Risk of Low Energy Availability (LEA) in New Zealand National Team and U20 Female Football Representatives

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

Background: The rates of low energy availability (LEA) seen among female footballers in collegiate, professional and youth environments range from 12% to 66%. Studies in female footballers are limited, and no research has yet looked at the prevalence of LEA in a cohort of international players. Due to the negative consequences associated with a state of LEA, research is needed for a more thorough investigation into possible prevalence rates and the associated risk factors of LEA within the international New Zealand female football environment.

Objectives: Identify the number of national team and U20 female football players at risk of LEA in New Zealand, the factors (age, years training in national environment, nutrition knowledge, occupation) that increase the risk of LEA and the prevalent symptoms (sleep, mood, disordered eating) of those that are at risk of LEA.

Methods: 22 members of the New Zealand U20 and full national women's football teams (age 20.8 ± 3.5 years) participated in this study. Participants completed an online questionnaire that was composed of five independent validated surveys to assess LEA risk (LEAF-Q), eating disorders/disordered eating risk (EDE-Q), sleep quality (ASS-Q), nutrition knowledge (ASNK-Q) and mood (POMS-Q).

Results: 59.1% (n = 13) of our participants were identified as being at risk of LEA. Players who reported menstrual disturbances (amenorrhea or oligomenorrhea) were 2.25 times more likely to be at risk of LEA than those who did not report a menstrual disturbance. Menstrual status was significantly associated with risk of LEA (R = -0.46, P = 0.030). Players at risk of LEA had significantly higher (p = 0.027) POMS-Q score's (109.4 ± 24.4) than participants not at risk of LEA (89.0 ± 11.7). POMS-Q was significantly and positively associated with LEA score (r = 0.46, p = 0.032). Player's spending >5 hours per week on non-football related training (gym, fitness, speed etc.) were 1.6 times more likely to be at risk of LEA compared to players who spent <5 hours on non-football related training. Players who were not full-time and had an additional occupation were 1.9 times more likely to be identified as being at risk of LEA compared to full-time players in the New Zealand squad. Players who had moderate and/or severe clinical sleep problems were 1.7 times more likely to be identified as being at risk of LEA, however the player's sleep score was not predicative of LEA risk.

There was no significant relationship between nutritional knowledge or disordered eating behaviours and risk of LEA. However, players who were identified as being at risk of LEA scored significantly higher on the negative mood subscales including anger ($p < 0.001$), depression ($p < 0.001$) and confusion ($p = 0.037$) compared to players who were not identified as being at risk of LEA. As a result, POMS-Q ($p = 0.032$) and menstrual status ($p = 0.030$) were the only two variables that showed significance in being able to predict the risk of LEA in our participant cohort.

Conclusion: This study confirms that a significant proportion (59.1%) of players in the New Zealand national and U20 female football team are at risk of LEA. The positive and predictive relationship observed between mood disturbances, menstrual status and risk of LEA may suggest that regular monitoring of mood and menstrual cycle health could potentially be used for the early identification of LEA in national level female footballers in New Zealand.

Acknowledgements

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List of Abbreviations

Abbreviation	**Term**
ASNK-Q	Abridged Sport Nutrition Questionnaire
ASS-Q	Athlete Sleep Score Questionnaire
DE	Disordered Eating
DXA	Dual-energy X-ray Absorptiometry
EA	Energy Availability
EDE-Q	Eating Disorder Examination Questionnaire
ED	Eating Disorder
EEE	Exercise Energy Expenditure
EI	Energy Intake
FFM	Fat Free Mass
GPS	Global Positioning Systems
IOC	International Olympic Committee
LEA	Low Energy Availability
LEAF-Q	Low Energy Availability in Females Questionnaire
LH	Luteinising Hormone
MET	Metabolic Equivalent
NEAT	Non-exercise Activity Thermogenesis
POMS-Q	Profile of Mood States Questionnaire
RED-S	Relative Energy Deficiency in Sport
RMR	Resting Metabolic Rate
SDS	Sleep Difficulty Score

Chapter 1: Purpose

1.0 Introduction

Energy availability (EA) has been operationally defined as energy intake (EI) minus exercise energy expenditure (EEE) relative to fat free mass (FFM) (Loucks & Thuma, 2003). It is the amount of energy available for normal physiological functioning such as resting metabolic rate (RMR), muscle recovery and cognition (Mountjoy et al., 2014). When athletes have inadequate EA they can enter a state of low energy availability (LEA) defined as, “an inadequacy of energy to support the range of body functions involved in optimal health and performance” (Mountjoy et al., 2014) (see Figure 2.2). This is the underlying cause of a syndrome defined in 2014 by the International Olympic Committee (IOC) as Relative Energy Deficiency in Sport (RED-S).

Low energy availability impacts the physiological functioning of numerous bodily systems and an athlete in a state of chronic LEA puts themselves at risk of serious acute and long term health consequences (Mountjoy et al., 2014). One of the biggest impacts of LEA, is its disruption to endocrine function and subsequently the process of menstruation in females (Mountjoy et al., 2014). These initial changes to menstrual cycle function may be a result of disruption to luteinising hormone (LH) pulse frequency or amplitude and present as anovulatory or irregular menstrual cycles (oligomenorrhea), inadequate concentrations of sex hormones (e.g., subclinical ovulatory disturbances such as luteal phase defects) and in severe cases the absence of menstruation (amenorrhea). In clinical studies with sedentary females, the threshold of EA where a disruption to LH pulsatility was seen occurred at an EA of <30 kcal/kg FFM (Loucks & Thuma, 2003). Research has subsequently demonstrated how LH and menstrual cycle disruptions can be accompanied by an array of other health consequences “including, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health caused by relative energy deficiency” (Mountjoy et al., 2014). Furthermore, the extent of these health consequences may be increased with the severity of LEA or greater reductions in kcal.kg^{-1} FFM in females as well as duration and frequency of LEA (Loucks & Thuma, 2003).

In addition to its impact on health, LEA can have a profound effect on athletic performance (Mountjoy et al., 2014). Once again, female athletes in a state of chronic LEA may experience an increase in injuries and illnesses, an inability to recover and adapt following training/competition, impaired judgement and concentration as well as limited muscle strength and glycogen stores (Mountjoy et al., 2018).

An athlete may enter a state of LEA as a consequence of either intentional or unintentional overtraining and/or under fuelling (inadequate energy intake) (Mountjoy et al., 2014). Research consistently shows that during periods of intense training, female athletes fail to match their EI with high EEE or increasing EEE that can occur throughout training and competitive seasons (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021).When inadequate EI is unintentional it often occurs as a by-product of athletes experiencing post exercise appetite suppression (Howe et al., 2016) or increased training load coupled with insufficient nutritional knowledge or external support to aid them in increasing their EI to meet their EEE (Costill et al., 1988). When provided with the correct education and support such as dietary changes from a dietician and management of training from the coach, these individuals will often approach recovery willingly in order to optimise their health and wellbeing for performance thereby, limiting the need of certain medical professionals such as a psychologist (Wells et al., 2020).

Conversely, reduced EI can also be a purposeful decision in which a female athlete will choose to restrict caloric intake in order to either enhance sport performance, meet aesthetic demands of the sport, or perceived societal pressure (Heather et al., 2021; Mountjoy et al., 2018). When LEA is the result of an intentional decision and involves some form of disordered eating (DE) and/or eating disorder (ED), then the use of a multidisciplinary team may be warranted (where available). The involvement of a psychologist as the primary lead may be essential in addressing changes to EI, EEE and where appropriate athletes may be fully removed from the training environment to aid their recovery (Mountjoy et al., 2015; Wells et al., 2020).

Initial research in female athletes suggested that the prevalence of LEA in team sports such as football is reportedly lower than that seen in endurance sports (Sundgot-Borgen & Torstveit, 2007). However, whilst research on female footballers is limited, recent studies have demonstrated that the prevalence of LEA ranges from 12% (Reed et al., 2013) to 66.7% (Magee et al., 2020) among players of various levels (professional, international, college, youth) which is actually consistent with that seen in weight dependent, aesthetic and endurance sports (Jagim et al., 2022; Logue et al., 2020; Melin et al., 2019). Additional studies have also shown that female footballers at an international level (Mara et al., 2015; Martin et al., 2006) have an EI that is significantly below the suggested values for female footballers of 47-60kcal/kg (Economos et al., 1993).

1.1 Aims

The aim of this research is to identify the proportion of national team and U20 female football players at risk of LEA in New Zealand, the factors (e.g. age, years training in national environment, nutrition knowledge, occupation) that increase the risk of LEA and the prevalent symptoms (e.g. sleep, mood, DE) of players that are at risk of LEA.

1.1.1 Objectives

a. Identify the number of national team and U20 female football players at risk of LEA in New Zealand.
b. Identify factors (age, years training in national environment, nutrition knowledge, occupation) that increase the risk of LEA in national team and U20 female football players.
c. Identify prevalent symptoms (sleep, mood, DE) of female footballers that are at risk of LEA.

1.1.2 Hypotheses

a. A significant proportion of players will be identified as being at risk of LEA.
b. The more training hours a player completes per week, the higher their risk of LEA.
c. Players with low nutritional knowledge scores will be at higher risk of LEA.

1.2 Structure of Thesis

The thesis begins by introducing the concept of LEA in female athletes and the health and performance consequences associated with this state, concluding with the study aims, objectives and hypotheses. This is followed by chapter two which is an in-depth review of the current literature of LEA in female footballers. It discusses the prevalence rates of LEA among collegiate, professional, youth and international female footballers as well as addressing possible risk factors and/or symptoms associated with being in a state of LEA in this cohort of athletes. Chapter three is the manuscript of the study that provides details on the methods and results of this research. Finally, chapter four summarises the implications of this study, the strength and limitations, and practical takeaways for New Zealand football and international female footballers as well as future directions for research looking at LEA in female footballers.

1.3 Researcher's Contributions

Table 1. 1: Summary of Researcher's Contributions to the Study

Author	Contribution to Thesis
Isabella Coombes Masters in Health Science Student (Sport and Exercise)	Primary author of thesis Designed research Applied for ethics Participant recruitment Data collection Statistical Analysis Interpreted of results
Dr Claire Badenhorst Primary Supervisor Senior Lecturer School or Sport, Exercise and Nutrition	Assisted in ethics application Assisted in interpretation of results Assisted in statistical analysis Revised and approved thesis

Chapter 2: Literature Review

2.0 Introduction

International football is a physically demanding endeavour. The energetic cost of both training and match play is a key parameter that national teams must account for to maximise the performance of their players (Thomas et al., 2017). A typical week for females playing in the top professional leagues and on the international stage usually consists of 4-5 football trainings, 2-3 strength sessions and 1-2 matches a week (Mara et al., 2015; Moss et al., 2021). GPS data from such environments has demonstrated that players will cover ~10km and make ~1400 activity changes in match play across various heart rate zones and intensities (Datson et al., 2014). However, the duration, intensity and frequency of training and match play for elite footballers is highly dependent on the time of year, playing position and individual ranking within the team (Mara et al., 2015). The majority of the distance covered on the field occurs via walking and low intensity running interspersed with short, sharp high intensity sprints (~200 per game) very close to maximum heart rate, every 40 seconds (Datson et al., 2014). As a result, average and peak heart rates during a match will be approximately 85% and 98% of maximal values respectively (Krustrup et al., 2005). To support training adaptations, functioning of physiological systems and ultimately optimal athletic performance, female athletes must therefore be encouraged to ingest adequate energy intake (EI) for training and exercise energy expenditure (EEE) to ensure sufficient energy availability (EA) (Burke et al., 2018).

Energy availability has been operationally defined as EI minus EEE relative to fat free mass (FFM) (Loucks & Thuma, 2003) (as seen in Figure 1). It is the amount of energy available for normal physiological functioning including but not limited to resting metabolic rate (RMR), muscle recovery and cognition (Mountjoy et al., 2014). When female athletes do not have an adequate EA they are likely to experience disruptions to their menstrual cycle associated with changes to the sex hormones estrogen and progesterone. These initial changes to menstrual cycle function accompanied by inadequate EA may arise from disruptions to luteinising hormone (LH) pulse frequency or amplitude and manifest as anovulatory or irregular menstrual cycles (oligomenorrhea), inadequate concentrations of sex hormones (e.g., subclinical ovulatory disturbances such as luteal phase defects) and in severe cases the absence of menstruation (amenorrhea). As such the EA threshold where there is noticeable disruption to LH pulsatility has been suggested as an indicator of inadequate EA for that individual. The proposed threshold for a state of low energy availability (LEA) in non-athletic females has been suggested to be EA<30 kcal.kg^{-1} FFM. This was demonstrated in a controlled laboratory setting where EA<30 kcal.kg^{-1} FFM suppressed LH pulse frequency and increased LH pulse amplitude compared to females achieving an EA~45 kcal.kg^{-1} FFM (Loucks & Thuma, 2003). The extent of this LH disruption was significantly increased with the severity of LEA or greater reductions in kcal per kg FFM in females. Restricting EA to ~20 kcal.kg^{-1} FFM and ~10 kcal.kg^{-1} FFM resulted in a 16% and 39% reduction in LH pulse frequency and 21% and 109% increase in LH pulse amplitude

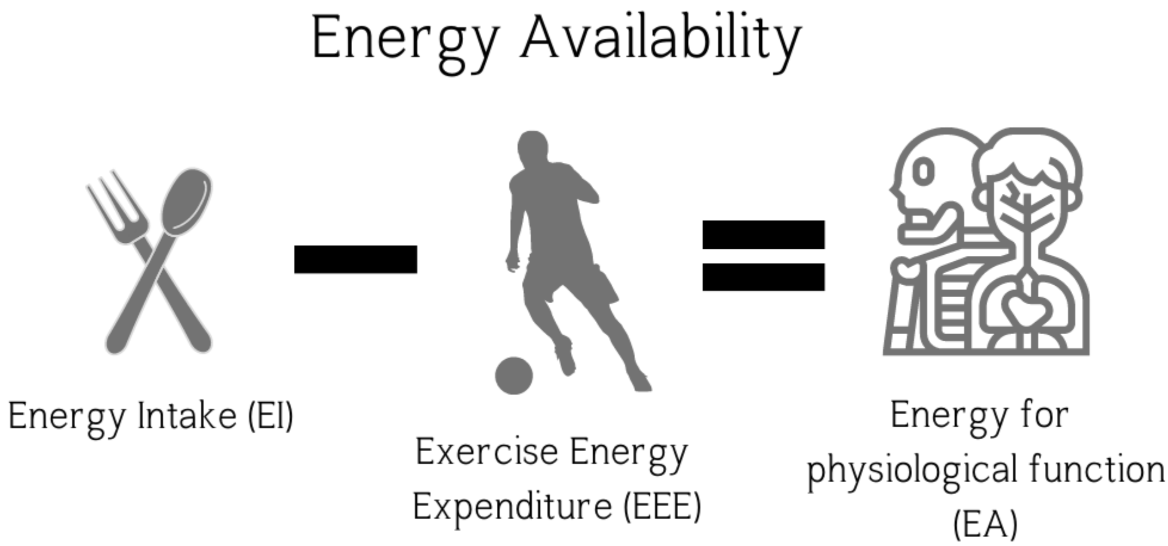

Figure 2. 1 EA is the dietary energy left over for physiological processes after EEE has been accounted for

respectively compared to the group achieving ~30 kcal.kg^{-1} FFM and ~45 kcal.kg^{-1} FFM (Loucks & Thuma, 2003). Despite current thresholds for EA being set in the literature, it is worth noting that the impact of the intensity of LEA (kcal.kg^{-1} FFM values), the duration or how long the individual has been below the threshold of <30 kcal.kg^{-1} FFM) and frequency of LEA (how many times have they been in a state of LEA in the last 12 months) relative to the extent of disruption of the females physiological functioning, or degree of adverse health symptoms is still an active area of investigation (Burke et al., 2018).

In a state of LEA athletes have "an inadequacy of energy to support the range of body functions involved in optimal health and performance" (Mountjoy et al., 2014) (see Figure 2). This physiological state of LEA is the underlying cause of a syndrome defined in 2014 by the International Olympic Committee (IOC) as Relative Energy Deficiency in Sport (RED-S) which may occur when an athlete does not or is unable to ingest sufficient food for EEE requirements, NEAT (non-exercise associated thermogenesis) and RMR (Mountjoy et al., 2014).

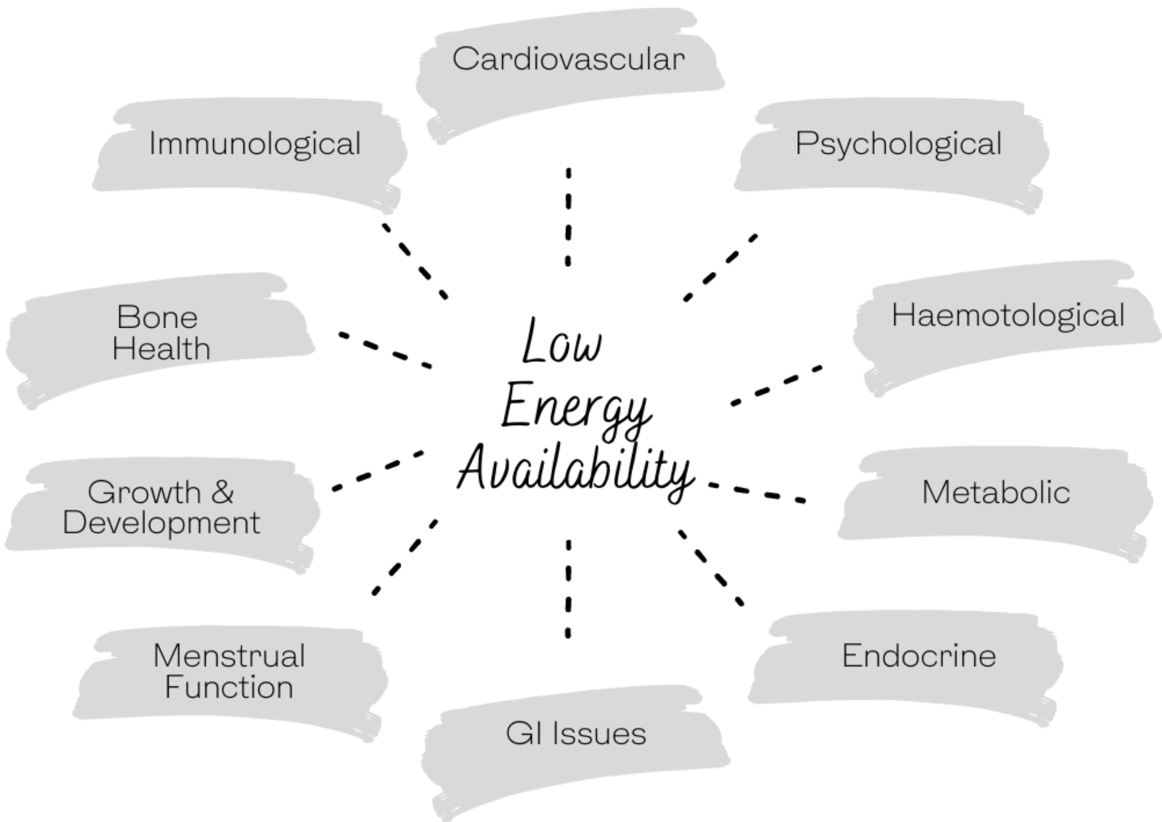

Figure 2. 2 Health consequences associated with a state of low energy availability (LEA)

Football is one of the most widely played sports throughout the world (FIFA, 2014). Within the female game, 54% of the players are youth athletes (<18 years of age) (FIFA, 2014). Whilst current research would suggest that the rate of LEA in team sports such as football is reportedly lower than that seen in endurance sports (Sundgot-Borgen & Torstveit, 2007), the growing number of youth and elite female footballers worldwide (FIFA, 2014) requires a deeper understanding of how the social and physical pressures in the current environment (Heather et al., 2021) are impacting the risk of LEA, health and performance of these athletes.

Based on the available literature, this review aims to highlight the prevalence of LEA among high performance female footballers and examine the factors that may be contributing to high EEE or low EI in this athletic population. This review will provide details on previous studies that have investigated a state of LEA in female footballers across various levels of performance (amateur through to professional). In addition, the review will provide details on nutritional trends of female footballers and how this may result in changes in EA and or contribute to the LEA state across training and competitive seasons. Finally, this review will aim to highlight areas in need of future research so that female footballers can minimise their risk of LEA for better health, wellbeing, and performance.

2.1 Prevalence of Low Energy Availability in Athletes

Low Energy Availability was first identified in the 1990's when researchers proposed the concept of a female athlete triad to demonstrate how LEA can have a negative impact on reproductive function and bone density in females (Nattiv et al., 1994). Since then, increased recognition regarding the prevalence of LEA within specific athletic populations has resulted in a large volume of research being undertaken in sports where athletes are considered to be at risk of LEA including, endurance, aesthetic and weight dependent sports (Logue et al., 2020). Observations from the initial and current research investigations would suggest that female athletes are at a higher risk of not meeting EI requirements that support their EEE (Heany et al., 2011; Nattiv et al., 2007). From this research, total EI and nutrient timing have been identified as important factors for recovery, growth/development and overall sport performance outcomes (Mountjoy et al., 2014). Research consistently shows that during periods of intense training, female athletes fail to match their EI with high EEE or increasing EEE that can occur throughout training and competitive seasons (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021). Inadequate EI may be an unintentional by-product of athletes experiencing post exercise appetite suppression (Howe et al., 2016) or increased training load, as well as having insufficient nutritional knowledge or support to aid them in increasing their EI (Costill et al., 1988). In contrast, reduced EI can also be a purposeful decision in which a female athlete chooses to restrict caloric intake in order to either enhance sport performance or meet aesthetic demands of the sport, or perceived societal pressure (Mountjoy et al., 2018). In recent research by Heather et al., (2021), 73% of elite female athletes in New Zealand (n=194) perceived that there were specific physical appearance pressures associated with high performance sport, which they suggested had a damaging effect on their overall health outcomes. Additionally, 33% of these New Zealand female athletes reported having disordered eating (DE) habits in order to obtain a perceived ideal body image (Heather et al., 2021).

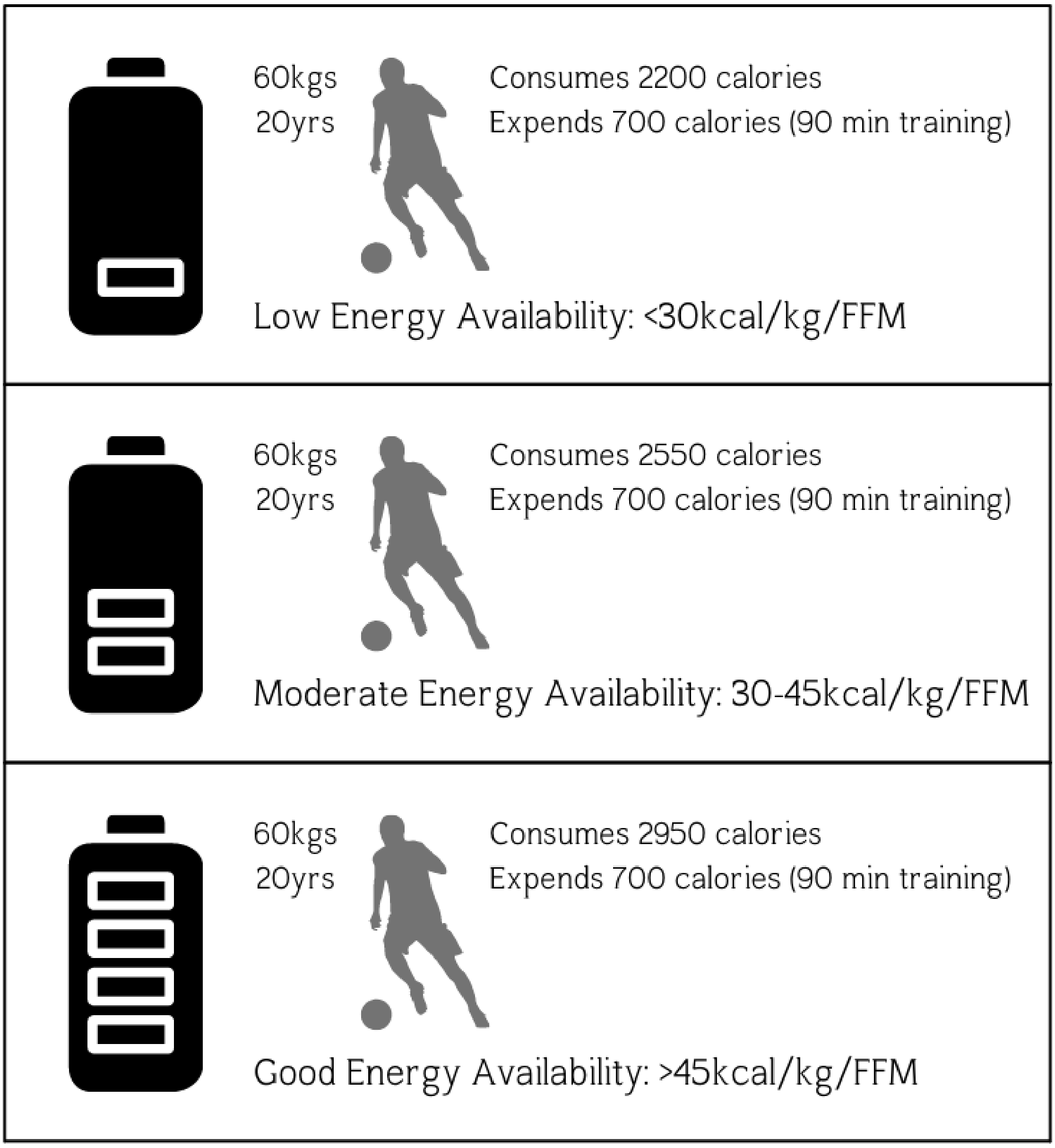

Figure 2. 3 Example of different levels of EA. Energy availability is calculated as EI-EEE/FFM.

The prevalence rates of LEA in the literature are highly variable, a result that may be due to the different physiological demands of endurance, power and team sports as well as the variety of research methods that have been used to measure and define LEA in both controlled laboratory and infield settings (Sundgot-Borgen & Torstveit, 2007). Currently there is no ‘gold standard’ assessment for EA and therefore, inconsistent study design and screening tools used throughout the literature may play a role in such variable prevalence rates of LEA (Logue et al., 2020).

Accurate determination of EA is challenging and whilst it can be calculated by examination and measurement of an athletes EI and estimations of total daily EEE relative to their FFM (Loucks & Thouma, 2003), the validity and reliability of such measures are often considered inaccurate, resource intensive and time consuming in the lab (Burke et al., 2018; Heikura et al., 2022). Resting metabolic rate can be determined with some accuracy through laboratory-based testing, but this is somewhat impractical, scarcely available and still prone to poor methodology (Heikura et al., 2022). Whilst field-based testing can take place, this presents even more reliability issues and can result in miscalculation of EA by up to 600 kcal/day (Burke et al., 2018). Acknowledged measurement errors for accurate EA determination may be due to over reporting of EI and under-reporting of EEE that can occur with athletes self-reporting their own data. However, a recent meta-analysis suggests that females of reproductive age may reliably record anthropometric (height and weight) data, such that the self-reported data collected on these methods may be equivalent to that obtained through clinical or lab-based measures (Seijo et al., 2018). A factor that may aid the reliability and validity of body mass/anthropometric measures that are used for infield EA estimates. However, the magnitude of measurement error in self-reported EI and EEE (up to 600 kcal/day) still presents a significant challenge to researchers and subsequently impacts the validity and reliability of their conclusions. Previous studies in female footballers have collected data on LEA symptoms and relative risk through various methods including self-reported food and exercise diaries, blood samples, dual-energy X-ray absorptiometry (DXA) scans and global positioning systems (GPS) tracking (Magee et al., 2020; Martin et al., 2006; Moss et al., 2021; Reed et al., 2013). The various methodologies used throughout the literature in female footballers and LEA likely contributes to the large variability in LEA prevalence in the results that will be presented and discussed in this review. By reviewing the available evidence in female footballers, the authors will endeavour to highlight the risk of LEA in female footballers, risk factors that may be contributing to the risk of LEA in females and areas for future research to focus on.

Table 2. 1: Summary of Research on Low Energy Availability in Female Footballer's

Year	Author	Age	Sample Size	Athlete Level	Study Design	Mean +/- SD EA (kcal.kg^{-1} FFM/Day)	Mean Relative EI (kcal/kg)	Participants with LEA (%)	Comments
2021	Moss et al.,	23.7 ± 3.4	13	Professional	5-day self-reported nutritional data, GPS training data, non-football MET values, LEAF-Q	35 ± 10	n/a	%	15% with optimal EA (>45kcal/kg/FFM) 62% with reduced EA (30<45kcal/kg/FFM)
2020	Dobrowolski & Wlodarek	21.5 ± 4.9	31	Professional	3-day self-reported food and exercise diary	25 ± 11	n/a	64.1%	Average EI = 1548 ± 452 kcal Average EEE = 2703 ± 392 kcal
2015	Mara et al.,	23-30	8	International	EEE measured via Sense Wear Mini Armband	n/a		n/a	EEE game = 12,242 kj EEE training = 11692 kj EEE rest = 9,516 kj
2006	Martin et al.,	25.5 ± 3.9	16	International	7-day self-reported food and exercise diary	n/a	30.9 ± 5.5	n/a	Non-significant ~250kcal/day energy deficit
2020	Magee et al.,	19.2 ± 1.1	18	College (D3)	5-day self-reported nutritional data, GPS training data, LEAF-Q	27.5 ± 8.9	n/a	66.7%	LEAF-Q showed only 56.3% of athletes as being high risk for LEA
2013	Reed et al.,	18-21	19	College (D1)	3-day self-reported food and exercise diary, GPS training data, body composition, performance testing, eating attitudes questionnaire, blood samples	Pre-season = 43 Mid-season = 34 Post-season = 44	n/a	Pre-season = 26% Mid-season = 33% Post-season = 12%	EA declined by 19% from pre to midseason and then improved by 35% at postseason
2003	Clarke et al.,	Pre-season = 19.7 ± 0.7 Post-season = 20.0 ± 0.9	13	College (D1)	3-day self-reported food and exercise diary, body composition, performance testing	n/a	Pre-season = 37 kcal/kg Post-season = 30 kcal/kg	n/a	EI Pre-season = 2290 ± 310 kcal EI Post-season = 1865 ± 530 kcal
2018	Braun et al.,		32	Youth	7-day self-reported food and exercise diary	30	40.5 ± 7	53%	n/a
2011	Gibson et al.,	15.7 ± 0.7	33	Youth	Blood sampling, body composition testing, 4-day self-reported food and exercise diary	n/a	35 ± 10	n/a	Average energy deficit of 462 ± 549 kcal

2.2 Professional Footballers

The work of Dobrowolski & Wlodarek (2020) was the first study to assess the prevalence of LEA in a group of professional female footballers. This research assessed EA using 3-day, self-reported food and exercise diaries over two training days and one rest day. Results from this data showed that across the 31 participants, average EI over 3 days (1548 +/- 452 kcal/day) was significantly lower than total EEE (2703 +/- 392 kcal/day). Moreover, average EA (25 +/- 11 $kcal.kg^{-1}$ FFM) was significantly below the suggested threshold of LEA (<30 $kcal.kg^{-1}$ FFM) in females (Dobrowolski & Wlodarek, 2020). As a result, 64.1% of participants (n=20 players) were classified as being in a state of LEA (EA<30 $kcal.kg^{-1}$ FFM) compared to 35.9% (n=11 players) presenting with adequate EA (30<45 $kcal.kg^{-1}$ FFM) or optimal EA (≥45 $kcal.kg^{-1}$ FFM) (Dobrowolski & Wlodarek, 2020). These results are consistent with a second study undertaken by Moss et al., (2021) that investigated the EA of 13 professional female footballers from the same team who were competing in the Women's Super League (top UK league). Prior to the data collection period, a series of tests were undertaken by each participant including fasted blood samples, RMR (indirect calorimetry), body composition via DXA, the Low Energy Availability in Females Questionnaire (LEAF-Q) and the Eating Disorder Examination Questionnaire (EDE-Q) (Moss et al., 2021). Unlike the research of Dobrowolski & Wlodarek (2020), participants in this study were asked to self-report dietary intake and exercise over a 5-day period (heavy training day, light training day, match day and two rest days) to better account for variation in EEE across the week (Moss et al., 2021). Exercise energy expenditure for on-field training and games was calculated using Viper GPS data whilst EEE for non-football sessions was estimated by the assignment of metabolic equivalent (MET) values (Moss et al., 2021). The results from the 5-day monitoring period indicated that 85% of participants (n=11) did not have optimal EA including 23% with LEA (EA<30 $kcal.kg^{-1}$ FFM, n=3) and 62% were considered to be in a state of reduced EA (30<45 $kcal.kg^{-1}$ FFM, n=8) (Moss et al., 2021). Furthermore, EEE on both the match day (881 kcal/day +/- 473) and the heavy training day (786 kcal/day +/- 159) was significantly higher than EEE on the light training days (299 kcal/day +/- 78) and rest day (15 kcal/day +/- 54). However, average EI did not differ significantly across the 5 days (Moss et al., 2021). As a result, when looking at heavy training days and game days in isolation, the proportion of players with LEA (EA<30 $kcal.kg^{-1}$ FFM) was significantly higher 69% (n=9) and 54% (n=7) respectively in comparison to rest days where all players were considered to have optimal EA (Moss et al., 2021). These findings provide more evidence to support the results of previous studies that suggest female athletes fail to account for changes in EEE through their EI and may experience appetite suppression on days with higher exercise intensities or training loads (competition and pre-season) (Howe et al., 2016; Nattiv et al., 2007). As a result, this may be contributing to the higher rates of LEA seen in both these studies over the 3 and 5-day periods (Dobrowolski & Wlodarek 2020; Moss et al., 2021).

The previous studies (Dobrowolski & Wlodarek 2020; Moss et al., 2021) utilise 24-hour EA measurements to determine the prevalence of LEA among participants. Whilst over a 24-hour period the daily EA total is important, the within day energy balance, which addresses the frequency of periods of energy deficit as a result of fluctuating EA over a 24-hour period (Bernadot, 2013), has also been shown to impact the prevalence of LEA and associated physiological health consequences (Mountjoy et al., 2014). This has been demonstrated by Fahrenholtz et al., (2018) who examined within day energy balance among a group of elite female endurance athletes for a 24-hour period. The participants were separated into eumenorrheic (n=10) and menstrual dysfunction (n=15) groups. Results from this study in female endurance athletes suggested that all athletes spent a large proportion of the day in an energy deficit (EI did not account for normal physiological functioning and EEE) regardless of menstrual status, however, athletes with menstrual dysfunction spent 24% more time in an intense state of LEA compared to eumenorrheic athletes. This could suggest that more intense and frequent states of energy deficit may be contributing to their potential menstrual dysfunction. Whilst no other study has assessed within day EA among female athletes, similar results have been observed within male endurance athlete populations (Torstveit et al., 2018). Consistent with the result presented in female athletes (Fahrenholtz et al., 2018), male athletes with the lower RMR spent significantly more time (~21 hours) in an intense state of LEA compared to male athletes with a normal RMR (~ 11 hours).

The results from these studies suggest that the variable states of EA observed in professional female footballers (Dobrowolski & Wlodarek, 2020; Moss et al., 2021) could play a role in the prevalence and relative risk of LEA. However, it is important to consider that these investigations have been completed in small sample sizes, for relatively short periods of time (3-5 days), and therefore may not provide a sufficient insight on the long-term EA variations that may occur throughout a season. As a result, further studies may need to look at EA and within day energy balance in a larger group of professional female footballers at different points throughout the season (pre, mid, post) for more reliable and valid results.

2.3 International

Elite international footballers are required to deal with the demand of their professional training environment and coordinate integration into their national team at varying points throughout the year (Folgado et al, 2015). International tournaments often involve 3-7 games separated by 48-72 hours, therefore, achieving adequate EA to support increasing EEE is essential to ensure improved recovery between games and ultimately elicit greater performance outcomes across all matches (Folgado et al, 2015). Whilst no studies have currently looked at the prevalence of LEA within international tournaments, a study by Martin et al., (2006) was the first to examine EI and EEE among a cohort of international players. For 7 days, 16 participants from the England national team self-reported dietary intake and physical activity which was subsequently analysed for appropriate calculation of EI (Dietmaster 4.0) and EEE (Diet Organiser 2.0) (Martin et al., 2006). The average EI (1904 +/- 366 kcal/day) was ~250 kcal/day less than EEE (2154 +/- 596 kcal/day) but was not considered statistically significant. The average EI of these players appeared to align with previous values reported amongst female professional (Dobrowolski & Wlodarek 2020; Moss et al., 2021), college (Clark et al., 2003; Magee et al., 2020) and youth (Gibson et al., 2011) footballers. However, the average EI relative to body mass (30.9 +/- 5.5 kcal/day) that was reported was well below the recommendation of 47-60 kcal/day for female soccer players (Economos et al., 1993). A later study out of the Australian Institute of Sport by Mara et al., (2015) aimed to define the energetic cost of elite female football players through assessment of EEE during a 7-day pre-season training phase (4 trainings, 1 game, 2 recovery days). Participants included eight Australian national team players who were required to wear the Sense Wear Mini Armband at all times for accurate calculation of EEE. Total average EEE ranged from 2274 kcal on recovery days to 2925 kcal on training and game days, which was significantly higher than the EI reported by Martin et al., (2006) suggesting that international female footballers may not be achieving adequate EI to match their EEE. Consistent with other studies (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021), daily EEE varied considerably throughout the week, further indicating that EI of female footballers should be periodised according to daily EEE to successfully meet EA requirements (Mara et al., 2015). Although specific values of EA were not presented by

Martin et al., (2006), their findings suggest that international players may not be meeting EI requirements due to high EEE and failure to adjust EI throughout the training week, and as such could unintentionally be at risk of LEA. Research examining EA among international players remains very limited and therefore, future studies should look at further quantifying the prevalence of LEA, particularly throughout demanding international tournaments such as the FIFA World Cups.

2.4 College

Similar to international match-play, the United States of America (US) college sports system hosts a physically demanding 4-month season during which players participate in 3-4 trainings as well as two 90-minute games per week (Gentles et al., 2018). The examination of EI and performance in college athletes was first undertaken by Clark et al., (2003) in their study of 14 Division 1 women's football players from a single south-western university. Participants underwent anthropometric measurements (height, mass, body composition), performance testing (VO_{2peak}, vertical jump, 20-yard shuttle test) and were asked to record a 3-day food diary (2 weekdays and 1 weekend day) during both pre-season training and post-season (Clark et al., 2003). Pre-season EI (2290 +/- 310 kcal/day) was significantly greater than post-season EI (1865 +/- 530 kcal/day) which is consistent with a later study by Reed et al., (2013). However, since EEE was not specifically measured, EA values were not provided, and the prevalence of LEA could not be discerned. The EA and the prevalence of LEA was further investigated by Magee et al., (2020) among 18 Division 3 female US college football players. All participants completed a 4-day monitoring period at the mid-point of the college season which included measuring anthropometric values (body mass, height, body composition) and dietary intake (myfitnesspal) for calculation of EI and football-specific EEE (Polar Team Pro). Additionally, participants completed the LEAF-Q and Abridged Sports Nutrition Knowledge Questionnaire (ASNK-Q) to assess the risk of LEA and current awareness of nutritional practises (Magee et al., 2020). Results from the 4-day monitoring period, whereby EA was calculated as EI minus EEE relative to FFM suggested that 66.7% (n=12) of athletes presented with LEA (<30 $kcal.kg^{-1}$ FFM). These results are consistent with those reported in the study by Dobrowolski & Wlodarek, (2020) (64.1%) but are significantly higher than Moss et al., (2021) (23%), both of which were undertaken in professional footballers. Athletes who were in a state of LEA also scored lower on the ASNK-Q (41%) compared to those with optimal EA (52%). This would suggest that reduced overall EI of female athletes may be due to limited nutritional knowledge and a lack of understanding on how to increase EI to meet the energy demands of high-performance football training and competition. For example, how much food to consume immediately after a game/hard training session even when appetite may potentially be supressed (Howe et al., 2016; Magee et al., 2020). Interestingly, results from the LEAF-Q only identified 56.3% of athletes as being at risk of LEA. The LEAF-Q is an indirect method for determining LEA risk and involves participants self-reporting physiological symptoms associated with LEA. The LEAF-Q is a useful screening tool that has an acceptable degree of sensitivity (78%) and specificity (90%) (Melin et al., 2014), and has been shown to be particularly reliable and valid in females of reproductive age (Howe et al., 2018). However, this questionnaire does not involve any direct measurement of EA (e.g., measurement of EI, EEE or FFM). It is worth noting that food and exercise records are time consuming (high participant burden), are subject to over or under reporting errors (Burke et al., 2018), and as a result may only be used for acute time periods in research (e.g., 4-day monitoring period). Conversely the LEAF-Q results, may be considered a reflective measure of long-term energy status and subsequent prevalence of LEA symptoms in female athletes. Future studies should look to examine the relationship between direct and indirect measures of EA for a more comprehensive understanding of how to identify the prevalence of LEA most effectively among female football athletes.

2.5 Youth

As shown in previous studies, the majority of international, professional and collegiate female footballers fail to consume an EI that meets both training/competition demands and normal physiological functioning (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021). For youth athletes, failure to achieve adequate EA may present different challenges, as these younger athletes require additional energy to facilitate growth, pubertal development, support other physical activities (e.g., school PE classes, playing more than one sport) and psychological/mental functioning for school (Petrie et al., 2004). All of which may suggest a higher or equivalent EI is needed to ensure adequate EA in these youth athletes, when compared to elite and international female athletes (Heather et al., 2021). A study by Braun et al., (2018) analysed EA and nutritional trends in a group of 56 national (elite) female youth footballers in Germany. Participants in the study were asked to track their food intake and physical activity over a 7-day monitoring period. In addition, anthropometric data was collected (body mass, height and body composition) and was used to calculate EA (Braun et al., 2018). The average EA across the cohort was 30 $kcal.kg^{-1}$ FFM and 53% of participants (n=18) were considered to be in a state of LEA as they did not meet the EA threshold of 30 kcal/kg/FFM (Braun et al., 2018). These results are similar to that seen in a previous study by Gibson et al., (2011), that evaluated the nutritional status of 33 junior elite female footballers in Canada. Athletes in this study underwent fasted blood sampling and body composition testing (skinfold thickness, mass, height), followed by the completion of a 4-day food and activity diary (1 rest day, 2 training days, 1 game day) to assess both EI and EEE. Results showed that participants had an average energy deficit of 466 +/- 549 kcal/day with daily EI (2079 +/- 460 kcal/day) being reported as significantly lower than daily EEE (2546 +/- 190 kcal/day). Although no direct assessment of EEE was measured in either of these studies (Braun et al., 2018; Gibson et al., 2011), the findings remain consistent with studies undertaken on mature players (>18 years of age) (Dobrowolski & Wlodarek, 2020; Reed et al., 2013, Magee et al., 2020; Moss et al., 2021). Cumulatively, these results suggest that highly competitive youth football players may frequently have suboptimal EI to meet the needs of their EEE, growth and development. Long term, this could affect overall physical performance, injury risk, illness frequency and recovery throughout competition and playing seasons. Unfortunately, disruption in these development years through injury or declines in performance may result in a large dropout rate from the sport in this female cohort. Therefore, understanding how these players fuel themselves and encouraging them to meet EA levels could be beneficial to maintaining engagement in the sport beyond school.

3.0 Nutritional Elements

3.1 Carbohydrate Intake

When examining the prevalence and risk of LEA among female footballers, a discussion on specific aspects of dietary intake and dietary trends that will influence overall macronutrient composition is required (Mountjoy et al., 2014). It has been well documented that increased carbohydrate intake is essential to replenish glycogen stores and maximise the performance of training and competition (Rodriguez et al., 2009). Yet, across a variety of sports, female athletes have been shown to consume insufficient amounts of carbohydrates for adequate glycogen resynthesis and therefore, the physical demands of their sport (Mullinix et al., 2003;

Nepocatych et al., 2017). In a study by Reed et al., (2014) examining the nutritional practices associated with LEA in Division 1 female footballers, 47% (n=9) of athletes in pre-season and 73% (n=14) of athletes during mid-season did not meet the American College of Sports Medicine recommendations for carbohydrate intake of 7-10 g/kg/day (Thomas et al., 2017). This trend for lower carbohydrate intake was more pronounced in athletes who were considered to be at risk of LEA as compared to those with optimal EA (pre-season = 100% vs 29%, post-season = 100% vs 60%). These results are consistent with other studies in US female collegiate footballers including Magee et al., (2020) and Clarke et al., (2003) who reported female footballers ingested only ~3.7g/kg/day and ~5.2 g/kg/day of carbohydrates. This suggests that overall carbohydrate intake and primarily carbohydrate restriction may play a role in reduced EA in female athletes. Carbohydrate restriction has been reported amongst players of a variety of different levels including professional (Dobrowolski & Wlodarek, 2020; Moss et al., 2021), international (Martin et al., 2006) and youth footballers (Braun et al., 2018; Gibson et al., 2011) who were considered to also be at risk of LEA. Therefore, it would appear that the development of targeted nutritional practices aimed at increasing consumption of carbohydrate-rich foods may aid in the prevention of a state of LEA and thereby reduce the risk of developing symptoms associated with RED-S. Since the sample size for these studies was fairly small (n=13-56), future studies should specifically assess the nutritional knowledge, behaviours and dietary patterns in a larger sample of female footballers both at risk of LEA and with adequate EA to help develop nutritional interventions and resources for these athletes as well as other intermittent team sports.

3.2 Changes Across the Season

Several studies suggest that female footballers keep a fairly consistent dietary intake despite changing energy demands of training and competition throughout each week, season and year (Costill et al., 1988; Nattiv et al., 2007). The first study to examine changes in EA across the football season was undertaken in Division 1 female athletes by Reed et al., (2013). The researchers assessed EI and EEE in 19 participants across a 3-day monitoring period during the pre (3 training days), mid (2 training and 1 game day), and post-season (3 non-training days). Prevalence of LEA ranged from 26% (n=5) in pre-season, 33% (n=5 (15)) in mid-season and 12% (n=2) in the post-season, with both average EEE and EI decreasing from pre to mid to post season. The greatest proportion of participants in a state of optimal EA occurred post-season, which is likely attributable to a decrease in EEE for these players

(Reed et al., 2013). The biggest contributor to LEA was low EI which is consistent with other studies (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021) and is likely due to inadequate dietary compensation for the increased EEE during pre and mid-season or appetite suppression with more frequent and intense training (Howe et al., 2016). Whilst a significant proportion of participants did enter a state of LEA at some point during the season, changes in EA appeared to be seasonal and reversible, with 88% of participants achieving optimal EA post season when competition volume and intensity of exercise was significantly reduced (Reed et al., 2013). However, this remains the only study to examine EA at different time points across the season and in order to get a more accurate representation of these changes throughout the playing seasons, future studies should look to examine the prevalence of LEA as well as nutrition and exercise behaviours, for international/professional, college and youth (recreational and national level) footballers throughout their playing seasons.

3.3 Nutritional Knowledge

Nutrition plays an essential role in producing optimal physical performance (Thomas et al., 2017) however, athletes often struggle to meet the nutritional guidelines that are specified for their intense training and competition schedule (Hoogenboom et al., 2009; Valliant et al., 2012) due to multiple factors. One proposed contributor to this inadequate dietary intake is a lack of sports nutrition knowledge, especially the misunderstanding of having a high EI to meet the energy demands of their chosen sport/activity (Jagim et al., 2019; Valliant et al., 2012). A recent study from Magee et al., (2020) had athletes complete the ASNKQ to examine the relationship between nutrition knowledge, EA and EI in Division 3 female college footballers. Their results showed that only 44.7% of questions about nutritional intake were answered correctly and athletes presenting with LEA scored lower (40.9 +/- 10.4%) than those in a state of optimal EA (52.4 +/- 9.8%). Research suggests that athletes across a variety of sports and competitive levels have a low level of nutritional knowledge which seems to stem from an inadequate understanding of how nutrition affects energy production (Heaney et al., 2011; Trakman et al., 2016). Whilst nutritional guidelines have been developed for athletes (Thomas et al., 2017) and more specifically female football players (Martin et al., 2006), the results from these studies indicate that more importance should be placed on including specific nutritional education seminars for athletes who may not have the direct support of a team nutritionist/dietician. Additionally, the relationship identified between low nutrition knowledge and increased prevalence of LEA in the study by Magee et al., (2020) emphasises the importance of nutrition education not only for optimal performance but also for the health and wellbeing of the athlete.

3.4 Eating Disorders

Disordered eating patterns and eating disorders (ED) are a common occurrence among elite female athletes and particularly those competing in weight categorised or leanness-demanding sports (Byrne, 2001). These ‘lean’ sports inclusive of running, cycling, ballet, gymnastics, diving and weightlifting may cause athletes of both genders to present with disordered eating habits to achieve the ‘desired’ or ‘perceived optimal’ physique (Beals, 2004). While football is not considered a high-risk sport for ED, studies have shown that between 25% and 33% of players are affected by DE behaviours at some point during their career, with female players considered to be at greater risk than males (Sundgot-Borgen & Torstveit, 2007). Individuals with DE patterns are likely to be at greater risk of entering a state of LEA and as such may experience the negative physiological outcomes associated with the LEA state (Byrne, 2001). This was demonstrated in a recent study by Kuikman et al., (2021) that investigated the relationship between exercise dependence, DE and risk of LEA. Out of the 650 female athletes who participated, 24% (n=151) were classified as having an ED or DE behaviour and 13% (n=82) with secondary exercise dependence (disordered eating + reliance on exercise) (Kuikman et al., 2021). The athletes with DE behaviours had 2.59 times greater risk of LEA, and this was further exacerbated in athletes with secondary exercise dependence who had a 5.74 times greater risk of LEA compared to the control group (Kuikman et al., 2021). Cumulatively, the results from this research (Kuikman et al., 2021; Sundgot-Borgen & Torstveit, 2007) would suggest that there may need to be more attention and research on the prevalence of ED and DE behaviours among female footballers and how this increases an athlete’s overall risk of LEA. Since research regarding DE practices are limited within team sports, future studies may look to validate current research findings, investigating different ages and training status cohorts. Additionally future research may consider factors that could be contributing to engagement in ED or DE behaviours in female footballers.

4.0 Conclusion

The physiological state of LEA is a highly topical area among female athletes. The physiological consequences of this condition are reported to be detrimental to an athlete's acute and long-term performance and health (Mountjoy et al., 2014). Whilst research has identified that there are a variety of strategies that can be employed to assess the EA status of athletes, producing accurate calculations can be a difficult task due to the risk of measurement error (Burke et al., 2018; Heikura et al., 2022) and the absence of a 'gold standard' assessment tool. This review has summarised the currently available research that has investigated the prevalence and risk of LEA for female footballers. Depending on the age and player ability classification (professional, international, college and youth athletes), the risk of being in a state of LEA ranges from 12% to 66.7%. The frequency and severity of LEA appears to be variable and is influenced by the time of the season and level of performance. Regardless, it remains evident that a significant proportion of female footballers do not meet the threshold of adequate EI to support the high energy demands of football training, games, and normal physiological functioning. Previous investigations that have attempted to discern the cause of LEA in female footballers suggest that inadequate carbohydrate consumption, disordered eating, lack of nutritional knowledge, and failure to upregulate EI on high training load and game days, all play a role in an athlete's total energy consumption and EA. Whilst there has been significant progress in understanding LEA among female footballers over the last decade, there are numerous gaps in the literature where more research is needed to further validate and improve the current knowledge. These include prevalence rates at each level of competition (professional, international, college, and youth athletes), within-day energy balance, carbohydrate intake, playing season and nutritional knowledge. Addressing these gaps in future research will aid in supporting the health and performance of female footballers throughout their athletic careers.

Chapter 3: Manuscript

3.0 Abstract

Background: The rates of low energy availability (LEA) seen among female footballers in collegiate, professional and youth environments range from 12% to 66%. Studies in female footballers are limited, and no research has yet looked at the prevalence of LEA in a cohort of international players. Due to the negative consequences associated with a state of LEA research is needed for a more thorough investigation into possible prevalence rates and the associated risk factors of LEA within the international New Zealand female football environment.

Objectives: Identify the number of national team and U20 female football players at risk of LEA in New Zealand, the factors (age, years training in national environment, nutrition knowledge, occupation) that increase the risk of LEA and the prevalent symptoms (sleep, mood, disordered eating) of those that are at risk of LEA.

Methods: 22 members (28%) of the New Zealand U20 and Full National Women's football teams (age 20.8 ± 3.5 years) participated in this study. Participants completed an online questionnaire that was composed of five independent validated surveys to assess LEA risk (LEAF-Q), eating disorders/disorder eating risk (EDE-Q), sleep quality (ASS-Q), nutrition knowledge (ASNK-Q) and mood (POMS-Q).

Results: 59.1% (n = 13) of our participants were identified as being at risk of LEA. Players who reported menstrual disturbances (amenorrhea or oligomenorrhea) were 2.25 times more likely to be at risk of LEA than those who did not report a menstrual disturbance. Menstrual status was significantly associated with risk of LEA (R = -0.46, P = 0.030). Players at risk of LEA had significantly higher (p = 0.027) POMS-Q score's (109.4 ± 24.4) than participants not at risk of LEA (89.0 ± 11.7). POMS-Q was significantly and positively associated with LEA score (r= -0.46, p= 0.032). Player's spending >5 hours per week on non-football related training (gym, fitness, speed etc.) were 1.6 times more likely to be at risk of LEA compared to players who spent <5 hours on non-football related training. Players who were not full-time and had an additional occupation were 1.9 times more likely to be identified as being at risk of LEA compared to full-time players in the New Zealand squad. Players who had moderate and/or severe clinical sleep problems were 1.7 times more likely to be identified as

being at risk of LEA, however the player's sleep score was not predicative of LEA risk. There was no significant relationship between nutritional knowledge or disordered eating behaviours and risk of LEA. However, players who were identified as being at risk of LEA scored significantly higher on the negative mood subscales including anger ($p < 0.001$), depression ($p < 0.001$) and confusion ($p = 0.037$) compared to players who were not identified as being at risk of LEA. As a result, POMS-Q ($p = 0.032$) and menstrual status ($p = 0.030$) were the only two variables that showed significance in being able to predict risk of LEA in our participant cohort.

Conclusion: This study confirms that a significant proportion (59.1%) of players within this subset of New Zealand national and U20 female football team are at risk of LEA. The positive and predictive relationship observed between mood disturbances, menstrual status and risk of LEA may suggest that regular monitoring of mood and menstrual cycle health could potentially be used for the early identification of LEA in national level female footballers in New Zealand.

3.1 Introduction

International football is a physically demanding endeavour (Thomas et al., 2017) and players will cover ~10km and make ~1400 activity changes in match play (Datson et al., 2014). Despite spending 76% of the game at low intensity (Holmes, 2002), there are continual periods of short, sharp high intensity sprints (~200 per game) very close to maximum heart rate (Datson et al., 2014). As a result, optimal performance and functioning of physiological systems require female footballers to consume adequate energy intake (EI) for training and exercise energy expenditure (EEE) to ensure sufficient energy availability (EA) (Burke et al., 2018). An inability to do so will likely result in a state of low energy availability (LEA), the causal factor of Relative Energy Deficiency in Sport (RED-S) syndrome. Athletes with RED-S may present with an array of health and performance consequences including, but not limited to, declines in metabolic rate, menstrual/reproductive function, bone health, immune function, protein synthesis, and cardiovascular health (Mountjoy et al., 2014).

Previous research on female footballers is limited yet from the available evidence prevalence rates of LEA range from 12% (Reed et al., 2013) to 66.7% (Magee et al., 2020) among players of various levels (professional, international, college, youth). Whilst there are only two studies that have looked at international cohorts of female footballers (Mara et al., 2015; Martin et al., 2006), of which neither commented on the prevalence of LEA, the study by Martin et al., (2006) in English International female football players reported a relative EA of 30.9 +/- 5.5 kcal/kg. This is significantly below the suggested values for female footballers of 47-60kcal/kg (Economos et al., 1993). This is consistent with previous research which suggests that female athletes are at a higher risk of not meeting EI requirements that support their EEE and subsequently being in a state of LEA (Heany et al., 2010; Nattiv et al., 2007). This trend of being in a state of LEA is exemplified during periods of intense training whereby female athletes fail to match their EI with high EEE which may be seen with increasing EEE that can occur throughout training and competitive seasons (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021). Furthermore, inadequate consumption of food around training may be an unintentional by-product of athletes experiencing post-exercise appetite suppression (Howe et al., 2016), and having insufficient nutritional knowledge or support to aid them in increasing their EI during intense training periods (Costill et al., 1988).

The high rates of LEA among female footballers and negative consequences associated with this state highlight the need for further investigation into possible prevalence rates and the associated risk factors of LEA within the international female football environment. Therefore, this study aims to determine the number of the national team and U20 female football players at risk of LEA in New Zealand and their associated symptoms (e.g., poor mood, sleep). Secondly, the study aims to identify factors including age, years of training in the national environment, nutrition knowledge, risk of disordered eating behaviours, mood, and occupation, that increase the risk of LEA in the national team and U20 female football players.

3.2 Methodology

This study was a cross-sectional study conducted in the New Zealand national team and U20 female footballers. Data collection commenced in March 2022 and concluded in April 2022.

3.2.1 Participants and Recruitment

22 members of the New Zealand U20 and full national women's football teams (age 20.8 ± 3.5 years) participated in this study. To be included in the study, participants had to be a member of the New Zealand U20 or full national women's football squad within the last 12 months. The study received approval from the New Zealand Football Head of High-Performance Gareth Jennings. An initial email with study details, participation requirements and a request for voluntary participation with written informed consent was sent to all eligible players (n =78). Once players returned their signed consent form, the online Qualtrics survey link was sent via email for players to complete in their own time on a home computer/tablet/phone. For players who had not yet submitted their approval to participate in the study, second and third emails were sent out from the primary researcher as a reminder at 7 and 14 days after the initial email. All three emails were followed up with an email from the New Zealand Football Head of High Performance, Gareth Jennings, to reiterate the importance of this study for the health and wellbeing of international female footballers in New Zealand. The study received ethics approval from Massey University Human Ethics Committee: Southern A (21/54).

3.2.2 Study Design

The survey was composed of five independent validated surveys to assess LEA risk (LEAF-Q), eating disorders/disorder eating risk (EDE-Q), sleep quality (ASS-Q), nutrition knowledge (ASNK-Q), mood (POMS-Q) and one non-validated survey used to collect demographic characteristics. The surveys were amalgamated into one online survey to streamline survey completion for the participants.

3.2.4 The Low Energy Availability in Female Athletes Questionnaire (LEAF-Q)

The LEAF-Q (Melin et al., 2014) is a validated 25-item questionnaire designed to assess the relative risk of LEA in females. Questions focus on symptoms related to LEA and the subsequent negative health consequences of RED-S including injury history, gastrointestinal function, menstrual cycle patterns and contraception use. Individuals that score ≥8 are classified as being at risk of LEA, likely presenting with a noticeable amounts of negative health consequences of RED-S (Melin et al., 2014).

3.2.5 Eating Disorder Examination Questionnaire (EDE-Q)

The EDE-Q is a validated 28-item questionnaire designed to assess the risk of eating disorder symptoms (Berg et al., 2012). Questions are rated on a 6-point Likert scale and are related to symptoms in 4 subscales: restraint, eating concern, shape concern, and weight concern with a score ≥4 considered clinically significant (Mond et al., 2006). Individuals were classified as being at risk of disordered eating (DE) if they had a global score ≥ 2.5 as females.

3.2.6 Athlete Sleep Score Questionnaire (ASS-Q)

The ASS-Q is a validated 15-item questionnaire designed as a sleep screening tool to identify athletes presenting with clinical sleep disturbances or daytime dysfunction (Bender et al., 2018). Questions are related to sleep and circadian factors of sleep quantity, sleep quality, insomnia, and chronotype within the athletes 'recent past' (last 3 months) (Samuels et al., 2015). Individuals scoring a sleep difficulty score (SDS) ≥12 are identified as having moderate and/or severe clinical sleep problems (Samuels et al., 2015).

3.2.7 Abridged Sport Nutrition Questionnaire (ASNK-Q)

The ASNKQ is a validated 37-item questionnaire that is used to assess general (n=17) and sport (n=20) nutrition knowledge (Trakman et al., 2018). Scores from the ASNKQ are calculated following the completion of the survey. Using the ASNKQ scoring system individuals are then classified with poor (0-49%), average (50-65%), good (66-75%), and excellent (75-100%) nutritional knowledge (Trakman et al., 2018).

3.2.8 Profile of Mood States Questionnaire (POMS-Q)

The abbreviated POMS-Q is a validated 40-item questionnaire that is designed to assess mood disturbances by assessing feelings related to tension, anger, fatigue, depression, esteem-related affect, vigour and confusion (Grove & Prappavessis, 1992). The total mood disturbance is immediately calculated following the completion of the survey by subtracting the total negative subscales from the total positive subscale. A low POMS-Q score is suggestive of limited mood disturbance and therefore, a more positive mood state. Conversely, a high POMS-Q score is suggestive of greater mood disturbance and therefore, a more negative mood state

3.2.9 Statistical Analysis

IBM SPSS Statistics 25 for Mac was used for all statistical analysis (IBM Corporation, Armonk, NY, USA). All descriptive statistics have been presented in table 3.1. Data are reported as means ± standard deviation to descriptively present the questionnaire variables. Participants were classified as being at risk of LEA if they had a global score ≥8. Independent samples t-tests were used to examine whether there was a difference in scores from the eating disorders (ED) and/or DE (EDE-Q), sleep (ASS-Q), nutrition knowledge (ASNK-Q), mood (POMS-Q) questionnaires and demographic characteristics between participants at risk of LEA and those not at risk of LEA. Pearson correlation coefficients were then used to analyse the relationships between LEAF-Q scores, ASNKQ scores, ASS-Q scores, EDE-Q scores, POMS-Q scores and menstrual status. Binary logistic regression was used to determine if there was an association between LEA risk and the risk factors and symptoms as assessed by the LEAF-Q, EDE-Q, ASS-Q, ASNK-Q, POMS-Q and demographics questionnaires. In the at risk of LEA cohort, the odds ratio was determined for measured symptoms of LEA in this cohort of female footballers. Significance was determined as $p < 0.05$.

3.3 Results

3.3.1 Participant Characteristics

A total of 22 responses were received from 78 invited players (28%). Average age of participants was 20.8 ± 3.5 years with 50% (n = 11) of respondents current members of the full national team and 50% (n = 11) members of the U20 team (see table 3.1 for full details). A total of 19 players (86.4%) had been playing football for >10 years, with 17 players (77.3%) reportedly competing at a national level (full national team/U20) for >3 years and the other 5 players (22.7%) for <3 years.

Table 3. 1: Summary of Descriptive Data

Age (mean ± SD) years	20.8 ± 3.5
Number of players with >10 years of football experience (n, %)	19, 86.4%
Number of players that have played >3 years with NZ Football (n, %)	17, 77.3%
Number of players who spend >8 hours/week doing Football training (n, %)	16, 72.7%
Number of players who spend >5 hours/week doing non-Football training (n, %)	7, 31.8%
Number of full time Footballers (n, %)	8, 36.4%
LEAF-Q Score (mean ± SD)	9.7 ± 4.2
EDE-Q Score (mean ± SD)	1.4 ± 0.8
ANSK-Q Score (mean ± SD)	40.7% ± 8.5
SDS Score (mean ± SD)	6.8 ± 3.3
POMS-Q Score (mean ± SD)	101.1 ± 22.3

3.3.2 LEAF-Q

The LEAF-Q responses revealed a mean score of 9.68 ± 4.22, with 59.1% (n = 13) of players scoring ≥ 8 which is classified as the global cut off score for being at risk of LEA (Melin et al., 2014). Table 3.2 presents the difference in questionnaire results when stratified according to risk of LEA.

Table 3. 2: Questionnaire Scores Relative to Risk of LEA

	At Risk of LEA (n=13)	Not at Risk of LEA (n=9)	p-value
Age	20.3 ± 2.5	21.6 ± 4.5	0.099
EDE-Q	1.43 ± 1.0	1.26 ± 0.61	0.197
ANSK-Q	40.4 ± 9.9	41.2 ± 6.7	0.290
POMS-Q	109.4 ± 24.4 *	89.0 ± 11.7	0.027
SDS	7.8 ± 3.9 *	5.4 ± 1.4	0.018
Abnormal Menstruation	81.8%	18.2%	n/a
Values represented as mean ± standard deviation. * p < 0.05, ** p < 0.01.			

There were only 8 full-time footballers (i.e. did not work outside of football) and of those 37.5% were identified as being at risk of LEA compared to 71.4% in the group who spent up to 40 hours working another job in addition to their football training. The players who were not full-time and had an additional occupation were 1.9 times more likely to be identified as being at risk of LEA compared to full-time players in the New Zealand squad. Only 7 players reported spending >5 hours per week on non-football related training (gym, fitness, speed etc.), and of those, 71.4% were identified as being at risk of LEA compared to only 53.3% of players who spent <5 hours on non-football related training. Our results suggested that players reportedly spending >5 hours per week on non-football related training (gym, fitness, speed etc.) were 1.6 more likely to be at risk of LEA compared to players who spent <5 hours on non-football related training. There was no significant difference between age (p = 0.099), football training hours (p = 0.386), years playing for New Zealand (p = 0.1), or years playing football (p = 0.583) and players risk of LEA. Players who reported a menstrual disturbance (amenorrhea or oligomenorrhea) were 2.25 times more likely to be at risk of LEA than those who did not report a menstrual disturbance. Furthermore, the pearson correlation coefficient indicated that the menstrual status was significantly associated with LEA score (r = -0.46, p = 0.032) and therefore abnormal menstrual function (oligomenorrhea and amenorrhea) may be predictive of whether a player is at risk of LEA or not.

3.3.3 POMS-Q

The mean score from the POMS-Q was 101.1 ± 22.3 (when a constant of 100 was added to avoid negative values). There was a significant difference (p = 0.027) in POMS-Q score between participants at risk of LEA (109.4 ± 24.4) compared to participants not at risk of LEA (89.0 ± 11.7), with a higher POMS-Q score suggestive of more negative mood state.

Pearson correlation coefficient indicated that the POMS-Q score was significantly and positively associated with LEA score ($r = 0.46$, $p = 0.030$) and POMS-Q score was also significantly and positively related to EDE-Q score ($r = 0.62$, $p = 0.002$) and SDS ($r = 0.586$, $p = 0.004$).

Those players who were identified as being at risk of LEA scored significantly higher on the negative mood subscales including anger ($p < 0.001$), depression ($p < 0.001$) and confusion ($p = 0.037$) compared to players who were not identified as being at risk of LEA. Conversely, there was no significant difference in score between those identified as having and not having LEA for the remaining four subscales (fatigue, esteem related affect, tension and vigour).

Table 3. 3: POMS-Q Subscale Scores

	At Risk of LEA (n=13)	**Not at Risk of LEA (n=9)**
POMS-Q	109.4 ± 24.4 *	89.0 ± 11.7
Anger	4.0 ± 4.3 **	0.2 ± 0.4
Fatigue	7.0 ± 5.7	4.1 ± 2.9
Depression	6.6 ± 7.5 **	1.0 ± 1.1
Confusion	5.7 ± 4.3 *	3.2 ± 2.4
Esteem Related Affect	12.8 ± 4.4	15.8 ± 3.3
Tension	5.8 ± 4.2	3.2 ± 3.1
Vigour	6.8 ± 2.4	7.0 ± 2.8
Values represented as mean ± standard deviation. * p < 0.05, ** p < 0.01.		

3.3.4 ASS-Q and SDS score

There was a significant difference in mean SDS between players at risk of LEA and players not at risk of LEA ($P = 0.018$) (table 3.2). Those who had moderate and/or severe clinical sleep problems were 1.7 times more likely to be identified as being at risk of LEA. Only 3 players scored above the global score for severe clinical sleep problems (≥11). The mean SDS score of 6.8 would be classified at the upper end of mild sleep problems (Samuels et al., 2015) for the participants in our cohort. However, there was no significant relationship between SDS score and risk of LEA.

3.3.5 ASNK-Q

The mean score from the ASNKQ indicated that 40.7% ± 8.5% of the questions were answered correctly. However, 19 players (86.4%) were classified as having poor nutritional knowledge (<49% questions answered correctly), whilst the remaining 3 players were classified with average nutritional knowledge (50% - 65% questions answered correctly). There was no significant difference between athletes at risk of LEA compared to athletes not at risk of LEA with regards to their level of nutritional knowledge ($p = 0.290$). Furthermore, there was no significant relationship between ASNKQ score and risk of LEA.

3.3.6 EDE-Q

The EDE-Q responses revealed a mean score of 1.4 ± 0.8, with no player scoring equal to or greater than the specified 2.5 cut-off (Mond et al., 2004). Participants identified as being at risk of LEA had higher body dissatisfaction subscale scores compared to participants who were not at risk of LEA (table 3.4). There was a significant difference in the weight concern subscale ($p = 0.02$) and shape concern subscale ($p = 0.003$) between participants classified at risk and not at risk of LEA (Table 3.4). However, there was no significant relationship between EDE-Q score and risk of LEA.

Table 3. 4: EDE-Q Subscale Scores

	At Risk of LEA (n=13)	**Not at Risk of LEA (n=9)**
EDE-Q	1.5 ± 1.0	1.2 ± 0.6
Shape Concern	2.4 ± 1.8 **	1.6 ± 0.5
Weight Concern	1.4 ± 1.3 **	1.1 ± 0.5
Eating Concern	0.8 ± 0.7	1.4 ± 1.6 **
Restraint	1.1 ± 1.3	1.0 ± 0.9
Values represented as mean ± standard deviation. * $p < 0.05$, ** $p < 0.01$.		

3.3.7 Risk factors that predict risk of LEA

POMS-Q ($p = 0.032$) and menstrual status ($p = 0.030$) were the only two variables that showed significance in being able to predict the risk of LEA. The analysis identified that 81.8% of LEA risk could be predicted by POMS-Q score and menstrual status, with this model being significant ($p < 0.05$). The model identified that female footballers with a higher

POMS-Q score, which is indicative of more negative mood states and those who had an abnormal menstrual cycle (oligomenorrhea, amenorrhea) were associated with LEAF-Q scores ≥8 and were therefore, more likely to be at risk of LEA.

3.4 Discussion

This study was designed to identify the number of national team and U20 female football players at risk of LEA in New Zealand as well as the factors that increase the risk of LEA. A secondary aim was to identify prevalent symptoms of those female footballers who were at risk of LEA. To our knowledge this is the first study to assess the risk of LEA in a cohort of international female footballers with results suggesting that 59.1% (n=13) of participants were identified as being at risk of LEA. The prevalence rates of LEA within female footballers in the available literature is highly variable due to inconsistent methodologies used across the limited number of studies in an array of different environments ranging from youth to college through to professional. Whilst it is concerning that the majority of players in this study were identified as being at risk of LEA, similar results have been observed in professional footballers (64.1%) (Dobrowolski & Wlodarek, 2020), division 3 collegiate footballers (66.7%) (Magee et al., 2020) and youth footballers (53%) (Braun et al., 2018). However it also remains significantly higher than rates seen in division 1 collegiate footballers (12-33%) (Reed et al., 2013) and professional footballers (23%) (Moss et al., 2021).

Previous research has reported that the risk of LEA is increased in weight dependent, aesthetic and endurance sports (Jagim et al., 2022; Logue et al., 2020; Melin et al., 2019). In comparison to these sports, female footballers may experience a lower training load and lack of emphasis on leanness due to their requirement for a combination of endurance, strength, power and speed. Therefore, it is interesting that the prevalence rates observed in both endurance sports and weight dependent sports (Logue et al., 2020) are consistent with those reported in this study. This was somewhat unexpected, but could be explained by the work of Loucks et al., (1998) which observed that it is not the stress of exercise but rather the presence of LEA arising from both nutritional and exercise stress that induces disruption to LH pulsatility and, the associated myriad of health and performance consequences associated with being in a state of LEA.

It is important to note that all previous studies assessing LEA in female footballers have employed quantifiable methods to measure EI and EEE (self-reported diaries, GPS, body composition etc.) in addition to the use of questionnaires (LEAF-Q) for their determination of EA/LEA. The majority of these studies examining LEA in footballers use 3-5 day monitoring periods that reflect only a small period of an athlete's season. Results from a study by Magee et al., (2020) in division 3 collegiate female footballers found that 66.7% of female players were in a LEA state when EA levels were quantifiably measured (e.g. assessed EI and EEE). This was markedly higher than the 56.3% of athletes at risk of LEA as identified by their LEAF-Q scores (Magee et al., 2020). The LEAF-Q is an indirect method of assessment that involves the use of self-reported physiological symptoms associated with LEA to determine a female's risk of being in a LEA state. Therefore the LEAF-Q, which has been shown to be particularly reliable and valid in females of reproductive age (Howe et al., 2018), could be used as a more reflective measure of long-term energy status throughout various playing seasons. Although the LEAF-Q has previously been shown to have an acceptable degree of sensitivity (78%) and specificity (90%) in female athletes (Melin et al., 2014) it may still have limited utility as a screening instrument for female footballers when used as a standalone tool. Future studies should look to examine the relationship between direct and indirect measures of EA for a more comprehensive understanding of how to identify the prevalence of LEA most effectively among female football athletes.

Abnormal menstrual function is one of the first and most prominently researched indicators of LEA (Mountjoy et al., 2014). Players who reported a menstrual disturbance (amenorrhea or oligomenorrhea) in this study were 2.25 times more likely to be at risk of LEA than those who reported normal menstrual function and this was predictive of being at risk of LEA ($p = 0.032$). There were three players with abnormal menstrual function who were not identified as being at risk of LEA. Their menstrual function results may be accounted for by numerous explanations including but not limited to, an acute period of LEA, non-football related stressors or other medical conditions that cause menstrual irregularity such as polycystic ovarian syndrome. However, some players who demonstrated abnormal menstrual function characteristics (oligomenorrhea and luteal phase defect) still self-reported and perceived they presented with normal menstruation, as defined by the literature. This indicates that players may be uneducated around the topic of menstruation and how it affects health and performance which not only emphasises the importance of player education but should also be considered a limitation for overall study validity. The lack of consensus as to what constitutes a 'normal' menstrual cycle could also explain the lower rates of LEA seen in previous studies on female athletes and more specifically female footballers. If athletes are not reporting symptoms of LEA correctly, especially those related to menstrual function, then the percentage of participants meeting the global cut off score for LEA would be reduced thereby impacting overall prevalence rates of LEA. Future studies may need to explain to athletes prior to assessment what symptoms would constitute an abnormal menstrual cycle and/or provide better written explanations as part of the LEAF-Q survey.

Nutritional recommendations have been established for female footballers (Martin et al., 2006) and all players in this study have access to a registered nutritionist, yet the majority of players (86.4%) were identified as having poor nutritional knowledge. Although there was no significant difference in nutrition knowledge scores between players identified as being at risk of LEA and those not at risk of LEA, the finding of inadequate nutrition knowledge across the entire cohort is consistent with findings in the literature that suggest athletes in a variety of sports and competitive levels have a low level of nutritional knowledge that seems to stem from an inadequate understanding of how nutrition affects energy production (Heaney et al., 2011; Trakman et al., 2016). Furthermore, research consistently demonstrates that during periods of intense training, female athletes fail to match their EI with high EEE or increasing EEE that can occur throughout training and competitive seasons (Dobrowolski & Wlodarek, 2020; Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021). Since total EI and nutrient timing are important factors for recovery, growth/development and overall sport performance outcomes (Mountjoy et al., 2014), insufficient nutritional knowledge could still play a role in the high prevalence rates of LEA seen in this study. This further supports the idea that risk of LEA may be occurring as a result of unintentional low EI caused by post exercise appetite suppression (Howe et al., 2016) increased training load, or insufficient nutritional knowledge to account for high EEE (Costill et al., 1988) and may be an area of further research and education for female footballers.

Only one player (4.5%) scored ≥ 2.5 on the EDE-Q (Mond et al., 2004), the cut-off for diagnosis of DE and/or an ED. This was significantly lower than previous research which has reported that between 25% and 33% female footballers are affected by DE behaviours at some point during their career (Sundgot-Borgen & Torstveit, 2007). However, further individual subscale analysis demonstrated that participants identified as being at risk of LEA had significantly higher body dissatisfaction scores (shape and weight) than those who were not at risk of LEA. This is consistent with research from Reed et al., (2013) who reported an association between body dissatisfaction and risk of LEA in division 1 collegiate female footballers and more recently from Heather et al., (2021) who reported 73% of elite female athletes in New Zealand (n=194) perceived that there were specific physical appearance pressures associated with high performance sport. In contrast, those players who were not identified as being at risk of LEA scored significantly higher on the eating concern subscale than those at risk of LEA. This suggests that players who weren't identified as being at risk of LEA on the LEAF-Q may still be intentionally restricting EI in order to meet the physical performance requirements of football and/or societal standards of ideal' body image.

Participants identified as being at risk of LEA had significantly higher POMS-Q scores than those not at risk of LEA indicating greater mood disturbance among these individuals. Psychological problems are the only factor that can both precede or be caused by LEA (Mountjoy et al., 2014) and therefore, it remains unclear as to whether these are a symptom or a risk factor for LEA. Upon further analysis, this significant difference in scores between those at risk of LEA and those not at risk of LEA was only observed in the negative subscales (depression, anger, confusion). This is consistent with previous research that has reported adolescent females with functional hypothalamic amenorrhea show greater tendencies toward depressive traits, psychosomatic disorders, lack of concentration and an inability to handle stress (Bomba et al., 2007: Marcus et al., 2001; Nagel, 2003). Concentration and resilience to adversity are two critical determinants of athletic performance (Nideffer, 1993) therefore, attentional errors or emotional decisions could make a difference to performance outcomes especially in a skill based sport like football. It remains important to note that hormonal changes during menstruation can be associated with increased distractibility and emotionality, particularly during the premenstrual phase (Blake 1995; Sabin & Slade 1999). Whilst this study did not assess the menstrual cycle phase of participants, POMS-Q scores could be further exacerbated in females at risk of LEA in this phase of their cycle (especially if presenting with anovulatory and luteal phase defects, so still bleeding). Future studies should therefore, look at the relationships between POMS-Q score, risk of LEA and phase of the menstrual cycle to help validate findings of a positive relationship between POMS-Q score and risk of LEA.

Diagnosis of LEA/RED-S is challenging as there remains no validated screening tool for assessment, yet the research points to early detection as an essential measure to improve the health and performance outcomes of an athlete (Mountjoy et al., 2015). As mentioned previously, it is hard for national team staff to accurately monitor the health and wellbeing of their players through objective data due to the limited time spent together each year within the five FIFA windows (periods of time allocated for international match play). Many national bodies therefore, employ the use of daily and/or weekly online surveys to collect subjective data around a players sleep, nutrition, mood and overall feelings of wellbeing. The strong relationship observed between greater mood disturbance, menstrual cycle health and risk of LEA confirms that measuring data in this way is highly valuable as it could serve as an early indication of LEA in the absence of quantifiable data. This would enable staff to support athletes into an optimal state of EA before experiencing the negative health and performance outcomes associated with prolonged or severe LEA.

This study occurred during the months of March and April when New Zealand and American based players were in pre-season and at the start of the season respectively whilst European based players were in the middle of their season. Previous research looking at changes in LEA across a season in division 1 collegiate female footballers showed that the prevalence rates were highest during pre-season (26%) and mid-season (33%) compared to post-season (12%) (Reed et al., 2013). These findings were attributed to a greater EEE during pre and mid-season due to the sheer volume and intensity of both training and competition which was significantly reduced in post-season and coincided with a 35% decrease in risk of LEA (Reed et al., 2013). Although data remains limited on whether time of season impacts risk of LEA, since all players in this study were either in pre- or mid-season, this could be a contributing factor as to why such a large proportion were identified as being at risk of LEA.

3.5 Conclusion

In conclusion, 59.1% of players within this subset of New Zealand national and U20 team players were identified as being at risk of LEA. The positive relationship observed between mood disturbances, menstrual status and risk of LEA suggests that both mood and menstrual status are highly predictive risk factors of LEA states. Furthermore, the risk of LEA was 2.25 times greater in those with abnormal menstrual function than those with normal menstrual function.

There was no significant relationship between nutritional knowledge or DE and risk of LEA. However, low nutrition scores across the entire cohort indicate the need for further education around nutrition and its implication on health and performance. In addition, participants identified as being at risk of LEA had significantly higher body dissatisfaction scores (shape and weight) than those who were not at risk of LEA, suggesting that these players may be intentionally restricting EI in order to meet the physical performance requirements of football and/or societal standards of ‘ideal’ body image.

Finally, the average SDS in the study score is classified at the upper end of mild sleep problems. Whilst those who had moderate and/or severe clinical sleep problems were 1.7 times more likely to be identified as being at risk of LEA, sleep score was not predicative of LEA. Therefore, it remains difficult to conclude whether disrupted sleep is a risk factor and/or a symptom of LEA. Further research is required to understand the implications of moderate and/or severe sleep problems on the health and performance of female footballers.

Chapter 4: Conclusion

4.1 Achievement of Aims and Hypotheses

The overall aim of the research was to identify the proportion of national team and U20 female football players at risk of low energy availability (LEA) in New Zealand, the factors (age, years training in national environment, nutrition knowledge, occupation) that increase the risk of LEA and the prevalent symptoms (sleep, mood, disordered eating) of those that are at risk of LEA.

The high percentage of players identified as being at risk of LEA (59.1%) suggests that LEA is a significant issue among international female footballers in New Zealand. Increased mood disturbance was significantly associated with risk of LEA which aligns with previous research that has indicated adolescent females with functional hypothalamic amenorrhea show greater tendencies toward depressive traits, psychosomatic disorders, lack of concentration and an inability to handle stress (Bomba et al., 2007: Marcus et al., 2001; Nagel, 2003). Since the IOC states that, “psychological stress and/or depression can result in LEA and can also be a result of LEA” (Mountjoy et al., 2018) it was important to understand whether greater mood disruption was a symptom of or a risk factor for LEA. There was a significant positive relationship between mood disturbances and risk of LEA which suggests that negative mood state is a highly predictive risk factor of LEA. There was also a significant relationship between menstrual status and risk of LEA suggesting that abnormal menstrual function is also a highly predictive risk factor of LEA. Our model would suggest that LEA risk could be predicted ~82% of the time when female footballers mood states, POMS-Q score and menstrual status are monitored. Whilst it remains unclear as to which individuals may be experiencing mood disturbance preceding or as a result of LEA, it is evident that recognition of mood disturbance and abnormal menstrual function in players could lead to early recognition of players being in a state of LEA and enable health and support staff to intervene. This could reduce the severity, frequency and duration of LEA and its associated health and performance consequences in current female footballers within New Zealand.

The percentage of participants identified as being at risk of LEA had significantly higher body dissatisfaction scores (shape and weight) than those who were not at risk of LEA. This is consistent with previous research in division 1 collegiate female footballers which found a strong association between body dissatisfaction and risk of LEA (Reed et al., 2013). These results are consistent with previous research in New Zealand athletes who reported that they believed there are physical appearance pressures associated with high performance sport (Heather et al., 2021). These pressures included the burden of remaining feminine in the pursuit of athletic ability that requires strength, power and speed, all of which result in a more athletic or muscular body shape. In addition, it is worth noting that these perceived pressures on body shape and image are likely exacerbated by the increased usage of social media, general media presentations of female bodies and the general public perceptions, all of which have been recognised as a major sources of impact on young female body image perception (Heather et al., 2021; Tiggerman & Slater, 2013).

It was hypothesised that increased training hours would be observed in players at risk of LEA. This was true for non-football training hours whereby players reportedly spending >5 hours per week on non-football related training (gym, fitness, speed etc.) were 1.6 times more likely to be at risk of LEA compared to players who spent <5 hours on non-football related training. Interestingly these findings did not translate to football training hours as no significant difference in football training hours was observed between those at risk and not at risk of LEA. The association between non-football training hours and risk of LEA could be due to the intense nature of this type of structured training (e.g. gym/strength work, cross training intervals) that focuses on working close to maximal effort (Taylor et al., 2015) in comparison to football specific training during which the majority of the distance covered on the field occurs via walking and low intensity running (Datson et al., 2019). Whilst non-football related training is essential to support the health and performance of players (Alahmad et al., 2020; Peterson et al., 2021), focusing on quality over quantity in these sessions through a reduction in volume could lessen the physiological stress on the body and potential appetite suppression after training that may be contributing to increased risk of LEA.

Previous research has posited low nutritional knowledge as a risk factor for LEA (Magee et al., 2020). The majority of players (86.4%) in this study were identified as having poor nutritional knowledge however, there was no significant difference in nutrition knowledge scores between players identified as being at risk of LEA and those not at risk of LEA. Unlike their male counterparts, it would appear that female athletes fail to match their EI with the high or increasing EEE associated with elite sport (Dobrowolski & Wlodarek, 2020;

Gibson et al., 2011, Magee et al., 2020; Moss et al., 2021). Previous research has associated this energy mismatch with post exercise appetite suppression (Enette Laron-Meyer et al., 2012; Howe et al., 2016), carbohydrate restriction (Mullinix et al., 2003; Nepocatych et al., 2017) and lack of nutritional knowledge (Costill et al., 1988; Magee et al., 2020). In contrast, reduced EI can be an intentional decision by the athlete to either enhance sport performance, meet aesthetic demands of the sport or perceived societal pressure (Mountjoy et al., 2018). It is more likely that most of the players in this study who have been identified as being at risk of LEA are doing so unintentionally as there are no specific weight or aesthetic demands associated with football and both average nutritional knowledge score and risk of DE/ED's were low. Therefore, interventions that help improve EA, such as nutritional education and foods to eat post training, may be beneficial to these athletes especially in the absence of psychological influences (e.g. ED/DE) (Mountjoy et al., 2018; Mountjoy et al., 2021).

We hypothesised abnormal menstrual function would be a risk factor for identification of risk of LEA. Players who reported menstrual disturbance (amenorrhea or oligomenorrhea) in this study were more than twice as likely to be at risk of LEA than those who reported normal menstrual function and subsequently menstrual cycle status was predictive of risk of LEA. However, of those players identified as being at risk of LEA, only 69% were experiencing abnormal menstrual function, which is consistent with research that shows abnormal menstrual function is only one of the symptoms of LEA (Mountjoy et al., 2014). Four players were identified as being at risk of LEA but did not experience abnormal menstrual function. These players all reported significant disturbances to gastrointestinal function and increased time out of football with injury whilst one player also reported taking the OCP. There were three players that reported having normal menstrual function and due to the LEAF-Q scoring were then considered to not be at risk of LEA. However, both players then self-reported that their last menstruation had only occurred in the last 2-3 months, and reported changes to their menstruation with intensity and/or volume of training. These two athletes would be considered to be at risk of LEA by the researchers, but their interpretation of a 'normal' cycle would have influenced their self-reporting of symptoms in the LEAF-Q. There is a definitive association between EA, reproductive hormones and menstrual function in female athletes (Gordon et al., 2017; Loucks & Thuma, 2003; Nattiv et al., 2007). Recent studies have demonstrated that the frequency of menstrual disturbances (including luteal phase defects, anovulation, and oligomenorrhea) is affected by the magnitude of LEA relative to an athletes individual requirements (Williams et al., 2015). However, EA <30 kcal/kg FFM/day over just

5 days has been shown to alter LH pulsatility (Loucks and Thuma, 2003), an indication of endocrine disruption, hence menstrual irregularities can be identified as an early indicator of LEA. Therefore, the inability of players in this study to recognise what constitutes a ‘normal’ menstrual cycle suggests a requirement for education around the process of menstruation as well as its impact on health and wellbeing. This is to ensure accurate reporting of menstrual cycle health for the early identification of LEA risk in female footballers.

Sleep is one of, if not the most essential components of recovery for an athlete (Cirelli & Tononi, 2008; Datillo et al., 2011). During this time, the body is able to repair both physically and cognitively due to the hormonal fluctuations that occur during deep (N-REM) and dream (REM) sleep (Dijk, 2010; Shapiro et al., 1981; Walker, 2008). Inadequate sleep therefore, acts as a significant stress on physiological functioning (Belenky et al., 2003; Krueger et al., 2011; Spiegel et al., 1999). Not only was the average SDS score in this study classified at the upper end of mild sleep problems (Samuels et al., 2015) but players who reported moderate and/or severe clinical sleep problems were 1.7 times more likely to be identified as being at risk of LEA. Nevertheless, since SDS score was not predictive of LEA, it remains difficult to conclude whether disrupted sleep is a risk factor and/or symptom of LEA. No study has yet looked at the relationship between sleep and risk of LEA. However, the international competition schedule observed by the players in this study, which involves entering numerous different time zones across the year, requires more research to be done in order to understand the implications of moderate and/or severe sleep problems on the health and performance of international female footballers.

4.2 Strengths

To the best of our knowledge this is the first study to assess the risk of LEA and associated risk factors in a cohort of international female footballers. It was unique in that it looked at prevalence of symptoms of LEA (mood, disordered eating, nutrition knowledge, sleep) and aimed to understand whether they were predictive of a player being at risk of LEA.

One of the study’s strengths is that there was a good representation of national team players (n = 11) and U20 players (n = 11) which increased the validity of the results being applicable to international female footballers. Furthermore, of the players who participated in the study, most of them (77.3%) had been playing in the New Zealand environment for >3 years. As a result, all players would have had consistent access to specific resources that are unique to high performance sport including a physio, doctor, nutritionist, sports scientist as well as education around best practises regarding health and wellbeing for performance.

Due to the various forms of contraception available for females, studies looking at LEA tend to have a significant proportion of players using contraception. This can make it difficult to accurately identify the prevalence of LEA. A strength in this study was that only three players were using a form of contraceptive and as a result, 86.4% of players responded to the LEAF-Q in relation to their natural menstrual cycle. Subsequently, this indirectly resulted in the recognition of low knowledge regarding the menstrual cycle and its function on health, wellbeing and performance thereby, identifying another area of education for athletes and staff to undertake.

A final strength of this study was the utilisation of online surveys. This method of assessment not only ensured accessibility to all players within the New Zealand national and U20 team independent of their current location, but it allowed those participating to do so in confidence that it would remain anonymous. Furthermore, the LEAF-Q, which has been shown to be particularly reliable and valid in females of reproductive age (Howe et al., 2016), may be a more reflective measure of long-term energy status throughout various playing seasons thereby increasing the validity of participant responses and ultimately the overall results of the study.

4.3 Limitations

Since the quality of the football leagues in New Zealand are not at an appropriate standard for national team players, a large proportion of New Zealand players play for teams in Europe, America and Australia. As a result, there is no time period during which the national and U20 team are all located in New Zealand, so to assess risk of LEA and the associated risk factors we had to employ the use of an online survey. The first significant limitation that resulted from the online survey was that we received a small sample size of only 22 respondents (28%). This impacted the validity of applying the findings to the entire cohort of players within the New Zealand national and U20 team but also to other international players across the globe. A second limitation from this online survey format was self-selection bias. All players were given the opportunity to participate in the study, hence it is possible that those who chose to take part were more interested in the subject of LEA due to past or present experiences which could have increased the percentage of participants identified as being at risk of LEA. A third limitation from the use of voluntary online surveys is that self-reported questionnaires may be subject to recall bias or reporting symptoms based on what participants think is correct compared to the symptoms they actually present with. Although we requested honest answers and emphasised that all responses would remain anonymous, this does create potential for some errors in data collection. Based on this bias we must admit that the results may be interpreted with caution.

Another limitation of the online format was that there was no direct assessment of EA through examination of EI and EEE. The LEAF-Q was the sole survey used to identify whether a participant was at risk of LEA or not. Whilst the LEAF-Q has previously been shown to have an acceptable degree of sensitivity (78%) and specificity (90%) in female endurance athletes (Melin et al., 2014), it has been designed to assess female athletes as a whole and may have limited utility as a screening instrument for female footballers when used in the absence of more quantitative methods of assessment (food diaries, GPS tracking etc.). Furthermore, it was evident within the analysis of survey responses that there was a lack of understanding from participants as to what qualified as ‘normal’ menstrual function. Whilst we were able to distinguish the percentage of players who were actually experiencing menstrual disturbances through the culmination of responses to several LEAF-Q survey questions, this could have limited the accuracy of these statistics and the percentage of players at risk of LEA may actually be higher.

A final limitation is that the age of participants was ~20.8 years hence gynaecological maturity could be considered quite immature. Research suggests that the longer a women has a menstrual cycle, the greater her resilience is to stressors that may impact her cycle (exercise, nutrition, psychological etc.) (Ackerman & Misra, 2018; van Hooff et al., 2018). With the average age in this study being so low, it is possible that we are seeing greater menstrual disturbances due to increased sensitivity to stress and therefore, this finding may not be replicated in national teams where the average age of players is closer to 25 or 30.

4.4 Recommendations and Future Directions for Research

Given that risk of LEA was high among a cohort of international female footballers, it is evident that prevalence of LEA is a significant issue within both football and at an elite level. Future research should focus on validating these findings within other international environments, as well as employing more quantitative methods of analysis to gain a better understanding of the true prevalence rates and associated risk factors.

- Since this study was conducted at a single point in time, further research looking at changes in LEA across the season in international environments would enable a better understanding of the fluctuations in EA with changes in intensity and volume of training and/or competition.
- New Zealand Football should incorporate mood surveys as part of their regular wellness questionnaires due to the significant relationship observed between mood disturbances and risk of LEA. By collecting this data on a weekly basis, staff can monitor changes in mood over time and identify who may be at risk of developing LEA earlier.
- The low nutrition score across the entire cohort in this study confirms the need for New Zealand Football to provide educational sessions around both general and high performance nutrition. These sessions should focus on macronutrients, micronutrients, fuel utilisation and fuelling for performance.
- The inability of players to recognise what constitutes a ‘normal’ menstrual cycle suggests a requirement for education around the process of menstruation as well as its impact on health, wellbeing and performance.
- Since players with abnormal menstruation were 2.25 times more likely to be at risk of LEA and abnormal menstrual function was predictive of risk of LEA, monitoring player menstrual cycles via an app such as Wild AI™ or Fitr Women™ would enable early recognition of changes to cycle length and frequency. Use of apps and regular monitoring may also be used as an education tool for individual players.
- With those showing moderate and/or severe sleep disturbances being 1.7 times more likely to be at risk of LEA, New Zealand Football should look at providing education around the impact of sleep of health and performance as well as analysing player sleep more closely to see where individual changes can be made.

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Appendices

Appendix A: Participant Information Sheet

Risk of Low Energy Availability (LEA) in New Zealand Full National Team and U20 Female Football Representatives

PARTICIPANT INFORMATION SHEET

Invitation to Participate in Research Study

This study will aim to identify the number of national team and U20 female football players at risk of low energy availability in New Zealand. The research will identify specific factors (e.g. age, years training in national environment, nutrition knowledge, occupation) that increase the risk of low energy availability in national team and U20 female football players and the specific symptoms (sleep, mood, disordered eating) experienced by players who are at risk of low energy availability. The results from this study will provide new information to inform the appropriate integration of a low energy availability segment into the current monitoring system for daily tracking of player menstrual cycle and associated symptoms (mood, digestion, sleep, weight etc.) that the New Zealand Football coaching team has full access too.

Participant Recruitment

All female footballers playing at full national or U20 national team level are invited to participate in this study. Participation in this research is voluntary and will have no impact on team selection within New Zealand Football. If you have any questions about your participation in this study, you are welcome to discuss these further with our team.

The surveys that will be completed as part of the questionnaire include the; LEAF-Q (Melin et al., 2014), ASSQ (Samuels et al., 2015), short form POMS Questionnaire (Shacham, 1983), ASNKQ (Trakman et al., 2018) and the EDEQ (Fairburn & Beglin, 1994).

From these surveys researchers will be able to identify risk of low energy availability, symptoms associated with a low energy availability states and risk factors that may lead to a state of low energy availability.

Project Procedures and Participant Involvement

If you agree to participate, you will be asked to complete a single online questionnaire from your home computer/tablet/phone. This questionnaire will take approximately 60 minutes to complete, and no further assistance will be required following this.

Following completion of the study, Presentations on female health and wellbeing will be provided at Massey or at New Zealand Football by the researchers. This will be available for yourself, other participants, coaches and any additional whānau who wish to attend. Additionally, you will be entitled access to individual results via email and can also request a hard copy print out of personal data.

Participant's Rights

You are under no obligation to accept this invitation.
Should you choose to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the study at any time, even after signing a consent form (if you choose to withdraw you cannot withdraw your data from the analysis after the data collection has been completed)
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded

Confidentiality

All data collected will be used solely for research purposes. There is a possibility that results will be presented in a professional journal. All personal information will be kept confidential, and participants will be assigned participant numbers at recruitment. No names will be visible on any papers on which you provide information and New Zealand Football will not know the identity of any participants. All data/information will be dealt with in confidentiality and will be stored in a password protected online system for 10 years within the Massey University System. After this time, it will be disposed of by an appropriate staff member from the School of Sport and Exercise.

Project Contacts

If you have any questions regarding this study, please do not hesitate to contact any of the following research team for assistance:

<u>Researchers:</u>

Isabella Coombes (School of Sport and Exercise, Massey University)
[redacted]

Supervisor: Dr. Claire Badenhorst (School of Sport and Exercise, Massey University)
+64 9 213 6410 ext. 43410 or c.badenhorst@massey.ac.nz

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/54. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 EXT 63363, email humanethicssoutha@massey.ac.nz

Appendix B: Ethics Approval

HoU Review Group:

ReviewerGroup:
Dr Claire Badenhorst

Researcher: Isabella Coombes
Title: Risk of Low Energy Availability (LEA) in New Zealand Full National Team and U20 Female Football Representatives

Dear Isabella,

Thank you for the above application that was considered by the Massey University Human Ethics Southern A Committee at their meeting held on 29/11/2021.
On behalf of the Committee I am pleased to advise you that ethical approval has been granted for your research.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested by contacting the Research Ethics Office at humanethics@massey.ac.nz.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

If you wish to print an official copy of this letter:

1. Please login to the RIMS system (https://rme.massey.ac.nz).
2. In the Ethics menu, select Ethics Applications.
3. Using the Advanced search with appropriate criteria to find only this application.
4. With the application on the Results tab, select Reports from the toolbar.
5. Select the "Human Ethics - Full Application Letter" link, this will open the report viewer.
6. Select the application code from the Report Parameters dropdown and submit. You can then select an export option from the top toolbar (Print, Save).

Yours sincerely
Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

Appendix C: Survey

Risk of Low Energy Availability among Full National Team and U20 Footballers in New Zealand

Dear Participant

My name is Issy Coombes, and I am a Masters student in Sport and Exercise at Massey University. New Zealand Football has identified you as a member of the U20 and/or Full National Women's Football Team and has kindly passed on your contact information so that we are able to request your participation in our research study looking at the risk of low energy availability and potential risk factors in U20 and Full National Team Footballers.

The research will be investigating some factors (e.g. age, years training in national environment, nutrition knowledge, occupation) that may increase the risk of low energy availability in national team and U20 female football players and any symptoms (sleep, mood, disordered eating) experienced by players who are at risk of low energy availability.

The results from this study will provide new information to inform the appropriate integration of a low energy availability segment into the current monitoring system for daily tracking of player menstrual cycle and associated symptoms (mood, digestion, sleep, weight etc.) that the New Zealand Football coaching and health support staff currently use.

If you agree to participate, you will be asked to complete a single online questionnaire from your home computer/tablet/phone. This questionnaire will take approximately 30 minutes to complete, and no further assistance will be required following this.

Your participation in this study is entirely voluntary and will have no impact on selection for any New Zealand Football Team. Additionally, all data will remain confidential and New Zealand Football will not have access to any personal information that is collected.

If you wish to proceed with participation in this study then please complete the consent question following this information.

If you have any questions regarding your participation, then do not hesitate to contact myself (Issy Coombes): [redacted] or my primary supervisor Dr Claire Badenhorst: c.badenhorst@massey.ac.nz

PARTICIPANT INFORMATION SHEET

Invitation to Participate in Research Study

This study will aim to identify the number of national team and U20 female football players at risk of low energy availability in New Zealand. The research will identify specific factors (e.g. age, years training in national environment, nutrition knowledge, occupation) that increase the risk of low energy availability in national team and U20 female football players and the specific symptoms (sleep, mood, disordered eating) experienced by players who are at risk of low energy availability. The results from this study will provide new information to inform the appropriate integration of a low energy availability segment into the current monitoring system for daily tracking of player menstrual cycle and associated symptoms (mood, digestion, sleep, weight etc.) that the New Zealand Football coaching team has full access too.

Participant Recruitment

All female footballers playing at full national or U20 national team level are invited to participate in this study. Participation in this research is voluntary and will have no impact on team selection within New Zealand Football. If you have any questions about your participation in this study, you are welcome to discuss these further with our team.

The surveys that will be completed as part of the questionnaire include the; LEAF-Q (Melin et al., 2014), ASSQ (Samuels et al., 2015), short form POMS Questionnaire (Shacham, 1983), ASNKQ (Trakman et al., 2018) and the EDEQ (Fairburn & Beglin, 1994).

From these surveys researchers will be able to identify risk of low energy availability, symptoms associated with a low energy availability states and risk factors that may lead to a state of low energy availability.

Project Procedures and Participant Involvement

If you agree to participate, you will be asked to complete a single online questionnaire from your home computer/tablet/phone. This questionnaire will take approximately 60 minutes to complete, and no further assistance will be required following this.

Following completion of the study, Presentations on female health and wellbeing will be provided at Massey or at New Zealand Football by the researchers. This will be available for yourself, other participants, coaches and any additional whānau who wish to attend. Additionally, you will be entitled access to individual results via email and can also request a hard copy print out of personal data.

Participant’s Rights

You are under no obligation to accept this invitation.
Should you choose to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the study at any time, even after signing a consent form (if you choose to withdraw you cannot withdraw your data from the analysis after the data collection has been completed)
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded

Confidentiality

All data collected will be used solely for research purposes. There is a possibility that results will be presented in a professional journal. All personal information will be kept confidential, and participants will be assigned participant numbers at recruitment. No names will be visible on any papers on which you provide information and New Zealand Football will not know the identity of any participants. All data/information will be dealt with in confidentiality and will be stored in a password protected online system for 10 years within the Massey University System. After this time, it will be disposed of by an appropriate staff member from the School of Sport and Exercise.

Project Contacts

If you have any questions regarding this study, please do not hesitate to contact any of the following research team for assistance:

Researchers:

Isabella Coombes (School of Sport and Exercise, Massey University)
[redacted]

Supervisor: Dr. Claire Badenhorst (School of Sport and Exercise, Massey University) +64 9 213 6410 ext. 43410 or c.badenhorst@massey.ac.nz

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics

Committee: Southern A, Application 21/54. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 EXT 63363, email humanethicssoutha@massey.ac.nz

CONSENT FORM FOR STUDY VOLUNTEERS

This consent form will be held for a minimum period of ten (10) years

I have read the information sheet and have has the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw from the study at any time and decline to answer particular questions.

I agree to provide information to the researcher on the understanding that my name will not be used without my permission but I will have access to my individual results. (The information will be used only for this research and publications arising from this research project.)

I agree to participate in this study under the conditions set out in the Information Sheet.

NOTE: If under the age of 18, a parent or legal guardian must give co-consent

If you choose to select 'Yes' to participating in the study, please can you provide your full name and date in the text box provided.

○ Yes, I agree to participate in this study

____

○ No, I do not agree to participate in this study

The low energy availability in females questionnaire (LEAF –Q), focuses on physiological symptoms of insufficient energy intake.

The following pages contain questions regarding injuries, gastrointestinal and reproductive function. We appreciate you taking the time to fill out the LEAF-Q and all responses will be treated as confidential.

Q1A Have you been unable to train, or participate in competition 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

Q1A1 For how many days have you been unable to train, or participate in competition during the last year due to injuries?

- ◯ 1-7 days
- ◯ 8-14 days
- ◯ 15-21 days
- ◯ 22 days or more

QA2 What kind of injuries have you had in the last year?

____

QA3 Comments or further information regarding injuries:

____

____

____

Page Break

Q5 Do you ever feel abdominal bloating or gas, when you are not menstruating?

- ◯ Yes, several times a day
- ◯ Yes, several times a week
- ◯ Yes, once or twice a week or more seldom
- ◯ Rarely or never

Q6 Do you get cramps or stomach ache when you are not menstruating?

- ◯ Yes, several times a day
- ◯ Yes, several times a week
- ◯ Yes, once or twice a week or more seldom
- ◯ Rarely or never

Q7 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

Q8 How would you describe your normal stool?

- ○ Normal (soft)
- ○ Diarrhoea-like (watery)
- ○ Hard and dry

Q9 Comments regarding gastrointestinal function:

____

Page Break

Q10 Do you use oral contraceptives?

- ○ Yes
- ○ No

Q11 Why do you use oral contraceptives?

- ○ Contraception
- ○ Reduction of menstruation pain
- ○ Reduction of bleeding
- ○ To regulate the menstrual cycle in relation to performances etc..
- ○ Otherwise menstruation stops
- ○ Other ____

Q12 Have you used oral contraceptives before?

- ○ Yes
- ○ No

Q13 When and for how long have you used oral contraceptives?

____

Q14 Do you use any other kind of hormonal contraceptives? (e.g. hormonal implant or coil)

- ○ Yes
- ○ No

Q15 What kind?

- ○ Hormonal patches
- ○ Hormonal ring
- ○ Hormonal coil
- ○ Hormonal implant
- ○ Other ____

Page Break

Q16 How old were 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 (If you have answered “I have never menstruated” there are no further questions to answer)

Q17 Did your first period come naturally (by itself)?

◯ Yes

◯ I don't remember

◯ No

Q18 What kind of treatment was used to start your menstrual cycle?

◯ Hormonal treatment

◯ Weight gain

◯ Reduced amount of exercise

◯ Other

Q19 Do you have normal menstruation?

- ◯ Yes
- ◯ No
- ◯ I don't know

Q20 When was your last period?

- ◯ 0-4 weeks ago
- ◯ 1-2 months ago
- ◯ 3-4 months ago
- ◯ 5 months ago or more

Q21 Are your periods regular? (Every 28th to 34th day)

- ◯ Yes, most of the time
- ◯ No, mostly not

Q22 For how many days do you normally bleed?

- ◯ 1-2 days
- ◯ 3-4 days
- ◯ 5-6 days
- ◯ 7-8 days
- ◯ 9 days or more

Q23 Have you ever had problems with heavy menstrual bleeding?

- ○ Yes
- ○ No

Q24 How many periods have you had during the last year?

- ○ 12 or more
- ○ 9-11
- ○ 6-8
- ○ 3-5
- ○ 0-2

Page Break

Q25 When did you have your last period?

- ◯ 2-3 months ago
- ◯ 4-5 months ago
- ◯ 6 months ago or more
- ◯ I’m pregnant and therefore do not menstruate

Q26 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

Q27 Do you experience changes to your menstrual cycle when you increase your exercise intensity, frequency or duration?

- ◯ Yes
- ◯ No

Q28 How is your menstrual cycle affected? (Check one or more options)

- ▢ I bleed less
- ▢ I bleed fewer days
- ▢ My menstruations stops
- ▢ I bleed more
- ▢ I bleed more days

End of Block: LEAF-Q

Start of Block: EDE-Q

Q175 The following questions are concerned with the past four weeks (last 28 days or past month) only. Please read each question carefully. Please answer all the questions.

We appreciate you taking the time to fill out the EDE-Q, all responses will remain anonymous and be treated as confidential. Thank you.

Page Break

Q31 Please tick the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days) only.

	No days	1-5 days	6-12 days	13-15 days	16-22 days	23-27 days	Every day
Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight?	○	○	○	○	○	○	○
Have you tried to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?	○	○	○	○	○	○	○
Have you tried to follow definite rules regarding your eating (for example, a calorie limit) in order to influence your shape or weight (whether or not you have succeeded)?	○	○	○	○	○	○	○

Have you had a definite desire to have an empty stomach with the aim of influencing your shape or weight?	○	○	○	○	○	○	○
Have you had a definite desire to have a totally flat stomach?	○	○	○	○	○	○	○
Has thinking about food, eating or calories made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	○	○	○	○	○	○	○
Have you had a definite fear of losing control over eating?	○	○	○	○	○	○	○
Have you had a definite fear that you might gain weight?	○	○	○	○	○	○	○
Have you felt fat?	○	○	○	○	○	○	○

Have you had a strong desire to lose weight?	○	○	○	○	○	○	○

Q42 Over the past 28 days, how many times have you eaten what other people would regards as an unusually large amount of food (given the circumstances)?

____

Q43 … On how many of these times did you have a sense of having lost control over your eating (at the time you were eating)?

____

Q44 Over the past 28 days, on how many DAYS have such episodes of overeating occurred (i.e. you have eaten an unusually large amount of food and have had a sense of loss of control at the time)?

____

Q45 Over the past 28 days, how many times have you made yourself sick (vomit) as a means of controlling your shape or weight?

____

Q46 Over the past 28 days, how many times have you taken laxatives as a means of controlling your shape or weight?

____

Q47 Over the past 28 days, how many times have you exercised in a “driven” or “compulsive” way as a means of controlling your weight, shape or amount of fat, or to burn off calories?

____

Q48 Over the past 28 days, on how many days have you eaten in secret (ie, furtively)? … Do not count episodes of binge eating.

- ○ No days
- ○ 1-5 days
- ○ 6-12 days
- ○ 13-15 days
- ○ 16-22 days
- ○ 23-27 days
- ○ Every day

Q50 On what proportion of the times that you have eaten, have you felt guilty (felt that you’ve done wrong) because of its effect on your shape or weight? (Do not count episodes of binge eating)

- ○ None of the times
- ○ A few of the times
- ○ Less than half
- ○ Half of the times
- ○ More than half
- ○ Most of the time
- ○ Every time

Q51 Over the past 28 days,

	Not at all	Slightly	Moderately	Markedly
How concerned have you been about other people seeing you eat? (Do not count episodes of binge eating)	○	○	○	○
Has your weight influenced how you think about (judge) yourself as a person?	○	○	○	○
Has your shape influenced how you think about (judge) yourself as a person?	○	○	○	○
How much would it have upset you if you had been asked to weigh yourself once a week (no more, or less, often) for the next four weeks?	○	○	○	○
How dissatisfied have you been with your weight?	○	○	○	○
How dissatisfied have you been with your shape?	○	○	○	○
How uncomfortable have you felt seeing your body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?	○	○	○	○

How uncomfortable have you felt about others seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?	○	○	○	○

End of Block: EDE-Q

Start of Block: ANSK-Q

Q186 The following questions are related to nutrition knowledge. Please read each question carefully. Please answer all the questions.

We appreciate you taking the time to fill out the ANSK-Q, all responses will remain anonymous and be treated as confidential. Thank you.

Q63 For the following questions tick the single most appropriate answer.

	Agree	Disagree	Not sure
Eating more energy from protein than you need can make you put on fat?	○	○	○
The body needs fat to fight off sickness?	○	○	○
The body has a limited ability to use protein for muscle protein synthesis.	○	○	○
Eggs contain all the essential amino acids needed by the body.	○	○	○
Thiamine (Vitamin B1) is needed to take oxygen to muscles.	○	○	○
Vitamins contain energy (kilojoules/calories)	○	○	○
Eating more protein is the most important dietary change if you want to have more muscle.	○	○	○
When we exercise at a low intensity, our body mostly uses fat as a fuel.	○	○	○
The optimal calcium intake for athletes aged 15 to 24 years is 500 mg	○	○	○
A fit person eating a balanced diet can improve their athletic performance by eating more vitamins and minerals from food.	○	○	○
Vitamin C should always be taken by athletes.	○	○	○

In events lasting 60 - 90 minutes, 30- 60 g (1.0 - 2.0 ounces) of carbohydrates should be consumed per hour	○	○	○
Eating carbohydrates when you exercise will help keep blood sugar levels stable	○	○	○
Supplement labels may sometimes say things that are not true	○	○	○

Q65 Do you think the following foods are high or low in fat? Tick the single most appropriate answer.

	High	Low	Not Sure
Cheddar Cheese	○	○	○
Margarine	○	○	○
Honey	○	○	○

Q73 For the following questions tick the single most appropriate answer.

	Yes	No	Not Sure
Do you think alcohol can make you put on weight?	◯	◯	◯
Do you think 100 g of chicken breast has enough protein to promote muscle growth after a bout of resistance exercise?	◯	◯	◯
Do you think 1 Cup Baked Beans has enough protein to promote muscle growth after a bout of resistance exercise?	◯	◯	◯
Do you think 1/2 Cup Cooked Quinoa has enough protein to promote muscle growth after a bout of resistance exercise?	◯	◯	◯
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)	◯	◯	◯
Do you think 1 medium banana has enough carbohydrate for recovery from intense exercise? (Assume the athlete weighs about 70 kg and has an important training session again tomorrow)	◯	◯	◯

Q74 "Binge drinking" (also referred to as heavy episodic drinking) is generally defined as:

- ○ Having two or more standard alcoholic drinks on the same occasion
- ○ Having four to five or more standard alcoholic drinks on the same occasion
- ○ Having seven to eight or more standard alcoholic drinks on the same occasion
- ○ Not sure

Page Break

Q81 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

Q83 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
- Not sure

Q87 Athletes should drink water to:

- Keep plasma (blood) volume stable
- Stop dry mouth
- Allow proper sweating
- All of the above
- Not sure

Q88 Experts think that athletes should:

- ○ Drink 50-100ml every 15-20 minutes
- ○ Suck on ice cubes rather than drinking during practise
- ○ 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

Q89 Before competition, athletes should eat foods that are high in:

- ○ Fluids, fat and carbohydrate
- ○ Fluids, fibre and carbohydrate
- ○ Fluids and carbohydrate
- ○ Not sure

Q93 Which is the best snack to have during an intense 90-minute training session?

- ○ Protein shake
- ○ Ripe banana
- ○ 2 Boiled eggs
- ○ Handful of nuts
- ○ Not sure

Q94 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

Q96 Which supplement does not have enough evidence in relation to improving body composition, sporting performance?

- ◯ Caffeine
- ◯ Ferulic acid
- ◯ Bicarbonate
- ◯ Leucine
- ◯ Not sure

Q97 The WORLD ANTI-DOPING AGENCY (WADA) bans the use of

- ◯ Caffiene
- ◯ Bicarbonate
- ◯ Testosterone
- ◯ Carnitine
- ◯ Not sure

End of Block: ANSK-Q

Start of Block: ASS-Q

Q179 The following questions relate to your sleep habits. Please choose the best answer which you think represents your typical sleep habits over the recent past.

We appreciate you taking the time to fill out the ASS-Q, all responses will remain anonymous and be treated as confidential. Thank you.

Page Break

Q98 During the recent past, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

- ◯ 5-6 hours
- ◯ 6-7 hours
- ◯ 7-8 hours
- ◯ 8-9 hours
- ◯ More than 9 hours

Q99 How many naps per week do you take?

- ◯ None
- ◯ Once or twice
- ◯ Three or four times
- ◯ Five to seven times

Q100 How satisfied/dissatisfied are you with the quality of your sleep?

- ◯ very dissatisfied
- ◯ Somewhat dissatisfied
- ◯ Neither satisfied nor dissatisfied
- ◯ Somewhat satisfied
- ◯ Very satisfied

Q101 During the recent past, how long has it usually taken you to fall asleep each night?

- ◯ 15 minutes or less
- ◯ 16-30 minutes
- ◯ 31-60 minutes
- ◯ Longer than 60 minutes

Q106 Do you consider yourself to be a morning type person or an evening type person?

- ◯ Definitely a morning type
- ◯ More a morning type than an evening type
- ◯ More an evening type than a morning type
- ◯ Definitely an evening type

Q102 During the recent past...

	None	Once or twice per week	Three or four times per week	Five to seven times per week
How often have you had trouble staying asleep?	○	○	○	○
How often have you taken medicine to help you sleep (prescribed or over-the-counter)?	○	○	○	○
How many times have you felt alert during the first half-hour after waking up?	○	○	○	○
Over the recent past, how often have you used an electronic device (example: cell phone, computer, tablet, T.V. etc.) within 1 hour of going to bed?	○	○	○	○

Q182 Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

- ○ 5:00 am – 6:30 am
- ○ 6:30 am – 7:45 am
- ○ 7:45 am – 9:45 am
- ○ 9:45 am – 11:00 am
- ○ 11:00 am – 12:00 pm (noon)

Q183 Considering your own “feeling best” rhythm, at what time would you go to bed if you were entirely free to plan your evening?

- ○ 8:00 pm – 9:00 pm
- ○ 9:00 pm – 10:15 pm
- ○ 10:15 pm – 12:30 am
- ○ 12:30 am – 1:45 am
- ○ 1:45 am – 3:00 am

Q108 Please answer the following....

	Yes	No
When you are travelling for your sport, do you experience sleep disturbance?	○	○
When you are travelling for your sport, do you experience daytime dysfunction (feeling generally unwell or having poor performance)?	○	○
Are you typically a loud snorer?	○	○
Have you been told that you choke, gasp, or stop breathing for periods of time during sleep?	○	○

Q112 On average, how many caffeinated products (caffeine pills, coffee, tea, soda, energy drinks) do you have per day? For coffee and tea, one drink = 6-8oz/177-237ml; for caffeinated soda, one drink = 1 can (12oz/355ml)?

- ◯ Less than 1 per day
- ◯ 1-2 per day
- ◯ 3 per day
- ◯ 4 per day
- ◯ 5 or more per day

End of Block: ASS-Q

Start of Block: POMS-Q

Q117 Below is a list of words that describe feelings people have.

Please SELECT THE NUMBER and DESCRIPTION THAT BEST DESCRIBES HOW YOU FEEL RIGHT NOW.

We appreciate you taking the time to fill out the POMS-Q, all responses will remain anonymous and be treated as confidential. Thank you.

	0) Not at all	1) A little	2) Moderately	3) Quite a lot	4) Extremely
Tense	○	○	○	○	○
Angry	○	○	○	○	○
Worn Out	○	○	○	○	○
Unhappy	○	○	○	○	○
Lively	○	○	○	○	○
Confused	○	○	○	○	○
Sad	○	○	○	○	○
Active	○	○	○	○	○
On edge	○	○	○	○	○
Grouchy	○	○	○	○	○
Ashamed	○	○	○	○	○
Energetic	○	○	○	○	○
Hopeless	○	○	○	○	○
Uneasy	○	○	○	○	○
Restless	○	○	○	○	○
Unable to concentrate	○	○	○	○	○
Fatigued	○	○	○	○	○

Competent	○	○	○	○	○
Annoyed	○	○	○	○	○
Discouraged	○	○	○	○	○
Resentful	○	○	○	○	○
Nervous	○	○	○	○	○
Miserable	○	○	○	○	○
Confident	○	○	○	○	○
Bitter	○	○	○	○	○
Exhausted	○	○	○	○	○
Anxious	○	○	○	○	○
Helpless	○	○	○	○	○
Weary	○	○	○	○	○
Satisfied	○	○	○	○	○
Bewildered	○	○	○	○	○
Furious	○	○	○	○	○
Full of pep	○	○	○	○	○
Worthless	○	○	○	○	○
Forgetful	○	○	○	○	○

Vigorous	◯	◯	◯	◯	◯
Uncertain about things	◯	◯	◯	◯	◯
Bushed	◯	◯	◯	◯	◯
Embarrassed	◯	◯	◯	◯	◯

End of Block: POMS-Q

Start of Block: General Information

Q184 What is your age?

____

Q171 How long have you been playing Football?

◯ <3 years

◯ 3-5 years

◯ 5-10 years

◯ >10 years

Q170 How long have you been in the New Zealand Football Environment (training or playing within New Zealand Football age group/full national teams)?

◯ <3 years

◯ 3-5 years

◯ 5-10 years

◯ >10 years

Q185 Are you currently residing and playing in New Zealand?

- ○ No
- ○ Yes

Q172 How many hours do you spend per week on football specific training? (including games)

- ○ <4 hours
- ○ 4-6 hours
- ○ 6-8 hours
- ○ 8-10 hours
- ○ 10-12 hours
- ○ >12 hours

Q173 How many hours per week do you spend on non-football specific training? (e.g. gym, fitness, mobility etc.)

- ○ <3 hours
- ○ 3-5 hours
- ○ 5-7 hours
- ○ 7-9 hours
- ○ >9 hours

Q176 Is football your primary source of income?

- ○ Yes
- ○ No

Q177 How many hours do you spend working for income (outside of football)?

- ○ <10 hours
- ○ 10-20 hours
- ○ 20-30 hours
- ○ 30-40 hours
- ○ >40 hours

Q181 If you are interested in participating in any more research studies performed by Massey University, tick yes or no in the boxes below and provide an email address.

- ○ Yes ____
- ○ Maybe ____
- ○ No

End of Block: General Information