthcare professionals, whereas somewhat comfortable and confident in addressing disordered eating/ eating disorders, weight management and advice on nutrition with female athletes/ active individuals. (Table 3.5).

3.3.1. Expert review (content validity)

Once the items had been identified, the questionnaire had very good agreement by the experts on the clarity and relevance of questionnaire. The responses derived from the Likert scale from all the experts were converted to a percentage and had a > 80 % acceptability, indicating good content validity (Polit et al., 2007; Wynd et al., 2016). One reviewer suggested the addition of a question about the age range that peak bone mineral density is reached in women. This was incorporated in the final version. Additionally, reviewers suggested rephrasing and appropriate rewording of several items to increase comprehension, while still maintaining the theme of the item. For example, it was suggested that "energy" should replace "calories" and "skipping" to be replaced by "irregular or absence of". These changes were incorporated into the final version of the questionnaire.

3.3.2. Face validity

In the interview method, a group of healthcare professionals including nutritionists and dietitians went through to answer each item, and any problems the questionnaire caused in this process were identified. Healthcare professionals, however, did not report difficulties with most of the items, and the interviews revealed their interpretation often did not differ from what the items intended to measure, resulting in valid responses. Additionally, alternations were further tested amongst healthcare professionals, those training to become healthcare professionals, and members of the general population. These revisions helped improve the readability and ensured branching has been correctly applied (Bolarinwa, 2015).

Table 3.6: *Item scores, difficulty, and discrimination (n=174).*

	Item[a]	Proportion correct (%)[b]	Difficulty index (SE) (p)[c]	Discrimination index (SE) (D)[d]
1	Have you ever heard of Low Energy Availability (LEA)?	35 (20.1%)	1.1 (0.19)	2.1 (0.53)
2	Have you ever heard of Relative Energy Deficiency in Sports (RED-S)?	27 (15.5%)	1.1 (0.16)	4.1 (1.85)
3	Have you ever heard of the Female Athlete Triad (Triad)?	72 (41.4%)	0.3 (0.12)	2.3 (0.51)
4	Having an irregular menstrual cycle is often a sign that female athletes/active individuals are in peak competitive shape	128 (73.6%)	-0.9 (0.19)	1.5 (0.33)
5	Indicate the approximate age that peak bone mineral density is reached in women? (the age at which maximum strength and density of bones is reached). [e]	119 (68.4%)	-4.3 (4.4)	0.18 (0.18)
6	Do you think it is normal for female athletes/active individuals to miss their periods? (Excluding pregnancy or purposely skipping periods by contraception)?	114 (65.5%)	-0.7 (0.2)	1.2 (0.27)
7	Do you think that not consuming enough energy could result in the absence of periods?	139 (79.9%)	-1.5 (0.33)	1.12 (0.29)
8	Do you think fractures (very small cracks or breaks) occur more often in girls/women who miss their period for 3 or more months than in girls/women who have regular periods? (excluding pregnancy or purposely skipping periods by contraception)	111 (63.8%)	-0.5 (0.14)	1.8 (0.42)
9	Do you think irregular or the absence of periods is associated with developing weaker bones?	100 (57.5%)	-0.3 (0.15)	1.5 (0.31)
10	'Intensive training with inadequate rest' can increase an athlete's risk of infections such as cold and flu?	163 (93.7%)	-3.5 (1.26)	0.9 (0.37)
11	'Insufficient intake of fluids' can increase an athlete's risk of infections such as cold and flu?	58 (33.3%)	-3.2 (2.72)	0.2 (0.18)
12	'Insufficient energy intake' can increase an athlete's risk of infections such as cold and flu? [e]	143 (82.2%)	-2.1 (0.57)	0.8 (0.26)

13	For the following statement, please answer true or false. Inadequate energy intake affects concentration. [e]	174 (100%)	-	-
14	For the following statement, please answer true or false. Inadequate energy intake affects coordination. [e]	156 (89.7%)	-9.0 (10)	0.2 (0.28)
15	"Improved endurance performance" is a result from chronic insufficient energy [e].	170 (97.7%)	-8.3 (9.33)	0.5 (0.55)
16	"Decreased (short term) performance" is a result from chronic insufficient energy.	139 (79.9%)	-2.9 (1.19)	0.5 (0.22)
17	"Increased sprint performance" is a result from chronic insufficient energy.	169 (97.2%)	-3.3 (1.04)	1.3 (0.59)
18	"Decreased sprint performance" is a result from chronic insufficient energy.	138 (79.3%)	-1.5 (0.35)	1.1 (0.27)
19	"Weight changes" is a result from chronic insufficient energy.	149 (85.6%)	-2.1 (0.50)	1.0 (0.29)
20	"Body composition changes" is a result from chronic insufficient energy.	148 (85.1%)	-1.7 (0.322)	1.4 (0.34)
21	"Increased bone mass" is a result from chronic insufficient energy.	168 (96.6%)	-5.2 (3.08)	0.7 (0.46)
22	"Decreased muscle strength" is a result from chronic insufficient energy.	160 (91.9%)	-1.9 (0.32)	1.9 (0.51)
23	"Increased muscle strength" is a result from chronic insufficient energy.	172 (98.9%)	-4.2 (2.11)	1.2 (0.82)
24	"Decreased muscle mass" is a result from chronic insufficient energy.	148 (85.1%)	-1.4 (0.23)	1.9 (0.44)
25	"Increased injuries" is a result from chronic insufficient energy.	147 (84.5%)	-1.5 (0.25)	1.7 (0.41)

Abbreviation SE= Standard Error

[a] This column shows the description of all the items in the questionnaire (25 items)

[b] This column shows all those who answered the item correctly. Percentage calculated from those that completed the question. Note that the first three items contribute to the total score to assess knowledge of LEA, but it is not incorrect to get a zero score for these items.

[c] Column represents the item difficulty (p) calculated by assessing the level of underlying attribute (e.g., knowledge of RED-S) when probability of getting the item correct is 50%.

[d] Column represents the discrimination (D) calculated by determining the rate at which the probability of getting the item correct with the level of ability (i.e., how they answer questions about knowledge of RED-S).

[e] Due to low scores on discrimination, all these questions were excluded from the final questionnaire.

3.3.3. Item analysis of individual items in the questionnaire.

Item analysis results, including the difficulty and discrimination indices for each item, are presented in Table 3.6. The difficulty index of the items is also presented. If a question's difficulty estimate is low, it is relatively easy; if it is high, it is considered to be somewhat hard. The items in the above table cover a variety of item difficulties, with item q1 being the most difficult (p1 = 1.1) and item q15 being the least difficult (p15 = −8.3). Note that items 1 to 3 ask whether participants had heard of LEA, REDS, or the Triad, so in these cases the difficulty index is reflecting how common this knowledge was, not how difficult the question was. Keeping this in context, this questionnaire consisted only of easy items with no difficult items (Hingorjo & Jaleel, 2012)

Item discrimination scores showed that the majority of the items scored above +1 indicating good discrimination. Two items (items 15 and 16) had moderate discrimination, and 3 items (item 5, 11 and 14) had low discrimination scores. In other words, these items needed improvement to increase the level of discrimination or needed to be removed from the questionnaire. Item 13 did not have difficulty and discrimination scores due to 100% of respondents answering the question correctly, indicating that this item is extremely easy, does not discriminate at all, and was removed.

To strengthen the utility of the questionnaire to discriminate appropriately between those with good awareness of the risks and consequences of RED-S, all the items with the discrimination index of +1 were retained. In addition, item 12 was also retained because it was considered to measure an essential part of RED-S which is not covered elsewhere in the questionnaire. This resulted in the final questionnaire comprising a total of 18 item questionnaire.

To strengthen the utility of the questionnaire to discriminate appropriately between those with good awareness of the risks and consequences of RED-S, all the items with the discrimination index of +1 were retained. In addition, item 12 was also retained because it was considered to measure an essential part of RED-S which is not covered elsewhere in the questionnaire. This resulted in the final questionnaire comprising a total of 18 item questionnaire.

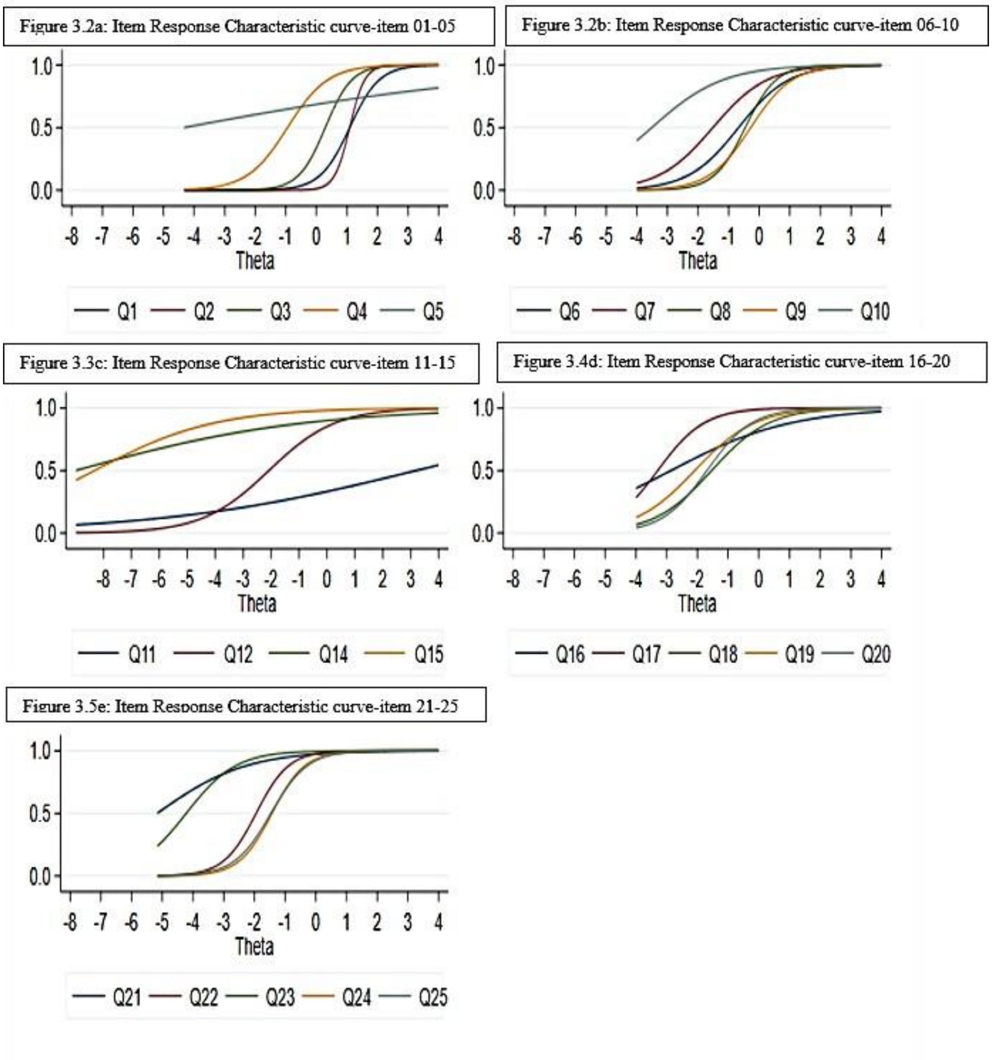


Figure 3.5: Each graph illustrates the item response characteristics curve for each item in the questionnaire (item=25).

Each curve represents the sum of individual item response with varying difficulty and discrimination. An item with good discrimination has an S-shaped curve (e.g., items 22, 24, and 25 have good discrimination but items 21 and 23 have poor discrimination).

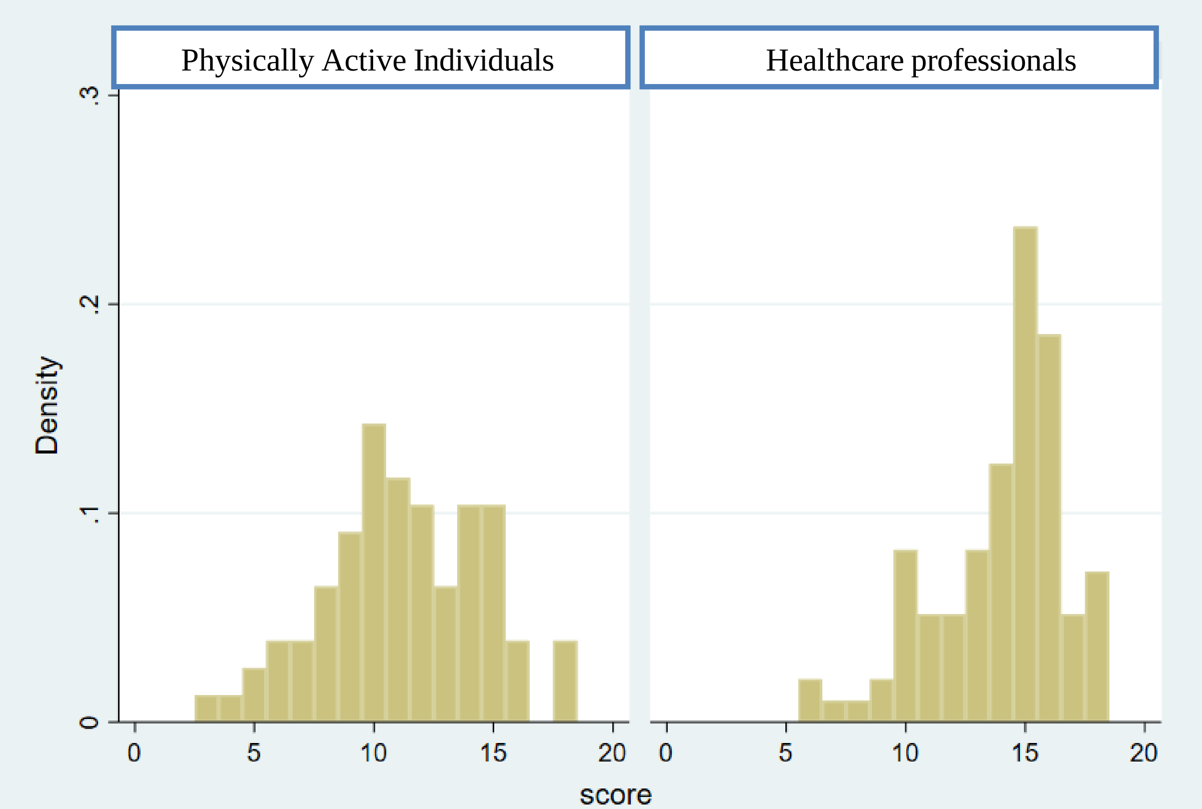


Figure 3.6: *Total scores for healthcare professionals (n=97) and physically active individuals (n=77) using histogram.*
The mean score of healthcare professionals (14 ± 3) was significantly higher that physically active individuals (11.2± 3), p<0.001.

Table 3.7: *Questionnaire scores between different groups of participants.*

Variables	**Observations**	**Mean ± SD**	**Mean difference (95% CI)**	**p-value**
Type of participant (n=174)				
Healthcare	97	14 ± 3	2.8 (1.9, 3.7)	<0.001
Physically active individuals	77	11.2± 3		
Healthcare professionals who worked with athletes/active individuals (n=52) [b]				
Yes	49	14 ± 2.8	1.6 (-4.2, 2.4)	0.583
No	3	15.3 ± 2.5	1(Reference)	
Nutrition education (n=174)				
Yes[1]	68	14.9 ± 2.5	2.8(13.3, 13.2)	<0.001
No[1]	106	11.6 ± 3	1(Reference)	
Self-rated knowledge of sports nutrition (n=174)				
Poor and Average knowledge[1]	64	12±3	2.5(1.6, 3.5)	<0.001
Good and Excellent knowledge[1]	110	14± 2.8	1(Reference)	

Abbreviations: Mean ± SD=mean and standard deviation; CI= Confidence Intervals
[1]The observation included all participants (n=174)
[b] Healthcare professionals who work/volunteer with athletes/active individuals (n=52).

3.3.4. Construct validity between two known groups.

Healthcare professionals scored significantly higher on the questionnaire (mean difference: 2.8; p<0.001) compared to physically active individuals (Table 3.7). Also, those with some nutrition education scored significantly better than those with no nutrition education (mean difference=2.5; p<0.001). Among Healthcare professional who worked with athletes/active individuals (who were not females) had slightly higher scores than those who work with female athletes; however, there were only 3 professionals who worked with athletes/active individuals which means the result is less reliable.

Table 3.8: *Correlations between total score and other factors assessed in the questionnaire.*

Variables	**Observations**	**Median**	**25^{th} -75^{th} percentile**	**Spearman's correlation r-value**
Confidence in giving advice	97[a]	53	0-97	0.26
Comfortable talking about disordered eating	97[a]	58	0-100	0.28
Comfortable discussing about weight management	97[a]	61	1-100	0.16
Comfortable talking about periods	97[a]	80	9-100	0.31
Rating of importance of an athlete's health?	174[b]	99	72-100	0.25
Rating of importance an athlete's/active individual's weight is for performance	172[c]	66	14-100	0.01
Rating of importance an athlete's/active individual's leanness is for performance	172[c]	62	7-100	-0.11

[a] Healthcare professional or previously worked as healthcare professional or who worked with female athletes (n=97)

[b] All participants (n=174)

[c] All participants, but 2 responses are missing.

3.3.5. Construct validity of the questionnaire

Participants who scored more highly on the questionnaire had more confidence giving advice about menstruation to female athletes/ active individuals, and were moderately comfortable discussing disordered eating, weight management and nutrition, as the median comfortability score to provide advice on menstruation was approximately 20% higher than weight management and disordered eating. Furthermore, all the participants agreed that athletes' health is the most important aspect during sports, and that female athletes' weight and leanness were less important.

3.3.6. Internal reliability and test –retest reliability of the questionnaire

Internal reliability of the 18-item questionnaire was assessed using Cronbach's α, which assesses how well the items in the questionnaire are correlated. The Cronbach's value was 0.79, which indicates good internal reliability.

The questionnaire was re-administered in same population with 117 participants; however, only 88 participants completed at a level considered accepted for statistical analysis. Intra-class correlation coefficients (ICC) were used to assess test-retest reliability of the questionnaire along with Spearman's correlation coefficients. Agreement between Test 1 and 2 scores for the overall questionnaire was good (ICC=0.80; Spearman's correlation = 0.84), showing that there is a strong positive correlation between Test 1 and 2 scores (Hinkle, 2003).

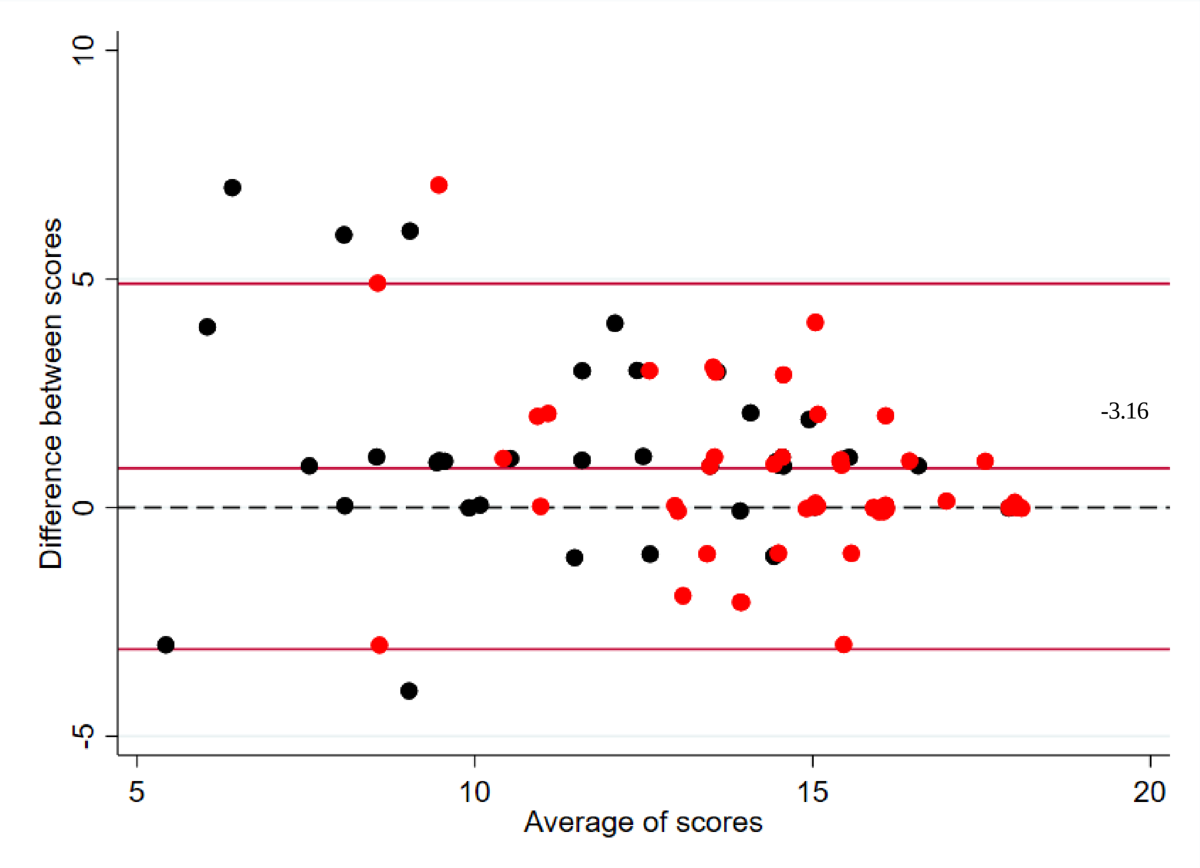


Figure 3.7: *Bland-Altman plot of agreement between Test 1 and Test 2.*

The middle line represents the mean difference between the 2 tests, the upper and lower line represent the 95% limits of agreement (LoA = mean difference ±1.96 standard deviation).

4.89

Black dots represent physically active individuals and red dots represent healthcare professionals.

3.3.7. Visual representation of test-retest reliability

The Bland-Altman plot shows the difference of the two paired measurements plotted against the mean of the two measurements (Bland & Altman, 2010; Ludbrook, 1997). The mean difference between the second and the first test was 0.86 (CI 0.44 to 1.30), which indicates that on average, participants were likely to score about one point higher the second time that they completed the questionnaire. Visual inspection of the Bland-Altman plot showed signs of unreliability in those with lower scores. This was mostly among those who were physically active individuals (Figure 3.7).

3.4. DISCUSSION

Identifying gaps in the knowledge of healthcare professionals and physically active individuals is important to determine the need to develop continuing education campaigns to ensure these groups are well equipped for the identification, treatment, and prevention of RED-S. As a starting point of any education intervention gaining of an understanding of baseline knowledge is important. In this study a self-administered online questionnaire which measured knowledge of the signs and symptoms of RED-S was developed and validated.

The questionnaire was revised over two phases of testing to improve its validity and reliability and enhance its potential for future use. Phase 1 had two stages; in the first stage the questionnaire achieved an acceptable standard of content validity, as judged by a panel expert. In the second stage, the questionnaire was pre-tested to ensure it was correctly interpreted by healthcare professionals and achieved face validity. In phase 2, the revised questionnaire met acceptability standards of construct validity, test-retest reliability, and internal reliability after administration in healthcare professionals and physically active individuals. This led to the development of final RED-S questionnaire which consisted of three domains and 18 items. This questionnaire can be used as a tool to identify knowledge gaps and provide important information on which to base education interventions/campaigns.

Expert review (content validity)

Content validation was crucial to determine whether the questionnaire was truly measuring knowledge on signs and symptoms of RED-S (Polit & Beck, 2006). Obtaining high content validity was prioritised in the study, as existing RED-S questionnaires are limited by their lack of content validity (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015; Tam et al., 2019). In this study content validity was achieved by following two- stage process: item development and expert review.

Previous questionnaire designed to assess knowledge and awareness of RED-S in healthcare professionals mainly focused on three components of triad (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015). They included questions about whether participants have heard of the Triad)/ RED-S, and whether or not they can identify components of the Triad or RED-S (Curry et al., 2015). However, limitations include lack of validation, the short length of the questionnaires contributing to the inability to provide a comprehensive measure of RED-S, and lack of assessment of many sub-components of RED- S, such as knowledge of the signs & symptoms of RED-S, knowledge of disordered eating, menstruation, bone health and RED-S, and knowledge of inadequate energy intake and performance consequences. In contrast to these other questionnaires, a strength of the current questionnaire was that it underwent review by an expert panel to identify whether any items had been omitted. This means it is a more comprehensive measure of knowledge on different aspects of RED-S. And all the experts agreed that this questionnaire reflects the novel nature of measuring knowledge of signs and symptoms of RED-S.

Pre-testing (face validity)

The concern with self-administered questionnaires is that respondents give invalid and unreliable responses because no interviewer is present to clarify the meaning of each item (DeVon et al., 2007). Moreover, there is no standardised method for assessing whether a questionnaire has achieved face validity and the conclusion is often left to the judgement and justification of the researcher. Therefore, to address these concerns and achieve face validity, considerable effort was invested in performing a combination of two methods (Bolarinwa, 2015), such as expert reviews (Parmenter & Wardle, 2000) (Hendrie et al., 2008) and having a group of target respondents to complete the questionnaire and report any problems experienced (Parmenter & Wardle, 2000).

The revisions made after the pre-testing the questionnaire appeared to result in fewer comprehension problems and reduced respondent burden, which are important factors for ensuring participants will not be too fatigued to provide good quality responses (Bolarinwa, 2015). Therefore, in this phase of the study the questionnaire was refined to ensure only items that were being interpreted correctly by healthcare professionals were retained in the questionnaire.

Construct validity

In the present study, healthcare professionals were more comfortable discussing menstruation than disordered eating which are complex to treat as it is multifaceted and require the expertise of experienced healthcare professionals. Additionally, healthcare professionals may be less comfortable discussing weight management with patients in comparison to menstruation, previous research has shown that healthcare professionals often fear patient and/or family reactions when discussing obesity (Michie, 2007; Steele et al., 2011). It is plausible that this fear could also be extended to discussing unintentional/intentional weight loss with patients. However, because some of the study populations were registered dietitians or personal trainers it is expected that these healthcare professionals have a higher comfortability, as dietitians/ personal trainers are specifically trained in discussing weight management. Hence, when comparing the total scores achieved by the two groups, healthcare professionals had significantly higher knowledge than physically active individuals. This distinction in scores suggests that this questionnaire had adequate construct validity (Smith, 2005).

To further strengthen the construct validity of the questionnaire total scores among different groups who would be expected to score differently were compared. This included: healthcare professionals who worked with females/active individuals vs those who do not work with females/active individuals, those who have had some formal nutrition education vs those with no training, and participants who have self-rated their knowledge on sports nutrition as above average vs those who self-rated their knowledge as below average.

Healthcare professionals who worked with athletes achieved higher scores than professionals who worked with female athletes/active individuals. However, this finding cannot be compared with previous studies as no studies have compared between healthcare professionals working with or without female athletes (Curry et al., 2015; Troy et al., 2006). Nevertheless, findings of previous studies in healthcare professionals such as nurses, physicians and dietitians who did not work with female athletes shown that they overlooked these risk factors of RED-S such as menstrual irregularities, osteoporosis/low BMD in female athletes (Curry et al., 2015; Troy et al., 2006). It has also been observed that these healthcare professionals who did not work with female athletes have a tendency to believe that osteoporosis is a disease that occurs in postmenopausal and elderly women and are unaware of the importance of nutrition and lifestyle factors throughout the lifecycle on these outcomes. (Otmar et al., 2012). Contrary to this, Kroshus et al found that healthcare professionals such as psychologists, natural therapists and fitness instructors working with female athletes were likely to correctly identify RED-S signs and symptoms. (Kroshus et al., 2018). Thus, it seems sensible to suggest that healthcare professionals working in these settings gain greater awareness and knowledge of the risk factors, through their experience and constant interaction with athletes. Hence, our finding of greater scores among healthcare professionals who work with physically active individuals adds weight to our construct validity.

Further evidence of construct validity was seen when comparing knowledge scores of subgroups. Those who had taken a nutrition course scored higher than those who had not. Also, those participants who self-rated their knowledge as good and excellent, scored significantly higher on the questionnaire (Mountjoy, et al., 2018).

Furthermore, the self-reported knowledge of sports nutrition by all the participants was compared to their score achieved in overall questionnaire. Participants who self-rated their knowledge as good and excellent, scored significantly higher on the questionnaire. Collectively, these results provide strong evidence that the questionnaire has good construct validity, indicating its ability to make accurate assessment of knowledge among a range of participants.

Internal consistency and reliability.

In phase 2, two methods were used to evaluate the reliability of the RED-S knowledge questionnaire on signs and symptoms: internal consistency and test-retest reliability. The questionnaire demonstrated good internal consistency (i.e., Cronbach's $\alpha \geq 0.70$) (Kimberlin & Winterstein, 2008). These results are unique to this study, as RED-S knowledge questionnaires developed for healthcare professionals have not reported Cronbach's α results (Curry et al., 2015; Kroshus et al., 2018; Kroshus et al., 2015; Troy et al., 2006) (Tam et al., 2019).

As Cronbach's α is a measure of the inter-correlation between items, these results indicate that each section is composed of items that measure different aspects of the same concept (e.g., knowledge of signs and symptoms), and thus these items are appropriately grouped in the questionnaire (Tavakol & Dennick, 2011). In this study there is a good internal reliability for the overall questionnaire, indicating that all the items are inter- correlated and appropriately grouped.

The results for test-retest reliability were good (i.e. ICC value ≥ 0.80) for the overall questionnaire. Test-retest methodology assumes no true change has occurred in participant's questionnaire scores from test 1 to 2 and any score difference is due to measurement error (Zinn et al., 2005). However, a slight increase in participant's scores for the overall questionnaire was found from test 1 to 2. This may indicate a learning effect. It is well known that performance on a cognitive test often improves when repeated, as unfamiliarity with study procedures can be stressful and confusing, leading to underperformance at the first administration (Wilson et al., 2000; Schmitt et al., 2005). Familiarity with test procedure and previous exposure to questionnaire items both contribute to improved scores at subsequent administrations (Schmitt et al., 2005). Though the questionnaire was not a cognitive test, its completion required similar cognitive processes, thus the same principles are likely to apply.

The test-retest reliability results of this study are comparable to a general nutrition knowledge questionnaire developed for athletes and show stronger reliability than a knowledge questionnaire developed for athletes (Spendlove et al., 2012; Tam et al., 2019). However, these comparisons are challenging, as no study has measured the knowledge on signs and symptoms of RED-S. Additionally, the strong reliability of this questionnaire may reflect the comprehensive expert review and pre-testing that revised ambiguous and incorrectly interpreted items. This is a recommended practice to increase the consistency of participant's responses, thus improving questionnaire reliability. (Furber et al., 2017; Zinn et al., 2005)

Whilst the ICC results indicate that participants received slightly higher score from test 1 to 2, the Spearman's correlation (ϒ) results show that on the whole, the reliability of individual items from test to re-test were strong.

Seven of the items were removed after performing item analysis; however, one item (item 11) with low difficulty and discrimination index was retained as it was deemed essential to ensure all components of signs and symptoms of RED-S were measured. Overall, this indicated that questionnaire scores represent accurate knowledge on signs and symptoms of RED-S.

It is also possible to identify any differences or variability in the differences of the test 1 and 2 scores among healthcare professionals and physically active individuals by plotting the mean difference and average knowledge score on a scatter plot (Bunce, 2009) (Bland & Altman, 1999). A trend was observed whereby the healthcare professionals scored slightly closer to zero while physically active individuals are scattered slightly away from zero. In other words, a higher percentage of healthcare professionals were found to fall within the 95% limits of agreement, which means this questionnaire has stronger reliability to assess knowledge of signs and symptoms of RED-S among healthcare professionals. The use of a number of measures of reliability is a strength of our study. Previous studies have not used Bland-Altman plots to analyse the reliability of knowledge questionnaire (Spendlove et al., 2012; Tam et al., 2019).

3.5. STRENGTHS AND LIMITATIONS

A major strength of this study was the robust methodology used, including a combination of qualitative and quantitative methods chosen to best match the aim of each phase. These included content validity, pre-testing, item analysis, and internal reliability and stability (Grant & Davis, 1997; Lynn, 1986; Wynd et al., 2016). This use of mixed methods enabled triangulation, or cross-examination of results, which highlighted appropriate revision that would not have been identified from the use of qualitative or quantitative methods alone (Jick, 1979).

A further strength was developing the questionnaire in online format that can be completed on an iPad, smartphone, or computer. Online self-administered questionnaires have considerable strengths over pencil and paper questionnaires. They cost less to administer to a large sample and reduce the time and error associated with a separate data entry phase, as the results can be downloaded directly into computer programmes for analysis. (De Leeuw & Nicholls, 1996). It also avoided the problem of missing data due to skipped items, as items can be made forced response, as was done in the present study (De Leeuw & Nicholls, 1996).

The limitations of self-administered questionnaires that have been discussed in the literature apply to this study (Kimberlin & Winterstein, 2008; Rattray & Jones, 2007). Briefly, these include: the inability to probe responses, the potential impact of literacy on responses, and the limits of what can be asked using closed questions. Furthermore, whilst the methodology of each phase was robust, the types of questionnaire validation used in the study (content, construct and face validity) were largely subjective, thus debate exists whether these as "true" methods of validation (Parmenter & Wardle, 2000). However as discussed in the literature review, the strongest forms of questionnaire validity, criterion validity were unable to assessed at the present time.

Another limitation of this study was the low response rates and possible selection bias.

Although the methods of distribution made it difficult to accurately determine the response rates, considering that just over 1200 healthcare clinics were contacted, the subsequent response rate is likely to be low. Possible reasons for this limited response could include lack of time, lack of interest, and large existing workloads of the health professionals, while the length of the questionnaire, minimal reimbursement and increased participant burden could be additional factors. The low response rate in combination with the limited respondents in each profession meant that the knowledge and awareness of RED-S could not be compared between professions. Additionally, the smaller sample size of the three healthcare professionals who did not work with athletes or active people compared to the 49 who did is another limitation of the analysis. The small sample size reduces precision, and limits conclusions and comparisons between the two groups. It would be useful to compare this with larger sample size of each professional in future studies to provide information on the types of professions that need targeted educational strategies. The present questionnaire was developed to assess signs and symptoms in female athletes. There is currently limited research into the signs and symptoms of RED-S among male athletes (Dipla et al., 2020). Once the signs and symptoms of RED-S in male athletes are better understood, an appropriate questionnaire can be developed. It's important to note that the transferability of the current questionnaire may be influenced by the education level of the athletes/physical active individual. As our questionnaire was validated in adults with secondary and tertiary education level, its applicability and accuracy in assessing RED-S signs and symptoms may differ when used with paediatric or adolescent athletes. Additionally, individuals with different educational backgrounds may have varying levels of comprehension when completing the questionnaire. Therefore, careful consideration should be given to the age group and educational background of the athletes when utilizing the questionnaire for different populations. Further research and validation may be necessary to ensure its appropriateness for varied athlete demographics

3.6. CONCLUSION

In conclusion, we have developed a questionnaire that has shown good content, face and construct validation, and reliability among both healthcare professionals and physically active individuals. The good level of validity and reliability, combined with the relative short length of the questionnaire, indicates it could be used as a screening tool to identify health professionals and physically active individuals who need additional education support. Future studies could also use the questionnaire to explore the association between risk of RED-S and knowledge of RED-S among female physically active individuals and athletes.

4. Risk of Low Energy Availability and nutrition knowledge among female team sport athletes

4.1. INTRODUCTION

Studies that have reported the prevalence of LEA across a variety of sports and disciplines have estimated rates between 12% and 100% (Beermann et al., 2020; Day et al., 2014; Folscher et al., 2015; Logue et al., 2018; Schaal et al., 2017; Torres-McGehee et al., 2020). This is concerning given the well-recognised adverse health and performance consequences of LEA.

Most research has focused on endurance athletes (Sharps et al., 2022) and there is less data on prevalence rates of LEA among team sport players (Sharps et al., 2022). Several recent studies have used the LEAF-Q (Melin et al., 2014) to detect athletes at risk of symptoms associated with LEA among team sport athletes. The LEAF-Q tool has been validated with sensitivity of 78% and a specificity of 90% and a test-retest reliability of 0.79 (Melin et al., 2014).

Recently, Luszczki et al. used the LEAF-Q to assess the prevalence of Triad/RED-S risk factors in female football players. They found 64.7% were at risk for the triad and RED- S based on LEAF-Q(Łuszczki et al., 2021). Other studies among elite rugby 7s and elite football have estimated prevalence rates of 30-55% (Christensen, 2019; Condo et al., 2019; Groom, 2019; Kumar, 2019; Łuszczki et al., 2021). These rates are concerning and suggest there is scope for education of athletes and their support networks to decrease the risk of LEA and its consequences.

Poor nutrition knowledge among athletes may contribute to an increased risk of LEA. The A-NSKQ (Trakman et al., 2017) has been considered a valid assessment tool in several previous studies examining the nutrition knowledge of athletes (Jagim et al., 2021; Magee et al., 2020; Mitchell et al., 2022; Renard et al., 2021). Previous studies which have used the A-NSKQ amongst team sport athletes have reported mean scores of around 40-50%, indicating poor nutrition knowledge (Jagim et al., 2021; Magee et al., 2020; Szczepańska. et al., 2021).

There is evidence to suggest that nutrition education is an effective way to reduce the number of female athletes with LEA (Logue et al., 2018). The link between nutrition knowledge and positive outcomes has been well documented in the literature (Alaunyte et al., 2015; Bond et al., 2001). In addition, athletes with better knowledge of nutrition were more likely to consume fruits, vegetables, and carbohydrate-rich foods than those with poor nutritional understanding (Bond et al., 2001; Alaunyte et al., 2015). Studies that use nutrition education interventions have shown improvements in both nutrition knowledge and self-efficacy among female athletes (Abood et al., 2004; Buffington et al., 2016). Despite this, limited studies have explored the link between nutrition knowledge and risk of LEA.

To the best of the author's knowledge, only one study has evaluated the risk of LEA and nutrition knowledge in athletes using a combination of the LEAF-Q and A-NSKQ. This study was conducted among collegiate female football players (n=18), during their preseason (Magee et al., 2020). Using the LEAF-Q, the study determined that 56.3% of the athletes were at risk of LEA, and the mean A-NSKQ score showed that 44.7% of the questions had been correctly answered. This indicated poor nutrition knowledge and a high prevalence of LEA. Additionally, athletes with LEA scored lower on the A-NSKQ (41% = poor) than athletes without LEA (52% = average), which indicates an association between nutrition knowledge and LEA risk. Although the authors did not test whether the difference in knowledge and LEA scores were statistically different, the 11% difference in knowledge scores suggest this is practically meaningful (Magee et al., 2020). More studies are needed to replicate or dispute this finding. It is possible that athletes who are less aware of how to meet the dietary requirements for their sport do not consume sufficient energy to meet their needs.

In the context of the athlete population in New Zealand, the risk of LEA has been assessed only among female athletes participating in elite rugby 7s, other team sport athletes participating in recreation, competitive, and/or professional level has not yet been assessed, nor has their knowledge of general and sports nutrition. It is crucial to use validated tools such as LEAF-Q and A-NSKQ to assess the risk of LEA and gauge gaps in general and sports nutrition knowledge in order to guide future research and develop more focused and effective education interventions. The main aims of this study were to assess risk of LEA and nutrition knowledge among team sports athletes.

4.2. METHODS

4.2.1. Study design

A cross-sectional study design using an online questionnaire was used to evaluate the risk of LEA, general nutrition, and sports nutrition knowledge among female athletes over the age of 16 years who participated in team sports at a recreational, competitive, and/or professional level. The Human Nutrition Department at the University of Otago provided ethics approval for this study (reference D18/068).

4.2.2. Participants and Recruitment

Females who participated in team sports and aged at least 16 years met the eligibility criteria. The survey took approximately 40 minutes to complete. If a participant skipped a question, their information was still included in the final sample as long as the skipped question had no impact on the participant's final risk assessment or knowledge score. The study aimed for a sample size of 100 or more, as it is deemed appropriate for statistical analysis, as it can provide a higher level of confidence in the generalizability of the findings to the larger population (Sandelowski, 1995).

Snowball sampling was used to recruit participants. Even though it involves a non-random selection of participants, snowball sampling reaches participants with similar attributes and is based on networks and relationships, which may increase the precision and accuracy of the research (Valerio et al. 2016). Sports organisations, coaches, and sports club managers in and around New Zealand were contacted via email with a request to inform their athletes about the online survey. Additionally, female athletes in any team sports such as netball, football, rugby, hockey, and handball were invited to complete the online questionnaire between February 2020 and September 2022 through email advertisements, social media networks like Facebook and Instagram, and face-to-face contact. Participants could email the researchers with any questions they had about the online questionnaire. All participants gave their informed consent by clicking "submit" after completed the questionnaire to indicate they agreed to participate.

4.2.3. Questionnaire

The survey, which had a total of 125 items, was uploaded to REDCap (Version 12.2.6) which is an electronic data capture tool hosted at University of Otago (Harris et al., 2019). Of the 125 items, 90 were used for analysis in the current study. Basic demographic information about the participants was collected in Section 1, including age, self-reported anthropometric measurements (height and weight), team sport played, ethnicity, and medication use (9 items). Section 2 contained questions on LEA knowledge (8 items) (Pai, Brown, & Black, 2022). The A-NSKQ (35 items) and LEAF-Q (25 items) questionnaires, which assess general and sports nutrition knowledge and the risk of LEA, respectively, were assessed in Sections 3 and 4 (Melin et al., 2014) (Trakman et al., 2018). Section 5 (n = 14) included questions about social media usage, willingness, and preferred method of receiving educational resources about LEA (**Appendix E)**. The remaining 34 of the 125 questions, were a combination of open-ended and multiple-choice questions about the use of oral contraceptives, the level of cooking confidence, and the history of injuries (such as the description, duration, and when they first experienced the injury) – none of which were examined in this thesis. Therefore, a total of 90 questions was used for the analysis.

4.2.3.1. Triad knowledge questionnaire.

The 8 items on Triad knowledge were taken from the paper by Brown et al., (2014). These questions focused on knowledge of bone and menstrual cycle health (Brown et al.,2014).

4.2.3.2. Low Energy Availability in Female Questionnaire (LEAF-Q)

The LEAF-Q assessed injury history, gastrointestinal symptoms, menstrual function, and contraceptive use on dichotomous and ordinal scale. A score of 0-49 is derived, with participants grouped according to their LEAF-Q score. Participant scores of ≥8 was classified as ‘at-risk’ of LEA, and those who scored seven or less were classified as ‘not at- risk’ of LEA (Melin et al., 2014) (**Appendix E**).

4.2.3.3. Abridged Nutrition for Sport Knowledge Questionnaire (A-NSKQ)

The validated 35-item A-NSKQ measured general (11 items) and sport (24 items) nutrition knowledge. Both agree/disagree, and multiple-choice options are included in the questionnaire. Participants were asked to select "not sure" when it was appropriate in order to prevent guessing. Scores for total, general, and sport nutrition knowledge were calculated by summing the correct answers. Scores were then categorised as poor (0–49%), average (50–64%), good (65-74%), and excellent (>75%) (Trakman et al., 2018).

4.2.3.4. Social Media

To assess social media use 14 items on the frequency and type of hashtag use, changes made after viewing a post, willingness to learn about LEA, and preferred platforms to receive educational resources were included. These were open-ended, multiple-choice questions (**Appendix E**). The 14-item survey was not validated, but it was used to assess how team sports athletes used social media and their willingness to learn, which could aid in the development of effective education strategies for future research.

4.2.4. Statistical analysis

The results are presented as means, standard deviations, maximum and minimum values, mean differences, and percentages. Participants' characteristics were compared between ‘at risk’ and ‘not at-risk’ using the Kruskal Wallis for independent samples and the Fishers exact and Chi-square tests. To investigate the association between the risk of LEA, general nutrition and sports nutrition, the Pearson's rank correlation test was used. Statistical significance was defined as a p-value ≤0.05. Stata 16.1 was used to conduct the statistical analyses (StataCorp LLC, College Station, TX).

4.3. RESULT

Table 4.1: *Demographic characteristic n (%) of female team sports athletes (n=100)*

Categories	
Age (years) Mean (SD)	21.9 (6.09)
Ethnicity	(%)[a]
New Zealand European	90%
Māori	13%
Samoan	2%
Cook Island Māori	2%
Tongan	1%
Niuean	1%
Chinese	3%
Other [b]	6%
Type of Team sports	n (%)
Football	44 (44%)
Rugby	15 (15%)
Netball	11 (11%)
Hockey	7 (7%)
basketball	8 (8%)
Volleyball	5 (5%)
Other [c]	10 (10%)
BMI Z-score (16-19 years) Median (25,57) (n=45)[d]	0.5 (0,1)
BMI (kg/m^2) Mean(SD) (n=55)[e]	25.1 (3.29)

Abbreviation: %= percentage, BMI=Body Mass Index, n=number of participants, SD= Standard Deviation, median (25,75) = 25th & 75th percentile.

[a]The percentage count do not add to 100 due to participants indicating more than one ethnicity.

[b] Other ethnicity listed were British=2, Fijian= 2, Swedish-American=1, Irish=1.

[c]Cricket (n=3), softball (n=3), and handball (n=4) were all counted under the "other" category.

[d] Weight status was calculated using WHO BMI z-score cut off points: ≥ -2 to ≤ +1 SD= healthy weight, >+1 to ≤ +2 SD=overweight, > +2 SD= obese. (n=45)

[e] All participants >19 years (n=55).

A total of 236 individuals participated in the study, of which 100 athletes completed the RED-S Knowledge and LEAF-Q questionnaires, 96 completed the ANSK-Q, and 89 athletes answered the entire questionnaire (38% of the participants completed the entire questionnaire). Characteristics of the participants are displayed in Table 4.1. Athletes ranged in age from 16 to 43 years, with a mean (SD) age of 21.9 (6.1) years. The majority of athletes identified as New Zealand European ethnicity (90%), followed by Māori (13%). Female athletes participated in a number of sports, with football (44%) being the most popular, followed by rugby (15%), and netball (11%). The majority of the athletes aged between 16- 19 years fell into the healthy weight category based on the z-score value, with the median of

0.5 (25th, 75th percentile:0,1), ranging from -1.4 to 2. Similarly, athletes above 19 years fell into the healthy range of BMI category, with a mean BMI of 24.2 (±3.55) kg/m2, ranging from 17.6 kg/m^2 to 36.1 kg/m^2.

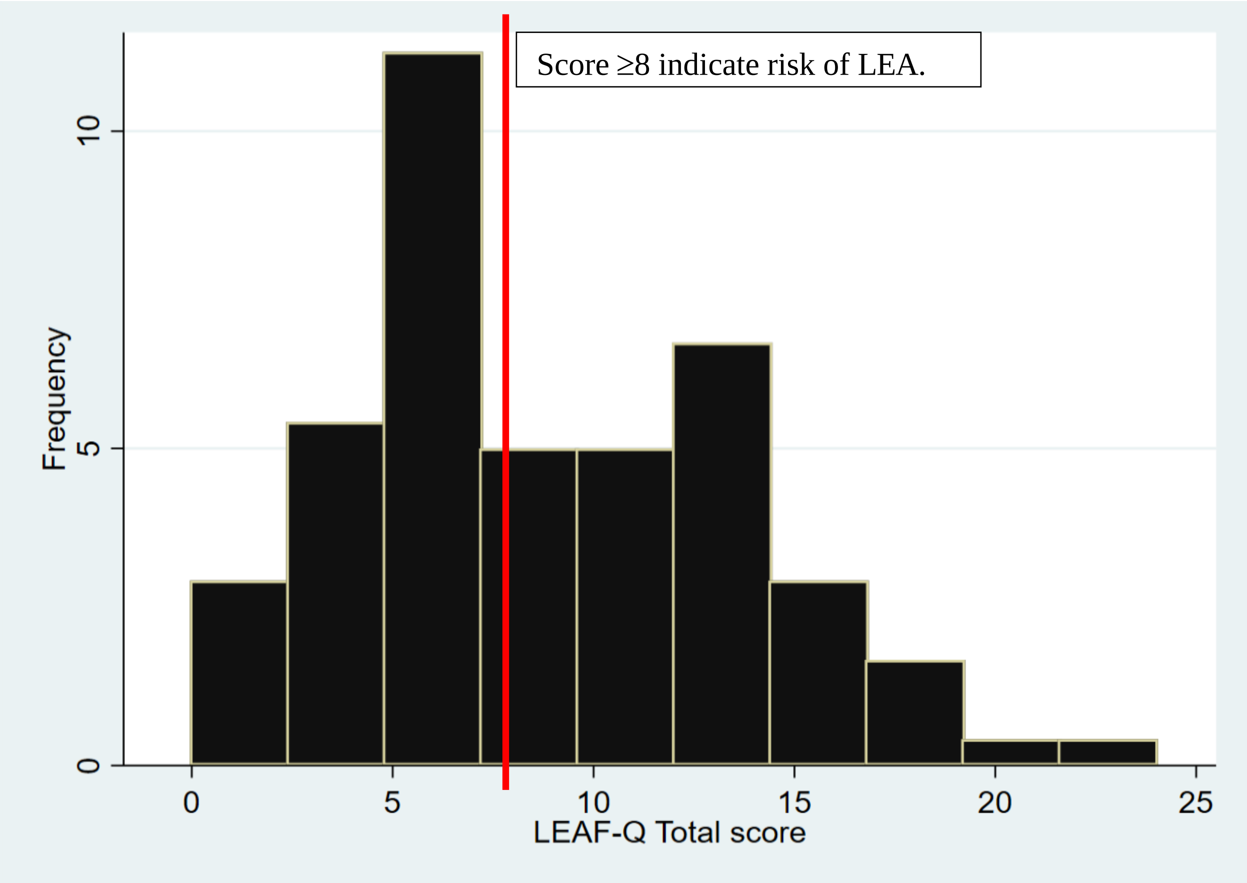


Figure 4.1: *Depicts the range of score received by the participants (n=100).*

The LEAF-Q scores of the participants ranged from 0 to 24, with the overall mean (SD) score being above the cut-off threshold at 8.8 (±4.78)

Table 4. 2: *Risk of LEA based on LEAF-Q scores (n=100).*

	At risk (≥8) n[a]	Not at risk (<8) n[a]	
All participants	53	47	
Team sports	**n (%)**	**n (%)**	**p-value[b]**
Football	19 (43%)	25 (57%)	
Rugby	9 (60%)	6 (40%)	0.430
Netball	5 (55%)	6 (46%)	
Hockey	4 (57%)	3 (43%)	
Basketball	5 (63%)	3 (37%)	
Volleyball	4 (80%)	1 (20%)	
Other[c]	7 (70%)	3 (30%)	

Abbreviation: LEAF-Q= Low Energy Availability in Females Questionnaire, n=number, %=percentage.

[a] LEAF-Q score ≥ 8 indicates risk of LEA; <8 indicates not at-risk.

[b] Kruskal Wallis rank test was used to compare the prevalence of LEA among the teams who are "at risk" and those who are "not at risk."

[c] Cricket (n=3), softball (n=3), and handball (n=4) were all counted under the 'Other' category.

According to the LEAF-Q scoring system, just over half of the participants (53%) were categorised as being 'at risk' of LEA (Table 4.2). The majority of female athletes who participated in volleyball (80%), basketball (63%), rugby (60%), hockey (57%) and netball (55%) were at risk of LEA. However, there was no statistical difference between the groups (p=0.430).

Table 4.3: *Median (25th & 75th percentile) score for A-NSKQ among participants (n=96).*

Score	Median (25, 75)	Min	Max
GNKQ	6 (5,7)	2	9
SNKQ	10 (8,12)	2	18
TOTAL A-NSKQ	16 (14,18)	5	26

Abbreviation: A-NSKQ= Abridged Nutrition for Sport Knowledge Questionnaire, GNKQ= General nutrition knowledge questionnaire, Median (25,75) = 25th & 75th percentile, SNKQ=Sports nutrition knowledge questionnaire.

The knowledge scores for participants are shown in Table 4.3. The median score of 6 (25th, 75th percentile:5,7) on the GNKQ out of 11 which represents a score of 52%. The median (25th, 75th percentile) score on the SNKQ was 10 (8,12) out of 24 equating to 40%. The total A-NSKQ median (25th, 75th percentile) score, which is calculated from the sum of the GNKQ and SNKQ scores, was 16 (14,18) out of 35 (44%). The overall knowledge score of the female athletes in the study was therefore lower than 50%, which is considered poor as per the A-NSKQ classification.

Table 4.4: *Number of participants in total and classed by LEA risk in each category of ANKSQ*

ANSK-Q	**Poor (0-49%)**	**Average (50-65%)**	**Good (66-75%)**	**p-value**[c]
All participants[a]	67 (70%)	26 (27%)	3 (3%)	
LEA at-risk (≥8)[b]	36 (54%)	12 (46%)	3 (100%)	0.273
LEA not at-risk (<8)[b]	31 (46%)	14 (54%)	0	

Abbreviation: ANSK-Q= Abridged Nutrition for Sport Knowledge Questionnaire.
All values represented in total count (n) and percentage (%).
[a] The knowledge categorised based on the total scores of all questions on ANSK-Q (n=96).
[b] LEAF-Q score ≥ 8 indicates risk of LEA; <8 indicates not at-risk (n=100).
[c] Fishers exact test was conducted to analyse the association between the level of knowledge among athletes ‘at risk’ and ‘not at risk’.

Participants' scores on the A-NSKQ ranged from 5 to 26, with a mean (SD) of 15.4 (4.1) out of 35 across all athletes. The majority (n=67, 70%) of athletes had poor A-NSK knowledge, which is defined as a score lower than 50%. In comparison, only 3% of participants had good knowledge, which is defined as knowledge between 66-75% and none had excellent knowledge (defined as a score >75%).

When comparing the participants' risk scores of LEA and A-NSK, 54% of the participants who were "at risk" for LEA had a poor A-NSK score, whereas 54% of the athletes who were "not at risk" for LEA had the scores between 50 and 60% (i.e., average knowledge). Three participants in the at-risk group had a good (i.e., 66-75%) A-NSK knowledge score. However, the Fisher's exact test result showed no significant difference between the groups (p=0.273).

REDS-Q was used to assess participant knowledge of LEA. The median (25th, 75th percentile) score received was 6 (4,7) out of 8, with a range of 0 to 8. Both the REDS-Q score and the LEAF-Q score showed no statistical correlation, rs= -0.083 (p=0.935).

Table 4.5: *Median (25th, 75th percentile) age, BMI, Triad knowledge score and A-NSKQ score between participants 'at-risk' of LEA and 'not at-risk' of LEA*.

Category	**n**	**At-risk of LEA (≥8)**	**Not at-risk of LEA (<8)**	**p-value[a]**
Age (years)	100	20 (17, 25)	21 (17, 27)	0.350
BMI z-score (16-19 years)	45	0.35 (0.00, 0.95)	0.60 (1.00, 1.10)	0.576
BMI (kg/m^2)	55	25.3 (23.1, 27.7)	23.3 (22.1, 26.0)	0.105
Triad knowledge score	100	6 (4, 7)	5 (4, 6)	0.306
A-NSKQ score	96	16 (14, 18)	16 (12, 18)	0.585

Abbreviation: BMI=Body mass index, ANSK- Q= Abridged Nutrition for Sport Knowledge Questionnaire.
All values are mean and standard deviation.
[a] Kruskal Wallis rank test

As shown in Table 4.5 there were no statistical differences between female athletes who were 'at-risk' for LEA and those who were 'not at-risk' for LEA in terms of age, BMI, Triad knowledge, or A-NSKQ scores (all p>0.05).

Table 4.6: *Social media usage patterns and other participant characteristics related to areas of interest in learning about LEA*

Use of social media (n=89)	N (%)
Yes	86 (97%)
No	3 (3%)
Type of networking site actively engaged (n=86) [a]	
Facebook	82 (92%)
Instagram	83 (93%)
Twitter	8 (9%)
Snapchat	62 (70%)
Tumblr	1 (1%)
Others (Tik Tok, WhatsApp)	8 (9%)

Follow hashtags, people, or companies related to exercise, food, training, body size, or weight loss (n=86)	
Yes	38 (44%)
No	39 (45%)
Not sure	9 (11%)
Number of hashtags people follow (mean (SD))	12.4 (3)
Change in diet or exercise habits after seeing a post on social media (n=86)	
Yes	20 (24%)
No	66 (76%)
Interested in learning more about Low energy availability (n=86)	
Yes	77 (90%)
No	9 (10%)
Topics of interest (n=86) [a]	
Nutrition for female athletes	78 (91%)
Bone health	26 (30%)
Injury prevention	53 (62%)
Menstrual function/hormonal health	53 (62%)
Supplements	41 (48%)
Signs and symptoms of LEA	52 (60%)
Preferred choices of learning about LEA (n=86) [a]	
Book	17 (20%)
Factsheet	48 (56%)
Video	54 (63%)
Group seminar	40 (46%)
Individual seminar/ consultation	27 (31%)
Self-education	22 (26%)
Scientific articles	21 (24%)
Social media	42 (49%)
pamphlet	11 (13%)

Abbreviation: n=number of participants, %=percentage, SD=standard deviation, LEA=Low energy availability.
[a] Percentage do not add to 100% due to participants choosing more than one characteristic.

The characteristics of the social media platforms used by female athletes are listed in Table 4.6. Nearly all participants reported using social media (96% (n=86)), with Instagram and Facebook being the most popular networking sites 93% (n=83) and 92% (n=82), respectively. When using social media, 44% (n=38) of the participants followed hashtags related to exercise, food, training, body size, or weight loss, with a mean (SD) of 12.4 (3) hashtags followed. Additionally, 24% (n=20) of social media users change their eating or exercise routines as a result of seeing a post on social media.

About 90% (n=77) of the 86 participants who responded to the question about their willingness to learn about LEA indicated that they would be interested in learning more. With the majority 91% (n=78), wanting to know more about nutrition for female health, followed by injury prevention, menstrual function/hormonal health 62% (n=53), and signs and symptoms of LEA 60% (n=52). The three most preferred methods to learn about LEA were through video (63%, n=54), fact sheets (56%, n=48), and social media (49%, n=42).

4.4. DISCUSSION:

To the best of the author's knowledge, this is the first study to evaluate the risk of LEA, and general nutrition and sports nutrition knowledge among female team sport athletes in New Zealand. The study used the LEAF-Q as a screening tool to determine the prevalence of LEA risk among female team sports athletes and the A-NSKQ to gauge general and sports nutrition knowledge. From the sample of 100 New Zealand female team sport athletes, 53% were considered to be at risk of LEA based on the LEAF-Q. Nearly 70% (n=67) of female athletes had a knowledge score that was considered "poor," which is defined as having a knowledge score below 50%. The knowledge scores of the athletes who were 'at risk' of LEA and those who were 'not at risk' of LEA were not practically different.

4.4.1. Risk of LEA

The proportion of female athletes in this study who were deemed to be "at-risk" for LEA (53%) is consistent with previously published research. For example, previous research found that approximately 50% of elite rugby 7's athletes (n=24) were "at-risk" of LEA, while Magee et al., (2020) observed that 56.3% (n=18) of colligate female football players are at risk of LEA. Although the current study's findings are similar to those of Groom (2019) Christensen (2019) Kumar (2019), we were able to investigate the risk of LEA in a larger sample size and include athletes who participated in recreational, competitive, and/or professional levels in a variety of team sports. Therefore, our larger sample size with an assortment of team sports participants, competing at different levels may be a more representative estimate of risk of LEA. Thus, the study's findings can be generalised to a wider group of team sports and the athletic population.

For those competing in volleyball (80%), basketball (63%), rugby (60%) and hockey (57%) more than half of the female athletes were at risk for LEA. Previous studies estimated the prevalence of LEA among these sports to range from 40% (Logue et al., 2019) to 55% (Rogers et al., 2021). The previous studies assessed the prevalence of LEA among individual sports like boxing, swimming, cycling, running, and others in addition to team sports like basketball, rugby, hockey, and volleyball. Moreover, Logue et al., (2019) and Rogers et al., (2021) did not distinguish between the prevalence of LEA in team sports and individual sports, so the prevalence mentioned in previous research might not match the prevalence of the current study.

4.4.2. General and sprots nutrition knowledge

The overall A-NSKQ score of the participants was 44% which is classified as poor. For the general nutrition knowledge section, the median score was classified as average (52%); and the median score on sport nutrition knowledge was poor (40%). These results are comparable to a recent study of a small group of female football players, who received scores of 40% and 30%, respectively, for their overall and sport nutrition knowledge (McCrink et al., 2021). A similar finding was found in professional male Australian footballers, who scored 46% overall and 47% in regard to their understanding of sport nutrition (Jenner et al., 2021). Although the tools used in each study varied and each study surveyed a different group of athletes, the overall lack of nutrition knowledge is consistent and needs to be addressed.

The results of two earlier studies that evaluated athletes' knowledge using the A-NSKQ were consistent with the current study's finding of an overall A-NSKQ score of less than 50%. In a study Magee and colleagues (2020) the mean score was 44.7% among (n=18) collegiate female football players (Magee et al., 2020). In addition, a mean score of 47.9% was observed by (Jagim et al., 2021) among 67 male and female participants from the National Collegiate Athletic Association (NCAA) Division III. Given the fact that dietary intake is altered by nutrition knowledge, the athletes in the current study may be unaware of the energy and nutrient intake recommendations for sports (Thomas et al., 2016). As a result, they might consume insufficient amounts of food for training and performance. The score obtained in the current group of team sports players suggest they may have only a basic understanding of general healthy eating guidelines, which may limit their ability to put these guidelines into practice.

Moreover, due to convenient sampling, survey response rates may be biased (Leiner, 2014). In other words, respondents may believe they have a greater understanding of general and sports nutrition than non-respondents (Pantano, 2006). Despite this bias, the current study found that questionnaire respondents had inadequate nutrition knowledge. This suggests that even those who believed they had greater understanding actually possessed inadequate levels of knowledge. Even among those who believe they have a higher level of knowledge; targeted educational interventions are warranted to improve nutrition knowledge.

Recently, the PEAKS-NQ questionnaire developed by Tam et al. (2021) has demonstrated validity and reliability in assessing sports nutrition knowledge among New Zealand athletes (Tam et al., 2021). However, the publication of this questionnaire occurred after the completion of the literature review and study design, resulting in its exclusion from the research. Future research in the area, however, may benefit from including the PEAKS-NQ questionnaire to get a more thorough understanding of athletes' knowledge.

4.4.3. Association of LEA and knowledge

A unique aspect of this study was assessing the association between LEA and nutrition knowledge. More athletes who were "at-risk" for LEA performed lower on the A-NSKQ (46%) than athletes who were not at-risk for LEA (54%). However, this difference was not statistically significant. Only one previous study found a similar association; athletes with LEA performed lower on the A-NSKQ (41% = poor) than athletes without LEA (52% = average) (Magee et al., 2020). This study did not indicate whether or not the difference was statistically significant (Magee et al., 2020).The fact that, in the present study 27% of the athletes scored below 65% (. i.e., average) on the A-NSKQ, and most athletes (70%) had poor A-NSK knowledge, which is defined as a score lower than 50%, indicates that majority of athletes had poor to average knowledge on general and sports nutrition (97%). Additionally, the lack of difference in knowledge could be because those at risk may be intentionally restricting or experiencing pressure from a coach, teammates, and/or through social media platforms. These influences may mean that an athlete may be less concerned about the consequences of LEA at this point in their lives/careers (Wasserfurth et al., 2020). However, the present study did not examine these additional factors which could put athletes at risk of LEA.

Additionally, some studies show that even though athletes have a some understanding of the nutritional needs for sports performance, their dietary knowledge may not always translate into dietary habits that consistently comply with best practise (Jagim er al., 2021; Magee et al., 2021). This may be the case in the present study, which showed lack of differences between the groups at risk and those who are not for LEA. Furthermore, the small sample sizes in each category may have reduced the precision of the estimate. Future studies should include larger samples.

Although there is not clear statistical evidence to support the link between risk of LEA and nutritional knowledge, it is generally assumed that higher levels of nutrition knowledge help athletes better understand their nutritional needs, which could help them improve their diets and lower their risk of LEA. The level of competition and the athlete's access to nutritional support or resources are likely to have an impact on this relationship (Bird & Rushton, 2020). Future research should also assess the relationship between nutrition knowledge and risk of LEA among athletes who participate at different levels of competition, as this was not assessed in the current study.

In the present study, the average score for Triad knowledge was 66%. This score is relatively similar to the mean scores reported in previous studies conducted by Pai et al. (2022) among physically active individuals (mean score of 61%) and female athletes (mean score of 64%) (Brown et al.,2014). Additionally, there was a weak negative correlation observed between athletes' Triad knowledge scores and their level of risk of LEA. Previous studies have not examined the relationship between Triad knowledge and LEA risk using the same questionnaire, making it challenging to draw reliable inferences.

It is important to note that the 8-item Triad knowledge questionnaire used in this study only evaluated knowledge about bone and menstrual health. In contrast, the recently created RED-S knowledge questionnaire (Pai et al., 2022) includes the initial 8 items from the Brown et al. (2014) questionnaire in addition to a wide range of items exploring the LEA signs and symptoms. Future studies can, therefore, make use of the newly validated RED-S questionnaire in order to better understand the relationship between knowledge of the Triad and the risk of LEA among athletes. As recently demonstrated in the study by Pai et al. (2022), using this extensive questionnaire can provide a broader view of athletes' knowledge on LEA.

4.4.4. Association of LEA with Age and BMI

In the current study, we also examined whether other factors, such as age and BMI were associated with the risk of LEA. There were no statistically significant differences in mean age and BMI among athletes at-risk for LEA and athletes who were not at-risk (mean difference was less than 1). Previous studies which have used the LEAF-Q, also reported no differences in age when comparing female athletes at-risk and not at-risk of LEA (Jesus et al., 2021; Fahrenholtz et al., 2022). Since LEA can affect individuals of any age, there is not enough evidence to indicate whether the age increases or decreases the likelihood of developing LEA.

There are contradicting results in the literature regarding the association between BMI and risk of LEA. According to Melin et al. (2014), in an analysis using the LEAF-Q, among six participants who fell into the underweight (BMI <18.5) category, five were at risk of LEA. However, this finding was not statistically significant (Melin et al., 2014). A recent study, which also used the LEAF-Q, found that athletes with a higher risk of LEA had lower BMIs than athletes with a lower risk of LEA. In their logistic regression analysis, they identified a that lower BMI was a risk factor for LEA (Fahrenholtz et al., 2022). This trend, however, was not evident in the current study, possibly because there were so few (n=3) participants in the underweight category. In an observational study, Melin et al., (2015) also found no difference in BMI among female endurance athletes at-risk of LEA and those with a low risk of LEA. In contrast, a recent study showed that the mean BMI of the low EA group was found to be significantly higher than that of the adequate EA group (23.8 $kg/m^2 \pm 3.9$ vs. 22.2 $kg/m^2 \pm 3.5$, $p<0.0001$) (Ackerman et al., 2018). This is conflicting evidence for the relationship between BMI and risk of LEA is likely due to a number of factors which differed between studies such as age, gender, body composition, level of physical activity, and diet. Additionally, BMI is a rough indicator of body fatness and does not account for factors such as muscle mass, which can affect energy availability.

Overall, the research on the association between BMI and LEA appears to be contradictory and suggests that BMI is not a reliable predictor of LEA and may not influence risk. Furthermore, it is interesting to note that the majority of the athletes in the current study who were at-risk for LEA had BMIs that were within the normal range, supporting the notion that BMI alone should not be used to screen for LEA. Also, BMI can be a poor indicator of body composition in athletes (Mountjoy et al., 2014).

4.4.5. Social media

In view of the widespread use of social media for enticing audiences and as a primary source of knowledge about food and nutrition, health issues, diagnoses, and treatment, the current study examined the social media usage patterns of team sports athletes. Overall, 97% of participants reported using social media. According to the study by Perrin and Anderson (2019), social media is used daily by undergraduate and graduate college students between the ages of 18 and 24 years (Perrin & Anderson, 2019). Platforms like Instagram (93%) were the most popular networking sites among athletes in this study. This is similar to previous research that revealed Instagram to be more popular (71%) than other platforms, such as Facebook, among young adults aged 18 to 24 years (Smith & Anderson, 2018).

Social media users can easily find timely information and avoid excess information by using hashtags (Kywe et al., 2012; Stieglitz & Dang-Xuan, 2013). In the current study, 44% of athletes who used social media follow hashtags, users, or organisations that are connected to training, eating, exercising, body size, or weight loss. Additionally, 24% of athletes report changing their diet or exercise plans in response to posts on social media. Previous research examined Instagram's effects on female athletes and how fitness accounts inspired people to exercise (Raggatt et al., 2018). This research found that 59.3% of social media users above 16 years follow content posted by personal trainers and athletes. Further, 10.3% of users were at-risk of developing an obsession with exercise after viewing fitness-related posts, while 17.4% expressed very high levels of distress after viewing content posted by athletes and personal trainers (Raggatt et al., 2018). However, due to the fact that the current research did not examine the effects of social media postings on athletes' knowledge and behaviour, the impact of social media use on behaviour cannot be fully determined. But according to 24% of the athletes in the current study, dietary or exercise regimens have been altered in response to posts on social media. However, it is unknown whether these modifications had a positive or negative impact on performance and health.

Overall, engaging with fitness-related content on Instagram has been shown to have both beneficial and detrimental effects (Tiggermann & Anderbard, 2020). Future research should focus on analysing the quality of research conducted on Instagram/Social media, as well as conduct an empirical study to understand the influence of social media posts on knowledge and its capacity to reinforce lifestyle changes and awareness of sports conditions like triad/RED-S. Additionally, social media platforms can be used as educational tools, as demonstrated by the fact that 49% of the athletes in the current study indicated they would be interested in learning more about LEA on social media Furthermore, female health nutrition, injury prevention, menstrual function/hormonal health, and LEA symptoms were the top topics that athletes wanted to learn more about.

4.5. LIMITATIONS

The results of this study should be interpreted with a number of limitations in mind. The LEAF-Q analyses symptoms to determine LEA risk and is validated using endurance sports, not team sports. Due to LEAF-Q's inability to adequately account for team sports' distinctive characteristics, such as the intermittent nature of the physical activity and the type and location of injuries (Sim & Burns, 2021), it may produce inaccurate prevalence figures. It would be useful for the LEAF-Q to be validated in team sport athletes in the future. Additionally, self-reported weight and height were used to calculate BMI in the current study, which increases the possibility of respondent bias. The LEAF-Q is not meant to be used as a method of LEA diagnosis, but rather as a screening tool to give an indication of developing LEA. Therefore, future research should also take into account hormonal measurements, hormonal markers, and resting metabolic rate (RMR) tests to allow for an accurate diagnosis of LEA in this population.

It is important to acknowledge the study's limitations, such as the possibility of self-selection bias, as they may affect the generalisability of the results. The sample of participants who completed the survey may not be representative of the larger population, and the results may not apply to those who declined to participate. Future research could employ random sampling techniques to ensure a more representative sample in order to mitigate this bias.

This research was carried out during the COVID-19 pandemic (February 2020 and September 2022). The type and intensity of training or competitions that the clubs were able to conduct may have changed during this period, as nearly all sports clubs encountered challenges to operate regularly. This could be a factor in the low response rate (38%) of the survey. Furthermore, it is unknown whether all of the study's athletes had returned to "normal" training and competition at the time of the study. LEA during "normal" training or competition may be less prevalent than was indicated in this study given that training intensity and time commitment may have decreased due to the pandemic. Additionally, the influence of the COVID-19 pandemic among female athletes has been linked to changes in activity, sleep patterns, and mental health problems (Bowes et al., 2022; Pillay et al., 2020), and there is concern that it may increase current eating disorders and increase the likelihood of disordered eating (Reardon et al., 2021; Touyz et al., 2020). One study indicated that 24.7% of elite Australian athletes' menstrual cycles were affected by the pandemic (McNamara et al., 2020). Therefore, it is unknown if or to what extent the pandemic impacted the athletes in the current research who had symptoms of LEA, and how it affected their health and performance.

While we were able to identify the different team sports that the athletes had participated in, we were unable to stratify the sample according to the level of competition, which hinders our ability to draw generalisations about the risk of LEA and knowledge scores of particular groups of athletes. Future research investigating recreational, competition, and professional/elite levels of athletes could determine the prevalence of LEA in each of these populations. Additionally, investigations looking at whether the prevalence of LEA increases as the level of competition rises would provide further insight.

Given that the questionnaire was distributed online, "cheating" cannot be ruled out, but is unlikely given the low A-NSKQ knowledge scores. To encourage a higher completion rate, the A-NSKQ was used instead of the full NSKQ (Trakman et al., 2018). This compact questionnaire evaluates declarative knowledge, an essential aspect of nutrition knowledge, but not procedural knowledge, such as how to prepare a high-carbohydrate meal (Spendlove et al., 2012). A longer questionnaire with procedural knowledge items, like the NSKQ, may be used to get a better understanding of an athlete's ability to apply knowledge to practise (Trakman et al., 2017). However, the added burden to participants needs to be considered.

This study is one of the few studies to examine LEA risk, general nutrition, and sports nutrition knowledge among female team sports athletes. Although the LEAF-Q has the aforementioned drawbacks, it is still a strength of the current study due to its widespread use in large populations, ease of use, and elimination of the expensive nature of routine blood samples and repetitive hormonal measurements, which are not always practical (Groom, 2019). When compared to earlier studies on athletes participating in team sports, the current study's relatively large sample size, which included athletes from a variety of teams sports, provides a more precise estimate of overall prevalence of the risk of LEA and level of nutrition knowledge in New Zealand. Additionally, this study identifies a few specific topics that athletes would be keen to learn about, along with their learning approach. Future education intervention studies can focus on these topics and any of the preferred approaches to educate these groups of athletes.

4.6. CONCLUSION:

Overall, 53% of female team sport athletes were at-risk for LEA, and 70% had poor general and sports nutrition knowledge. Additionally, more than half of the athletes in each category of team sports were at-risk for LEA, which emphasises the necessity of regular screening to support early interventions and prevent a potential decline in performance and health. Age and BMI was not associated with the risk of LEA. The knowledge scores of the athletes who were "at risk" of LEA and those who were "not at risk" of LEA were not practically or statistically different.

However, the overall findings of poor nutrition knowledge among team sports athletes implies the need more nutrition education. It was encouraging that 90% of athletes were interested in learning more about LEA and relevant concepts, and 49% said they preferred to learn through social media. Future research should address the following topics: the relationship between additional team sports-specific factors (e.g., athletic calibre and homogeneous group of team sports) and nutrition knowledge, and possible effects on performance in this population; the effect of educational interventions on general and sports nutrition knowledge, as well as dietary behaviours in team sport population.

5. Systematic review on RED-S related posts on Instagram

5.1. INTRODUCTION

There is evidence that RED-S is highly prevalent in physically active people; however, there are gaps in knowledge among athletes, parents, coaches, athletic trainers, physicians regarding the syndrome and its diagnosis (Dave & Fisher, 2022). To lower the risk of RED-S, athletes and support staff must be able to identify its signs and symptoms and understand the health and performance consequences of this syndrome. Previous studies indicate that among physically active people, athletes, and healthcare professionals, there is limited understanding of the definition, causes, and effects of RED-S (Charlton et al., 2022; Dave & Fisher, 2022). Furthermore, prior research on awareness of RED-S has demonstrated that young athletes and physically active individuals are not fully aware of the term (Brook et al., 2019). As a result, innovative methods for RED-S education or increasing awareness are required. According to the research, a thorough understanding of the term RED-S is important, which can assist athletes and physically active individuals in reducing the associated short- and long-term risk factors (Charlton et al., 2022). Therefore, there is a need to increase awareness of the definition of RED-S, as a thorough understanding of the definition, which explains how both men and women can experience impaired physiological function due to a low energy availability status, could be beneficial and could potentially encourage concerned athletes/physically active individuals to seek professional assistance. Social media platforms such as Instagram may be well-suited for promoting RED-S related education.

Social media is a rapidly growing global platform that connects millions of people and enables the rapid exchange of a wide variety of materials. The results of the previous chapter (chapter 4) showed that 96% of athletes used social media and that Instagram was the most popular networking platform in NZ. Therefore, Instagram is a potential for educating athletes about RED-S. There is currently no research that has assessed educational material on Instagram on the topic RED-S. It is important to assess the quality and accuracy of information as well as its reach and engagement. This can help inform future educational initiatives.

Before creating an Instagram education programme, it is important to first review recent posts to understand what is currently available. Therefore, to determine the reliability, accuracy, clarity, and level of engagement of current posts, this study will audit existing Instagram posts on the definition of RED-S. It will provide an insight on whether there is currently suitable material that can be recommended to active individuals and/or identify gaps that could be the focus of future educational resources.

The objectives of this study were:

- To systematically review the accuracy of the definition of RED-S on RED-S related posts on Instagram.
- To describe the characteristics of relevant posts on the definition of RED-S, based on level of engagement, self-reported qualification/background of account holder, and popularity.

5.2. METHODS

A systematic search of publicly available Instagram accounts that provided information on RED-S was undertaken. The data search on RED-S related photos, infographics, and videos posted on Instagram were selected over a 3-week period (February 15, 2022, to March 7, 2022). The initial search (i.e., step 1) was conducted using three hashtags: #relativeenergydeficiencyinsports, #relativeenergydeficiency and #lowenergyavailability. These three hashtags were selected as they are commonly tagged with RED-S related information. It was noted that the hashtag #red-s provided no results, and the hashtag #reds attracted a large number of posts primarily about a football team and not exclusively about RED-S. Hence, these two hashtags were excluded.

Step 2 of the process involved choosing posts that contained the word "RED-S" in the image. Additionally, a snowballing approach was used to find additional posts based on the tags and recommendations mentioned in the selected posts. The criteria listed in Table 5.1 were applied to the posts that were selected for screening.

Table 5.1: *Inclusion and exclusion criteria*

Criteria	Inclusion[a]	Exclusion[b]
1	Most recent posts from hashtags #relativeenergydeficiencyinsports #relativeenergydeficiency or #lowenergyavailability found in the public domain	Instagram posts having less than 3 posts on RED-S with very little information
2	Instagram account mostly focused on sport nutrition related content.	Instagram account predominantly posting on concepts like pregnancy, fertility, medical conditions, supplements, product promotions etc.
3	Posts/infographics or videos that described key concepts of RED-S, its signs, symptoms, consequences, diagnosis and treatment.	Posts/infographics or videos that describe RED-S or LEA's association with food, nutrient, recipes, pre-workout snack, eating disorders, mental health, inspirational quotes, athletes pre-post photo and description on their journey on recovery from RED-S, body image issues, and special events like webinars, podcast, Instagram live etc.

[a] Posts which were included in this review, if they met all 3 of the criteria

[b] Posts which were excluded if they met any of the criteria

In step 3, the selected posts were reviewed to identify RED-S related content specific to its definition, signs and symptoms, health and performance consequences, and diagnosis and treatment. The posts selected in step 3 were assigned with an identification number. Additionally, Instagram post URL, the caption text, the account holder's qualification, the image/video posted, the number of followers for the account, the number of likes for the post, and the hashtags for the post were recorded for each post. In the fourth step, the research team reviewed the selected posts and identified those posts which contained the key words, "What is RED-S", "Define RED-S", "Do you know about RED-S", Heard of RED-S", or "RED-S is" on the images/descriptions. This final step led to the selection of posts which specifically described key concepts/definition of RED-S which were included in the final analysis.

5.2.1. Data analysis:

The data extracted from each of the selected posts were recorded on an excel spreadsheet. One researcher performed the data extraction from Instagram, the second researcher double-checked the data extracted. To assess the level of engagement, the number of likes the individual post received and the number of followers per account were collected (Sharp et al., 2021).

To determine the accuracy, clarity, level of understanding, and level of engagement of the posts, the images/photos/infographics of each post and its description were assessed by two academic experts who specialise in RED-S. The expert panel evaluated the quality of the content based on four criteria, accuracy ('not accurate' (=1) to 'extremely accurate (=5)), clarity ('not clear'(=1) to 'extremely clear'(=5)), understandability ('not easy to understand' (=1) to 'extremely easy to understand (=5)) and engagement ('not engaging'(=1) to 'extremely engaging (=5)). Details of each criterion is outlined in Table 3. The scale was used to assess the post's quality, amount of evidence-based information, clarity, and presentation. Due to the lack of a validated tool to assess the information quality in these types of social media posts, a total quality score was determined for each post based on the 4 criteria used by the experts to evaluate the posts (presented in Table 5.2). This quality score ranged from 4 to 20, with 4 being the lowest possible score. In addition, the like-to-follower ratio, which reflects the percentage of followers who react by "liking" the post was calculated (Kabata et al., 2022).

A recent definition of RED-S from a study by (Charlton et al., 2022), was used as the standard reference to evaluate the posts. This definition states: "The new term, Relative Energy Deficiency in Sport (RED-S), expands on the previous Triad framework by including males, recreational athletes, and exercisers as populations that are susceptible to the LEA- related symptoms. RED-S also includes a range of adverse health and performance outcomes that stem from an LEA state in addition to the already established menstrual irregularities and impaired bone health seen in the Triad framework" (Charlton et al., 2022, p.445). In addition, the expert reviewers considered whether the posts/descriptions had evidence-based scientific information, or if they cited scientific references in order to conduct a comprehensive evaluation of the RED-S definition.

5.2.2. Statistical analysis:

Data were described using counts and percentages, medians, 25th and 75th percentiles, means, and standard deviation. The Kruskal-Wallis rank test was utilised to determine the difference between the type of image used in the posts (i.e., infographic or written content) with the number of likes, followers, and total quality score received. Spearman's rank correlation test was conducted to examine the relationship between the total quality score of the post and the number of likes; followers; and like-to-follower ratio. A p-value of <0.05 was deemed statistically significant. Statistical analyses were carried out using Stata 16.1 (StataCorp LLC, College Station, TX), as well as providing graphically represented of estimates.

Table 5.2*: Criteria to analysis the posts*[a].

Criteria	1	2	3[b]	4	5
Accuracy of the information on the image/description	The content is not accurate	The content is somewhat accurate	Neutral	The content is accurate	The content is extremely accurate
The meaning of image/description is clear.	The meaning is not clear	The meaning is somewhat clear	Neutral	The meaning is clear	The meaning is extremely clear
The image/description is easy/simple to understand	The content is not simple and easy to understand	The content is somewhat simple and easy to understand	Neutral	The content is simple and easy to understand	The content is extremely simple and easy to understand
The image/ description is engaging/interesting	The content is not engaging/ interesting	The is content is somewhat engaging/interesting	Neutral	The content is engaging/ interesting	The content is extremely engaging/interesting

[a] These criteria can be used to analyse the description or images or both.

[b] When a post contained some information that was either missing or not fully explained, it received a neutral rating.

Examples of few posts selected for review on Instagram with the scores received are provided in Appendix F & G. It also provided the few examples of images which was considered as infographics and written content images.

Ethics

This study did not require ethical approval because only secondary, unidentified data from public social media platforms were examined, which was in accordance with international web data regulations and Instagram's data policy.

5.3. RESULTS:

An overview of components of posts under each hashtag is shown in Table. 5.3 to provide an understanding of the types of posts that exist. More posts (n=3,322) were made under the hashtag #relativeenergydeficiencyinsports than under #relativeenergydeficiency (n=202), and the content covered a wide range of topics, including information about RED-S risk factors, food alternatives, and its relation to eating disorders. There were 1,085 posts with the #lowerenergyavailability hashtag, and the content covered a wide range of topics, such as definitions, associations with body image, and inspirational quotes.

Table 5.3: *A overview of the various topic discussed on Instagram posts under the hashtags #relativeenergydeficiencyinsports, #relativeenergydeficiency, and #lowenergyavailability*.

Hashtag	No. of posts[a]	Overview of the contents
#relativeenergydeficiencyinsports	3,322	• Information on the definition of RED-S, its risk factors, signs & symptoms, health & performance consequences, and psychological implications.
#relativeenergydeficiency	202	• RED-S associated with low energy availability, and female and male athletes' triad. • Association of eating disorders/ disordered eating, over-training, under-fuelling with RED-S. • Food alternatives, recipes to increase energy intake, options of pre-workout snacks. • Video posts of real-life experiences from athletes on diagnosis and recovery from RED-S • Special events hosted by account holder/sports nutritionists via Instagram live, podcasts, webinars, seminars, workshops on RED-S. • Infographics outlining basic information on RED-S
#lowenergyavailability	1,085	• Information on the definition of LEA, its potential causes, warning signs and symptoms, and treatment. • Information on energy availability, energy balance. • Association of body image and ED/DE with LEA. • Infographic on low EA and optimal EA. Association of LEA with bone and menstrual health. • Inspirational quotes to increase energy intake and encourage positive attitudes towards body image.

[a] At the time of review.

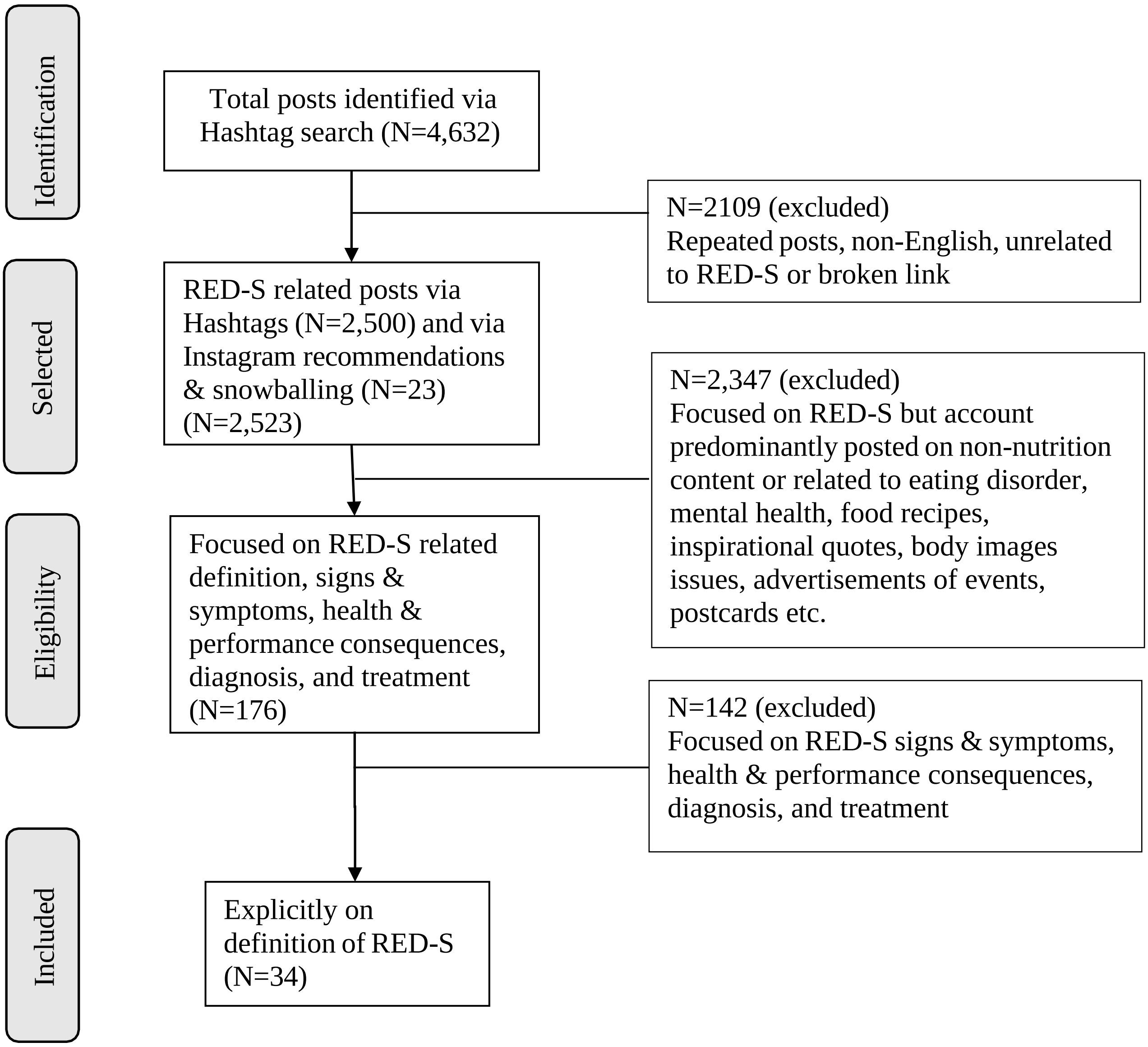


Figure 5.1: *The selection process of Instagram posts.*

Over the three-week period, 4,632 posts with RED-S related hashtags were identified (see Figure.5.1). Of these 2,109 (45%) were excluded because they were repeated, not in English, or unrelated to RED-S. A total of 2,347 (51%) of the posts were excluded because although these posts focused on RED-S, the account predominantly posted on non-nutrition content or information related to eating disorders, mental health, food recipes, inspirational quotes, body images issues, advertisement of events or postcards. After applying the inclusion and exclusion criteria (outlined in Table 5.1) only 176 (4%) posts were included as their content was specific to RED-S definition, signs and symptoms, health and performance consequences, and diagnosis and treatment. Of the 176 posts, 34 (0.8%) posts specifically addressed the definition of RED-S, while 142 (3.2%) focused on the signs and symptoms, health and performance consequences, diagnosis, and treatment of RED-S. As a result, 34 posts were included in the final analysis. The 34 RED-S-related posts had a median of 29 likes (25th/ 75th percentile:11,137) and a median of 1,714 followers (25th/ 75th percentile: 454/ 10,800).

According to the qualifications of the account holder listed in their Instagram profile for the posts that were included in the final analysis (n=34), the plurality was managed by dietitians (23%) and nutritionists (17%), followed by coaches (14%) and educators (14%). It is worth noting that as there was more than one profession mentioned by two account holders, they have been included in more than one category (See Table 4). Only three of the six nutritionists specified they were registered. There were seven educators with different titles, such as “education on REDS & eating disorders,” “nutrition, health & education,” “health & wellness education,” etc. The three students whose account posts were included stated they were either studying nutrition science, sport medicine, or sports and health at the Ph.D. or M.Sc. level. Non-profit organisations included the Athlete Triad Coalition and International Olympic Committee (IOC). There were four accounts which did not specify qualification, which were categorised as ‘unspecified’.

Table 5.4: *Demographic information, number of likes, followers, and qualification for the account holders of the 34 eligible posts*.

	Median (25th, 75th percentile)
Number of likes	29 (11/137)
Number of Followers	1714 (454/ 10800)
Qualification of IG account administrators [a]	**N (%)**
Dietitian [b]	7 (21%)
Nutritionist [c]	5 (15%)
Coach	5 (15%)
Educator	7 (21%)
Student	3 (9%)
Physiotherapist	3 (9%)
Non-profit organisation	2 (6%)
Unspecified	4 (12%)

Abbreviations: N=number, %= percentage, median (25,75) = 25th & 75th percentile.
[a] Percentage do not add to 100% due to account holders indicating more than one profession.
[b] One of the seven dietitian was also a physiotherapist.
[c] Of the five nutritionists, one was also a coach.

5.3.1. Images of RED-S on Instagram

A total of 24 (71%) of the 34 RED-S definition related posts contained infographic images with different designs. Among these 24 posts, 46% (n=11/24) used the standard circular diagram, which was published by IOC in 2015 (Mountjoy et al., 2015) and lists the health and performance consequences of RED-S. In comparison to the original diagram, three posts (12.5%) modified these consequences and highlighted fewer health and performance consequences. The energy availability concept graph, which explains intentional and unintentional low energy availability as well as the ideal energy availability for life processes, was also used in three posts (12.5%) (Keay & Francis, 2019). Only one post used the female athlete triad triangular diagram from (Nattiv et al., 2007), to define RED-S, which mentions the three conditions of menstrual disturbance, energy deficiency, and low bone mass. In three posts (12.5%), the account holder also used a diagram (not previously published) relating to energy balance, under fuelling, psychological effects, and behavioural consequences due to RED-S. Ten (29%) of the 34 posts related to RED-S definitions used written content on the image of the post attached to define RED-S, or simply stated “heard of REDS? Or what is REDS?”.

Table 5.5: *Characteristics of the posts based on expert review.*

	Score	Avg. no. of rating (%) [a]	Mean (SD)
Accuracy			3.5 (1.1)
Not accurate	1	0	
Somewhat inaccurate	2	4 (12%)	
Neutral	3	12 (36%)	
Accurate	4	9 (26%)	
Extremely accurate	5	9 (26%)	
Clarity			3.4 (1.1)
Not clear	1	2 (6%)	
Somewhat unclear	2	3 (9%)	
Neutral	3	9 (27%)	
Clear	4	13 (38%)	
Extremely clear	5	7 (20%)	
Understanding			3.4 (1.1)
Not simple to understand	1	1 (3%)	
Somewhat lack to understand	2	5 (15%)	
Neutral	3	11 (32%)	
Simple to understand	4	8 (24%)	
Extremely simple to understand	5	9 (26%)	
Engaging/interesting			2.9 (1)
Not engaging/Interesting	1	2 (6%)	
Somewhat not engaging/interesting	2	11 (32%)	
Neutral	3	9 (27%)	
Engaging/interesting	4	11 (32%)	
Extremely engaging/interesting	5	1 (3%)	

Abbreviations: %= percentage, SD= Standard Deviation.

[a] Average number of rating received for each post; n=34 posts.

5.3.2. Experts review

Two experts evaluated the 34 posts using a predetermined evaluation template (see Table 3). Table.5.5 lists the mean scores of the two experts for each of the evaluation criteria. Different concepts were used to define RED-S, with 52% rated as being ‘extremely accurate’ or ‘accurate’, according to the experts some interpretation varied from the actual definition. Only four posts were rated as ‘somewhat inaccurate’, indicating that they contained some inaccurate information. Of the posts, for 38% the meaning was ‘clear’, while 20% were ‘extremely clear’. For ratings of understanding, the plurality of posts was rated as ‘neutral’ (32%), followed by ‘extremely simple’ and ‘simple’ (24% and 26%, respectively). Nearly 30% of posts were deemed to be ‘engaging’, 30% to be ‘slightly engaging’ (. i.e., neutral), and 30% were deemed to be ‘somewhat not engaging’. Only one post was rated as ‘extremely engaging’. Overall, according to the experts’ review, most posts had a clear meaning and were relatively accurate and understandable, but not particularly engaging / interesting. The total quality score for each post ranged from 7 to 16 (out of 20) with a mean (SD) of 13.3 (4.1).

Table 5.6. *Median (25th, 75th percentile) for the type of images used in the post along with the number of total likes, followers, and total quality scores.*

Category	**Infographics[a] (n=24)**	**Written content[b] (n=10)**	**p-value[c]**
Number of likes	29 (11,168)	27 (8,112)	0.705
Number of followers	1680 (305-14000)	1813 (1194-10400)	0.791
Total quality score	14.5 (12-18.5)	11.5 (10-16)	0.171

Abbreviations: n= total number of posts.
All values are medians and 25th and 75th percentiles.
[a] Information visually representation in graphical format with minimal text.
[b] Information visually represented using only text.
[c]Kruskal Wallis rank test

There was no evidence of statistically significant differences between the number of likes, followers, and total quality score received by the two types of posts (all p>0.05) (Table 5.6). However, the median scores indicate that the post with Infographic images received slightly more likes and had a higher overall score, although not practically significant. Additionally, posts with written text on the image contained a greater number of followers.

Table 5.7. *Spearman's rank correlation among number of followers, number of likes, and total quality score.*

	Number of likes	Total quality score [b]
Number of followers [a]	0.791**	0.434*
Number of likes [a]	-	0.321
Like ratio [c]		-0.216

**p<0.001, *p<0.005
[a] Number of likes and followers at the time of writing.
[b] The overall score each post received after being reviewed by experts.
[c] Like ratio=number of likes: number of followers.

According to Table 5.7, the more followers an account has, the more likes its posts receive (rs=0.791, p<0.001). Also, as the total quality scores of a post increased, the number of followers increased (rs= 0.434, p<0.005). Total quality score and the number of likes (rs=0.321, p=0.064) and like ratio (and rs= -0.216, p=0.220) did not significantly correlate. The Like ratio was negatively correlated with the total quality score of Instagram posts (i.e., accuracy, clarity, understanding, and interesting).

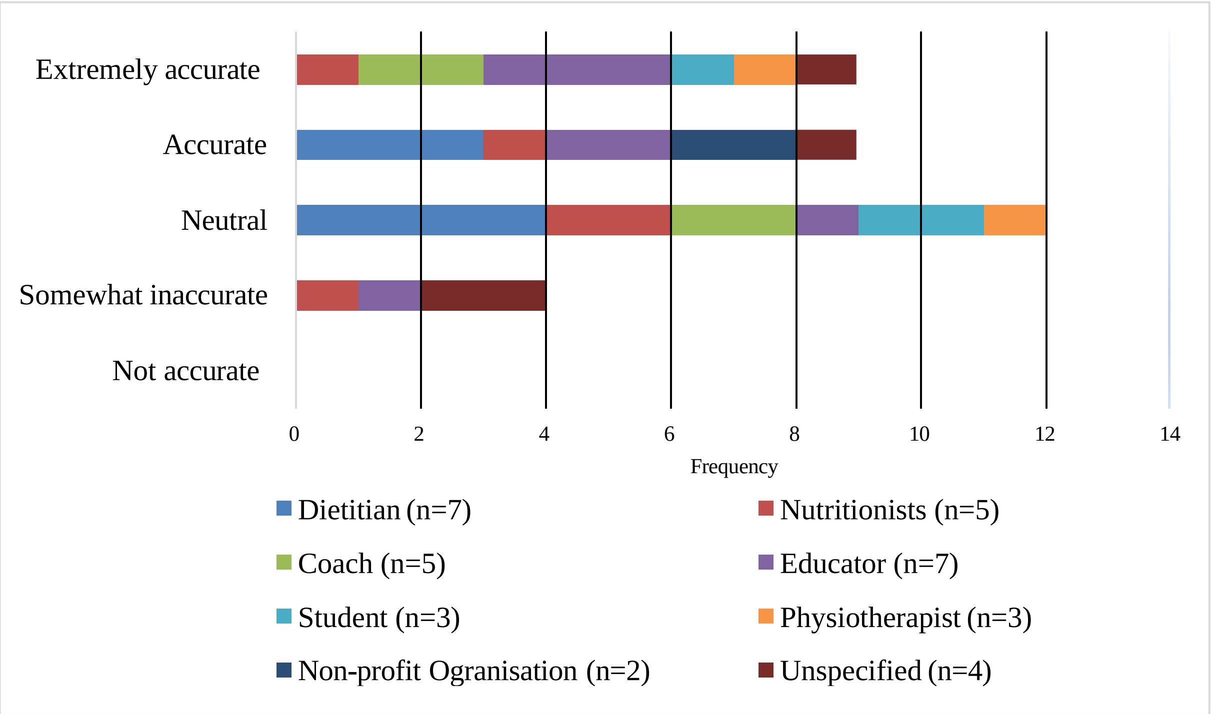


Figure 5.2: *The accuracy score of Instagram posts based on the qualifications of account holders.*

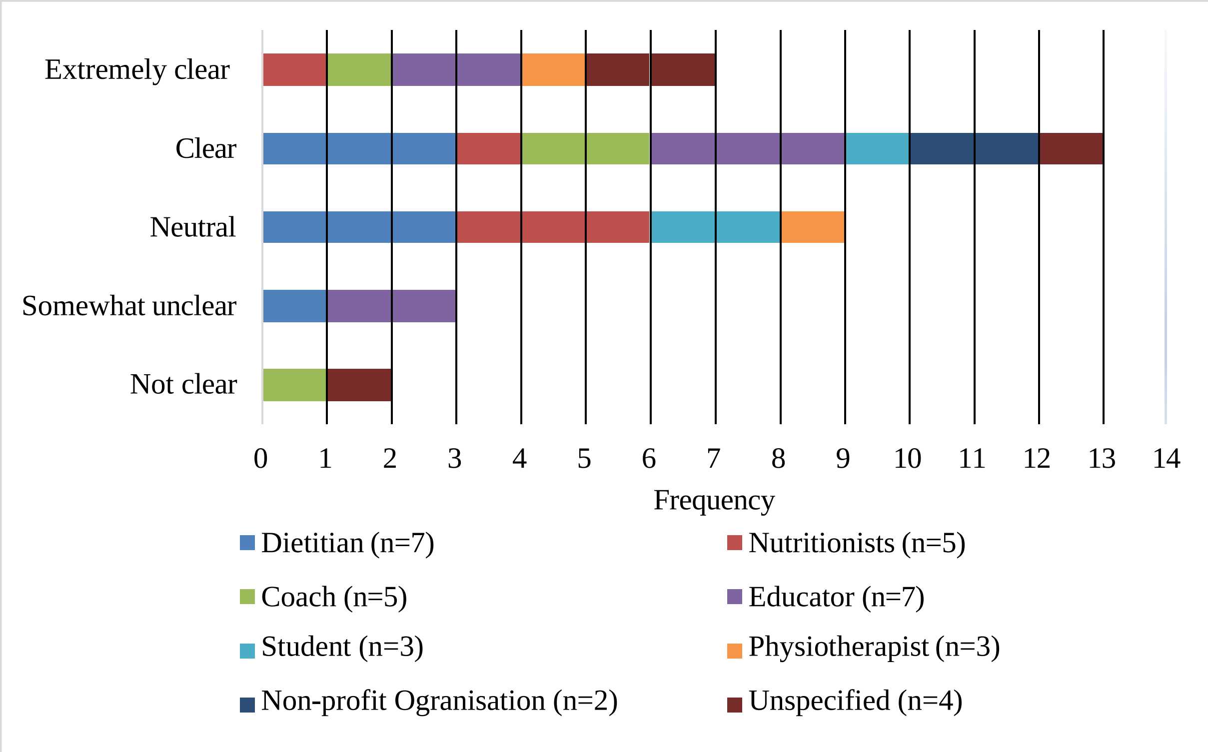


Figure 5.3: The clarity score of Instagram posts based on the qualifications of account holders.

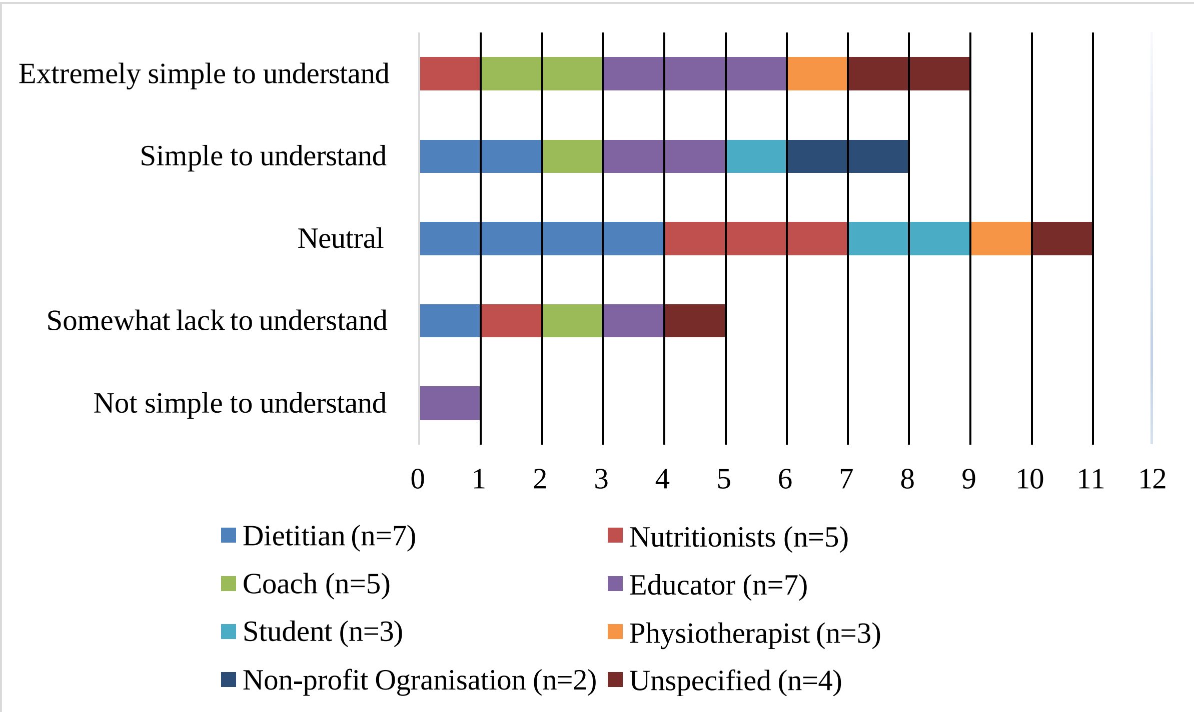


Figure 5.4. *The understanding score of Instagram posts based on the qualifications of account holders*.

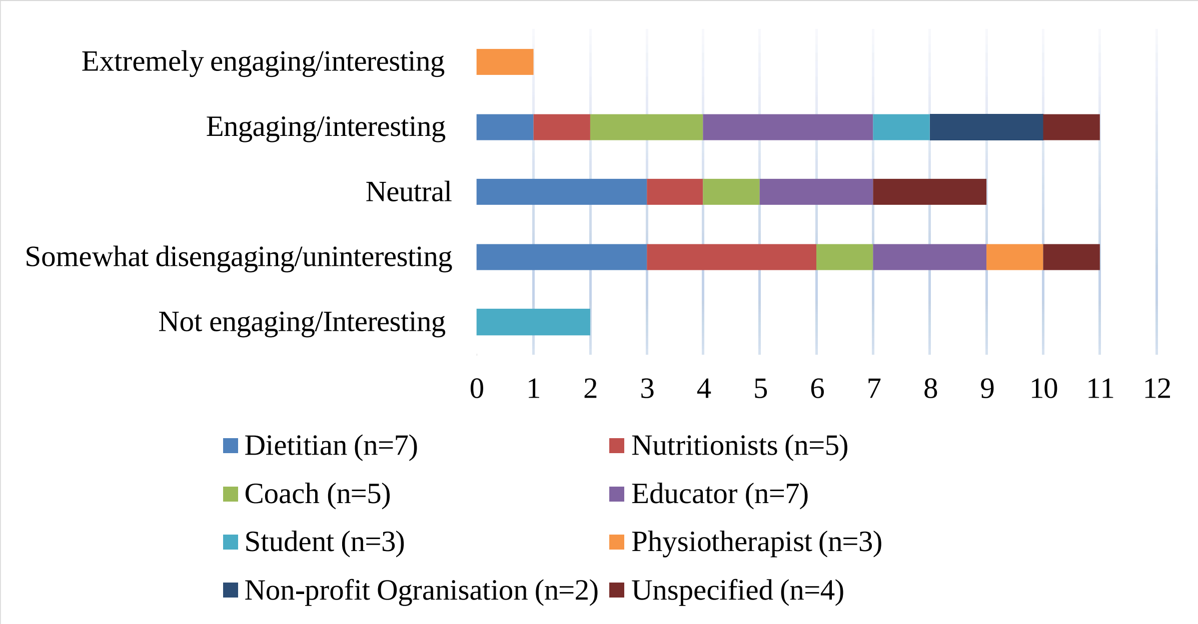


Figure 5.5. *The engaging/interesting score of Instagram posts based on the qualifications of account holders.*

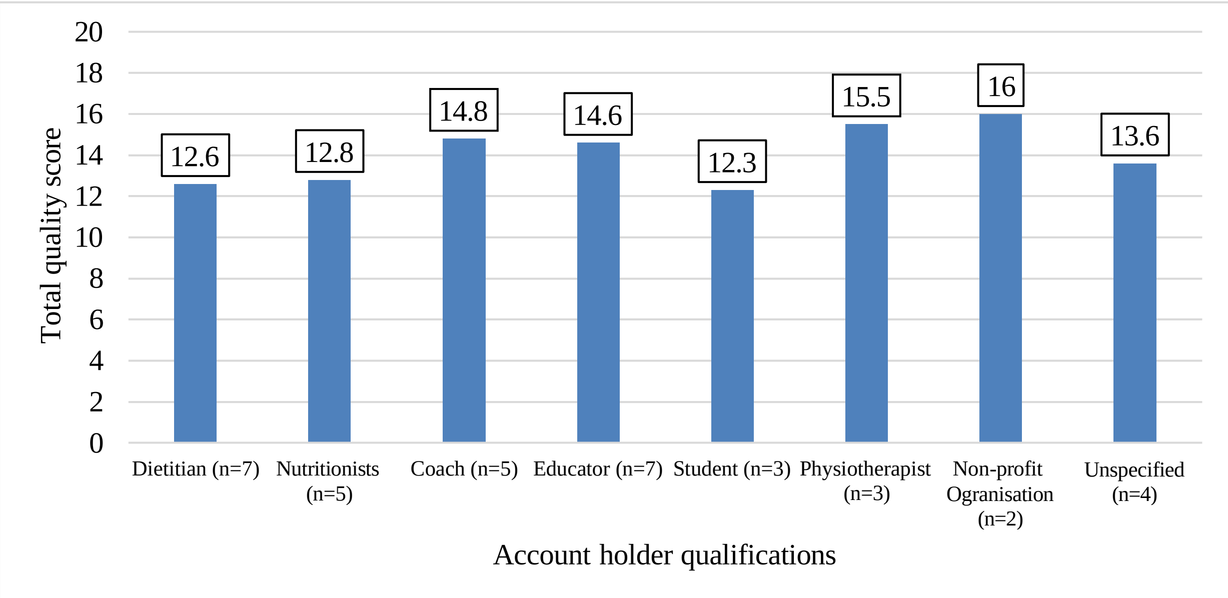


Figure 5.6: *Mean quality score based on the qualifications of account holders***.**

Figures 5.2 to 5.5 illustrate the characteristics of the posts such as accuracy, clarity, understanding and engaging content based on the qualification of the account holders. Among posts by dietitians (n=7), the majority were rated as 'neutral' for accuracy and understanding (4 out of 7). Clarity was mainly rated as 'neutral' or 'clear' (3 out of 7 posts each). Engagement ratings were mostly 'neutral' and 'somewhat not engaging/uninteresting' (3 out of 7 posts each).

The plurality of posts created by nutritionists (n=5) were rated as being 'accurate' (2 out of 5 posts). For understanding, the majority of posts (3 out of 5 posts) were rated 'neutral'; for clarity, most were rated as 'clear' (3 out of 5 posts). For engagement the majority were rated as were 'somewhat not engaging/uninteresting' (3 out of 5).

Both posts written by non-profit organisations (n=2) received the following ratings: 'accurate', 'clear', 'understanding' and 'engaging'.

The majority of the posts created by coaches (n=4) were rated as 'extremely accurate', 'clear', 'extremely understandable' and 'engaging' (2 out of 4 posts). The educator's posts (n=7) received a wide range of ratings, with three of the posts being rated as 'extremely accurate', 'extremely understandable', 'clear' and 'interesting' while two of the seven posts each were rated as 'somewhat unclear' and 'somewhat not engaging'.

Figure 5.6 displays the overall rating of the account holders. Quality scores ranged between 12 and 16, with non-profit organisations receiving the highest score (16), followed by physiotherapists (15.5), coaches (14.8), and educators (14.6), dietitians (12.6), and nutritionists (12.8). The lower end of the mean score belonged to the category of students (12.3) and the unspecified (13.6) group.

5.4. DISCUSSION:

Instagram has the potential to be used to spread evidence-based health-related information, including information about RED-S. Aspects of the digital environment that offer opportunities to support health awareness initiatives include engagement, accessibility, collaboration, awareness-raising opportunities, and research potential (McGloin & Eslami, 2015). Instagram is quickly accessible and constantly expanding, and so provides a large number of people immediate access to information. The current study aimed to assess what information on the definition of RED-S currently exists on Instagram. The definition of RED-S was chosen because...With our audit, we sought to evaluate the reliability, accuracy, clarity, and level of engagement of recent posts on RED-S. We found 176 posts that discussed various aspects of RED-S, but only 34 specifically mentioned the definition of RED-S. Of these 34 posts, 52% were rated high for accuracy, 58% for clarity, 50% for level of understanding, and 36% for level of engagement.

The accessibility of social media makes it a useful tool for education, but lack of quality control is a drawback (Carpenter et al., 2020). Using the three hashtags #relativeenergydeficiencyinsports, #relativeenergydeficiency and #lowenergyavailability resulted in a combined total of 4,632 posts about RED-S topics with 34 posts meeting our inclusion criteria. Of these posts, only 12% contained inaccurate or misleading information, but 36% provided an incomplete picture of the definition of RED-S, which may lead to some confusion. For instance, five posts described RED-S as a condition caused by overtraining rather than inadequate fuelling. Overtraining is a physiological condition that occurs when there is excessive exercise without enough rest (Kreher, 2020). Low energy availability occurs when either dietary energy intake (ranging from unintentional under fuelling to severe eating disorders) is too low or energy expended through exercise is too high, leading to an insufficient amount of energy left to maintain normal physiological functions (Wasserfurth et al., 2020). Thus, these posts overlooked the importance of explaining the concept of insufficient energy availability to meet the demands of exercise, which is the primary risk factor for developing RED-S.

A further three posts used energy balance to define RED-S and did not mention energy availability. Energy balance is a term that refers to the relationship between energy intake and all types of energy expenditure, including EEE, RMR, dietary-induced thermogenesis, non-exercise activity thermogenesis, and exercise-induced thermogenesis. (Areta et al., 2021). It is frequently used to refer to changes in body weight and/or body composition in dietary and/or exercise interventions (Areta et al., 2021). The term "energy availability" refers to the amount of energy available per kilogram of fat free mass to support physiological functions after the energy expended during exercise has been utilised. In short, EA focuses on the energy remaining following exercise-related energy expenditure and is related to metabolically active tissue; conversely, energy balance takes into account all aspects of energy expenditure. The RED-S model describes a variety of physiological dysregulations, and “energy availability” is thought to be a major contributing factor to these dysregulations (Areta et al., 2021). Previous research has shown that energy balance it is not a useful concept for athletes because energy balance refers to the amount of dietary energy gained to or lost from the body's energy storage after all physiological processes for the day have been finished and does not provide accurate information about the amount of energy needed, and it is not even the goal of athletic training (Loucks et al., 2011). Therefore, for athletes, the concept of energy availability is more practical than the concept of energy balance.

Additionally, in five posts, account holders in the unspecified (3 posts) and physiotherapists (2 posts) categories failed to mention that RED-S can affect both men and women. Although RED-S affects both sexes, the physiology of the sexes still differ, necessitating further study to fully understand the effects of male hormones and RED-S on the male physiology (DeSouza et al., 2014; Mountjoy et al., 2015; Tenforde et al., 2016). Researchers have examined the awareness of LEA among healthcare professionals such as athletic trainers, who are essential members of the sports medicine team and responsible for identifying, treating, and rehabilitating athletes of both sexes who may be experiencing LEA. According to one study, there was a lack of knowledge about the most recent definition of the athlete triad, specifically how male athletes fit into it, and whether assessing EA should be included on the pre-participation exam (Jagim et al., 2022). Therefore, the most recent definition of RED-S (Charlton et al., 2022) and the inclusion of males in the RED-S model should be equally emphasised in educational materials provided by healthcare professionals and social media sources.

As a measure of overall quality, in addition to assessing accuracy, we also considered clarity, level of understanding, and level of engagement. Posts received a score out of 20 based on these four criteria. The posts with higher quality scores received more likes and followers, although this was only statistically significant for the latter. Similar correlations between higher number of likes and comments and post quality were found in a previous study on nutrition and dietetic information (Kabata et al., 2022). Although in the current study, there was a positive correlation between the overall quality score and the number of likes and followers, the correlation between quality score and Like ratio showed that the quality score decreased as the ratio of likes to followers increased. Additionally, the average mean-quality-ratio score was 14.5, which indicates that there is still a considerable number of poor-quality posts, which may cause confusion among followers. A similar finding was presented in a prior study that looked at the technical-scientific accuracy of exercise and health information posted by Instagram influencers. This study found a negative correlation between the number of followers, the qualification of the account holder, and the low mean- quality-ratio score, which meant that the higher the follower count, the lower the quality score (Marocolo et al., 2021). Due to the inaccurate information provided by the account holder and the study's low-quality score, concerns were raised by the author about the potential impact on the quality of life for many people. For instance, unsupervised physical activity can result in musculoskeletal injuries, dietary disturbances (bulimia and bigorexia) and mental disorders (Marocolo et al., 2021). Thus, certain types of posts may be visually appealing, attract more followers' attention (i.e., likes) while detracting from the essential details needed for a thorough understanding of RED-S. Additionally, it should be noted that there were no standards or criteria for the 'level of engagement' measurement, which might have affected the outcomes of the level of engagement of some posts. For instance, if an Instagram post was published for a longer period of time, it would generate more engagement over time, whereas the data collection was only conducted over a three-week period. This could have an impact on the results.

The number of infographics-images used in the study can also contribute the negative correlation between quality and like-to-follower ratio. Instagram's popularity among users is assumed to be due to its focus on visual content, which has been shown to be more engaging for followers (Tom et al., 2012). In this study, infographics were used to present educational content in 71% of posts along with written RED-S descriptions. According to our findings, infographic-images in the posts received slightly more likes. More research with a larger sample size is necessary to determine the strength of this association because there were relatively few posts in each category and the difference was not statistically significant. Previous research has shown that infographics tend to receive more likes from followers than images that are predominantly composed of written text (Antoniadis et al., 2019). Previous research on Instagram hashtag searches for content on nutrition and dietetics demonstrated that educational content with image-oriented information attracted more followers, likes, engagement and average quality score (Kabata et al., 2022). The current study also found that infographics were frequently used in posts with higher average scores, though the difference in scores was small and not statistically significant (i.e., the infographic received a score that was +2 higher than the written content on the image). However, a recent study raised concerns about the reliability and accuracy of 73% of image-related educational posts on other social media sites like Twitter (Alassiri & Alowfi, 2019). As mentioned earlier infographic-based posts may attract more attention from followers, but it is unclear whether they successfully communicate a thorough understanding of RED-S. Although not measured in the current study, future research should examine the impact of infographics on the followers' interpretation of the condition.

Overall, approximately 80% of account holders (based on their Instagram profile) had formal academic or professional qualifications. This may account for the low degree of inaccuracy observed in the present study. Overall, 30% of the account holders were dietitians and nutritionists, who are likely to have received specialised training in individualised dietary care and medical nutrition therapy and may be in a unique position to educate, prevent, and identify RED-S among athletes. However, posts shared by dietitians and nutritionists were mostly rated as 'neutral' for all ratings, indicating that while the definition of RED-S described on the posts was accurate, clear, and understood, some information was either missing or was not completely explained. The majority of these posts had low engagement, with an average quality score of 12.6 (dietitian score) and 12.8 (nutritionist score). Instagram does not restrict the sharing of content by unlicensed professionals, so anyone can post content, regardless of their qualifications (Instagram, 2021). Therefore, it cannot be confirm that these account holders were actually dietitians and nutritionists, which may explain why some of these professionals had low quality scores. On the other hand, it can also be assumed that dietitians and nutritionists may not have included all necessary information in an effort to keep the post brief and retain followers' attention. Although this was not examined in the current study, it would be an interesting topic for future research to determine whether including more information in a post reduces engagement.

The goal of the post created by the account holder, the preferences and traits of the target audience, and the overall content strategy all play a role in determining the proper balance between brevity and depth of information. Topics like RED-S may necessitate more in-depth explanations due to the complexity of the condition, which brevity may not always be able to provide. Some factors that experts in the current study took into account when determining the post's quality, included visually appealing elements that complement the post's text and improve readers' comprehension of complex information, thereby making it easier to learn. Examples included images, infographics, or videos, and fact-based information or a case study illustration that can keep the audience interested while successfully delivering the required information. Overall, the post's quality was assessed based on its content, which defined RED-S and struck the right balance between accurate, factual information and clarity while still keeping the reader interested. Nonetheless, it is essential to recognise that there is no one-size-fits-all solution, and that finding the best quality post frequently involves trial and error and has an element of subjectiveness.

However, it is not surprising that the posts with the highest overall quality scores were from non- profit organisations who specialise in RED-S – the Athlete Triad Coalition and the IOC. These organisations specialise in nutrition and medical care of athletes and physically active individuals. This specialist knowledge is reflected in the quality of their posts, which contained evidence-based information, supported by peer-reviewed citations. It should be noted that although the posts from non-profit organisations had the highest quality scores, they did not receive a score of 20. The reasons for these included posts which were too long in the opinion of the experts, and used abbreviations and less common terminology, such as FAT (Female athletes' triad) and FFM (Fat Free Mass). Given the high ratings of these posts, future research can encourage athletes and physically active people to follow such accounts managed by non-profit organisations. Additionally, future studies can also address some of the drawbacks which were noted in the present study. For instance, instead of providing definitions, signs, symptoms, prevention, and treatment all in the same post, account holders could provide concise and short educational content on the post, avoid using complex terminology, and concentrate on just one aspect of REDS in each post.

In the present study, although the majority of posts were developed by health professionals, there was still some degree of inaccuracy in the information provided. Results from earlier research showed that only 33% of healthcare professionals were familiar with the RED-S concept (Kroshus et al., 2018). Additionally, healthcare professionals lack knowledge of the most recent definition of RED-S, and the importance of assessing EA during pre-participation screening (Jagim et al., 2022). This limited understanding on the condition is reflected in some of the poor-quality posts shared by healthcare professionals in the current study. As previously outlined, some posts neglected to mention that RED-S can affect both men and women or described RED-S using the concept of energy balance and overtraining instead of low energy availability. This highlights the potential problems with acquisition of information from social media. Followers may receive false or inaccurate information and subsequently adopt potentially harmful health practices (Helm & Jones, 2016; Vaterlaus et al., 2015).

5.5. LIMITATIONS

This study has several limitations to bear in mind when interpreting the findings. Firstly, only posts that were accessible in Instagram's public domain were included in our analysis. There may be selection bias because we were unable to search through private posts or posts that user had deleted. The definition of RED-S may be better explained by some of these private account holders' posts. Secondly, by using hashtag searches, the information was gathered and posts that met the requirements for inclusion were examined. The generalizability of our findings may depend on our exclusion criteria, which excluded posts written in languages other than English and posts that did not use the three hashtags. This resulted in only a relatively small number of posts that were analyzed. Although there are social media analytics tools that can be time-dependently configured to provide more in- depth searches and potentially provide more sophistication, they were not accessible at the time of data collection and were, therefore, outside the scope of this study. The primary goal of this study was to assess whether there was accurate information on the definition of RED-

S. Future research can concentrate on analysing339 the data with analytical tools to get a broad overview of the information on RED-S. In addition, we collected posts during a 3-week period in early February of 2022. This is only a snapshot of the different kinds of RED-S definition-related Instagram posts that were published at one point in time; it is possible that some posts were missed. Data collection over a longer period and/or during randomly chosen times of the year could have resulted in a more thorough examination of posts associated with the RED-S definition. Additionally, the reviewed posts may have been part of a series, and therefore we did not capture the complete information shared by the account. On Instagram, the number of likes and comments can be modified using automated chatbots (i.e., computer programs that are automated to increase the liking or followers of the account). It was impossible to identify these so-called fake followers. Lastly, Instagram is unable to provide a count of the number of people who viewed (without engaging) the RED-S-definition related post, and thus, the reach of these posts cannot be determined.

There is a lack of specialised tools for evaluating the quality of posts. In order to address these concerns and to understand the accuracy, clarity, level of understanding, and level of engagement of the description used in the RED-S-definition related posts, a combination of qualitative (to gather in-depth insights of the post the comments on each post given by the two experts where combined and described in the study) and quantitative (A Likert scale rating scales was used that quantitatively assesses accuracy, clarity, understanding and engaging content of the post) methods were used in the current study. The study's main strengths were the combination of methods used to analyse the reliability of the posts based on the four criteria, which were reviewed by two experts, and compared the information present in the post with the most recent definition of RED-S. Our data provides a good snapshot of the information about RED-S-definition-related content that is currently available on Instagram.

Further research is required to understand other areas of information present in Instagram relating to the RED-S condition such as signs, symptoms, and treatment strategies. While our analysis indicates that approximately 50% of Instagram posts contain accurate information on

RED-S, there is still room for improvement in terms of providing in-depth and more accurate information, which can be addressed in future education programmes. Further research should also assess the effect of these posts on RED-S awareness and provide information on how to use educational posts on Instagram sites to enhance the right kind of help-seeking advice for those who are at risk.

5.6. CONCLUSION

In the current study more than half of the posts contained accurate information on the definition of RED-S, and only 12% contained inaccurate information. This demonstrates that overall, most Instagram posts have sufficient accurate information defining RED-S, which could be used as a source of educational material for future research. As Instagram does not restrict unlicensed professionals to share content on RED-S, we cannot confirm that these account holders were dietitians and nutritionists, which may explain why some of these professionals had low quality scores 12.6 (dietitian score) and 12.8 (nutritionist score). Additionally, there is currently no way to verify the qualifications of account holders, which can make it challenging for followers to recognise authentic Instagram posts. Given the need to share more quality content on the Instagram platform because it has the potential to reach a large audience, our findings suggest that physically active people and athletes should be encouraged to follow the specific Instagram accounts of appropriate non-profit organisations like the IOC and Athlete Triad Coalition to obtain accurate information on RED-S.

6. Conclusion

This dissertation contains three independent studies, in which **Study I** aimed to develop and validate a questionnaire which assessed knowledge on signs and symptoms of RED-S among healthcare professionals and physically active individuals; **Study II** aimed to compare nutrition knowledge among those at risk and those not at risk of LEA among team sports; **Study III** aimed to review the accuracy of the definition of RED-S on RED-S related posts on Instagram. The conclusions derived from the main aims in the three studies are presented below:

I. The newly developed questionnaire has 18 items which assess theoretical and practical knowledge of signs and symptoms of RED-S. The findings of this study suggest that the questionnaire is a valid tool for measuring RED-S knowledge, with good internal reliability and test-retest reliability.

- This 18-item questionnaire measures existing knowledge and beliefs that healthcare professionals and physically active individuals have about menstrual irregularities, osteoporosis, Low Energy Availability (LEA), the Female Athlete Triad (Triad) and Relative Energy Deficiency in Sport (RED-S).
- Healthcare professionals scored significantly higher on the questionnaire (mean difference (95% CI): +2.8 points (1.9, 3.7), $p<0.001$) compared to physically active individuals, indicating a good construct validity on the questionnaire.
- Test-retest reliability was assessed based on the correlation between test scores of individuals who repeated the questionnaire and the differences in overall scores from test 1 to 2 were minor. The questionnaire had good internal consistency (i.e., Cronbach's α 0.70) indicating that all the items are inter-correlated and appropriately grouped.

II. Among female team sport athletes, 53% were at-risk for LEA, and 70% had poor (below 50%) and 27% of athletes have average (below 65%) general and sports nutrition knowledge. The knowledge scores of the athletes who were "at risk" of

LEA and those who were "not at risk" of LEA were not practically or statistically significantly different.

- Among the different team sports which were investigated, volleyball (80%), basketball (63%), rugby (60%) and hockey (57%) had more than half of the female athletes who were at risk of LEA. This high prevalence emphasises the necessity of regular screening of athletes to support early interventions and prevent a potential decline in performance and health.
- The median knowledge score on general nutrition knowledge section was classified as average (52%); and the knowledge score on sport nutrition knowledge was poor (40%), indicating that overall A-NSKQ score was below <50%, which is considered as poor.
- The median RED-S knowledge score was 66%, and although it was not statistically significant, there was a weak negative correlation between the athletes' RED-S knowledge scores and their level of risk of LEA. It could be challenging to generalise this relationship between knowledge of RED-S and risk of LEA among athletes because the entire questionnaire on RED-S knowledge was not used in the current study.
- Most athletes (96%) acknowledged using social media, with Facebook and Instagram the most popular platforms (93% and 92%, respectively). Additionally, 44% of athletes who used social media subscribe to hashtags, users, or organisations that are concerned with training, eating, exercising, body size, or weight loss. In addition, 24% of athletes reported that social media posts have encouraged them to alter their diet or exercise regimens. However, we did not measure whether these changes had a favourable or unfavourable effect on performance and health.
- Encouragingly, 90% of athletes said they wanted to learn more about LEA. Nutrition for female health was the most popular topic (91%), followed by injury prevention, menstrual function/hormonal health (62%), and LEA symptoms (60%). Additionally, 49% of athletes would like to learn more about LEA on social media.

III. The non-profit organisations such as the Athlete Triad Coalition and the IOC accounts on Instagram shared the most adequate (i.e., evidence-based information which was simple to understand) and accurate information on the definition of RED-S definition, which was determined by the highest overall quality scores received based on expert review. This suggests these Instagram posts may be used as a source of learning materials for future work.

- A small number of Instagram posts failed to explain that inadequate energy availability to meet exercise demands is the main risk factor for developing RED-S, which had an impact on overall quality score of posts (i.e., 13.3 (4.1) out of 20).
- According to the qualification mentioned on the Instagram account, three posts by an unspecified account and two posts shared by physiotherapists did not mention that RED-S can affect both men and women.
- Infographic-based posts attracted more attention from followers and received more likes than images that are predominantly composed of written text; however, it is unknown whether they successfully communicate a thorough understanding of RED-S.
- As Instagram does not restrict unlicensed professionals to share content on RED-S, we cannot confirm that these account holders were dietitians and nutritionists, which may explain why some of these professionals had low quality scores.
- Overall, among 48% of the posts shared by account holders with a professional qualification, 12% (n=4) contained inaccurate or misleading information, and 36% (n=14) provided an incomplete picture of the definition of RED-S reflecting that there is limited understanding on RED-S condition.

Overall, the finding of **Study I** indicate that the newly developed RED-S knowledge questionnaire on signs and symptoms could be used as a screening tool to identify health professionals and physically active individuals who need additional education support. In **Study II**, more than half of the team sport athletes were at risk for LEA, which is similar to prevalence rates observed in other athletic populations in New Zealand. Additionally, the overall results showed that team sports athletes had poor nutrition knowledge and had average knowledge of RED-S. These findings, emphasise the need for nutrition education and initiatives to increase awareness of the LEA/RED-S condition. In **Study III**, the findings suggest that physically active individuals and athletes should be encouraged to follow the specific Instagram accounts like the IOC and Athlete Triad Coalition to obtain accurate information on RED-S. Additionally, there is a need to share more high-quality content on the Instagram platform because it has the potential to reach a large audience and could address the educational needs identified in **Studies I and II**.

6.1. RECOMMENDATION FOR FUTURE STUDIES:

The results of this thesis may be valuable for athletes, coaches, medical professionals, support staff, sports federations, and researchers. The findings highlight that the risk of RED-S/LEA is relatively high among New Zealand female athletes who participate in team sports above 16 years and who are competing at various levels of competition. Position statements have established that RED-S is multifactorial and may have serious, negative effects on one's health and ability to perform (Mountjoy et al., 2018; Mountjoy et al., 2014). Based on the three studies the following recommendations are outlined below:

Study I:

- The validated questionnaire could be used to assess the knowledge of RED-S among healthcare professionals and athletes. The information derived from this could questionnaire provide valuable information on current knowledge, which can help determine further education requirements and priorities.
- As there is little or no information on the knowledge on other aspects of RED-S such as treatment and recovery among athletes; future studies should identify the education gaps which would help areas of future studies.

Study II

- This study shows that the prevalence of LEA risk among team sports athletes competing at various levels of sport is 53%. The differences in risk that exist between the various team sports remain unclear. Future research should, therefore, determine whether any particular team sport athlete is at a higher risk and would benefit from including a larger sample of competitors in each type of team sport to better understand the variation in risk.

- There was no evidence of a difference in knowledge between athletes who were at risk for LEA and those who were not, and it is unknown whether other factors affected those who are at risk. Therefore, to fully understand the additional factors affecting the risk of LEA along with their level of knowledge, future research should evaluate dietary behaviour, performance, social pressure, coaches' and supporting staffs' knowledge of RED-S/LEA along with the risk of LEA.
- Future education intervention studies should focus on nutrition for female health, injury prevention, menstrual function/hormonal health, and LEA symptoms.

Study III

- Instagram is well suited for disseminating knowledge about the RED-S condition and the findings of study II noted it to be a source of information for 49% of athletes. Before creating the educational materials, it is necessary to assess the impact of infographics on the followers' interpretation of the condition. The current study provides limited information, therefore, a wider study of RED-S content on Instagram and other social media is required.
- The impact of RED-S social media posts and behaviour change also needs to be investigated. Based on this knowledge, future research can create relevant educational materials for Instagram.

Finally, it must be acknowledged that the RED-S model is multi-faceted. And it should be more widely acknowledged as the cause for decline in performance and health, and that maintaining athletes' general health requires education and awareness on this condition (Mountjoy et al., 2018). Additionally, greater research into the health impacts and recovery from RED-S is required, which will help with the design of educational material.

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Appendices

Appendix A: Ethical approval of Study I

Form Updated: December 2017

UNIVERSITY OF OTAGO HUMAN ETHICS COMMITTEE APPLICATION FORM: CATEGORY B

(Departmental Approval)

1. University of Otago staff member responsible for project:

Black Katherine Dr

2. Department/School:

Human Nutrition

3. Contact details of staff member responsible:

E-mail: katherine.black@otago.ac.nz
Telephone: 03 479 8358

4. Title of project:

Knowledge of LO"Å Energy Availability and the Female Athlete Triad amongst registered health care professionals

5. Indicate type of project and names of other investigators and students:

Staff Research	Names	Dr Lisa Daniels Assoc Prof Rachel Brown
Student Research	Names	Lieke Smit
Level of Study (e.g., PhD, Masters, Hons)		N/A internship project

6. When will recruitment and data collection commence?

February 2018
When will data collection be completed?

May 2019

7. Brief description in lay terms of the aim of the project, and outline of the research questions that will be answered (approx. 200 words):

There is a specific group of active women, girls and female athletes who on some level, either intentionally or unintentionally, restrict their food intake. As a result they are putting their health at risk. This is called Low Energy Availability (LEA) and subsequently the Female Athlete Triad (FAT). In New Zealand, our research has shown that almost 50% of the exercising female population is at risk of LEA. LEA impacts women's health both acutely, via reproductive hormonal changes resulting in fertility issues, and chronically by reducing bone density resulting in an increased risk of stress fractures and osteoporosis. Limited research from overseas suggests that the awareness and knowledge of LEA and its associated risks seem to be inadequate among healthcare professionals and those who work with physically active individuals. Given that LEA/FAT is avoidable, healthcare professionals need to be aware of the signs and symptoms of LEA and the Triad in order for early intervention. An understanding of the current awareness and knowledge is required to provide us with information on how to target educational initiatives for these groups. At present there is no questionnaire available to assess the knowledge of LEA amongst healthcare professionals and those who are working with athletes/active individuals. Therefore, the present study aims to develop a suitable questionnaire for use in future studies to assess the level on LEA.

8. Brief description of the method.

This will be a three phase project:

Phase 1 : Expert review
Phase 2: Pre-testing (face validity)
Phase 3: Pilot testing (reliability)

Phase I : Expert review

The aim of this phase is to eliminate irrelevant questions, supply new wording to improve relevance and clarity and to ensure that no areas relevant to the topic have been omitted from the questionnaire. Participants will be recruited via e-mail and in person.
In this phase we will ask 5 experts, defined as having a peer reviewed paper in the area of LEA or who work in the applied setting with a speciality in low energy availability, to review each question in the questionnaire and respond to each question using a fourpoint Likert scale, used for relevancy, clarity and phrasing. The responses (data) will be

compiled and modifications will be made to the questionnaire where necessary prior to the commencement of phase 2. Responses vall be kept on a password protected computer in a locked office and will be identified only by ID only.

Phase 2: Pre-testing (face validity)

Participants will be recruited via personal contacts, posters, emails and social media. We will recruit 12 individuals who have an awareness of Low Energy Availability and its symptoms. However, they will not be able to participate in this phase if they were involved in phase l . To participate they must be able to attend the Department of Human Nutrition for one hour on one occasion, or be available and have internet access to complete the interview over Skype.

After the questionnaire has been modified from phase l , the questionnaire will be pretested for clarity, readability and interpretation by participants in phase 2. Twelve participants will be asked to complete the questionnaire one on one with an interviewer by completing the questions out loud. This is a form of cognitive interviewing to ascertain any misunderstanding of the questions. Responses and notes on responses to each question will be recorded and will be stored by ID only on a password protected computer and locked office. The final manuscript will only state how questions were modified and therefore, no individual data will be published in an attempt to preserve anonymity.

Each participant will receive a $20 grocery voucher to cover their costs of attending the interview to reimburse them for the time invested and possible costs associated with travel to the clinic.

Phase 3: Pilot testing (reliability)

We will recruit 85 health care professionals working in the area of low energy availability, or Mho are familiar with LEA and 85 participants from the general population.

Following phase I and 2, 170 participants will be recruited to complete the questionnaire online on two occasions separated by two weeks. This is based on the need for at least one more participant than the number of items in the questionnaire (Rust and Golombo, 1992) and assuming a drop out rate of 20%. Participants will be recruited via email, social media, posters and personal communications, where they will be directed to the webserver REDCAPS. The questionnaire (Sections 1-5) will be hosted by REDCAPS and participants will be asked to provide their email address for the link to be resent for the follow-up. Two weeks following their initial completion of the questionnaire, participants will be sent a reminder email with a unique ID to complete the questionnaire again. It is likely that the questionnaire will take —45 minutes to complete on two occasions so a total time requirement of 90 minutes. Upon completion of the second questionnaire, participants will be entered into a draw for $50 grocery voucher.

Data will be analysed for:

l. Item facility - which indicates the extent to which participants answer in the same way;

2. Item discrimination - the ability of the item to discriminate between those who do well overall and those who do not;

3. Construct validity — the ability to determine if the questionnaire measures what it is supposed to measure and will be assessed by comparing the differences between the two groups.

4. Reliability - the repeatability of the measure and this will be assessed by repeating the questionnaire in the same population

All data will be downloaded and saved by ID only onto a password protect computer and stored on the Department of Human Nutrition server.
For all phases access to the data will be by Dr Katherine Black, Dr Lisa Daniels, Assoc Prof Rachel Brown and Lieke Smit. For all phases participants must be older than 18 years old and have internet access.

9. Disclose and discuss any potential problems and how they will be managed:

*Applicant's Signature: Katherine Black

Name (please print): Katherine Black

Date: 20/12/18

*The signatory should be the staffmember detailed at Question 1.

ACTION TAKEN

Approved by HOD

Approved by Departmental Ethics Committee

Referred to UO Human Ethics Committee

Signature of **Head of Department':

L HOUGHTON

Name ofHOD (please print) •

Appendix A1: Outlines interview questions during face validity and scores received from expert review.

Question[a]	Criteria[b]	Average[c]	Median[c]	Minimum[c]	Maximum[c]
Q1: Have you ever heard of Low Energy Availability (LEA) ?	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q2: Have you ever heard of Relative Energy Deficiency in Sports (RED-S)?	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q3: Have you ever heard of the Female Athlete Triad (Triad)?	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q4: Having an irregular menstrual cycle is often a sign that female athletes/active individuals are in peak competitive shape	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q5: Do you think it is normal for female athletes/active individuals to miss their periods?	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q6: Do you think that not consuming enough energy could result in the absence of periods?	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q7:Do you think fractures (very small cracks or breaks) occur more often in girls/women who miss their period for 3 or more months than in girls/women who have regular periods?	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q8: Do you think irregular or the absence of periods is associated with developing weaker bones?	Content Relevance	4	4	4	4
	Clarity	4	4	4	4
Q9: 'Intensive training with inadequate rest' can increase an athlete's risk of infections such as cold and flu?	Content Relevance	3.75	4	3	4
	Clarity	4	4	4	4
Q10:'Insufficient energy intake' can increase an athlete's risk of infections such as cold and flu?	Content Relevance	3.75	4	3	4
	Clarity	4	4	4	4

Q11: Inadequate energy intake affects concentration (please answer true or false)	Content Relevance	3.75	4	3	4
	Clarity	4	4	4	4
Q12: Inadequate energy intake affects coordination (please answer true or false)	Content Relevance	3.75	4	3	4
	Clarity	4	4	4	4
Q13:"Improved endurance performance" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q14: "Decreased (short term) performance" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q15:"Increased sprint performance" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q16:"Decreased sprint performance" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q17: "Weight changes" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q18:"Body composition changes" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q19:"Increased bone mass" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q20:"Decreased muscle strength" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q21: "Increased muscle strength" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q22:"Decreased muscle mass" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q23: "Increased injuries" is a result from chronic insufficient energy.	Content Relevance	4	4	4	4
	Clarity	3.75	4	3	4
Q24. Is the questionnaire as a whole comprehensive i.e., are the collective questions a fair					

representation of RED-S among athletes?
Q25. Are there any questions you feel have been omitted from the questionnaire?
Q26. General comments

[a] Closed and open-ended questions asked during the expert review and face validity interview.
[b] Evaluation of the items was based on two criteria, 'Content relevance' ('not relevant' (=1) to 'relevant (=4)), and 'Clarity' ('not clear' (=1) to 'clear' (=4)), additionally each question contained an open-ended 'comment' section for suggestions or modifications.
[c] Average, Median, Minimum and Maximum score of four Healthcare Professionals.

Appendix A2: List of all the items involved in the questionnaire with their response options and scoring protocol.

Item	Question	Response options	Scores
1	Have you ever heard of Low Energy Availability (LEA) ?	Yes	1
		No	0
2	Have you ever heard of Relative Energy Deficiency in Sports (RED-S)?	Yes	1
		No	0
3	Have you ever heard of Female Athlete Triad (Triad)?	Yes	1
		No	0
4	Having an irregular menstrual cycle is often a sign that female athletes/active individuals are in peak competitive shape	True	0
		False	1
		Unsure	0
5 [a]	Indicate the approximate age that peak bone mineral density is reached in women? (the age at which maximum strength and density of bones is reached)	Any age range that does not include 18 to 29	0
		Any age range that includes 18 to 29 years	1
6	Do you think it is normal for female athletes/active individuals to miss their periods? (excluding pregnancy or purposely skipping periods by contraception)?	Yes	0
		No	1
		Depends on the situation	0
		Unsure	0
7	Do you think that not consuming enough energy could result in the absence of periods?	Yes	1
		No	0
		Unsure	0
8	Do you think fractures (very small cracks or breaks) occur more often in girls/women who miss their period for 3 or more months than in girls/women who have regular periods? (excluding pregnancy or purposely skipping periods by contraception)	Yes	1
		No	0
		Unsure	0
9	Do you think irregular, or the absence of periods is associated with developing weaker bone	Yes	1
		No	0
		Unsure	0
10-11	Which of the following can increase an athlete's risk of infections such as cold and flu? (please tick all that apply)	Intensive training with inadequate rest	1

		Insufficient intake of fluids' (2)	0
		Insufficient energy intake' (3)	1
		Don't know' (treat as three items)	0
12[a]	For the following statement please answer true or false. Inadequate energy intake affects concentration	True	1
		False	0
		Unsure	0
13[a]	Inadequate energy intake affects coordination	True	1
		False	0
		Unsure	0
	Which of the following do you think could result from chronic insufficient energy? (Please tick all that apply)	Treat as eleven different items – this means that those who don't tick the false items, get a point for that too. 1= ticked 0= non-ticked	
14[a]	Improved endurance performance	Ticked	0
		Non-ticked	1
15[a]	Decreased (short term) performance	Non-ticked	0
		Ticked	1
16	Increased sprint performance	Ticked	0
		Non-ticked	1
17	Decreased sprint performance	Non-ticked	0
		Ticked	1
18	Weight changes	Non-ticked	0
		Ticked	1
19	Body composition changes	Non-ticked	0
		Ticked	1
20[a]	Increased bone mass	Ticked	0
		Non-ticked	1
21	Decreased muscle strength	Non-ticked	0
		Ticked	1
22	Increased muscle strength	Ticked	0
		Non-ticked	1
2	Decreased muscle mass	Non-ticked	0

3		Ticked	1
24	Increased injuries	Non-ticked	0
		Ticked	1
Total possible score			24

[a] Item 5,12,13,14,15, and 20 were removed from the final questionnaire.

Appendix B: Ethical approval of Study II

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Form Updated: November 2019

UNIVERSITY OF OTAGO HUMAN ETHICS COMMITTEE APPLICATION FORM: CATEGORY B (Departmental Approval)

Please ensure you are using the latest application form available from: *http://www.otago.ac.nz/council/committees/committees/HumanEthicsCommittees.html*

1. University of Otago staff member responsible for project:
Black Katherine Dr

2. Department/School:

Human Nutrition

3. Contact details of staff member responsible:
E-mail: katherine.black@otago.ac.nz
Telephone: 03 479 8358

4. Title of project:
Nutrition and energy availability knowledge and risk of low energy availability amongst female team sport players

5. Indicate type of project and names of other investigators and students:

Staff Research **Names**
Student Research **mes** Prof Rachel Brown
Level of Study (e.g. PhD, Mast X *Hons)* PhD

External Research/ Collaboration X **Names** Alice Sharples
Institute/Company Sharpe Nutrition

6. When will recruitment and data collection commence?
January 2020

When will data collection be completed?
December 2022

7. Brief description <u>in lay terms</u> of the aim of the project, and outline of the research questions that will be answered (approx. 200 words)**:**
Nutrition is an important component for optimal sporting performance. Poor nutritional practices in athletes can lead to poor health with almost 50% of the athletic female population in New Zealand being at risk of Low Energy Availability (LEA) caused by

insufficient energy intakes relative to energy expended. LEA impacts women's health both acutely, via reproductive hormonal changes resulting in fertility issues and chronically by reducing bone density resulting in an increased risk of stress fractures and osteoporosis.
Limited research from overseas suggests that the awareness and knowledge of LEA and its associated risks seem to be poor. Given that LEA/Triad is avoidable, athletes need to be aware of the signs and symptoms of LEA and the Triad in order for early intervention. An understanding of the current awareness and knowledge is required to provide us with information on how to target educational initiatives. Pilot data from a small sample of elite athletes in New Zealand would suggest knowledge is also low amongst New Zealand athletes. Nutrition knowledge is also limited amongst many athletes who are barraged by social media about nutritional practices, fad diets and supplements which claim to improve performance. However, much of this information is not based on scientific evidence and at best could impair performance but in some cases could harm health.
Therefore, the present study aims to assess the level of nutrition knowledge, LEA knowledge and influences on knowledge amongst New Zealand team sport athletes. A secondary outcome is to determine if differences in knowledge exist between those at risk and not at risk of LEA and by different levels of play.

Brief description of the method. Include a description of who the participants are, how the participants will be recruited, and what they will be asked to do and how the data will be used and stored *(Note: if this research involves **patient data or health information** obtained from the Ministry of Health, DHBs etc please refer to the UOHEC(H) Minimal Risk Health Research - Audit and Audit related studies):-*

Participants:
Participants will be competitive female team sport athletes, aged over 16 years. Participants will be recruited via social media, email, posters and word of mouth, (See Appendix).
Interested participants will be sent a copy of the information sheet, a link to the survey and an ID to enter at the start at the survey.
Questionnaire:
The questionnaire will be based on one designed previously by the research team which has undergone expert review and face validity. It covers topics of LEA awareness and knowledge of LEA and its health consequences and will include the Low Energy in Females Questionnaire and the nutrition for sport questionnaire (see Appendix). Additionally, the questionnaire will include questions on social media engagement and aims to examine whether participants have changed dietary or exercise behaviours following exposure to such content. The online version of the questionnaire (a link to this will be provided in all emails, social media posts and posters) will be hosted by REDCAPS and participants will be asked to provide their email address in order to enter the draw to win one of three, $50 vouchers.
Data will be analysed for:
Data will initially be checked for incomplete information and poorly completed responses which will be excluded from the final analysis.
If a particular section of the survey has constant contradictory responses to similar questions, and/or several unrealistic responses that are physically or biologically impossible, these will also be excluded.
Descriptive data will be reported for each section of the questionnaire and for specific questions. A two-sided test of two proportions will be used to determine if there are any statistically significant differences between the proportions of participants with knowledge

of LEA for different variables, including LEA risk. A level of <0.05 will be used to detect significant differences.

Access to the data will be by Dr Katherine Black, Namratha N Pai and Alice Sharples.

9. Disclose and discuss any potential problems and how they will be managed: (For example: medical/legal problems, issues with disclosure, conflict of interest, safety of the researcher, safeguards to participant anonymity if open access to data is proposed etc)

It is unlikely that this project will raise any problems but some of the questions may raise some questions or concerns for the athletes. We have added in the information sheet that if an athlete feels uncomfortable they should contact their GP and we have also added this at the end of the survey.

***Applicant's Signature:** ....

Name (please print): ……Katherine Black…………………………………………………….

Date: .....22/01/2020..........................

Appendix C: Study recruitment advertisement

Appendix D: Participant information sheet

Nutrition and energy availability knowledge and risk of low energy availability amongst female team sport players

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate, we thank you. If you decide not to take part, there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

Having knowledge about how nutritional needs can impact human health is important. An understanding of the current awareness and knowledge about the nutritional needs of female athletes is required in order to provide targeted educational initiatives, however, there is currently only limited information from overseas on the knowledge of these needs amongst female athletes and active women. The aim of this research is to assess the current level of knowledge amongst female athletes and active women so that we can design and deliver targeted education interventions in the future.
This project is being undertaken as part of the requirements for Namratha N Pai's PhD thesis.

What Types of Participants are being sought?

Provide a statement of the types of participants being sought which includes information about the following:

- *Recruitment method*
  We will recruit participants via social media, email, posters and word of mouth

- Selection criteria (where relevant)
  - To participate in this study you must be a female athlete aged 16 years or older, who plays a team sport.

- Exclusion criteria (where relevant)
  - If you are under 16 years of age or if you do not play a team sport you will be unable to participate.

- *Number of participants to be involved*
- 100

- Details of compensation/reimbursement of expense/payments offered for participation
    - You will be asked to provide your email address to be in the draw to win one of three $50 vouchers.

- Description of any benefit or access to information which the participant will have access to as a result of participating in the research
    - Upon completion of the questionnaire, you will receive a nutrition information sheet.

What will Participants be asked to do?

Should you agree to take part in this project, you will be asked to complete a questionnaire online. The questionnaire includes a series of questions covering the following topics: weight, current medications used, level of sport played, contraceptive use, some details of your menstruation status and current experience, social media use followed by questions examining your current understanding of nutrition the above topics. It is likely that the questionnaire will take approximately 40 minutes to complete. There is unlikely to be any adverse physical or psychological effects from participating. If you feel any discomfort during the questionnaire, please discontinue and make an appointment with your GP.

Please be aware that you may decide not to take part in the project without any disadvantage to yourself.

What Data or Information will be collected and what use will be made of it?

We will collect your answers to the questionnaire. The information will be used to assess the knowledge of the nutritional needs of female athletes. Dr Katherine Black, Alice Sharples and Namratha N Pai will have access to the information and data. This research is funded by the Department of Human Nutrition, University of Otago.

All data will be downloaded and saved by ID only onto a password protected computer and stored on the Department of Human Nutrition server. It will be analysed to provide us with information on the knowledge of female athletes.

The data collected will be securely stored in such a way that only those mentioned above will be able to gain access to it. Data obtained as a result of the research will be retained for at least 5 years in secure storage. Any personal information held on the participants may be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

Data will be kept by ID only. The final manuscript will only state how questions were modified and therefore, no individual data will be published in an attempt to preserve anonymity. Responses will be kept in a on a password protected computer and locked office and by ID only.

No individual data will be reported in the final paper instead we will use averages, percentages and ranges in the final report. We will therefore make every attempt to preserve your anonymity. You can withdraw or correct the information they have provided at any point throughout the study. Participants will be sent a copy of the final study if they wish. If they would like a copy you should inform us in the comments at the end of the questionnaire.

The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand). You can be informed of the results after the study is completed if you wish, you must inform us in writing, providing us with contact details.

No material that could personally identify you will be used in any reports on this study. Results of this research may be published.

Can Participants change their mind and withdraw from the project?

You may withdraw from the project, before its completion and without any disadvantage to yourself until data analysis has been completed.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either:- Katherine Black

Department of Human Nutrition

University Telephone Number:- 03 4798358

Email Address:- katherine.black@otago.ac.nz

This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix E: Main study questionnaire

Demographics

Age (years): ______________________

Height (cm): ______________________

Weight (kg): ______________________

What is your desired weight (kg)? ______________________

Which ethnic group do you belong to?
(Please tick any boxes which apply to you)

- ☐ New Zealand European
- ☐ Māori
- ☐ Samoan
- ☐ Cook Island Māori
- ☐ Tongan
- ☐ Niuean
- ☐ Chinese
- ☐ Indian
- ☐ Other

If 'Other' please specify: ______________________

Do you use any medication (excluding oral contraceptives)?

- ○ Yes
- ○ No

If 'Yes', what kind of medication?

Knowledge and Appetite

Have you ever heard of 'Low Energy Availability'?	◯ Yes ◯ No
If 'Yes', please describe 'Low Energy Availability' and its symptoms:	
What do you believe are the consequences of consuming insufficient energy?	
Before a heavy training session or matches what do you normally eat or drink?	
After a heavy training session or matches what do you normally eat or drink?	
After a heavy training session or matches how hungry do you usually feel?	◯ Extremely hungry ◯ Very hungry ◯ Neither hungry nor full ◯ Not very hungry ◯ Not hungry at all
Skipping my period makes my bones weak	◯ Yes ◯ No
Skipping my period is my body's way of saying I'm training too hard and not eating correctly	◯ Yes ◯ No
Teenagers with weaker bones will likely still have weaker bones as adults	◯ Yes ◯ No
I feel that skipping my period while playing sports is healthy and normal	◯ Yes ◯ No
I'm not old enough to have weak bones	◯ Yes ◯ No
Not eating enough could cause me to lose my period	◯ Yes ◯ No
Stress fractures (very small cracks or breaks) occur more often in girls that skip their period	◯ Yes ◯ No
How much I eat does not affect bone health	◯ Yes ◯ No

Not eating enough calories could cause me to have brittle bones	◯ Yes ◯ No
Can you identify the 3 distinct conditions that are associated with the female athlete triad?	◯ Yes ◯ No ◯ Not sure ◯ Do not know
If you can, please list the 3 conditions associated with the female athlete triad:	
Do you believe that irregular menstruation or absent menstruation is a healthy consequence of exercise and diet in female athletes?	◯ Yes ◯ No ◯ Not sure ◯ Do not know
Having an irregular menstrual cycle is often a sign that I am in peak competitive shape	◯ Never ◯ Almost never ◯ Sometimes ◯ Fairly often ◯ Very often ◯ Always

Section 3: LEAF

Have you had absences from your training, or participation in competitions during the last year due to injuries?	◯ No, not at all ◯ Yes, once or twice ◯ Yes, three or four times ◯ Yes, five times or more
If yes, for how many days absence from training or participation in competition due to injuries have you had in the last year?	☐ 1-7 days ☐ 8-14 days ☐ 15-21 days ☐ 22 days or more
If yes, what kind of injuries have you had in the last year?	☐ Muscle ☐ Ligament ☐ Fracture ☐ Other
Muscle - please describe the injury:	
Muscle - when did you first experience this injury?	______________
Muscle - how long did this injury last?	______________
Ligament - please describe the injury:	
Ligament - when did you first experience this injury?	______________
Ligament - how long did this injury last?	______________
Fracture (stress fracture or other) - please describe the injury:	
Fracture - when did you first experience this injury?	______________
Fracture - how long did this injury last?	______________
Other - please describe the injury:	
Other - when did you first experience this injury?	______________
Other - how long did this injury last?	______________

Gastro-intestinal Function	
Do you feel gaseous or bloated when you do not have your period?	○ Yes, several times a day ○ Yes, several times a week ○ Yes, once or twice a week or more seldom ○ Rarely ○ Never
Do you get cramps or stomach aches that are not related to your menstruation?	○ Yes, several times a day ○ Yes, several times a week ○ Yes, once or twice a week or more seldom ○ Rarely ○ Never
On average, how often do you have bowel movements?	○ Several times a day ○ Once a day ○ Every second day ○ Twice a week ○ Once a week or more rarely
How would you describe your normal stool?	○ Normal (soft) ○ Diarrhoea-like (watery) ○ Hard and dry
Comments regarding gastrointestinal function:	

Use of Oral Contraceptives	
Do you use oral contraceptives?	○ Yes ○ No
Why do you use oral contraceptives?	☐ Contraception ☐ Reduction of menstruation pains ☐ Reduction of bleeding ☐ To regulate the menstrual cycle in relation to performances etc ☐ Otherwise menstruation stops ☐ Other
Have you used oral contraceptives in the past?	○ Yes ○ No
When and for how long?	______________________
Do you use any other kind of hormonal contraceptives? (e.g. hormonal implant or coil)	○ Yes ○ No
What kind?	○ Hormonal patches - Ortho Evra ○ Hormonal ring - Nuva Ring ○ Hormonal coil - Mirena, copper IUD ○ Hormonal implant - e.g. Jadelle, Implanon ○ Other

Menstrual Function	
How old were you when you had your first period?	◯ 11 years or younger ◯ 12-14 years ◯ 15 years or older ◯ I don't remember ◯ I have never menstruated
Did your first menstruation come naturally (by itself)?	◯ Yes ◯ No ◯ I don't know
What kind of treatment was used to start your menstrual cycle?	◯ Hormonal treatment ◯ Weight gain ◯ Reduced amount of exercise ◯ Other
Do you have normal menstruation - (regular monthly period)?	◯ Yes ◯ No, I'm pregnant ◯ No ◯ I don't know
When was your last period?	◯ 0-4 weeks ago ◯ 1-2 months ago ◯ 3-4 months ago ◯ 5 months ago ◯ 6 months ago or more
Are your periods regular? (Every 28th to 34th day)	◯ Yes, most of the time ◯ No, mostly not
For how many days do you normally bleed?	◯ 1-2 days ◯ 3-4 days ◯ 5-6 days ◯ 7-8 days ◯ 9 days or more
Have you ever had problems with heavy menstrual bleeding?	◯ Yes ◯ No
How many periods have you had during the last year?	◯ 12 or more ◯ 9-11 ◯ 6-8 ◯ 3-5 ◯ 0-2
If no or "I don't remember", when did you have your last period?	◯ 2-3 months ago ◯ 4-5 months ago ◯ 6 months ago or more
Have your periods ever stopped for 3 consecutive months or longer (besides pregnancy)?	◯ No, never ◯ Yes, it has happened before ◯ Yes, that's the situation now
Do you experience that your menstruation changes when you increase your exercise intensity, frequency or duration?	◯ Yes ◯ No
If yes, how? (Check one or more options)	☐ I bleed less ☐ I bleed fewer days ☐ My menstruation stops ☐ I bleed more ☐ I bleed more days

Cooking Confidence

What kind of cooking do you do at the moment? (Please tick any boxes that apply to you)	☐ Cook convenience foods and ready-made meals ☐ Put together ready-made ingredients to make a complete meal (e.g. packet/jar sauces) ☐ Prepare dishes from basic ingredients (e.g. raw veg, pasta and raw meat) ☐ Don't cook at all ☐ Other

If 'Other', please specify:

In a normal week, how often do you prepare and cook a main meal from basic ingredients, for example, Spaghetti Bolognaise, starting with raw mince and tomatoes? Please choose one.	○ Daily ○ 4-6 times a week ○ 2-3 times a week ○ Once a week ○ Less than once a week ○ Never

For the following questions please select a number between 1-7, where 1 = 'Not at all confident' and 7 = 'Very confident'

	1	2	3	4	5	6	7
How confident do you feel about being able to cook from basic ingredients?	○	○	○	○	○	○	○
How confident do you feel about following a simple recipe?	○	○	○	○	○	○	○
How confident do you feel about tasting foods that you have not eaten before?	○	○	○	○	○	○	○
How confident do you feel about preparing and cooking new foods and recipes?	○	○	○	○	○	○	○

General Nutrition Knowledge

Eating more energy from protein than you need can make you put on fat	QAgree 0 Disagree O Not sure
The body needs fat to fight off sickness	QAgree 0 Disagree O Not sure
Do you think cheddar cheese is high or low in fat?	QHigh OLow O Not sure
Do you think margarine is high or low in fat?	QHigh OLow O Not sure
Do you think honey is high or low in fat?	0High OLow O Not sure
The body has a limited ability to use protein for muscle protein synthesis	0Agree 0 Disagree O Not sure
Eggs contain an the essential amino acids neededby thebody	0Agree ODisagree 0 Not sure
Thiamine (Vitamin Bl) is needed to take oxygen to muscles	0Agree ODisagree 0 Not sure
Vitamins contain energy (kilojoules/calories)	0Agree ODisagree 0 Not sure
Do you think alcohol can make you put on weight?	OYes ONo 0 Not sure
'Binge drinking' (al.soreferred to as heavy episodic drinking) is generally defined as:	O Having two or more standard alcoholic drinks on the same occasion O Having four to five or more standard alcoholic drinks on the same occasion O Having seven to eight or more standard alcoholic drinks on the same occasion 0 Not sure

Sport Nutrition Knowledge	
Do you think 1 medium banana has enough carbohydrate for recovery from intense exercise? Assume the athlete weighs about 70kg and has an important training session again tomorrow.	○ Enough ○ Not enough ○ Not sure
Do you think 1 cup of cooked quinoa and 1 tin of tuna has enough carbohydrate for recovery from intense exercise? Assume the athlete weighs about 70 kg and has an important training session again tomorrow.	○ Enough ○ Not enough ○ Not sure
Do you think 100 g of chicken breast has enough protein to promote muscle growth after a bout of resistance exercise?	○ Yes ○ No ○ Not sure
Do you think 1 cup baked beans has enough protein to promote muscle growth after a bout of resistance exercise?	○ Yes ○ No ○ Not sure
Do you think 1/2 cup cooked quinoa has enough protein to promote muscle growth after a bout of resistance exercise?	○ Yes ○ No ○ Not sure
Eating more protein is the most important dietary change if you want to have more muscle	○ Agree ○ Disagree ○ Not sure
Which is a better recovery meal option for an athlete who wants to put on muscle?	○ A 'mass gainer' protein shake and 3 - 4 scrambled eggs ○ Pasta with lean beef and vegetable sauce, plus a dessert of fruit, yoghurt and nuts ○ A large piece of grilled chicken with a side salad (lettuce, cucumber, tomato) ○ A large steak and fried eggs ○ Not sure
When we exercise at a low intensity, our body mostly uses fat as a fuel	○ Agree ○ Disagree ○ Not sure
Vegetarian athletes can meet their protein requirements without the use of protein supplement	○ Agree ○ Disagree ○ Not sure
The daily protein needs of a 100 kg (220 lb) well trained resistance athlete are closest to:	○ 100g (1g/kg) ○ 150g (1.5g/kg) ○ 500g (5g/kg) ○ They should eat as much protein as possible ○ 5. Not sure
The optimal calcium intake for athletes aged 15 to 24 years is 500 mg	○ Agree ○ Disagree ○ Not sure
A fit person eating a balanced diet can improve their athletic performance by eating more vitamins and minerals from food	○ Agree ○ Disagree ○ Not sure

Vitamin C should always be taken by athletes	◯ Agree ◯ Disagree ◯ Not sure
Athletes should drink water to:	◯ keep plasma (blood) volume stable ◯ stop dry mouth ◯ allow proper sweating ◯ all of the above ◯ Not sure
Experts think that athletes should:	◯ drink 50 - 100 ml (1.7 - 3.3 fluid ounces) every 15 - 20 minutes ◯ suck on ice cubes rather than drinking during practice ◯ drink sports drinks (e.g. Powerade) rather than water during intense sessions ◯ drink to a plan, based on body weight changes during training sessions performed in a similar climate ◯ not sure
Before competition, athletes should eat foods that are high in:	◯ fluids, fat and carbohydrate ◯ fluids, fibre and carbohydrate ◯ fluids and carbohydrate ◯ not sure
In events last 60 - 90 minutes, 30- 60 g (1.0 - 2.0 ounces) of carbohydrates should be consumed per hour	◯ Agree ◯ Disagree ◯ Not sure
Eating carbohydrates when you exercise will help keep blood sugar levels stable	◯ Agree ◯ Disagree ◯ Not sure
Which is the best snack to have during an intense 90-minute training session?	◯ A protein shake ◯ A ripe banana ◯ 2 Boiled eggs ◯ A handful of nuts ◯ Not Sure
How much protein do you think experts say athletes should have after completing a resistance exercise session?	◯ 1.5g/kg body weight (~ 150 - 130 g/ 5.3 -10.6 ounces for most athletes) ◯ 1.0 g/kg body weight (~ 50 - 100 g /1.9 - 2.3 ounces) for most athletes) ◯ 0.3g/kg body weight (~ 15 - 25 g/0.53 - 0.88 ounces) for most athletes) ◯ Not sure
Supplement labels may sometimes say things that are not true	◯ Agree ◯ Disagree ◯ Not sure
All supplements are tested to make sure they are safe and don't have any contamination	◯ Agree ◯ Disagree ◯ Not sure
Which supplement does not have enough evidence in relation to improving body composition, sporting performance?	◯ Caffeine ◯ Ferulic acid ◯ Bicarbonate ◯ Leucine ◯ Not Sure
The WORLD ANTI-DOPING AGENCY (WADA) bans the use of:	◯ Caffeine ◯ Bicarbonate ◯ Carnitine ◯ Testosterone ◯ Not Sure

Social Media

Question	Response
Do you use social media?	◯ Yes ◯ No
What social media platforms are you actively engaged in (i.e. use at least once a week)?	☐ Facebook ☐ Instagram ☐ Twitter ☐ Snapchat ☐ Tumblr ☐ Other (please specify)
If 'Other', please specify:	______________________________
Do you follow hashtags, people or companies related to exercise, food, training, body size or weight loss?	◯ Yes ◯ Not ◯ Not sure
If yes, please list which hashtags, people or companies you follow?	
How many hashtags, people or companies related to exercise, food, training, body size or weight loss do you follow?	______________________________
Have you ever changed your diet or exercise habits after seeing a post on social media?	◯ Yes ◯ No
What changes did you make?	

Energy Availability

Energy availability is the amount of dietary energy left to fuel physiological functions after the energy used from exercise has been taken away. When energy expenditure from exercise is greater than the energy consumed from food, there is less energy available to fuel normal physiological function, such as reproduction, immunity and growth. This is called low energy availability and is a component of the female athlete triad. The female athlete triad consists of three components: energy availability, bone health and menstrual function. Low energy availability and the female athlete triad are important considerations for the health and performance of athletes now, but also determine long term health and disease risk.

Would you like to learn more about low energy availability/female athlete triad?	○ Yes ○ No
What topics would you find most useful?	☐ Nutrition for female athletes ☐ Bone health ☐ Injury prevention ☐ Menstrual function/hormonal health ☐ Supplementation ☐ Signs and symptoms of female athlete triad/low energy availability
How would you prefer to learn about low energy availability and the female athlete triad?	☐ Books ☐ Factsheet ☐ Video ☐ Group seminar ☐ Individual seminar/consultation ☐ Self-education ☐ Scientific articles ☐ Internet/social media ☐ Pamphlet ☐ Other (please specify)
If 'Other', please specify:	________________________
Please add your email address to be added into the prize draw:	________________________
Would you like a copy of the final results?	○ Yes ○ No

Appendix F : Examples of posts selected on Instagram for review on RED-S definition.

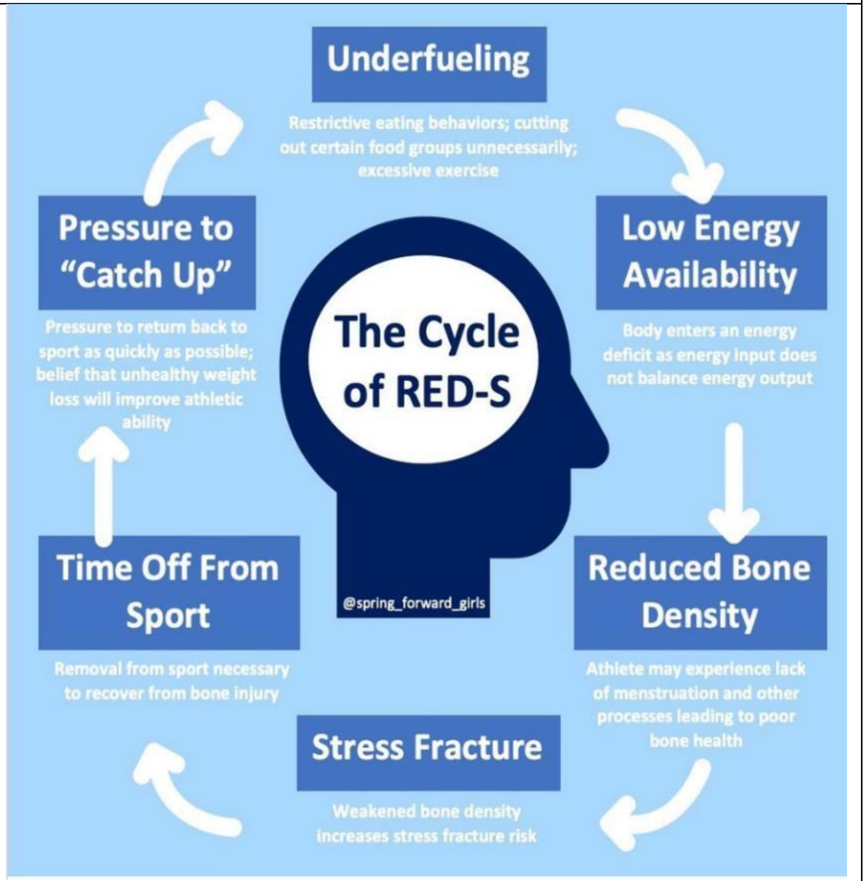
Description of the post	**Image used**
Image 1[a]	
"Relative energy deficiency in sport (RED-S) can be thought of as a cycle of action and negative health consequences - with some of the consequences having a long-term impact on our physical and mental wellness. In order to break this cycle, it is important we fuel properly and provide sufficient energy for daily exercise, physical activity and growth/development (for high school athletes) in addition to seeking professional help to rule out other health issues. The cycle of RED-S often goes as follows: 1. Underfueling - either through purposeful restriction of food or by lack of awareness regarding energy needs 2. Low energy availability - the combination of underfueling in addition to daily energy demands + exercise causes the body to enter a state of energy deficit 3. Reduced bone density - lack of adequate fuel + the loss of menstruation (a common occurrence in athletes with RED-S) can lead to decreased bone density 4. Stress fracture - reduced bone density often results in stress fractures (or other bone/connective tissue injuries) for athletes stuck in the RED-S cycle 5. Time off from sport - the athlete now must allow time off from physical activity in order for injury recovery 6. Pressure to "catch up" - upon returning to sport, an athlete may feel pressure to quickly get to their pre-injury fitness (this can lead to bringing back training too quickly, overtraining or still engaging in previous underfueling behaviors) all restarting the cycle of RED-S In order to prevent falling into the cycle of RED-S, athletes need to aim for adequate, nutrient-dense energy intake in addition to meeting with a trusted healthcare provider to rule out other areas of concern.	

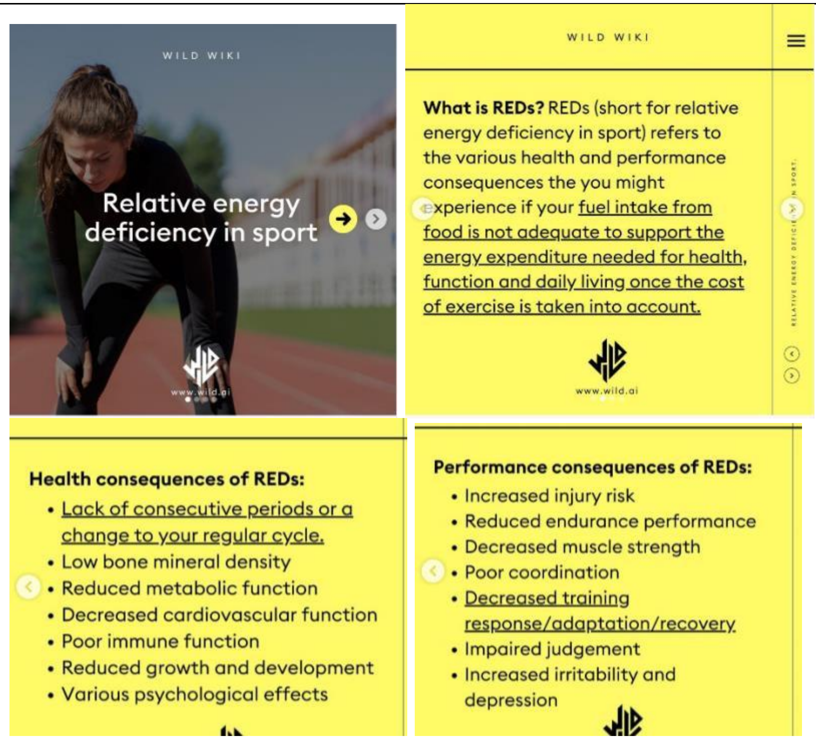
Image 2[a]	
Relative energy deficiency in sport (aka REDs) refers to when your energy intake (i.e., fuel from food) is insufficient to match the energy requirements going out (i.e., physiological functioning, daily life and any additional activities such as training). Swipe to see some of the common consequences of REDs. 👉 At Wild AI we know it's important to fuel any activity you're doing not only to prevent the likes of REDs, but to get the most out of your body and enhance your recovery post-training also. This is why we developed our pre and post-training nutrition recommendations to help you stay on track! Simply add in your training to see your personalised recommendations. Top tip: Tracking your cycle in the app allows you to keep track of your periods, giving you an early indication that something might not be 'normal' for you.	

Image 3[a]

Relative energy deficiency in sport (RED-S) is a syndrome that affects the health and performance of both female and male athletes and is an outcome of low energy availability. Formerly known as the Female Athlete Triad.

Low energy availability is when an athlete restricts their energy intake to a level below what is needed to maintain optimal health. This can lead to a number of consequences such as:

- Impaired metabolic function

Studies of women with RED-S have discovered disruptions in hormones, such as their thyroid function and changes in appetite–regulating hormones.

- Menstrual disturbances

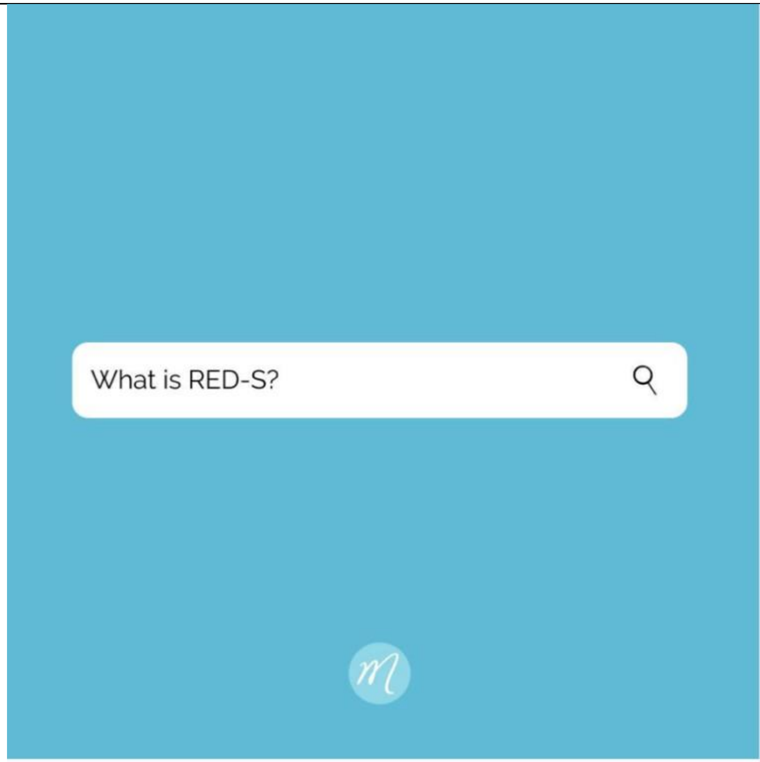
RED-S can have an impact on reproductive hormones, resulting in disrupt menstrual cycles and impaired ovulatory function, ultimately affecting fertility.

- Increased risk of osteoporosis

A decrease in oestrogen and low intake of nutrients causes bones to lose their strength resulting recurrenting fractures

Although the severity and physical manifestations of RED-S symptoms vary between individuals, there are some symptoms you should follow up on. They include irregular or non-existent menstrual cycles, recurringing injuries and illness, fatigue, decreased performance and mood swings.

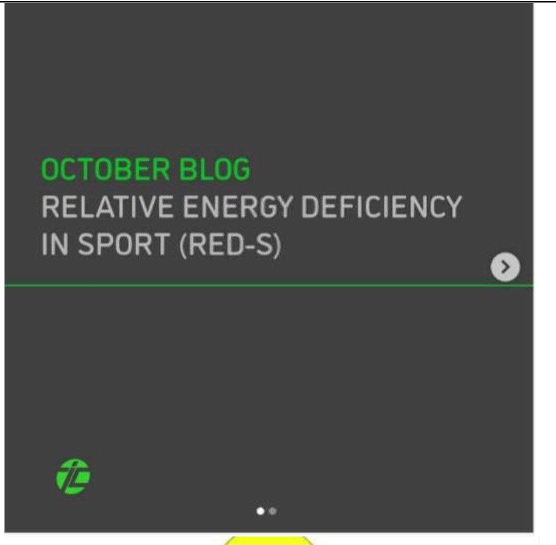
So what should you do if you think RED-S might be affecting your fertility? The first step is to seek out the advice of a healthcare professional who has experience with RED-S. This might be your local doctor, fertility specialist or dietitian.



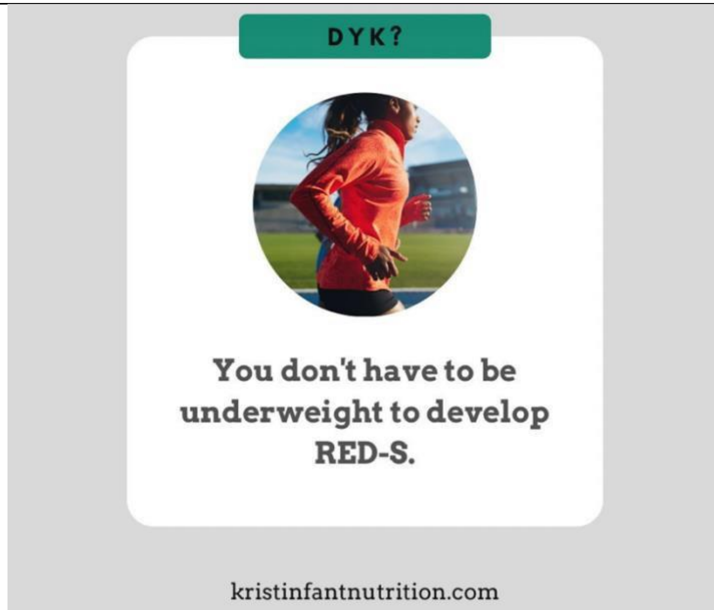
<table>
<tr><td>Image 4[a]</td><td></td></tr>
<tr><td>
✋ Have you tried to reduce your food intake to help you lose weight or reduce body fat without seeing results?

✋ Do you have reccurring injuries that you can’t seem to shake?

👉 RED-S is caused when energy intake from food is lower than the energy required for exercise and normal bodily processes. RED-S is common in both males and females and can occur in recreational or elite athletes.

👉 RED-S has many serious performance and health implications if left untreated. A sports dietitian can help to ensure you have sufficient energy to support your training load without causing these implications.
</td><td>


</td></tr>
</table>

Image 5[a]	
RED-S = Relative Energy Deficiency in Sport. This is what happens when you ask your body to keep up with high demands of activity while providing it with too little fuel to get the job done. It can manifest in a lot of different ways, including things like: 🦴 bone injuries (like frequent stress fractures) 🌡 lab abnormalities ☐ missing or irregular menstrual cycles 💘 low resting heart rate (or a heart rate that jumps up dramatically going from sitting to standing) 😴 fatigue, poor performance during workouts 💩 GI problems 😩 Anxiety ⬇️ unintentional weight loss Sounds fun right? Well guess what - you don't have to be a certain weight, race or gender to experience RED-S. This affects athletes at ALL levels, recreational to elite. You cannot take your weight or BMI and assume all is good (or that you need to keep trying to lose weight to improve) ❌ Better idea: Nourish your body and fuel for your training! This way you can stay healthy and continue to see improvements. 🎉 If you need help with this, reach out to me. I have limited spots for 1:1 coaching available this spring. Link in my bio to get on the list! ✨	

Note: **Image 1** & **4** is considered as infographic images; **Images 2, 3** & **5** is considered as written text on images.

[a] Quality score received by these images are given the Appendix G.

Appendix G: The average score based on an expert's evaluation of the images.

	Accuracy[a]	Clear[a]	Understanding[a]	engaging/interesting[a]
Image 1	2	1	2	2
Image 2	5	5	5	3
Image 3	4	2	2	2
Image 4	3	4	4	3
Image 5	3	3	3	2

[a] Evaluation of the items was based on two criteria, ‘accuracy (‘not accurate’(=1) to ‘extremely accurate (=5)), clarity (‘not clear’(=1) to ‘extremely clear’(=5)), understandability (‘not easy to understand’ (=1) to ‘extremely easy to understand (=5)) and engagement (‘not engaging’(=1) to ‘extremely engaging (=5)), additionally each question contained an open- ended ‘comment’ section.