Risk of low energy availability and level of nutrition knowledge in recreational trail runners in Aotearoa/New Zealand

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Abstract

Introduction: Trail running as an endurance sport is growing in popularity. It is characterised by long event durations and extreme environments that are likely to result in high exercise energy expenditure. Energy availability is defined as the amount of energy available to support normal physiological functions after subtracting the energy cost of exercise from energy intake. Insufficient energy intake, increased exercise, or a combination of both can result in a state of low energy availability (LEA). Research has demonstrated a high prevalence of risk of LEA (~19%-85%) among both elite and recreational athletes, across both sexes and in endurance sports such as running. One possible contributor to LEA risk is poor nutrition knowledge. However, little is known about the risk of LEA and nutrition knowledge in trail runners. The aim of this study was to determine the prevalence of LEA risk in recreational trail runners and investigate associations with nutrition knowledge.

Methods: This study was a cross-sectional study of adult trail runners in Aotearoa/New Zealand. The study required the completion of an amalgamated survey consisting of the Low Energy Availability in Females Questionnaire (LEAF-Q), the Low Energy Availability in Males Questionnaire (LEAM-Q), and the Platform for Evaluating Athlete Knowledge in Sports Nutrition Questionnaire (PEAKS-NQ). Demographics and trail-running experience questions were integrated into the survey. LEAF-Q scores ≥8 were classified as LEA risk, and for LEAM-Q, a higher score indicated lower sex drive. Data were analysed in SPSS version 29 (IBM Corporation). Comparisons between groups (e.g. 'low LEA risk' vs. 'LEA risk') were performed using a chi-square test for categorical variables, and an independent samples t-test for continuous variables. Results are presented as mean ± standard deviation.

Results: The final survey sample was 217 (140 females, 42.0 ± 10.7 years; 77 males, 47.9 ± 12.1 years) for the LEAF-Q, LEAM-Q, and trail running questions; and 152 for the PEAKS-NQ. Participants ranged from beginners to very experienced trail runners who regularly participated in short 5-9km events through to ultramarathons. Thirty-one percent of females met the classification for LEA risk. Twenty-three percent of males were identified as having low sex drive, a marker of LEA risk. The LEAF-Q/sex drive score was higher in those with LEA risk (10.7 ± 2.3 / 4.5 ± 2.0) compared to those with low LEA risk (3.9 ± 2.3 / 1.5 ± 1.1, $p < .001$).

Education, body mass index, weekly training hours and level of trail running experience did not differ between trail runners with LEA risk or low LEA risk. However, females with LEA risk were younger (38.0 ± 12.6 vs. 43.6 ± 9.4, $P < .05$), and more likely to report a weight change in the last six months (75.9% vs. 40.3%, $P < 0.5$). Males with LEA risk more readily reported a chronic illness (23.5% vs. 6.8%, $P < 0.5$) or food allergy/intolerance (27.7% vs. 8.6%, $P < 0.5$). For the general nutrition knowledge questions, 78.6 ± 10.1% for females and 75.8 ± 10.7% for males were answered correctly. However, sports nutrition scores were lower (females, 66.3 ± 13.4%; males, 63.2 ± 15.5%) with the lowest mean scores observed for 'fuel for during events' (8.8% correct). There was no difference in nutrition knowledge between individuals classified as low LEA risk vs LEA risk.

Conclusion: The findings suggest that recreational trail runners are a group of active individuals who are at risk of LEA and that they might benefit from more sports-specific nutrition education.

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List of abbreviations

Abbreviation	Term
BMD	Bone Mineral Density
BMI	Body Mass Index
BW	Body Weight
DE	Disordered Eating
DEXA	Dual-Energy X-Ray Absorptiometry
EA	Energy Availability
ED	Eating Disorder
EDE-Q	Eating Disorder Examination Questionnaire
EE	Energy Expenditure
EEE	Exercise Energy Expenditure
EI	Energy Intake
FFM	Fat Free Mass
FFQ	Food Frequency Questionnaire
MET	Metabolic Equivalent
LEA	Low Energy Availability
LEAF-Q	Low Energy Availability in Females Questionnaire
LEAM-Q	Low Energy Availability in Males Questionnaire
PEAKS-NQ	Platform to Evaluate Athlete Knowledge of Sports Nutrition Questionnaire
REDs	Relative Energy Deficiency in Sport
RMR	Resting Metabolic Rate
TCRAT	Triad Cumulative Risk Assessment Tool

Chapter 1: Introduction

Running is one of the most common types of exercise worldwide (Raghunandan et al., 2021); and is accessible to most people. Research has demonstrated that regular running can provide significant health benefits including the prevention of chronic diseases and benefits to bone health across the lifespan (Kohrt et al., 2004). Subsequently, running is argued to be the "most cost-effective lifestyle medicine from a public health perspective" (Lee et al., 2017, p. 53). Trail running differs from road running in that it takes place off-road, in natural environments (e.g., forests, mountains, deserts) and must include no more than 20% paved roads (International Trail Running Association, 2021). Nature-based recreation activities have been shown to positively affect mental health outcomes, supporting improved wellbeing and reductions in stress and anxiety (Lackey et al., 2021). Therefore, trail running has the potential to benefit both physical and mental health.

Trail running is one of the fastest growing sports in the world. The sport has seen an annual increase in participation of 15% since the mid-1990s, and has a current estimated trail running population of 20 million worldwide (World Athletics, 2021). Trail running events can range from a short 5km fun run and half marathons to ultra-marathons and multi-day races with the world's ultimate event being the Ultra-Trail du Mont-Blanc (171km and 10,000m of positive elevation gain). As such, compared to road running, trail races are not just about the distance - it is the combination of the distance, terrain and elevation for each race that offers participants a unique physical and mental challenge. Aotearoa/New Zealand has the terrain for trail running which facilitates numerous events throughout the year and ensures diversity between each event.

People from all age groups and sexes participate in trail running races. However, worldwide participation data trends show that the average age of trail runners has increased from 37.7 years in 2000 to 39.5 years in 2022 (Andersen, 2022). The proportion of females participating in trail running races, including participation in ultra-marathon races has also increased significantly from 13% in 1997 to 46% in 2022 (Andersen, 2022; Hoffman & Wegelin, 2009). This increase in female participation in trail running events may be due to the fact that females enjoy participating in social gatherings and that they may feel more comfortable and safe when exercising in a group setting (Navalta et al., 2018). Finally, there is also a trend that trail races are getting longer, with only 45% of races in 2022 being 5k races, compared to 75% of races 20 years ago (Andersen, 2022). This trend is likely indicative of the increased popularity of the ultra-marathon distances (Cejka et al., 2014).

Trail running is an endurance sport characterised by high exercise energy expenditure (EEE) due to long event durations and extreme environments (Scheer et al., 2020). High EEEs require athletes to have high energy intake (EI) to support both training and physiological functions. Subsequently, previous research has recommended that a possible threshold of EI to support high EEE is >45 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$ (Melin et al., 2019). In meeting this level of EI, trail running athletes are likely to meet the classification of optimal energy availability (EA). Energy availability is calculated as EI minus EEE relative to fat free mass (FFM). Therefore, after energy from EEE has been accounted for from daily EI, the result represents the amount of energy left available for basal physiological processes.

Energy availability can exist on a spectrum from adaptable to problematic (Mountjoy et al., 2023). Athletes are able to tolerate a state of adaptable low energy availability (LEA) (30-45 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$) for short periods of time and this can be beneficial for manipulating body composition and training adaptations. If an athlete is in a state of problematic LEA that becomes severe or prolonged it can have a multitude of health, physiological and performance consequences (Melin et al., 2019; Mountjoy et al., 2023). These states of problematic LEA describe the aetiology of the syndrome known as Relative Energy Deficiency in Sport (REDs) (Mountjoy et al., 2023).

Intentionally or unintentionally restricting EI and/or increasing EEE for either a prolonged period of time or in a severe manner are known factors that contribute to an athlete being in a state of problematic LEA (Burke et al., 2018). Research shows that endurance athletes such as runners are a high risk group for problematic LEA as they may intentionally try to manipulate body composition in a sport where leanness may be perceived as favourable for performance (Kuikman & Burke, 2023). In addition, running is a sport characterised by high EEE in locomotion, and athletes may unintentionally under fuel during periods of intense training, which may be a result of them not being aware of the large amounts of energy they are expending and how much they need to consume (Kuikman & Burke, 2023). Trail running also has additional logistical challenges which may impact EI such as eating and drinking while running, and limitations on the amount of food and drink one can carry (Costa et al., 2019). Prior research has also demonstrated that it is common for endurance athletes to experience exercise induced appetite suppression, often resulting in inadequate EI (Loucks, 2007). Individually or cumulatively, these factors contribute to trail running athletes' elevated risk of not meeting adequate EI to fuel for the work required (high EEE); in other words, they may not be in a state of optimal EA.

The most well-documented outcomes of problematic LEA are impairments of reproductive function and bone health in female and male athletes which are based on the original research related to the female and male athlete triads (Fredericson et al., 2021; Nattiv et al., 2021; Nattiv et al., 2007). While the majority of research has been in females (Nattiv et al., 2007), it is now clear that the syndrome of REDs impacts both female and male athletes (Mountjoy et al., 2023). Problematic LEA can also have a profound effect on athletic performance including preventing training adaptations, increased risk of injuries and illnesses, sleep disturbances, depression and stress (Melin et al., 2023). More recently, an athlete's individual characteristics such as sex, training and nutrition characteristics, are recognised as moderating factors that amplify or attenuate the effects that problematic LEA has on the individual (Mountjoy et al., 2023).

Studies investigating problematic LEA prevalence in runners have on average found a prevalence rate of 29-60% for females (Matt et al., 2022; McCormack et al., 2019) and 25-45% for males (Beermann et al., 2020; Heikura et al., 2018) in predominantly competitive to elite runners. Studies investigating the risk of problematic LEA in runners have reported risk prevalence of 19-80% in females (Jesus et al., 2021; Karlsson et al., 2023) and 10-54% in males (Høeg et al., 2022; Jesus et al., 2021). While the majority of studies have been conducted with elite athletes, risk of problematic LEA prevalence is also evidenced among recreational runners (Dervish et al., 2023; Karlsson et al., 2023). There is limited research on problematic LEA in recreational trail runners – a sport that is characterised by high EEE, potentially putting a large proportion of recreational trail runners at risk of problematic LEA.

Having appropriate nutrition knowledge including how to choose and prepare foods that meet energy requirements is important to reduce the risk of unintentional under fuelling which can lead to the inadvertent development of problematic LEA (Kuikman & Burke, 2023). Subsequently, when provided with education to increase nutrition knowledge, athletes may be better equipped to understand their fuelling needs for various training periods (Valliant et al., 2012). However, few studies have investigated the relationship between problematic LEA risk and nutrition knowledge and have shown inconsistent results (Coombes, 2022; Magee et al., 2020). To our knowledge, the association between nutrition knowledge and risk of problematic LEA in recreational trail runners have not been investigated.

1.1 Aims

The aim of this research is to identify the proportion of recreational trail runners in Aotearoa/New Zealand who are at risk of problematic LEA. A secondary aim is to identify the factors associated with increased risk of problematic LEA in this cohort of runners.

1.1.1 Objectives

1. Determine the prevalence of recreational trail runners at risk of problematic LEA in Aotearoa/New Zealand.
2. Describe associations between risk of problematic LEA and demographic factors e.g., age, education, body mass index (BMI), weekly training hours and level of experience in recreational trail runners.
3. Determine the association between nutrition knowledge and problematic LEA risk.

1.1.2 Hypotheses

1. Over 40% of recreational trail runners will be at risk of problematic LEA with higher prevalence in females vs. males.
2. The more total training hours a trail runner completes per week, the higher their risk of problematic LEA.
3. Trail runners with low nutrition knowledge scores will be at higher risk of problematic LEA.

1.2 Structure of thesis

This thesis begins with an introduction to trail running and the concept of problematic LEA in endurance athletes and highlights where further research on problematic LEA is needed. This is followed by chapter two which is an extended review of the current literature of problematic LEA in female and male runners, outlining the prevalence rates of problematic LEA in runners, the risk factors for developing problematic LEA, and briefly reviewing the current literature of nutrition knowledge in athletes/runners. Chapter three is the manuscript of the study for publication which provides details on the methodology and results of this research. Finally, chapter four presents a summary of the study, including strengths and limitations, and future implications for both research and in practice.

1.3 Researchers' contributions

Researchers	Contributions
Tina Buch	Primary researcher, prepared ethics application, setup survey on Qualtrics, participant recruitment, data analysis, interpretation and discussion of results, author of report.
Dr Claire Badenhorst	Primary supervisor, provided advice on scope, ethics, methodology, data analysis and interpretation, thesis structure and revision.
Prof Kathryn Beck	Secondary supervisor, provided advice on scope, ethics, methodology, data analysis and interpretation, thesis structure and revision.
Dr Ryan Tam & Dr Janelle Gifford	Provided advice regarding use and analysis of the Platform to Evaluate Athlete knowledge of Sports Nutrition Questionnaire.

Chapter 2: Literature review

2.1 Introduction

Trail running is a demanding endurance sport, and in a similar manner to long-distance and track running has a high rate of exercise energy expenditure (EEE) in locomotion (Loucks, 2007). Of note, EEE may be further exacerbated in trail running with the added challenges of extended race or event duration, physical exertion, environmental extremes, course topography, carrying load, circadian and physiological disturbances (Balducci et al., 2017; Scheer et al., 2020). As such, trail runners are required to train not only their aerobic capacity but also running economy, running skill, thermoregulation, gastrointestinal integrity, nutrition strategies, and health management (Costa et al., 2019).

Long-distance runners, and trail runners, tend to have high training volumes throughout the year (Melin et al., 2019). Distance runners may follow a periodised training programme covering base training, a pre-competition phase, and a tapering phase leading up to the race followed by a recovery phase (Stellingwerff et al., 2007). Trail runners have varying training volumes with some reporting 700km+ over 12 months and may participate in multiple events during the year (McKay et al., 2019). Training for and participating in multiple trail events ultimately results in a high EEE. Hence adequate nutrition, especially carbohydrate intake, is crucial for appropriate fuelling before, during, and after the race (Burke et al., 2007).

A low level of body fat is a common feature of successful distance runners which may be contributing to the perception in runners that 'leaner is better'. However long-distance runners and walkers will often differ in body size (Burke et al., 2007). Similarly, ultramarathon (trail) runners have been found to vary in physical characteristics with a range of body mass index (BMI) values from underweight to overweight/obese (Hoffman, 2008). In the trail running population, a large proportion of participants are likely to be recreational runners who may have alternative motives for participating outside of performance and body composition including personal challenges, mental health benefits, and social connections (Myburgh & Kruger, 2021). Of note though is that distance running, inclusive of trail running, is a weight-bearing sport where the runner must carry their body mass over the specified long distance, either during training or competition. As a result, a higher body mass translates to a higher energy cost of running. For long-distance trail runners, an increase in muscle mass may be beneficial for moving across varying terrain, while greater fat stores may be advantageous as an additional energy source (Hoffman, 2008). Research however shows conflicting results regarding associations between fat mass or BMI and race time with some finding negative correlations and others none (Hoffman, 2008; Knechtle et al., 2011; Knechtle et al., 2010).

While some runners will genetically have smaller, leaner frames those with larger body frames may report perceived pressure to decrease body weight (BW) in order to be competitive (Burke et al., 2007). For this reason, runners can be prone to developing eating disorders (ED) or disordered eating behaviours (DE) in an attempt to maintain a lean physique, which contributes to adverse health and performance effects (Melin et al., 2019). In cases where ED/DE patterns may not be present, an individual who attempts to reduce weight may also experience adverse health and performance consequences, especially if they have inadequate nutritional knowledge or professional support resulting in them severely under-eating for a prolonged period of time (Logue et al., 2020; Neglia, 2021). Therefore, a key consideration for long-distance runners is ensuring that they have the knowledge and awareness of how to achieve sufficient energy intake (EI) to help maintain adequate energy availability (EA) to support both training and other basal physiological functions.

2.2 Energy availability

Energy is required for multiple physiological processes including resting metabolic rate (RMR), dietary induced thermogenesis, non-exercise activity thermogenesis and EEE (Thomas et al., 2016). These energy expenditure (EE) processes are all fuelled by the individual's EI. In active individuals, adequate EI is recommended to support EEE and these physiological processes. This concept of ensuring adequate EI for both EEE and physiological functions is referred to as EA. The EA of an individual is determined as the result of EI minus EEE relative to fat free mass (FFM) (Figure 1). Subsequently, EA is defined as the amount of energy left available for all physiological processes including but not limited to growth, thermogenesis, reproduction, and cellular maintenance, after energy from EEE has been accounted for from EI (Burke et al., 2018). It is worth noting that EA is different from the concept of energy balance (Areta et al., 2021). While both concepts relate to EI in relation to EEE, energy balance accounts for total energy expenditure whereas EA focuses specifically on EEE hereby referring only to the energy available to fuel all other physiological processes after energy for locomotion from skeletal muscle has been considered. In healthy young adults, an energy balance of zero is proposed to occur at an EA of 45 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$ (Loucks et al., 2011).

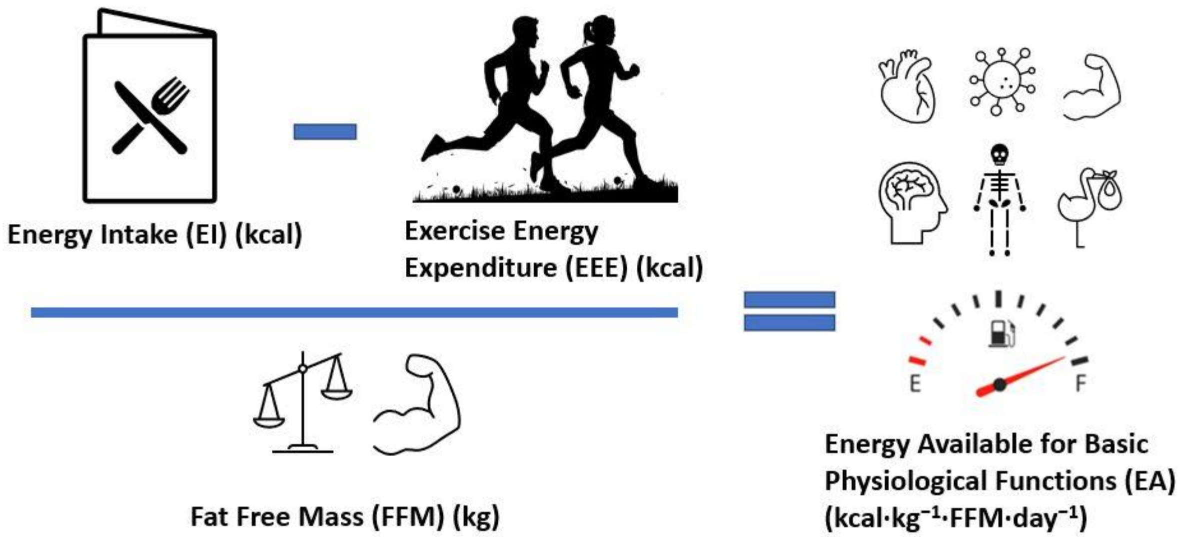


Figure 1: Energy availability calculation

Assessment of EA can be done in two ways: directly via measurement and calculations of EA, EEE and FFM, and indirectly via assessment of symptoms associated with problematic low energy availability (LEA) (Heikura et al., 2022). However, many limitations exist with assessing EI and EEE in both the lab and the field (Burke et al., 2018; Heikura et al., 2022). There is currently no single tool to accurately measure EA among female and male athletes, and while dietary surveys and exercise logs can provide estimates, the reliability of these are questionable (Burke et al., 2018). Measurement of EA in the lab usually involves subjecting participants to a certain level of EA for a short period (3-5 days) where EA is manipulated under controlled experimental conditions to establish a causal link (Areta et al., 2021). This is usually done by carefully controlling EI e.g., by providing meals that have homogenous calorie reduction and macronutrient composition, and EEE e.g., by controlling the exact amount of activity/exercise/rest that the participant is doing (Heikura et al., 2022). However, these standardised conditions may not necessarily provide a true indicator of how LEA occurs in the real world (Burke et al., 2018; Heikura et al., 2022). It is not possible, or ethical, to expose participants to purposeful long-term problematic LEA. Therefore, the majority of studies in this field are cross-sectional and completed in populations at risk of problematic LEA such as athletes participating in leanness sports (Areta et al., 2021).

In the field, the measurement of key factors required for EA determination currently poses many concerns and limitations for researchers and practitioners. Typically, EI can be estimated via self-report such as dietary records, interviews (e.g. 24-h recall) or food frequency questionnaires (FFQ) all of which are prone to significant errors (Capling et al., 2017). Errors include poor compliance due to high participant burden, under/over/misreporting due to recall bias and the tendency for participants to adjust their habitual intake, and variability in data entry, coding and analysis protocols (Burke et al., 2018). Thus, current recommendations are to use a combination of dietary assessment methods to provide a more effective means of quantifying EI in athletes (Capling et al., 2017). For EEE determination, methods such as training records, heart rate monitors, metabolic equivalent (MET) values, Global Positioning System units and accelerometers all present challenges (Burke et al., 2018; Heikura et al., 2022). Wearable devices have been shown to underestimate EEE (Murakami et al., 2019), METs are standardised and hence do not consider individual characteristics (e.g., body mass, age, sex) (Ainsworth et al., 1993), and training logs are subject to respondent burden and recording errors (Burke et al., 2018). Finally, accurate calculation of FFM requires equipment such as dual-energy X-ray absorptiometry (DEXA) or bioelectrical impedance analysis which may be limited by cost and availability (Warrick et al., 2020). Skinfold measurements are more readily done in the field; however, requires specialist training to reduce measurement error (Heikura et al., 2022). Consequently, the errors of estimating EI and EEE in free-living individuals can be up to 300-600 $kcal \cdot day^{-1}$ of total energy balance which may mask any energy surplus or deficit in terms of EA calculations (Burke et al., 2018). For these reasons, it has been suggested that initial use of screening tools, followed by in depth biomarkers review may be a better representation of an individual’s long-term EA compared to a single time point measure of EI and EEE (Heikura et al., 2018).

2.3 Low energy availability

When an active individual fails to achieve adequate EI to support EEE and basal physiological functions they are likely to be at risk of entering a state of LEA (Loucks et al., 2011). The formative research on LEA has primarily been conducted in females due to the initial origins of this concept being in the female athlete triad (De Souza et al., 2019). Within the continuum of LEA exposures as detailed in Figure 2, adaptable LEA is considered the small and professionally prescribed dose/s required to adjust body composition. Adaptable LEA, between 30-45 $kcal{\cdot}kg^{-1}{\cdot}FFM^{-1}{\cdot}day^{-1}$, may be tolerated for short periods within a well-structured weight loss program (Burke et al., 2018; Loucks et al., 2011). Whereas, the aetiological factor in the syndrome known as Relative Energy Deficiency in Sport (REDs) that has a spectrum of adverse health and performance outcomes such as impaired wellbeing, increased injury risk and decreased sports performance is primarily associated with problematic LEA (Mountjoy et al., 2023). Problematic LEA may occur from insufficient EI, increased exercise volume or load, or a combination of the two over a prolonged period of time. Alternatively, problematic LEA may result from severe disruptions to EI and EEE as a result of sociological, psychological and behavioural influences that the individual is exposed to (Melin et al., 2019; Mountjoy et al., 2023). It is generally accepted from the literature in females that problematic LEA occurs at a threshold below 30 $kcal{\cdot}kg^{-1}{\cdot}FFM^{-1}{\cdot}day^{-1}$, at which observed health implications including the impairment of many body systems and poor training adaptations and performance may occur (Melin et al., 2019). Refer to Figure 2 for different scenarios of EA (based on daily intake).

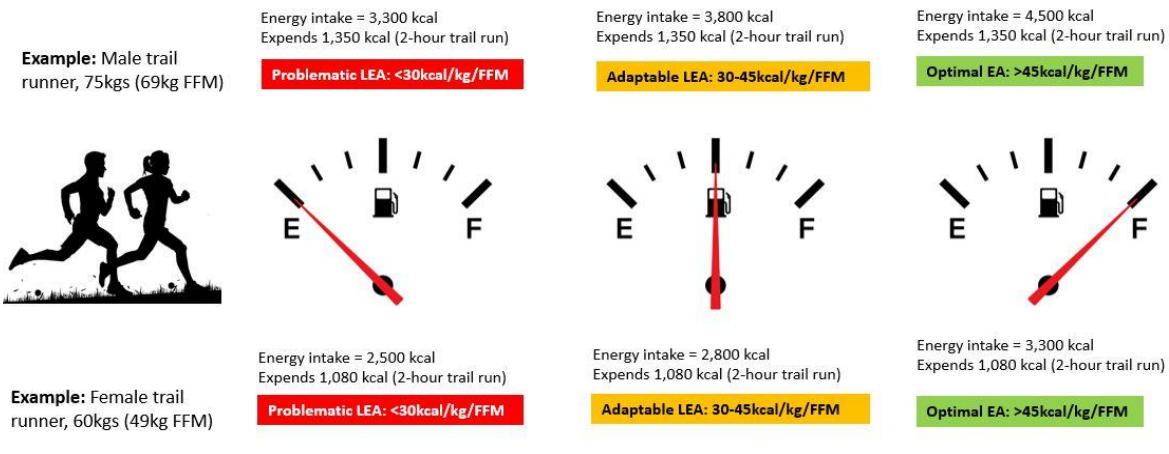


Figure 2: Different levels of energy availability (calculated as EI-EEE/FFM)

In males, however, the literature to date has not identified a clear threshold of EA below which impairment of basal physiological function inclusive of reproductive function is evidenced (Nattiv et al., 2021). Some studies have suggested a range between 9-25 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$ as the problematic LEA threshold for males (Fagerberg, 2018; Jurov et al., 2022; Koehler et al., 2016). At the optimal end, a cut-off of >40 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$ has been proposed (Koehler et al., 2016) however the use of these thresholds in males is still debated (Melin et al., 2023). It does however appear that men's physiology is more resistant to problematic LEA (Areta et al., 2021). Hence, most studies on problematic LEA in males have used the female cut-offs to remain consistent with the literature while still acknowledging its limitations (Lane et al., 2019). There are, however, ongoing discussions around the problematic LEA and EA thresholds and whether this is more likely to be a linear dose-response relationship (De Souza et al., 2019; Lieberman et al., 2018), and that individual moderating factors also need to be considered in addition to LEA duration and magnitude when determining the impact on health and performance outcomes experienced by the individual athlete (Mountjoy et al., 2023).

2.4 Risk factors for problematic low energy availability

Reasons for the development of problematic LEA in athletes are diverse (Melin et al., 2019). EI and EEE can be manipulated in many ways, which can happen gradually along the continuum from intentional to unintentional (Burke et al., 2018). It is important to note that an athlete can be in a state of problematic LEA in the absence of ED/DE, and still have a stable BW (Statuta, 2020) hence signs of problematic LEA are not always obvious. Refer to Table 1 for an overview of contributing factors to problematic LEA.

Table 1: Contributing factors to problematic low energy availability

Dietary behaviours	Exercise behaviours
• Disordered eating/eating disorders • Inadvertent under fuelling • Intentional but misguided weight loss • Food insecurity • Poor nutrition knowledge, limited cooking skills • Reduced appetite due to increased training load • Fad diets/restricted food choices • Food allergies/intolerances • Less time to cook and eat due to training, work or study commitments	• Increased training load not accompanied by increased EI • Changing training loads/periodisation • Competition period • Multiple sports/training types • High cost of living e.g. walking to work • Exercise addiction • Physique pressure within sport to look a certain way

Athletes participating in sports with high EEE (e.g. running, rowing or cycling) may be at risk of unintentional problematic LEA (Wasserfurth et al., 2020). Athletes may unintentionally reduce EA by failing to periodise their EI to their EEE requirements and changes throughout a training and competitive season (Kuikman & Burke, 2023). Previous research has shown that ad libitum EI tends to remain unchanged during periods of increased training in elite athletes (Schaal et al., 2021; Woods et al., 2017). Understanding the timing of fuelling in and around training to ensure optimal within-day energy balance is also an important consideration for athletes as it has been shown that within-day energy deficits may also elicit metabolic disturbances (Fahrenholtz et al., 2018; Torstveit et al., 2018). Therefore, individuals with low nutrition literacy may be unaware of the large energy needs associated with an increased training load and may not be aware that they need to increase EI concurrently.

Exercise-induced appetite suppression is noted in athletes (elite and recreational) with training of high intensity or prolonged duration and is often experienced in endurance athletes such as marathon runners (Loucks, 2007). In addition, fatigue and long training hours can reduce motivation and time to prepare and eat food which also adds to the increased risk of the athlete not meeting adequate EI requirements (Burke et al., 2018; Melin et al., 2019).

An athlete may choose to adopt a diet such as vegetarian or gluten-free due to a food allergy or intolerance or for environmental reasons or dietary trends (Neglia, 2021). Restricted diets such as vegetarian or gluten-free diets, if not carefully planned, may put an athlete at risk of problematic LEA due to these diets being low in energy density and high in fibre which may increase satiety and significantly impair an athlete's ability to meet adequate EI (Cialdella-Kam et al., 2016; Logue et al., 2019; Melin et al., 2016).

An intentional change in dietary intake is often due to a desire to change body composition (Wasserfurth et al., 2020). This is frequently seen in weight-sensitive sports where leanness or physique changes may be perceived as favourable for performance (Burke et al., 2018; Kuikman & Burke, 2023). For example, a study in ultramarathon runners found that half of both male and female runners reported trying to lose weight for performance (Høeg et al., 2022), and in another study, the majority of female ultramarathon runners believed their weight was related to their running performance, and restrictive eating was reported by nearly half of the participants (Folscher et al., 2015). Athletes may also alter their dietary behaviours due to pressure to look a certain way, with perceived appearance related pressure reportedly from their coach, teammates, and social media (Heather et al., 2021; Wasserfurth et al., 2020). An athlete may intentionally restrict food intake to manipulate body composition but may not have the nutritional skills and knowledge to do this in a safe way which results in the athlete resorting to pathogenic weight loss methods such as skipping meals, limiting calories or specific nutrients or food groups (Tam et al., 2021; Turocy et al., 2011). In some cases, individuals with DE patterns may develop an ED such as anorexia or bulimia which can result in severe problematic LEA (Kuikman & Burke, 2023; Nattiv et al., 2007). Therefore, athletes aiming to change body composition should ideally work alongside a sports dietitian or nutritionist to ensure their long-term health is not compromised (Kuikman & Burke, 2023).

While athletes participating in leanness sports are more likely to experience problematic LEA, athletes participating in any sport or strenuous physical activity can experience one or more consequences of problematic LEA (Nattiv et al., 2007; Torstveit & Sundgot-Borgen, 2005). Being an elite athlete has traditionally been seen as a risk factor for problematic LEA as elite athletes are exposed to extreme physical training efforts and physiological demands (Jesus et al., 2021). Nevertheless, recreational athletes have also been shown to be at risk of problematic LEA (Karlsson et al., 2023; Logue et al., 2019; Meng et al., 2020; Slater et al., 2016), as they can also be exposed to the same dietary and exercise behaviours as elite athletes but are more likely to lack the support of a coach or nutritionist (Slater et al., 2016).

Endurance athletes, both elite and recreational long-distance runners are recommended to follow official sports nutrition guidelines to meet their carbohydrate intake for fuel and recovery (Burke et al., 2007; Thomas et al., 2016). Recent research suggests low carbohydrate availability has an independent and additive effect on the development of problematic LEA (Lodge et al., 2023; Mountjoy et al., 2023). Some studies have found associations between problematic LEA and low carbohydrate intake, with athletes in a state of problematic LEA consuming significantly lower amounts of carbohydrates than those with optimal or sufficient EA (Magee et al., 2020; Reed et al., 2014). While suboptimal carbohydrate intake has been reported in both male and female athletes (Lohman et al., 2019; Viner et al., 2015), female athletes are reported to be less likely to achieve these carbohydrate guidelines than males (Burke et al., 2001; Matt et al., 2022). In addition, a study of the fuelling practices of 1,081 endurance athletes (Reinhard & Galloway, 2022) found that recreational athletes (10.2%) were less likely than amateur (28.9%) or professional athletes (40.0%) to use grams of carbohydrate per hour as a fuelling strategy. Therefore, evidence would suggest that education on the sports nutrition guidelines for recreational athletes is needed to help educate and prevent both low carbohydrate availability and problematic LEA risks.

2.5 Screening tools to identify athletes at risk of problematic low energy availability

To counter the challenges already identified in accurately measuring EA, several screening tools and questionnaires (such as the Low Energy in Females Questionnaire (LEAF-Q), Triad Cumulative Risk Assessment Tool (TCRAT)) have been developed to help identify individuals at risk of problematic LEA (Joy et al., 2014; Melin et al., 2014). However, not all available screening tools are validated (Sim & Burns, 2021). Of note, these screening tools should not be used for diagnostic purposes, instead they should be used to screen for risk of problematic LEA, in order to help identify individuals who should then be referred for clinical follow-up (Stellingwerff et al., 2023). The advantages of using screening tools include convenience, speed and a cost-effective way of assessing risk of problematic LEA in a large number of athletes (e.g. in sports teams where expensive equipment and know-how is not available) and therefore they are more readily used in epidemiological research (Sim & Burns, 2021). Many of the current screening tools isolate sexes and type of sport (e.g., male cyclists, female endurance athletes) which increases sensitivity of the tools but make them less applicable across multiple sports and sexes (Sim & Burns, 2021). Using a combination of a screening tools with a selection of biomarkers (e.g., reproductive hormone concentrations, Bone Mineral Density (BMD)) might provide a more accurate assessment of problematic LEA risk (Heikura et al., 2018; Logue et al., 2018). A recent review found that the most widely used validated questionnaire was the LEAF-Q (Sim & Burns, 2021).

2.5.1 Low Energy Availability in Females Questionnaire

The 25-item LEAF-Q was developed in 2014 in a sample of 84 female endurance athletes (mean age 26.6 ± 5.4) to help detect females 'at risk' of problematic LEA (Melin et al., 2014). This questionnaire is based on the physiological symptoms related to problematic LEA, not behaviours that may place an individual at risk of problematic LEA (Rogers et al., 2021; Sim & Burns, 2021). The instrument includes questions pertaining to injuries, gastrointestinal function, and menstrual function. Based on the total score of the three sections, a score of ≥8 is considered at risk of LEA and a score of <8 is considered as low risk (Melin et al., 2014). The LEAF-Q has an acceptable sensitivity (78%) and specificity (90%) when classifying female athletes at risk of problematic LEA (Melin et al., 2014). The questionnaire can be used as a stand-alone tool or in conjunction with ED/DE screening tools such as the Eating Disorder Examination Questionnaire (EDE-Q). When used in conjunction with the EDE-Q the results can help identify females at risk of problematic LEA with or without an ED/DE (Logue et al., 2018; Sim & Burns, 2021).

Since its development, the LEAF-Q has been used in multiple studies with a range of female athletic populations including young endurance runners (Clark et al., 2018), older ultra-marathon athletes (Folscher et al., 2015), recreational exercisers (Logue et al., 2019; Slater et al., 2016), collegiate athletes (Magee et al., 2020), elite athletes (Ihalainen et al., 2021; Rogers et al., 2021), aesthetic sport athletes (Meng et al., 2020) and Australian rules football players (Condo et al., 2019). A recent validation study by Rogers et al. (2021) using a sample of mixed sport female elite and pre-elite athletes cohort (mean age 23, range 18-32), confirmed that the LEAF-Q can be administered in populations other than those for which it was originally validated (e.g. endurance athletes). This study also importantly highlighted that the LEAF-Q as a screening tool should only be used to rule out those at low risk of problematic LEA. This means that individuals scoring ≥8 cannot be considered as 'high risk' but should rather be considered as 'not low risk' and as a result should be referred for further clinical follow-up. Those scoring <8 have a low risk of consequences associated to problematic LEA.

2.5.2 Low Energy Availability in Males Questionnaire

With the LEAF-Q being widely used in research since 2014, there has been widespread interest in the development of an equivalent for males (Mountjoy et al., 2018). Previously, to counter for the lack of a Low Energy in Males Questionnaire (LEAM-Q), studies have used a range of inventive and unvalidated approaches to assess the risk of problematic LEA in males. Slater (2015) used the LEAF-Q but with the menstrual questions removed and an adjusted cut-off score for males. However, nearly half of the LEAF-Q items relate to menstrual function as a core feature of problematic LEA and there is no acceptable substitute for males in this modified method (Sim & Burns, 2021). Keay et al. (2018) developed a sport-specific questionnaire and clinical interview to assess problematic LEA; however, this was specific to cyclists and involved a time intensive approach. Kuikman et al. (2021) replaced the menstrual section with items around erectile dysfunction, and Fenton (2022) used the gastrointestinal section from the LEAF-Q in conjunction with the Sexual Desire Inventory and the Androgen Deficiency in Aging Males questionnaire. These screening methods reflect the increasing interest from researchers in the relationship of sex drive and libido as a proxy for exercise hypogonadal male condition and the potential associations with problematic LEA (Hackney, 2020; Lundy et al., 2022).

In 2022, the LEAM-Q was developed followed by attempted validation in a group of 352 male athletes (mean age 27.9 ± 6.9) representing a range of weight sensitive and non-weight sensitive sports (Lundy et al., 2022). The questionnaire consisted of 42 content-validated questions covering dizziness, gastrointestinal function, thermoregulation, injury and illness, wellbeing and recovery (fatigue, fitness, sleep, recovery) energy levels, and sex drive. Thermoregulation and sleep scores were excluded from further analysis as they were not associated with any problematic LEA clinical markers. The sex drive questions were not included initially due to the personal nature of these questions; however, they were added in later to improve the sensitivity of the questionnaire. Ultimately, it was only the sex drive questions that were able to distinguish between problematic LEA cases or controls and showed perturbations in key clinical markers (e.g., total testosterone, triiodothyronine, insulin and free testosterone:cortisol ratio) (Lundy et al., 2022). To our knowledge, few studies have to date utilised the LEAM-Q due to its recent development (Mathisen et al., 2022; Tan, 2022). The varying approaches used to assess the risk of problematic LEA in males in previous research have therefore limited the ability to compare results and further research studies using the LEAM-Q are warranted.

Limitations of using the LEAF-Q/LEAM-Q include the very personal nature of some of the questions such as describing stool type and frequency, menstrual function, use of contraceptives (Melin, 2013), and sex drive questions (Lundy et al., 2022), which can be considered sensitive and intimidating to some people, especially in some cultures. The self-report nature of the questionnaire can lead to response bias and under-reporting (Sim & Burns, 2021). Inaccurate reporting of menstrual status may be an issue as not all females have the required menstrual health literacy to know what is considered a 'normal' menstrual cycle (Coombes, 2022), and the accuracy of self-reports of sex drive has not yet been established (Lundy et al., 2022). The age of participants could also be a limiting factor on the LEAF-Q/LEAM-Q scoring as increased age lowers sex drive in males, and females enter peri- and post-menopause and cease to have a regular menstrual cycle. Table 2 provides an overview of advantages and limitations of using the LEAF-Q/LEAM-Q.

Table 2: Advantages and disadvantages of screening tools (LEAF-Q/LEAM-Q)

Advantages	Disadvantages
• Convenience, speed	• Sex specific
• Little respondent burden	• Self-report: recall bias, under-reporting
• Reach large cohorts	• Self-completion: understanding and honesty
• Research and practice	• Not a diagnostic tool
• Cost-effective	• Sensitive questions, e.g. menstrual function, sex drive
• Can be used in conjunction with other tools (e.g., EDE-Q) and/or biomarkers	• Not validated in all age groups, types of sport, athlete levels (elite/recreational)
• Can be used across a variety of sports	• Inaccurate reporting of menstrual status
• Screening for risk only	• Need professional interpretation of results
• Paper or online survey	• No objective assessment of EA or biomarkers
• No need for expensive equipment e.g. DEXA	• Translation into other languages may need further validation
• English	

2.6 Research on problematic low energy availability in runners

Several studies have investigated either problematic LEA prevalence or the prevalence of relative risk of problematic LEA in runners. Study populations of interest have predominantly been younger (15-25 years) (Heikura et al., 2018; Matt et al., 2022), with only a few studies in runners aged ~40 years or older (Folscher et al., 2015; Høeg et al., 2022). Studies have primarily been conducted in competitive to elite runners (Høeg et al., 2022; Ihalainen et al., 2021), and in a range of different running categories such as cross-country, middle- and long-distance runners, and ultra-marathon runners (Beermann et al., 2020; Folscher et al., 2015; Goodwin et al., 2014). While most investigations on problematic LEA have focussed on females, those in runners do appear to have some studies including both sexes (Høeg et al., 2022; Jesus et al., 2021; McCormack et al., 2019). The interest in endurance running as a focus of problematic LEA studies may be related to the high EEE of these athletes that increases their risk of problematic LEA exposure (Folscher et al., 2015). Table 3 outlines a summary of research investigating problematic LEA in runners. A critical review of these studies is presented in the subsequent sections highlighting how moderating factors such as personal/demographic, training and nutritional characteristics may influence results from research on problematic LEA in runners (Mountjoy et al., 2023).

2.6.1 Personal and demographic characteristics

The number of studies on the prevalence of problematic LEA risk in runners are primarily completed in females, an outcome that is likely the result of the LEAF-Q being developed and verified in this cohort ~8 years prior to the LEAM-Q. As such, research including both female and male participants, may have excluded the males from this specific component of the results (Heikura et al., 2018), or have adapted the LEAF-Q scoring for males (Jesus et al., 2021; Schimek et al., 2021). For example, Jesus et al. (2021) adapted the LEAF-Q score for males to ≥7 (≥8 for females) and reported that 54.0% of male and 79.5% of female elite cross-country athletes were 'at risk' of problematic LEA; however, due to the LEAF-Q scoring for males not being validated this is not considered a reliable comparison. Both these practices have made for limited research comparisons and reduced result validity which should be taken into consideration when reviewing these studies.

Research investigating prevalence of problematic LEA risk or problematic LEA prevalence have predominantly been conducted with Caucasian participants (Mountjoy et al., 2014). However, there has been some interest from researchers in studying problematic LEA in Kenyan distance runners as these runners have been shown to have very low EI (Õnnik et al., 2022). It has been noted that more diverse athlete populations need to be included in future REDs research (Mountjoy et al., 2018). Research on problematic LEA in female runners have found varying degrees of prevalence levels among geographical locations. Heikura et al. (2018) found overall prevalence of 31% in a cohort of elite middle- and long-distance runners from Finland, Canada, Australia and the US; whereas Kinoshita et al. (2021) reported 33.3% prevalence in Japanese adolescent competitive middle- and long-distance runners, and Goodwin et al. (2014) found prevalence rates as high as 56% in elite Kenyan middle- and long-distance runners. It is evident that variability of LEA prevalence exists among these varying populations, however whether these results were affected by race or ethnicity factors remains unknown. These results reaffirm the current REDs consensus statement that individual characteristics (e.g., sex, age, genetics) need to be considered when reviewing problematic LEA.

Table 3: Summary of studies investigating problematic low energy availability in runners

Study	Population Sex, n (mean age (years) ± SD or range)	Runner characteristics	Methods	Prevalence of problematic LEA risk*	Problematic LEA prevalence**	Notes
(Dervish et al., 2023)	F: 524 (18-40+)	Endurance runners Competitive/ Recreational, UK	LEAF-Q, FAST	47.3% (248)	N/A	LEA risk: recreational 45.4%; competitive 53.7%
(Karlsson et al., 2023)	F: 85 (32.4±4.3)	Active runners Recreational, Sweden	EDE-Q, LEAF-Q	19% (16)	N/A	LEAF-Q score based on ≥8 with injury score ≥2 and/or MD score ≥4 (only subjects without contraceptive use)
(Høeg et al., 2022)	F: 40 (41.8±7.6) M: 83 (46.2±10.3)	Ultra-marathon runners (100-mile trail race) Professional/ Competitive, USA	TCRAT, EDE-Q, menstrual history, anthropometry, blood samples	F: 22.5% (9) high risk, 40% (16) mod risk, 37.5% (15) low risk M: 9.6% (8) high risk, 34.9% (29) mod risk, 55.4% (46) low risk	N/A	NB only trail running study. TCRAT Score: Moderate risk: F: 61.1% (22), M: 29.2% (21) High risk: F/M: 5.6% (2/4)
(Matt et al., 2022)	F: 60 (15.7±1.1) M: 12 (15.8±1.5)	Endurance runners (cross country, track and field) High school/ Competitive, USA	Block FFQ, anthropometry, EEE via heart rate monitor/running mileage, VO_2Max	N/A	F: 60% (33) M: 30% (3)	Two cohorts (2008/2017) combined data
(Ihalainen et al., 2021)	F: ATH: 13 (19.6±2.3) CON: 8 (21.4±1.1)	Elite endurance runners (800m to 5K events) Finland	LEAF-Q, anthropometry, VO_2Max, daily training logs, 7-day food diaries	LEAF-Q mean scores: ATH (12.4±5.2) vs. CON (6.4±4.3, *P*<.028)	8% (1)	No difference between groups for EA (ATH vs. CON)
(Jesus et al., 2021)	F: 83 (21.8±4.0) M: 124 (22.3±4.1)	Elite cross-country athletes, Portugal	LEAF-Q	F: 79.5% (66) M: 54.0% (67)	N/A	LEAF-Q: Used cut-off of ≥7 for males
(Kinoshita et al., 2021)	F: 18 (16.8±0.9)	Middle- and long-distance runners High school/ Competitive, Japan	7-day diet records, training logs, RMR, anthropometry, VO_2Max, menstrual history	N/A	33.3% (6)	50% were AME but no significant difference between LEA groups
(Schimek et al., 2021)	F: 10/M:3 (19.8)	Long-distance runners College, USA	LEAF-Q, EAT-26, 3-day food diary and exercise log, anthropometry	54% (F/M) (7)	46% (6)	Only combined results on LEA for F/M; LEAF-Q cut-off for males ≥3.2

(Beermann et al., 2020)	F: 20 (20.2±1.7) M: 21 (19.6±1.2)	College (Division I) cross country runners, USA	Block FFQ, anthropometry, training records	N/A	F: 41% (7) M: 45% (9)	EA did not differ between F/M
(Olcott & Anstrom, 2020)	F: 20 (19.9±1.3)	University level cross country runners, USA	LEAF-Q, SNKI	55% (11)	N/A	No difference in nutrition knowledge scores between the two groups (*p*=0.684)
(McCormack et al., 2019)	*ATH* F: 33 (20.3±1.8) M: 27 (19.7±1.2) *CON* F: 24 (19.8±0.6) M: 23 (20.0±0.8)	Cross-country runners College (Division I), USA	Block FFQ, EDE-Q, training logs, anthropometry	N/A	*ATH* F: 28.6% (8) M: 42.3% (11) *CON* F: 29.2% (7) M: 13.6% (3)	No difference in EA between ATH and CON (*p*>0.05). ATH had higher scores for dietary restraint than CON (F: *p*=0.008, M: *p*=0.001)
(Clark et al., 2018)	F: 15 (19-22)	Endurance runners (track and field 800m to 10K events) College (Division I), USA	LEAF-Q, EAT-26, anthropometry, blood samples, RMR, VO_2Max, 3-day diet record, accelerometer, heart rate monitor	40% (6)	53% (8)	40% (6) reported clinical MD and scored ≥8 on LEAF-Q and had LEA
(Heikura et al., 2018)	F: 35 (LEA: 25.0±4.5 / Mod EA: 25.9±3.5) M: 24 (LEA: 26.9±3.8 / Mod EA: 27.2±4.2)	Middle- and long-distance runners and race walkers National and world-class/Olympians Finland/USA	LEAF-Q, TCRAT, REDs Tool, 7-day food/training diaries, anthropometry, blood samples	LEAF-Q score: LEA group (11): 11.1±4.8 Mod EA group (24): 9.4±4.6	F: 31% (8) M: 25% (6)	LEAF-Q females only. TCRAT adapted for males; replace AME with low TES. 37% of females AME; 40% of males were low TES
(Folscher et al., 2015)	F: 306 (39.5±8.0)	Elite/recreational ultra-marathon athletes South Africa	LEAF-Q, FAST	44.1% (135)	N/A	Association between athletes with LEA risk and DE (X^2, *p*=0.014)
(Goodwin et al., 2014)	F: ATH: 25 (25±3.2) CON:14 (24±8.8)	Elite middle- and long-distance runners, Kenya	3-day food record, accelerometer, anthropometry, EDE-Q, 9-month menstruation log	N/A	ATH: 56% (14) CON: 7% (1)	EA was lower in long-distance (23.27±9.94) vs. middle-distance runners (33.26±11.02, *p*<0.001)

* LEAF-Q score ≥8; ** <30 $kcal \cdot kg^{-1} \cdot FFM^{-1} \cdot day^{-1}$; LEA risk values are presented as percentages (frequencies)

AME = amenorrheic; ATH = athletes; CON = controls; DE = Disordered Eating; DEXA = Dual-Energy X-ray Absorptiometry; EA = Energy Availability; EAT-26 = Eating Attitudes Test; EDE-Q = Eating Disorder Examination Questionnaire; EEE = Exercise Energy Expenditure; FAST = Female Athlete Screening Tool; FFQ = Food Frequency Questionnaire; LEA = Low Energy Availability; LEAF-Q = Low Energy Availability in Females Questionnaire; MD = menstrual dysfunction; REDs = Relative Energy Deficiency in Sport; RMR = Resting Metabolic Rate; SD = Standard Deviation; SNKI = Sports Nutrition Knowledge Instrument; TES = testosterone; TCRAT – Triad Cumulative Risk Assessment Tool

Research shows that any age group of runners is at risk of problematic LEA (Folscher et al., 2015; Kinoshita et al., 2021). There is no indication that age influences an individual's risk of LEA (Slater et al., 2016), and indeed most studies have failed to show an association between age and problematic LEA prevalence (Kinoshita et al., 2021; McCormack et al., 2019) or problematic LEA risk in runners (Jesus et al., 2021; Karlsson et al., 2023). Young collegiate cross-country or distance runners appear to be a common focus for problematic LEA studies, perhaps due to the relative ease of recruitment (Trakman et al., 2016). Studies in these younger runners have generally found relatively high problematic LEA prevalence levels (29-53%) (Clark et al., 2018; McCormack et al., 2019), and prevalence of problematic LEA risk (40-54%) (Clark et al., 2018; Schimek et al., 2021). These levels of problematic LEA are concerning especially in these young athletes who are still reaching their peak bone mass and suggests that attitudes towards a thin physique may be a common perception in these cohorts of competitive runners (Kinoshita et al., 2021). It is also likely that pressure to be lean and to improve performance puts these younger athletes at a higher risk of problematic LEA.

Conversely, studies in more mature adults have focussed on ultra-marathon athletes (Folscher et al., 2015; Høeg et al., 2022), which tend to be predominantly in the 40-49 year age bracket (Hoffman, 2008). Both studies investigated prevalence of problematic LEA risk (Folscher et al., 2015; Høeg et al., 2022). Folscher et al. (2015) reported that 44.1% of female ultra-marathon athletes were at risk based on a LEAF-Q score of ≥8. Whereas Høeg et al. (2022) classified 61.1% of females and 29.2% of males as moderate risk and 5.6% of both females and males as high risk based on the TCRAT. Of note, being of mature age, especially for females, may impact results from studies using the TCRAT, LEAF-Q, and DEXA. This is due to the primary risk factor considered in these questionnaires being the individual's menstrual status and bone mineral density (BMD) z-scores. During peri- and post-menopause, natural declines in reproductive function and reproductive hormones will reduce the occurrence of menstrual bleeds and are associated with declines in BMD (Nattiv et al., 2007). Therefore, research that has used these screening tools may not be sensitive in determining problematic LEA risk in this age group of females, and future research may need to consider alternative methods to increase the validity of their results.

2.6.2 Training characteristics

In the literature, increased training volume has been associated with an increased risk of problematic LEA (Logue et al., 2019; Slater et al., 2016). In runners, this has also been reported in both elite (Heikura et al., 2018) and recreational athletes (Karlsson et al., 2023). However, not all studies agree with these findings (Jesus et al., 2021). Inconsistent results may also be due to the variations in the type of running (e.g. distance, intensity), level of athlete (elite, recreational) and personal characteristics such as genetics which may offer additional risk to one athlete while being protective to another (Mountjoy et al., 2023).

Karlsson et al. (2023) reported that female recreational runners at risk of problematic LEA trained more compared with those not at risk (7 hours per week vs. 4.5 hours per week). Heikura et al. (2018) found that elite distance runners with problematic LEA ran significantly more kilometres per week compared to runners with moderate EA. In a study of elite female Kenyan distance runners, of the 14 athletes who had problematic LEA, 11 were long-distance and 3 were middle-distance runners, and the average EA was lower in long-distance runners (23.3 ± 9.9 kcal·kg^{-1}·FFM^{-1}·day^{-1}) versus mid-distance runners (33.3 ± 11.0 kcal·kg^{-1}·FFM^{-1}·day^{-1}) (Goodwin et al., 2014). Inference from these results would suggest that longer distances which means higher training volumes are likely associated with an increased risk of problematic LEA. It could also be considered that it is not the training volume per se that influences problematic LEA risk but the athlete's lack of nutrition knowledge in terms of the high energy cost of exercise and how to appropriately fuel for the work completed.

2.6.3 Nutritional characteristics

Dietary composition has long been speculated as a potential moderating factor for problematic LEA (Areta et al., 2021). Factors such as macro- and micronutrient composition, nutrient timing, and carbohydrate availability may have an exacerbating or protecting effect on the development of problematic LEA (Areta et al., 2014; Melin et al., 2016). In addition, current carbohydrate guidelines for athletes have been critiqued for failing to consider the unique physiology of females (e.g. influence of reproductive hormones on carbohydrate oxidation rates) which may put female athletes at higher risk of problematic LEA (Lodge et al., 2023). Some of the studies investigating problematic LEA prevalence in runners have reported low carbohydrate intakes (Beermann et al., 2020; Matt et al., 2022). Beerman et al. (2020)

investigated EA in collegiate distance runners and reported problematic LEA in 45% of males and 41% of females; a further 35% and 41% respectively had suboptimal EA. Nearly three quarters of all athletes in this study (73%) consumed less than the recommended carbohydrate intake (6-10g·kg^{-1}BW) for high-intensity endurance athletes, with females (85%) being more likely to not meet the recommended intake than males (62%). Matt et al. (2022) reported problematic LEA prevalence rates of 30% in male and 60% in female competitive adolescent endurance runners. Specifically, it was observed that both females and males had below the recommended intake of fruit, vegetables, dairy, and grains which would contribute to the nutritional risk of problematic LEA. Less than 30% of these young endurance runners met carbohydrate guidelines with females again being more likely than males to not meet carbohydrate needs. Both male and female athletes in these studies may have inadequate knowledge of the increased carbohydrate needs of endurance runners and therefore could benefit from nutrition education to promote health and performance (Matt et al., 2022). As nutrition knowledge was not assessed when reviewing EI and carbohydrate intake in these previous studies, the association between problematic LEA and/or low carbohydrate intake with nutrition knowledge remains to be investigated.

Moderating factors may also refer to behaviours that impact EI such as restrictive eating behaviours and weight loss practices (Mountjoy et al., 2023). Indeed, while problematic LEA can occur without ED/DE and with stable BW (Statuta, 2020), the risk of problematic LEA is often associated with restrictive eating behaviours and recent weight loss (Mountjoy et al., 2018). Few studies investigating the prevalence of problematic LEA risk in runners have reported on associations between the risk of problematic LEA and restrictive eating and weight loss practices (Folscher et al., 2015; Jesus et al., 2021). Folscher et al. (2015) reported a positive association between runners at risk of problematic LEA and DE behaviours with one-third (32%) of female ultra-marathon runners demonstrating DE behaviours, nearly half (47.7%) reporting restrictive eating behaviours, and 44.5% limiting carbohydrate intake. Jesus et al. (2021) found that elite male and female cross-country runners who reported a weight change of >3kg in the previous 3 months (70.8%) were more likely to be at risk of problematic LEA compared to those athletes who did not report a weight change (57.4%). Overall, these studies support the current REDs position statement that dietary and nutritional characteristics may act as moderating factors that influence an athlete’s risk of developing problematic LEA, and therefore these factors must be investigated and controlled for in future research studies.

2.7 Nutrition knowledge

General nutrition knowledge is the knowledge around nutrition and health including nutrients, dietary guidelines, and the links between diet and disease (McKinnon et al., 2014). Sports nutrition knowledge extends upon this and includes nutrition that can affect training, sports performance and recovery (Klein et al., 2021). Athletes need to understand basic nutrition knowledge to enable them to eat a healthy, balanced diet and when this is combined with sports-specific nutrition knowledge it may support them in optimising their training and performance (Thomas et al., 2016). Several studies have investigated the level of nutrition knowledge of athletes (Heaney et al., 2011; Janiczak et al., 2022; Trakman et al., 2016). A review by Trakman et al. (2016) found that elite athletes had better knowledge than non-elite, possibly a result of their access to accurate nutrition resources and support. Several studies have identified 'supplement use' as an area where nutrition knowledge is lacking in athletes (Condo et al., 2019; Janiczak et al., 2022; Lohman et al., 2019). The review by Trakman et al. (2016) found inconsistent evidence around whether athletes have better nutrition knowledge than the general population, and whether sex or type of sport affects nutrition knowledge. Regardless, some studies have found that females tend to have higher nutrition knowledge scores than males (Heaney et al., 2011). It should also be noted that studies have used different and/or unvalidated instruments to determine both general and sports nutrition knowledge, which limits comparability (Heaney et al., 2011; Janiczak et al., 2022; Tam et al., 2019). Within the available research, higher nutrition knowledge has been linked to better diet quality (Klein et al., 2021), a result evident in both the general population as well as in elite athletes (Spronk et al., 2015; Spronk et al., 2014). However, it should be noted that where nutrition knowledge has been shown to improve diet quality there seems to be only weak positive associations (Heaney et al., 2011; Janiczak et al., 2022; Spronk et al., 2014).

Several validated instruments have been developed to assess nutrition knowledge (Tam et al., 2022). An 88-item sports nutrition knowledge questionnaire developed by Zinn, Wall and

Schofield (2005) showed good construct validity and test-retest reliability and covered both general and sports nutrition knowledge concepts. It was validated in nutrition students, dietitians, and university business staff, but not in athletes. Since then several instruments have been developed and validated in groups of athletes, for example in non-elite football and netball athletes (Trakman et al., 2018), in young endurance athletes and their coaches (Heikkilä et al., 2018), and adult athletes and registered dietitians (Karpinski et al., 2019). The most recent instrument was developed by Tam et al. (2021) and validated in Australian and New Zealand developmental athletes and sports dietitians. The final instrument consists of a 50-item online instrument that uses pictures to improve understanding of the questions (Platform to Evaluate Athlete Knowledge of Sports Nutrition Questionnaire (PEAKS-NQ)). The unique part of this questionnaire is that it is available online for practitioners and coaches to assess knowledge gaps in athletes and therefore can be a supportive tool in nutrition interventions, both in-field and in research.

While nutrition education interventions have been shown to improve nutrition knowledge in athletes (Valliant et al., 2012), the relationship between nutrition knowledge and problematic LEA is still subject to investigation (Magee et al., 2020). Few studies have investigated the relationship between the risk of problematic LEA and nutrition knowledge in athletes and of those that have, the results have been inconclusive. A study by Condo et al. (2019) assessed sports nutrition knowledge and the risk of problematic LEA in female Australian rules football players. The risk of problematic LEA was evident in 30% of players (assessed via LEAF-Q), and players answered 54.5% of sports nutrition knowledge questions correctly. No results were reported on associations between the risk of problematic LEA and knowledge scores. Magee et al. (2020) compared the risk of problematic LEA with nutrition knowledge in female collegiate soccer athletes and found that 56.3% were at risk of problematic LEA (based on LEAF-Q) and overall, 44.7% of the sports nutrition knowledge questions were answered correctly. In addition, they reported that those athletes who were at risk of problematic LEA scored lower on sports nutrition knowledge questions compared to athletes not at risk (40.9 ± 10.4% vs. 52.4 ± 9.8%). Olcott and Anstrom (2020) found that while 55% of female cross-country runners were at risk of problematic LEA, there were no significant differences in the sports nutrition knowledge between those at risk of problematic LEA and those not at risk. Similar findings were reported by two recent New Zealand studies on female athletes

(Coombes, 2022; Pai, 2023). To the best of our knowledge, no research to date has investigated the relationship between the risk of problematic LEA and nutrition knowledge in recreational trail runners, and therefore this remains an area in need of investigation.

2.8 Conclusion

Trail running is a demanding endurance sport growing in popularity. It is characterised by long event durations and extreme environments that are likely to result in high EEE. Insufficient EI, increased exercise, or a combination of both can increase the risk of being in a state of problematic LEA (Thomas et al., 2016). Short-term, adaptable LEA may be useful as a tool to enhance training adaptations in athletes, whereas long-term problematic LEA is likely to result in detrimental consequences to the athletes' health and performance, known as REDs (Mountjoy et al., 2023). However, it is critical that athletes, coaches, and healthcare professionals are educated around the signs and symptoms of REDs to be able to identify these for early diagnosis, support, and treatment. Despite the considerable variation in study designs of research on problematic LEA, there appears to be a high prevalence of problematic LEA in endurance sports such as running (Heikura et al., 2018). Research also shows that problematic LEA risk is present in recreational runners (Karlsson et al., 2023). Runners may be influenced by the 'leaner is better' stereotype which may (in)advertently result in insufficient EI, increased exercise, or a combination of both, placing them at risk for problematic LEA and the subsequent adverse outcomes of REDs. Research shows that nutrition knowledge among athletes needs improving as this may be an important moderating variable for the prevention and treatment of problematic LEA, the aetiology of REDs. However, the association between increased nutrition knowledge and better diet quality is still uncertain (Heaney et al., 2011). Little is known about the risk of problematic LEA and nutrition knowledge in recreational trail runners. Future research should address this to support the health and performance of recreational trail runners and the provision of nutrition education where required.

Chapter 3: Manuscript

3.1 Abstract

The aim of this study was to determine the risk of problematic low energy availability (LEA) prevalence in recreational trail runners in Aotearoa/New Zealand and investigate associations with nutrition knowledge. Risk of problematic LEA was assessed using the Low Energy Availability in Females Questionnaire (LEAF-Q), and the Low Energy Availability in Males Questionnaire (LEAM-Q). Nutrition knowledge was measured via the Platform for Evaluating Athlete Knowledge in Sports Nutrition Questionnaire (PEAKS-NQ). Demographics and trail-running experience questions were integrated into the survey. Comparisons between groups (e.g. 'low LEA risk' vs. 'LEA risk') were performed using a chi-square test for categorical variables, and an independent samples t-test for continuous variables. The final sample was 217 (140 females, 42.0 ± 10.7 years; 77 males, 47.9 ± 12.1 years) for the LEAF-Q, LEAM-Q, and trail running questions; and 152 for the PEAKS-NQ. Thirty-one percent of females were classified as 'LEA risk'. Twenty-three percent of males were identified as having low sex drive, a marker of LEA risk. There was no difference between nutrition knowledge and risk of problematic LEA in both sexes. Sports nutrition knowledge sections that participants scored poorly included the use of supplements, strategies for gaining lean mass and fuel for during events. The findings suggest that recreational trail runners are at risk of problematic LEA and might benefit from more sports-specific nutrition education.

3.2 Introduction

Trail running is increasing in popularity, and has seen an annual growth in participation of 15% since the mid-1990s (World Athletics, 2021). This endurance sport is characterised by high exercise energy expenditure (EEE) which can be exacerbated as events often take place in extreme environments (e.g., forests, mountains, deserts) and have long event durations (Scheer et al., 2020). Distance runners, which includes trail runners, tend to have high training volumes and participate in multiple events throughout the year (McKay et al., 2019; Melin et al., 2019). Trail runners therefore need to make sure that they have sufficient energy intake (EI) to support both training and physiological functions to ensure adequate energy availability (EA) (Melin et al., 2019). Failure to do so may result in the athlete entering a state of low energy availability (LEA) which if severe or prolonged may lead to an increased risk of problematic LEA. Problematic LEA can have a multitude of health, physiological and performance consequences as defined by the syndrome, Relative Energy Deficiency in Sport (REDs) (Mountjoy et al., 2023).

Athletes who participate in weight-sensitive sports where leanness is seen as favourable for performance, such as running, may be at increased risk of problematic LEA (Burke et al., 2018; Kuikman & Burke, 2023). Running is commonly seen as a sport where 'leaner is better' and hence trail running athletes may feel pressure to maintain a lean physique (Burke et al., 2007). This can lead to intentional under fuelling which may put the athlete at risk of problematic LEA. Distance runners, such as trail runners, often have periods of intense training throughout the year where they may unintentionally fail to meet their required EI (Kuikman & Burke, 2023). In addition, endurance athletes may experience exercise induced appetite suppression resulting in inadequate EI around training (Loucks, 2007).

Previous research in runners have reported problematic LEA risk prevalence of 19-80% in females (Jesus et al., 2021; Karlsson et al., 2023) and 10-54% in males (Høeg et al., 2022; Jesus et al., 2021). While most research has been undertaken with elite athletes, the risk of problematic LEA prevalence has also been evidenced in recreational runners (Dervish et al., 2023; Karlsson et al., 2023). Other studies have similarly reported evidence that recreational exercisers may be at an increased risk of problematic LEA with risk prevalence rates of 40-45% (Logue et al., 2019; Meng et al., 2020; Slater et al., 2016). One reason for this may be that recreational athletes do not have the same access to support staff such as coaches and nutritionists as elite athletes do (Slater et al., 2016; Stellingwerff et al., 2021). Previous research has identified possible risk factors for problematic LEA in athletes including but not limited to age, education, body mass index (BMI), weekly training volume, level of experience and nutrition knowledge (Dervish et al., 2023; Jesus et al., 2021; Magee et al., 2020; Slater et al., 2016). Having appropriate knowledge and skills to optimise nutrition for training and performance may help reduce the risk of problematic LEA (Kuikman & Burke, 2023). However, few studies have investigated the relationship between problematic LEA risk and nutrition knowledge in athletes and results have so far been inconclusive (Coombes, 2022; Magee et al., 2020).

To our knowledge, the associations between nutrition knowledge and the risk of problematic LEA in recreational trail runners have not been investigated. Therefore, this study aims to a) determine the prevalence of recreational trail runners at risk of problematic LEA in Aotearoa/New Zealand; b) describe associations between risk of problematic LEA and demographic factors e.g., age, education, BMI, weekly training hours and level of experience in recreational trail runners; and c) determine the association between nutrition knowledge and problematic LEA risk.

3.3 Methods

3.3.1 Participants and recruitment

This study was conducted with recreational trail runners in Aotearoa/New Zealand. Recruitment was done with the assistance of two key New Zealand trail organisations: Total Sport and Wild Things who shared the recruitment advertising through their email newsletters and social media platforms. Data was collected between June and December 2022. Participants completed an online screening questionnaire to determine eligibility for the study, and if eligible, they then were asked to read the attached information sheet and complete an online consent form. To be included in the study, participants had to be aged 16 years or over, be based in Aotearoa/New Zealand, and train for trail running or walking for at least 2½ hours per week (including running/walking and other exercise such as strength training). This cut-off was based on the minimal physical activity recommendations for adults (Ministry of Health, 2023). After signing the consent form, participants were asked to complete two anonymous online surveys, hosted on the Qualtrics^{XM} Survey Software (Qualtrics, Provo, UT). The study received ethics approval from the Massey University Human Ethics Committee: Northern (22/24).

3.3.2 Study design and questionnaires

This cross-sectional study used two online surveys comprised of validated questionnaires that assessed problematic LEA risk (Lundy et al., 2022; Melin et al., 2014) and general and sports nutrition knowledge (Tam et al., 2021). The anonymous online surveys were in two parts: Part 1 was comprised of demographic and general trail running questions (e.g. weekly training hours, level of experience) and concluded with the Low Energy Availability in Females/Males Questionnaires (LEAF-Q/LEAM-Q), and Part 2 consisted of the Platform for Evaluating Athlete Knowledge in Sports Nutrition Questionnaire (PEAKS-NQ). Part 1 and 2 were on two separate Qualtrics platforms as PEAKS-NQ was already available online. Participants were given a personalised numerical code at the end of Part 1 which they were instructed to enter at the start of Part 2, to help researchers link their responses from the two surveys. All responses collected were anonymous and no personal identification data was obtained from participants.

3.3.3 Low Energy Availability in Females Questionnaire

The LEAF-Q is a validated 25-item questionnaire to assess the relative risk of problematic LEA in female athletes (Melin et al., 2014). The LEAF-Q consists of three sections, (i) injuries; (ii) gastrointestinal function; and (iii) menstrual function and use of contraceptives. The LEAF-Q should only be used to identify those at low risk of problematic LEA (Melin, 2013; Rogers et al., 2021). Participants scoring <8 were considered to have a low risk of consequences associated with problematic LEA (i.e. 'low LEA risk'). Participants scoring ≥8 could not be considered as 'high risk' but instead were classified as 'LEA risk'. Minor edits to sentence structure were made to enhance the readability and understanding of the questionnaire for the participants.

3.3.4 Low Energy Availability in Males Questionnaire

The LEAM-Q is a 42-item questionnaire developed based on the LEAF-Q to measure symptoms of problematic LEA in males (Lundy et al., 2022). The questionnaire covers questions related to dizziness, gastrointestinal function, thermoregulation, injury and illness, wellbeing, and recovery (including fatigue, fitness, sleep, and recovery), energy levels, and sex drive. A multi-country validation study with males from different sports, however, found that thermoregulation and sleep were not related to any clinical markers, and only the sex drive questions were able to distinguish between problematic LEA cases and controls (Lundy et al., 2022). The sex drive section included four questions about general sex drive and morning erections and were ranked on a 4-point Likert scale. Low sex drive was identified as scoring ≥2 on "sex drive in general" or ≥2 on "the number of morning erections" and ≥1 for "morning erections compared to normal" (a higher score indicated lower sex drive). These results were then grouped into either low or normal libido and served as an indicator of symptoms of problematic LEA. In this study, we included all sections apart from thermoregulation and sleep in the online questionnaire and used only the sex drive section to assess the risk of problematic LEA as per Lundy et al.'s (2022) scoring criteria.

3.3.5 Platform for Evaluating Athlete Knowledge in Sports Nutrition Questionnaire

The PEAKS-NQ is a validated 50-item online instrument measuring general and sports nutrition knowledge in athletes (Tam et al., 2021). It has a maximum score of 75 across the two sections. The questionnaire is unique in that it visually uses pictures and food photography to improve understanding of the questions. It is available online for practitioners and coaches to assess knowledge gaps in athletes and therefore can be a supportive tool in nutrition interventions, both in the field and in research (https://sportsnutritionassessment.com/peaks-nq).

3.3.6 Statistical analysis

Data was exported to SPSS version 29 (IBM Statistics) for analysis. Normal distribution of the data was assumed based on the Central Limit Theorem. Descriptive statistics are presented as mean ± standard deviation. Independent samples t-tests were used to compare between groups (e.g., 'low LEA risk' vs. 'LEA risk') for continuous variables, and chi-square tests were used to compare categorical variables. Statistical significance was set at a level of P <.05.

3.4 Results

Two hundred and fifty-nine trail runners completed the survey of which 42 responses were excluded due to duplicate or incomplete responses. The sample characteristics of 217 female and male trail runners by categorisation of either low LEA risk or LEA risk are presented in Table 4. Participants were predominantly of New Zealand European ethnicity (female 81.2%; male 92.2%), and most participants (97.0% of females; 90.2% of males) had completed tertiary education. The majority of female (91.4%) and male (83.1%) participants regularly completed other training activities such as strength training (81.0%) and flexibility (50.4%) for females, and strength training (68.3%) and cycling (65%) for males. A total of 43 female participants (30.7%) and 18 male participants (23.4%) were classified with LEA risk according to the LEAF-Q/LEAM-Q scoring systems. Education, BMI, weekly training hours and level of trail running experience did not differ between trail runners with LEA risk or low LEA risk. Compared to females with low LEA risk, females with LEA risk were younger (38.0 ± 12.6 vs. 43.6 ± 9.5, $P = .038$) and more likely to report a weight change in the last six months (75.9% vs. 40.3%, $P = .001$). Males with low LEA risk more readily reported a chronic illness (23.5% vs. 6.8%, $P = .047$) or food allergy/intolerance (27.7% vs. 8.6%, $P = .036$), when compared to male participants with LEA risk.

Table 4 : Participant characteristics

	Females (n=140)	Low LEA Risk (n=97, 69.3%)	LEA Risk (n=43, 30.7%)	Males (n=77)	Low LEA Risk (n=59, 76.6%)	LEA Risk (n=18, 23.4%)
Age# (years)	42.0 ± 10.7	43.6 ± 9.5*	38.0 ± 12.6	47.9 ± 12.1	47.8 ± 12.7	48.1 ± 9.9
Height# (cm)	165.9 ± 6.2	165.2 ± 6.1	167.7 ± 6.2	178.3 ± 5.3	178.2 ± 5.7	178.8 ± 3.6
Weight# (kg)	64.2 ± 10.1	64.3 ± 10.5	64.0 ± 9.1	79.8 ± 11.6	77.5 ± 8.1	88.0 ± 17.9
BMI# (kg/m^2)	23.3 ± 3.4	23.5 ± 3.4	22.8 ± 3.4	25.1 ± 3.7	24.4 ± 2.5	27.6 ± 6.1
Highest level of education#:						
Secondary School	3 (3.0)	3 (4.2)	-	5 (9.8)	3 (7.5)	2 (18.2)
Tertiary	98 (97.0)	69 (95.8)	29 (100.0)	46 (90.2)	37 (92.5)	9 (81.8)
Employment status#:						
Full time	51 (50.5)	38 (52.8)	13 (44.8)	39 (76.5)	31 (77.5)	8 (72.7)
Other (e.g., self-employed, part-time)	50 (49.5)	34 (47.2)	16 (55.2)	12 (23.5)	9 (22.5)	3 (27.3)
Level of trail runner:						
Beginner	8 (5.8)	7 (7.4)	1 (2.4)	-	-	-
Beginner-Intermediate	23 (16.8)	17 (17.9)	6 (14.3)	7 (9.3)	4 (7.0)	3 (16.7)
Intermediate	45 (32.8)	30 (31.6)	15 (35.7)	29 (38.7)	20 (35.1)	9 (50.0)
Intermediate-Experienced	49 (35.8)	31 (32.6)	18 (42.9)	30 (40.0)	25 (43.9)	5 (27.8)
Very Experienced	12 (8.8)	10 (10.5)	2 (4.8)	9 (12.0)	8 (14.0)	1 (5.6)
Total weekly training hours (running and other training)	9.3 ± 4.4	9.4 ± 4.6	9.0 ± 3.9	8.0 ± 3.8	7.8 ± 3.8	8.6 ± 4.0
Years trail running:						
< 1 year	6 (4.3)	5 (5.2)	1 (2.3)	3 (3.9)	3 (5.1)	-
1 year to 4 years 11 months	53 (38.1)	36 (37.5)	17 (39.5)	31 (40.3)	21 (35.6)	10 (55.6)
5 years to 9 years 11 months	32 (23.0)	20 (20.8)	12 (27.9)	17 (22.1)	15 (25.4)	2 (11.1)
10 years or more	48 (34.5)	35 (36.5)	13 (30.2)	26 (33.8)	20 (33.9)	6 (33.3)
Usual trail event distances†:						
Short (5-9km)	21 (15.6)	17 (17.9)	4 (10.0)	7 (9.7)	7 (12.7)	-
Mid (10-15km)	52 (38.5)	35 (36.8)	17 (42.5)	15 (20.8)	14 (25.5)	1 (5.9)
Long (16-21km)	78 (57.8)	53 (55.8)	25 (62.5)	25 (34.7)	19 (34.5)	6 (35.3)
Super long (21.1-42.2km)	85 (63.0)	56 (58.9)	29 (72.5)	45 (62.5)	34 (61.8)	11 (64.7)
Ultra (42.3+km)	67 (49.6)	53 (55.8)	14 (35.0)	43 (59.7)	32 (58.2)	11 (64.7)
100km	19 (14.1)	14 (14.7)	5 (12.5)	18 (25.0)	14 (25.5)	4 (23.5)

100 miler 24-hour races Other	10 (7.4) 8 (5.9) 4 (2.9)	8 (8.4) 6 (3.6) 2 (2.2)	2 (5.0) 2 (5.0) 2 (5.0)	6 (8.3) 5 (6.9) 2 (2.8)	5 (9.1) 4 (7.3) 2 (3.6)	1 (5.9) 1 (5.9) -
Longest distance completed in trail event (km)	62.0 ± 55.4	66.6 ± 61.2	51.3 ± 36.6	72.2 ± 46.9	71.3 ± 45.0	75.6 ± 54.2
Highest level competed for your sport#						
Recreational	66 (65.3)	50 (69.4)	13 (44.8)	37 (72.5)	28 (70.0)	9 (81.8)
Other e.g., regional, national	35 (34.7)	22 (30.6)	16 (55.2)	14 (27.5)	12 (30.0)	2 (18.2)
Weight change in last 6 months#	51 (50.5)	29 (40.3)*	22 (75.9)	23 (45.1)	17 (42.5)	6 (54.5)
Have a chronic illness	14 (10.0)	87 (89.7)	39 (90.7)	8 (10.5)	4 (6.8)*	4 (23.5)
Have a food allergy/intolerance	37 (26.4)	23 (23.7)	14 (32.6)	10 (13.2)	5 (8.6)*	5 (27.8)

Note. Values are presented as mean ± standard deviation; frequencies (percentages)
† Multiple response option; # Missing data for these variables (PEAKS-NQ), n=101 female; n=51 male
*Difference between low LEA risk and LEA risk (*P* < .05)

Table 5 shows the total scores of each LEAF-Q/LEAM-Q section for female and male participants. The percentage of females with LEA risk did not differ greatly when females on hormonal contraception were excluded from the analysis (30.2%). Females with low LEA risk had significantly lower mean scores on all three sections of the LEAF-Q. For males with low LEA risk, significantly lower scores on the LEAM-Q were found in the gastrointestinal, fatigue, recovery, energy levels and sex drive sections.

Table 5: Risk of low energy availability (LEAF-Q/LEAM-Q)

	Females (n=140)	Low LEA Risk (n=97, 69.3%)	LEA Risk (n=43, 30.7%)	Males (n=77)	Low LEA Risk (n=59, 76.6%)	LEA Risk (n=18, 23.4%)
LEAF-Q score	6.0 ± 3.9	3.9 ± 2.3**	10.7 ± 2.3	-	-	-
LEAF-Q score (not on HC, n=96)	5.9 ± 3.7	4.0 ± 2.2 ** (n=67, 69.8%)	10.3 ± 2.4 (n=29, 30.2%)	-	-	-
LEAM-Q score	-	-	-	26.3 ± 12.3	23.0 ± 10.2**	37.2 ± 12.7
Injuries section	2.2 ± 2.1	1.4 ± 1.9**	3.8 ± 1.7	4.8 ± 3.7	4.6 ± 3.7	5.5 ± 3.7
Gastrointestinal section	1.8 ± 1.8	1.3 ± 1.5**	3.0 ± 2.1	1.3 ± 1.3	1.1 ± 1.2*	2.1 ± 1.6
Menstrual function and contraceptive use section	2.0 ± 2.5	1.2 ± 1.6**	3.9 ± 3.1	-	-	-
Dizziness section	-	-	-	0.7 ± 1.0	0.6 ± 0.8	1.1 ± 1.6
Fatigue section	-	-	-	4.3 ± 3.1	3.6 ± 2.6**	6.7 ± 3.5
Fitness section	-	-	-	5.6 ± 3.3	5.3 ± 3.1	6.6 ± 3.7
Recovery section	-	-	-	3.6 ± 2.2	3.2 ± 2.1*	4.7 ± 2.4
Energy levels section	-	-	-	3.9 ± 2.7	3.2 ± 2.4**	6.2 ± 2.5
Sex drive section	-	-	-	2.2 ± 1.9	1.5 ± 1.1**	4.5 ± 2.0

Note. Values are presented as mean ± standard deviation; HC = hormonal contraception
LEAF-Q score: Low LEA risk <8; LEA risk ≥8; LEAM-Q score: LEA risk = low sex drive score (≥2 on "Sex drive in general" or ≥2 on "The number of morning erections" and ≥1 for "Morning erections compared to normal".
*Difference between low LEA risk and LEA risk (P < .05); **Difference between low LEA risk and LEA risk (P < .001)

A total of 101 female and 51 male participants completed PEAKS-NQ (Part 2). Nutrition knowledge scores are presented in Table 6. Female participants were more likely to have received previous nutrition education (52.5%) compared to their male counterparts (27.5%). There were no difference found between LEA risk and nutrition knowledge for either females (*P* = .283) or males (*P* = .194). Participants scored highest on identifying the roles of micronutrients, food groups and training/competing in hot environments and lowest on understanding the roles of fat, and fuel for during events (Figure 3 and 4).

Table 6: Nutrition knowledge characteristics (% total score)

	Females (n=101)	Low LEA Risk (n=72, 71.3%)	LEA Risk (n=29, 28.7%)	Males (n=51)	Low LEA Risk (n=40, 78.4%)	LEA Risk (n=11, 21.6%)
General nutrition knowledge	78.6 ± 10.1	77.9 ± 9.7	80.4 ± 11.0	75.8 ± 10.7	77.2 ± 9.6	70.8 ± 13.2
Sports nutrition knowledge	66.3 ± 13.4	65.6 ± 12.6	68.0 ± 15.5	63.2 ± 15.5	64.1 ± 16.5	59.8 ± 11.3
Overall nutrition knowledge	72.0 ± 10.5	71.3 ± 9.8	73.8 ± 12.1	68.8 ± 11.8	70.0 ± 12.2	64.7 ± 9.8

Note. Values are presented as mean ± standard deviation

Figure 3: General nutrition knowledge scores (n=152)

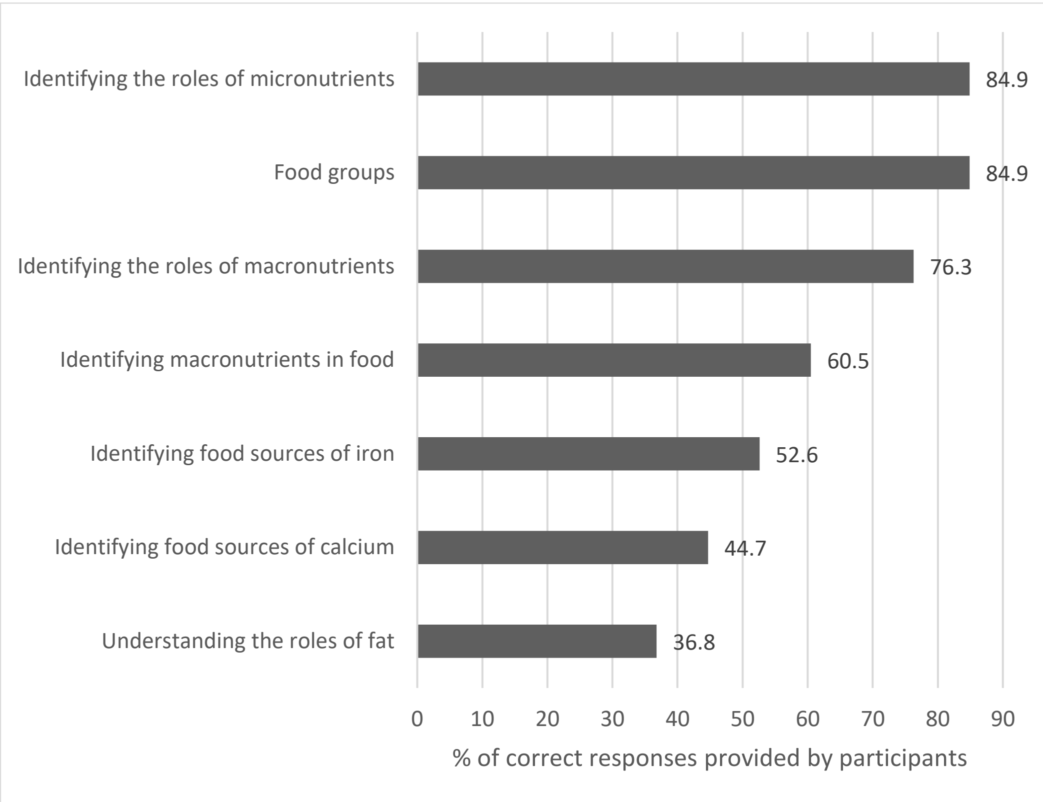
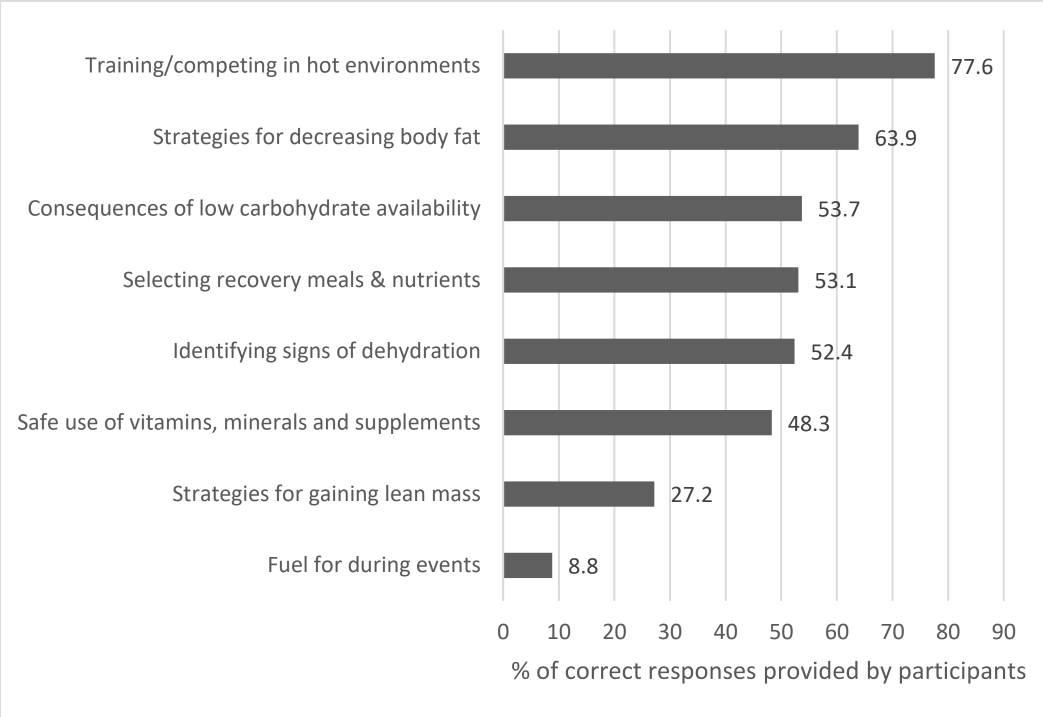


Figure 4: Sports nutrition knowledge scores (n=147)



3.5 Discussion

To our knowledge, this is the first study to investigate the prevalence of recreational trail runners at risk of problematic LEA in Aotearoa/New Zealand and the possible association between nutrition knowledge and problematic LEA risk. Approximately one-third (30.7%) of female and one-quarter (23.4%) of male participants were classified with problematic LEA risk when assessed through LEAF-Q and LEAM-Q respectively. Yet despite this high risk of problematic LEA, there was no difference between LEA risk and nutrition knowledge.

When comparing our results on problematic LEA risk to other studies on female athletes, results vary. Thirty-one percent of female recreational trail runners in the present study were classified with problematic LEA risk which is higher than the 19% which was recently reported in recreational female runners by Karlsson et al. (2023) and lower than the 45% reported by Dervish et al. (2023) in recreational female endurance runners. Similarly to Dervish et al. (2023), this current study recruited participants based on the volume of training hours which may help explain the difference between the results of these two studies and Karlsson et al. (2023) which did not have a weekly training cut-off. Endurance runners are often suggested to be at the highest risk of problematic LEA due to the high EEE (Folscher et al., 2015; Loucks, 2007). However, it could be expected that trail runners are at even higher risk due to the added challenges of extended race duration and environmental extremes (Scheer et al., 2020). Therefore, as a result, the subsequent training that trail runners may do could increase their risk of problematic LEA. This may help explain the difference between the results of this current study and the research by Karlsson et al. (2023) who looked at organised group running sessions, not trail runners. Dervish et al. (2023) included runners training for varying distances including half marathon and marathon/ultra and it is possible this may have included trail runners which could help explain the higher problematic LEA risk in their study.

The prevalence of problematic LEA risk has been more extensively investigated in females compared with males. As such, it becomes more difficult to make direct comparisons for our results on male trail runners. Our results showed that 23.4% of male trail runners were at risk of problematic LEA (based on low sex drive) which is almost identical to the results from the LEAM-Q validation study reporting 23.7% of participants categorised as having low sex drive (Lundy et al., 2022). From our knowledge, to date two studies have used the LEAM-Q (Mathisen et al., 2022; Tan, 2022). These studies have reported problematic LEA risk prevalence rates of 93% and 0%, respectively. Both studies were conducted in younger male athletes (age 20-30 years) and had small sample sizes (n=14-20) which may not have been sufficiently powered to effectively capture problematic LEA risk in these two cohorts. The LEAM-Q was validated in younger male elite and sub-elite athletes (mean age 27.9 ± 6.9) (Lundy et al., 2022) which is different to the cohort of this current study of recreational male athletes with a mean age of 47.9 ± 12.1. Furthermore, increasing age could affect the LEAM-Q sex drive scores as older males may be more likely to experience erectile dysfunction and lowered libido (Hackney et al., 2017; Panser et al., 1995). Further research is required to validate these findings using the LEAM-Q in similar aged runner cohorts.

Our results showed that education, BMI, weekly training hours and level of trail running experience did not differ between trail runners with LEA risk or low LEA risk in both sexes. Females with LEA risk were younger (38.0 ± 12.6 vs. 43.6 ± 9.4, $P < .05$), an outcome that aligns with Dervish et al. (2023) who reported that LEAF-Q categories differed based on age. In this previous research, a higher proportion of female athletes in the 18-24 age group presented with a risk of problematic LEA compared to other age groups. However, many studies have failed to show an association between age and problematic LEA risk in recreational female athletes (Karlsson et al., 2023; Logue et al., 2019; Slater et al., 2016). Age is one factor that could affect the LEAF-Q results as athletes of older age may be less sensitive to the menstrual function screening questions of the LEAF-Q which was originally validated in a cohort of female athletes aged 26.6 ± 5.4 (Melin et al., 2014). During peri- and post-menopause, natural declines in reproductive function and reproductive hormones will reduce the occurrence of menstrual bleeds and alter menstrual function (Nattiv et al., 2007). It is possible that the higher mean age of female participants in this current study (42.0 ± 10.7) and Karlsson et al.'s (2023) study (32.4 ± 4.3) could partially explain the lower risk prevalence rates when compared to other studies in recreational exercisers with a lower mean age (~23-24 years) (Black et al., 2018; Slater et al., 2016). Folscher et al. (2015) reported that menstrual dysfunction was not a useful screening tool for many older female ultramarathon athletes (mean age 39.5 ± 7.8) due to Mirena (hormonal intrauterine device) use or postmenopausal status. Therefore, research that has used these screening tools may not be sensitive in determining problematic LEA risk in this age group of females, and future research may need to consider alternative methods to increase the validity of their results.

Our results showed that females with LEA risk were more likely to report a weight change in the last six months (75.9% vs. 40.3%, $P < .05$). Similarly, Jesus et al. (2021) reported that athletes (male and female) reporting a weight change in the previous three months were more likely to be at risk of problematic LEA when compared to those whose weight did not change (70.8% vs. 57.4%, $p = .045$). While the direction of weight change was not reported in both these studies, endurance running can be a strong motivation for weight control in females (Folscher et al., 2015). Female endurance athletes are also recognised to be at a higher risk for eating disorders (ED)/disordered eating (DE) (Graybeal et al., 2022), factors that may contribute to the association between problematic LEA risk and weight change. Of note, the risk of ED/DE was not assessed in this present study; however, the addition of ED/DE to future research may need to be considered when assessing problematic LEA risk in female athletes/runners.

Our results showed that male participants with LEA risk more readily reported a chronic illness (23.5% vs. 6.8%, $P < .05$) or food allergy/intolerance (27.7% vs. 8.6%, $P < .05$) compared to males with low LEA risk. Research on problematic LEA risk and associations with chronic diseases and/or food allergies/intolerances are limited (Fahrenholtz et al., 2022). Some studies have excluded participants with existing chronic illnesses (Logue et al., 2019; Logue et al., 2021). In this current study, 13.2% of male participants reported a food allergy or intolerance which compares similarly to the 14.4% reported by Fahrenholtz et al. (2022) in young female endurance athletes. However, conversely to this current study, Fahrenholtz et al. (2022) did not report any difference in the prevalence of food intolerance between those at risk of problematic LEA compared to those with low risk. It is possible that the risk of problematic LEA increases in athletes with food allergies/intolerances as these conditions commonly result in dietary restriction and hence increase the risk of under fuelling for sports performance (Lis et al., 2016). In this current study, it could be speculated that athletes who reported food allergies or intolerances are not familiar with finding suitable dietary alternatives to compensate for potential nutritional deficiencies resulting in unintentional under fuelling. However, the causality between the risk of problematic LEA and food allergies/intolerances cannot be determined in a cross-sectional study. The links between the risk of problematic LEA and potential under fuelling due to a chronic illness or food allergy/intolerance could be an area for future research.

In this current study, we found no difference between problematic LEA risk and nutrition knowledge for either females or males. Similar results have been reported in other studies investigating the relationship between problematic LEA risk and nutrition knowledge. Olcott and Anstrom (2020) found no significant difference between problematic LEA risk and nutrition knowledge in female cross-country runners, and similar findings were reported by two recent New Zealand studies in female footballers and team sport athletes (Coombes, 2022; Pai, 2023). To our knowledge, only one study has found positive associations between problematic LEA prevalence and nutrition knowledge (Magee et al., 2020). Magee et al. (2020) reported that female collegiate soccer athletes with problematic LEA scored lower on the sports nutrition knowledge questions compared to athletes without problematic LEA (40.9 ± 10.4% vs. 52.4 ± 9.8%; $p = .04$), suggesting that lower nutrition knowledge may influence the adequacy of nutrition intake in collegiate female soccer players. While studies have shown that education can increase sports nutrition knowledge (Fahrenholtz et al., 2023; Tam et al., 2019), a higher level of sports nutrition knowledge only has a weak positive association with better diet quality (Fahrenholtz et al., 2023; Heaney et al., 2011; Spronk et al., 2014). Regardless, the previous literature on endurance athletes (such as trail runners) has reported that these individuals may unintentionally reduce EA by failing to periodise their EI to their EEE requirements. There are likely to be changes to EEE throughout training and the competitive seasons which if not accounted for with changes to EI can increase their risk of problematic LEA (Kuikman & Burke, 2023; Wasserfurth et al., 2020). This current study also reported low sports nutrition knowledge among recreational trail runners about how to fuel during events which is a key factor to prevent under fuelling. Therefore, associations between problematic LEA risk, nutrition knowledge and dietary behaviour in recreational trail runners may be an area of research that requires further investigation.

The strengths of the study include the use of three previously validated instruments i.e. LEAF-Q, LEAM-Q, and PEAKS-NQ. In addition, the study was sufficiently powered, and the large sample comprised a single sport discipline, i.e. trail runners. However, the study does have certain limitations which must be acknowledged. First, the participants were recruited online via self-selection which is subject to selection bias as people with greater interest in the topic may choose to participate. The online survey was self-administered which is subject to memory bias and underreporting which could be an issue for questions of a more sensitive nature e.g. around menstrual dysfunction and morning erections and sex drive. The study used two separate, but linked surveys which may not be ideal as it could have contributed to the drop-off of some responses on the PEAKS-NQ. The nutrition knowledge questions in the PEAKS-NQ were also not focused on problematic LEA. The survey period was following the Covid-19 lockdown period in Aotearoa/New Zealand which could have affected the ‘usual’ training volume of participants. Finally, while this study did use validated instruments to assess problematic LEA risk, these instruments have only been validated in younger athletes (Lundy et al., 2022; Melin et al., 2014; Rogers et al., 2021) and so may lack sensitivity to assess problematic LEA risk in the older population of this current study. In addition, the LEAM-Q has only recently been developed and currently only the sex drive section is validated for determining problematic LEA risk. Hence, the findings from this current study on problematic LEA risk in males should be interpreted with caution.

3.6 Conclusion

In conclusion, female and male recreational trail runners are a group of active individuals who present as being at higher risk of problematic LEA. There were no difference found between problematic LEA risk and nutrition knowledge in both sexes. Despite this, recreational trail runners may benefit from more sports-specific nutrition education that focuses on the performance implications of appropriately fuelling for trail events of varying distances.

Chapter 4: Research conclusions and recommendations

The overall aim of this research was to identify the proportion of recreational trail runners in Aotearoa/New Zealand who are at risk of problematic low energy availability (LEA), and the factors that influence the risk of problematic LEA in this cohort of runners e.g., age, education, body mass index (BMI), weekly training hours, level of experience and nutrition knowledge.

This current study has demonstrated that both female (30.7%) and male (23.4%) recreational trail runners are at risk of being in a state of problematic LEA. These results do compare to problematic LEA prevalence rates of 31% for females and 25% for males as reported by Heikura et al. (2018) in elite middle- and long-distance runners where EA was assessed directly through dietary analysis and training diaries. While our findings did not quite reach the hypothesised levels (≥40% at risk), our results did support the hypothesis that females would have higher problematic LEA risk prevalence than males. This sex difference is consistent with previous research investigating the prevalence of problematic LEA risk in both females and males (Høeg et al., 2022; Jesus et al., 2021). However, studies assessing problematic LEA prevalence in both sexes have found mixed results (Beermann et al., 2020; Heikura et al., 2018; Matt et al., 2022; McCormack et al., 2019). These differences in research findings are most likely due to the variability in study designs, the methods used to assess problematic LEA risk prevalence (e.g. Low Energy Availability In Females Questionnaire (LEAF-Q), Triad Cumulative Risk Assessment Tool) and problematic LEA risk (e.g. 3-day food record vs. block food frequency questionnaire, body composition vs. dual-energy X-ray absorptiometry (DEXA) etc), and variations in the age, calibre and type of running sport of the athletes.

Research into problematic LEA in recreational runners has to the best of our knowledge only been conducted with females. Our finding that 30.7% of female recreational trail runners are at risk of problematic LEA is consistent with recent research reporting 45% and 19% risk prevalence rates in recreational female runners (Dervish et al., 2023; Karlsson et al., 2023). These two studies and this current study used LEAF-Q as the screening tool, however, the definition of ‘recreational’ between all three studies varied which could have affected the results. Karlsson et al. (2023) recruited female runners participating in organised running group sessions, whereas Dervish et al. (2023) defined recreational athletes as those undertaking 4-6 hours of training per week (≥6 hours was considered 'competitive'). Conversely, this current study classified recreational trail runners as those completing the minimal recommendations of at least 2.5 hours of physical activity per week (Ministry of Health, 2023). In addition, this current study included both trail running training and other training activities (such as strength training) as part of the weekly training hours; it is unclear whether other training activities were also included in the other two studies. These variations make it difficult to directly compare results.

We know from the literature that athletes participating in sports with high exercise energy expenditure (EEE) (such as trail runners) may be at risk of unintentional problematic LEA (Wasserfurth et al., 2020). It is likely that the recreational trail runners in this current study who were categorised with problematic LEA risk are doing so unintentionally. Trail runners have various training and event periods throughout the year and these athletes may simply fail to recognise the need to match their energy intake (EI) with varying EEE (Kuikman & Burke, 2023; Wasserfurth et al., 2020). Previous research has shown that even elite athletes fail to match their EI to increased training loads (Schaal et al., 2021; Woods et al., 2017), hence it is likely that this is a similar case for these recreational athletes. However, dietary intake was not assessed in this present study hence no associations can be made. Therefore, nutrition education with a focus on how to fuel before, during and after various training loads may be beneficial to these recreational trail running athletes.

Several studies on recreational athletes have found that increasing weekly training volume is a predictor of problematic LEA risk (Karlsson et al., 2023; Logue et al., 2019; Slater et al., 2016). On the contrary to our hypothesis, our results did not support this finding. The current study was comprised of a single sport discipline, i.e. trail runners, which is likely to provide a more robust measure of training load as if the sample had been comprised of more diverse sports (Lundy et al., 2022). While our sample of trail runners did have a wide range of weekly training hours and a broad variety of usual trail event distances, it is likely that the timing of the data collection period (June-December 2022) may have influenced the 'usual' total weekly training hours of participants. This period was at the end of Covid-19 in Aotearoa/New Zealand where events were still progressively returning so it is possible that athletes were not running as much as they would have in a 'normal' year. At any given point, trail running athletes will be at different stages of their training cycle depending on when their next race is. Hence it is possible that a higher proportion of athletes could have been in the initial stages of their training cycle with lower training volume when they completed the survey which could have also affected the results.

Previous research has shown inconsistent results as to whether nutrition knowledge is associated with problematic LEA (Coombes, 2022; Magee et al., 2020; Pai, 2023). In this current study, there was no significant difference in the level of nutrition knowledge between those with LEA risk and those with low LEA risk. The mean overall nutrition knowledge score was 70.9% ± 11.0% which is comparable to the 70.7% ± 10.5% reported by Tam et al. (2021) in their study using the Platform for Evaluating Athlete Knowledge in Sports Nutrition Questionnaire (PEAKS-NQ) in a cohort of elite Australian athletes. It could be hypothesised that nutrition knowledge increases with athlete level however studies have found mixed results (Lohman et al., 2019; Spronk et al., 2015; Trakman et al., 2016). A higher level of education has also been found to be correlated with higher nutrition knowledge scores (Trakman et al., 2016). In this current study, a higher proportion of recreational athletes had undertaken tertiary education (94.7%) compared to the elite athletes (28.0%) in the study by Tam et al. (2021). However, the opposite was the case for having received previous nutrition education with the elite athletes (90.8%) (Tam et al., 2021) probably having better exposure to nutrition education via their sporting institution than their recreational counterparts (44.1%) in this current study. It could be speculated that the higher education level of the recreational trail runners in this current study influenced the overall nutrition knowledge scores, however, this association was not investigated as part of this study.

Levels of nutrition knowledge between studies vary due to the range of assessment tools that have been used (Tam et al., 2019; Tam et al., 2022). Studies generally report that athletes have poor sports nutrition knowledge (Condo et al., 2019; Coombes, 2022; Pai, 2023) and that they score higher on general nutrition knowledge than sports specific nutrition knowledge (Pai, 2023; Tam et al., 2021). This latter finding is comparable to the results from this current study where both female and male participants scored lower on the sports nutrition knowledge section compared to the general nutrition knowledge section. It is possible that participants may have a basic understanding of general healthy eating guidelines as these are publicly available. Yet they may have difficulty in applying these general concepts into sport-specific contexts which are queried in the PEAKS-NQ (Pai, 2023; Tam et al., 2021).

Research tells us that current knowledge of problematic LEA and Relative Energy Deficiency in Sport (REDs) among recreational exercisers is low (Miller et al., 2012; Winter et al., 2019); however, increased knowledge may help athletes in managing these conditions. The literature recommends that a multidisciplinary approach is taken to prevent problematic LEA including a team specialising in nutrition, medicine, physiology and psychology (Nattiv et al., 2007; Stellingwerff et al., 2021; Torstveit et al., 2023). However, recreational athletes (including trail runners) do not have access to such extensive multidisciplinary expertise. Without a support team, the recreational athlete may turn to their healthcare professional for knowledge of problematic LEA. However, healthcare professionals have varying levels of knowledge of problematic LEA, and there is a need for improvement in this area to support athletes around awareness, diagnosis and treatment (Ashby, 2019; Warrick et al., 2023). The recreational athlete may instead seek information about problematic LEA on social media (Neglia, 2021); however, social media is providing new challenges to athletes and can lead to pressure to look, train, or eat a certain way (Heather et al., 2021; Wasserfurth et al., 2020). Recreational athletes should therefore be encouraged to follow specific official social media accounts of non-for-profit organisations such as the Female and Male Athlete Triad Coalition which presents evidence-based information (Pai, 2023). For this type of information to be easily accessible to the recreational athlete this could also be disseminated via public health programs through local sports organisations (e.g. trail running clubs), gyms, general practitioners and allied health professionals (Slater et al., 2016).

4.1 Strengths

To the best of our knowledge, this was the first study to investigate the risk of problematic LEA and associations with nutrition knowledge in recreational trail runners. It was unique in that the target group was recreational athletes and nutrition knowledge was assessed as a separate factor.

In this current study, there was a good representation of both female (n=140) and male (n=77) participants from a homogenous group of recreational trail runners, and the fact that it included both female and male trail runners helps address this gap in the literature. It included a broad representation of trail runners from beginners to advanced who participated in short to ultra trail distance events. The mean age was higher than in most other research on problematic LEA risk; however, comparable to other research on ultra-marathon athletes (Folscher et al., 2015; Høeg et al., 2022) and recreational runners (Dervish et al., 2023; Karlsson et al., 2023) investigating the risk of problematic LEA. Hence, this sample may be a reasonable representation of recreational trail runners in Aotearoa/New Zealand which may be a result of the broad reach of the two trail running organisations that helped with recruitment and survey promotion.

This study utilised previously validated instruments to assess the risk of problematic LEA i.e., LEAF-Q, the Low Energy Availability in Males Questionnaire (LEAM-Q), and nutrition knowledge (PEAKS-NQ). While the LEAF-Q has been used in numerous studies, a consideration in research has been the lack of a validated instrument for males which has led to a range of unvalidated and inventive approaches being used to assess problematic LEA risk in males. A strength of this current study is the use of the newly developed LEAM-Q. While it is recognised that the LEAM-Q is still in its infancy and more research is required to further adjust and validate the questionnaire, this current study adds value to this research. In addition, using the PEAKS-NQ to assess the level of nutrition knowledge in a study investigating problematic LEA risk prevalence was also a new approach. PEAKS-NQ has the advantage of being set up on an existing platform and in its use of images which may make it easier for recreational athletes to relate to the questions.

A final strength of this study was the use of anonymous online surveys. Both the LEAF-Q and LEAM-Q include questions of sensitive and personal nature around menstrual function for females and sex drive for males. This issue was discussed by the research team who acknowledged that it can be difficult to get accurate and honest information on these types of personal questions. Having an anonymous online survey that a participant could complete in the comfort of their own space for privacy (rather than face-to-face at an event), and an information sheet specifically informing participants about these questions and that they had the right to withdraw at any time, was deemed to be a suitable solution.

4.2 Limitations

One main limitation of this current study was the use of two separate survey platforms. The trail running questions and LEAF-Q/LEAM-Q section (Part 1) were hosted on Qualtrics via Massey University and the already existing PEAKS-NQ section (Part 2) was hosted at the University of Sydney. It was recognised that linking these two survey parts would be a challenge while also trying to minimise participant drop-off. The solution was to generate a personalised numerical code at the end of Part 1 which the participant was instructed to enter at the start of Part 2 to help the research team link the two surveys. Pilot testing indicated that this was an acceptable solution. However, the data analysis showed that there was a 31% drop-off rate in respondents who completed Part 1 and not Part 2. Whether this was due to survey fatigue with the combined survey being quite long or due to technical issues with the code linkage is uncertain. A final issue with the dual survey scenario was that some key demographic questions (e.g. age, education) were already in the PEAKS-NQ and to not duplicate questions, these were not also included in Part 1. However, this did result in some key missing demographic data that was only available for respondents who completed Part 2.

While online surveys are a good way of canvassing survey information from a large sub-group within a population, it is considered a convenience sample that does not allow for generalisations of the findings to the rest of the trail running population. Another issue with online surveys is the self-selection bias. Trail runners who chose to participate may have been more interested in the topic for example due to past or present personal experiences with problematic LEA or a particular interest in sports nutrition. Finally, recall bias can be an issue when respondents are instructed to self-report symptoms in a survey. While the anonymous survey format may have removed some of the issues with regard to sensitive questions, there are likely still some concerns around the honesty and accuracy of answering questions about sex drive and menstrual function due to stigma and inaccurate knowledge (Coombes, 2022; Lundy et al., 2022).

A final potential limitation of this current study is the older mean age of participants compared to the participants with whom the LEAF-Q/LEAM-Q instruments were validated (Lundy et al., 2022; Melin et al., 2014). These instruments focus on symptoms of problematic LEA related to menstruation and sex drive; processes that are driven by sex hormones that change over the course of a lifespan. Some studies using LEAF-Q have excluded female participants in early or post-menopause in the recruitment criteria (Dervish et al., 2023; Logue et al., 2019), perhaps due to these potential issues. Twenty percent of females in this current study were either going through peri- or post-menopause. This group of female trail runners are at even greater risk of accelerated bone loss if exposed to a state of problematic LEA and hence are an important group to include in research (Folscher et al., 2015). Similarly for the LEAM-Q, it is also possible that increasing age could have an effect on the scoring as with increasing age there is an increase in erectile dysfunction and a decrease in libido (Hackney et al., 2017; Panser et al., 1995).

4.3 Research recommendations and future implications

Based on the main findings of this study, it is evident that the risk of problematic LEA is prevalent among recreational trail runners in Aotearoa/New Zealand. A proportion of recreational trail runners may currently be in a state of problematic LEA or will be at increased risk of entering a state of problematic LEA in the future. Based on these findings, several recommendations for research and practice are presented here:

- This study investigated the risk of problematic LEA prevalence among recreational trail runners, not the prevalence of problematic LEA. Hence, future research should investigate LEA prevalence through direct assessment of EI and EEE as well as other clinical markers such as blood samples and DEXA scans. This could help validate the use of the LEAF-Q and LEAM-Q to ensure these are appropriate screening tools for the assessment of problematic LEA risk in recreational trail runners.
- There is a need for future research to validate the use of the LEAF-Q and LEAM-Q in older age groups of recreational runners and may also need to consider alternative methods for assessing problematic LEA risk for these age groups.

- Future research in recreational athletes should aim to have a more standardised definition of ‘recreational’ to allow for better comparison of study results.
- This current study was the first study of problematic LEA risk to use PEAKS-NQ to assess the level of nutrition knowledge. PEAKS-NQ is a validated and useful tool that could be used more widely in future research.
- This research found an association between the risk of problematic LEA and chronic illness or food allergy/intolerance in males – this may be worth exploring further in future research.
- The associations between problematic LEA risk, nutrition knowledge and dietary intake in recreational trail runners are still unknown and are areas of research that require further investigation.
- Recreational athletes are exposed to the same general healthy eating guidelines as the general population which focus on ‘eat less, move more’; however, these messages are not necessarily suitable for recreational trail runners who instead need to receive the message to ‘fuel for the work required’.
- Results from this research showed that there is a knowledge gap among recreational trail runners on how to fuel during events. Resources to support recreational trail runners should first and foremost address this issue.
- Recreational trail runners have less access to credible nutrition information as they are not part of a team or national sporting organisation, and not everyone can afford the services of an individual Registered Dietitian/Registered Nutritionist. Therefore, other ways to disseminate this important information to recreational trail runners need to be explored.
- There is a need to upskill healthcare professionals (including general practitioners, and allied health professionals) around problematic LEA and REDs including how to identify the signs and symptoms of problematic LEA and REDs in recreational athletes, and when to refer for appropriate treatment.
- Evidenced-based information around problematic LEA and REDs should be made easily accessible to recreational trail runners. Trail running organisations, coaches and trail event companies should be encouraged to share evidence-based information with their members/followers/participants. These include official social media

accounts from non-for-profit organisations such as the Female and Male Athlete Triad Coalition, credible social media accounts run by Registered Dietitians or Registered Nutritionists, and websites such as the Australian Institute of Sport and Sports Dietitians Australia.

- It is also important to target young people around the development of healthy performance in athletes to avoid over-training and under fuelling. Education as part of the Health and Physical Education curriculum in secondary schools which is a time when young people may become more serious about their sport would be a good place to start.

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APPENDICES

Appendix A: Participant Information Sheet

Nutrition knowledge and risk of low energy availability in trail runners and walkers.

INFORMATION SHEET

Researcher introduction
Kia ora, my name is Tina Buch. I am a New Zealand Registered Nutritionist, a trail runner and a Master of Science in Nutrition student at Massey University's School of Sport, Exercise and Nutrition.

My primary supervisor is Dr Claire Badenhorst, and co-supervisor is Ass Prof Kathryn Beck (New Zealand Registered Dietitian). Other researchers involved in the project are Dr Ryan Tam (Australian Catholic University) and Dr Janelle Gifford (University of Sydney).

What is this research about?
We are investigating the association between nutrition knowledge and risk of low energy availability (LEA) in trail runners and walkers in Aotearoa/New Zealand (NZ). Chronic LEA states result from athletes/individuals not getting enough food in to support exercise and normal physiological processes. A state of chronic or severe low energy availability has been linked to numerous health consequences including declines in bone health and reproductive function, impaired sport performance and an increased risk of injuries. Studies have shown that there is a high prevalence of risk of LEA among both elite and recreational athletes, across both sexes and particularly in endurance sports such as running. There is limited evidence around risk of LEA in trail runners and walkers.

Nutrition knowledge is important for athletes to ensure they know how to fuel for the work/training required. Minimal research has been undertaken to investigate associations between nutrition knowledge and risk of LEA, and none in trail runners/walkers. By choosing to take part in this study you will help us understand how differing levels of nutrition knowledge may be linked to risk of LEA in trail runners/walkers in Aotearoa/NZ. This information may be used to provide nutritional knowledge and support to trail runners/walkers to ensure both health and sport performance is maintained.

Who are we inviting to participate?
We are looking for trail runners and walkers of all experience levels. To participate you should be:

- 16 years or older
- Based in Aotearoa/NZ
- Training for trail running/walking for at least 2½ hours per week.

To thank you for your participation, you can provide us with your email address which will be entered into monthly prize draws to win one of two $100 gift vouchers. Prizes will be drawn each month during the survey data collection period (June to November 2022).

You would like to participate, what will you need to do?
We will ask you to complete an online anonymous survey. The survey will be in two parts: Part 1 has general trail running questions as well as questions around your risk of LEA, which will be based on the presentation of symptoms associated with severe or chronic states of LEA. Part 2 will be asking

questions about your nutrition knowledge. At the end of Part 1, you will be given a code which you will be asked to copy and paste at the start of Part 2. This will allow us to link the two surveys.

Full instructions will be provided in the survey. The survey will take approximately 30-40 minutes to complete.

What data or information will be collected?
During Part 1, you will be completing validated surveys that will assess your risk of LEA. The risk of LEA will be determined through questions that assess your presentation or experience with symptoms associated with severe or chronic states of LEA. These questions for both males and females will include your history of injuries, and gastrointestinal function. For females you will also be asked questions on your menstrual cycle status (including pre- or post-menopausal state), and use (current or previous) of contraceptives. For males you will be asked questions on fatigue levels, recovery and sex drive. We ask you these questions because research has shown that these areas are key indicators of being at high risk of LEA.

During Part 2, you will complete a nutrition knowledge survey with a range of questions to assess your general and sport nutrition knowledge. You can choose to receive a personalised results summary on your scores which you will be able use to seek out further nutritional information.

What will happen with the information you provide?
During Part 1 of the survey a study ID will be generated (Example of study ID: TrailNZ3465). All information collected during this study will be stored under this study ID to ensure that no individual is identifiable once the data is analysed. Storing your responses under the study ID will ensure that all responses remain confidential. To protect your privacy, your email address (if given for the purpose of the prize draw and/or receiving the results) will be stored separately from your survey responses. All email addresses will be deleted upon completion of the project.

Your location data and IP address will not be collected when you select the survey link. As this is an online only survey, results will be stored in a password protected account with restricted access to members of the research team only. We do acknowledge there is a small possibility of re-identification through demographic information (i.e., age, sex, trail running/walking experience, ethnicity), however we have extensively discussed various processes to assure anomality of our participants.

Data for Part 1 is collected by the research team at Massey University. Data for Part 2 is collected by the research team at the University of Sydney and then sent to the research team at Massey to combine and analyse the full data set.

After completion of the data collection, the study findings will be written up as part of Tina’s Master of Science in Nutrition thesis project. A summary of research results will be available upon request. Results of this project may also be published or presented at conferences or seminars. De-identified data may be used in future research collaborations. No individual will be able to be identified in the results with group averages only being presented.

Participant’s rights:
You have the right to decline to answer any question, and you may stop answering questions at any time. You may withdraw from the study at any time up until submission of the survey without any disadvantage to you.

What are the benefits and risks of taking part in this study?
As part of the nutrition knowledge questionnaire, you can receive a personalised results summary on your nutrition knowledge scores – this will provide you with feedback on where you performed well and where your knowledge may not be as strong. You can also receive a summary of research results via email once available.

There is minimal risk to you by participating in this project. However, some of the questions around menstruation for women and sex drive for men may cause you some discomfort or embarrassment. We have taken every measure to ensure that your survey answers are kept confidential and anonymous.

Support processes
In case you have concerns regarding your personalised results summary on your nutrition knowledge scores – you may contact the Massey University Nutrition and Dietetic Centre in Auckland for personalised nutrition advice.
Email: nutritiondieteticcentre@massey.ac.nz
Phone: 09 414 0800 extension 43653

Or you can search for an NZ Registered Nutritionist in your local region here:
https://www.nutritionsociety.ac.nz/find-a-nutritionist

Note that both services have a cost attached.

Project Contacts
If you have any further questions or concerns about the project, either now or in the future, please contact:

Tina Buch, MSc student –
Human Nutrition
School of Sport Exercise and Nutrition,
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Phone: [redacted]

Dr Claire Badenhorst
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Massey University
Email: c.badenhorst@massey.ac.nz
Phone: 09 213 6410

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 22/24. If you have any concerns about the conduct of this research, please contact A/Prof Fiona Te Momo, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800, x 43347, email humanethicsnorth@massey.ac.nz

Thank you for considering participating in this study

Appendix B: Survey Part 1

Nutrition knowledge and risk of low energy availability in trail runners and walkers

Welcome to the TrailNZ Survey page

A study investigating how nutrition knowledge influence health and performance in trail runners and walkers in Aotearoa.

Please read the information sheet (Information sheet trailnz study) before continuing with the survey. It is important that you have read and understood the details of this study before you proceed to give consent to participate.

The Survey is in two parts:

Part 1: Will ask you general trail running/walking questions as well as questions around your risk of low energy availability.

Part 2: Will ask you questions about your nutrition knowledge.

At the end of Part 1, you will be given a code which you will be asked to copy and paste at the start of Part 2. This will allow us to link the two surveys we are using in the study. You will then be asked to click 'next' and you will be redirected via a URL to Part 2.

The two parts will take approximately 30-40 minutes to complete. Please try and set aside the time to complete the two parts in one go as this works best.

To thank you for your time, you can go into the draw to win one of two $100 gift vouchers. Prizes will be drawn each month during the survey data collection period.

I am 16 years of age or over

- O Yes
- O No

I am based in Aotearoa/New Zealand

- O Yes
- O No

I train at least 2 1/2 hours per week for trail running/walking

- O Yes
- O No

I would like to receive a summary of the research findings

- O Yes
- O No

I would like to enter the draw to win a $100 gift voucher

- O Yes
- O No

Display This Question:
If I would like to receive a summary of the research findings = Yes
Or I would like to enter the draw to win a $100 gift voucher = Yes

Please add your email address here so we can send you the summary and/or enter you into the prize draw:
(NB your email will be used for this purpose only and will be stored separately from your survey response) ____

I agree to participate in this study under the conditions set out in the Information Sheet
- O I consent
- O I do not consent

TRAIL RUNNING AND DEMOGRAPHIC QUESTIONS

Q1 How would you classify yourself?
- O Trail Runner
- O Trail Walker

Display This Question:
If How would you classify yourself? = Trail Runner

Q2 How long have you been trail running?

	Years	Months
Please select years and/or months	▼ 0 (1 ... 10+)	▼ 0 (1 ... 11)

Display This Question:
If How would you classify yourself? = Trail Walker

Q3 How long have you been trail walking?

	Years	Months
Please select years and/or months	▼ 0 (1 ... 10+)	▼ 0 (1 ... 11)

Display This Question:
If How would you classify yourself? = Trail Runner

Q4 How much time do you usually spend on trail run training each week?

	Hours	Minutes
Please type total number of hours/minutes		

Display This Question:
If How would you classify yourself? = Trail Walker

Q5 How much time do you usually spend on trail walk training each week?

	Hours	Minutes
Please type total number of hours/minutes		

Q6 Are there any other type(s) of training activities that you usually do each week?
- O Yes
- O No

Display This Question:
If Are there any other type(s) of training activities that you usually do each week? = Yes

Q7 What type(s) of other training do you do?

	Select all that apply
Walking	☐
Running	☐
Swimming	☐
Cycling	☐
Strength training	☐
HIIT (High Intensity Interval Training)	☐
Flexibility (e.g. yoga, pilates)	☐
Technique training	☐
Other	☐

Display This Question:
If Are there any other type(s) of training activities that you usually do each week? = Yes

Q8 How much time per week do you usually spend on these other types of training?

	Hours	Minutes
Please type total number of hours/minutes		

Q9 What level (Trail Runner/Trail Walker) would you classify yourself as?

- O Beginner
- O Beginner-Intermediate
- O Intermediate
- O Intermediate-Experienced
- O Very Experienced

Q10 How many trail events would you usually (when not impacted by COVID restrictions) participate in a year?

- O I haven't participated in a trail event yet
- O 1-2 events per year
- O 3-4 events per year
- O 5-6 events per year
- O 7-8 events per year
- O 9-10 events per year
- O 10+ events per year

Skip To: Q14 If How many trail events would you usually (when not impacted by COVID restrictions) participate in... = I haven't participated in a trail event yet

Q11 Which trail event distances do you usually participate in?

	Select all that apply
Short distances (5-9km)	☐
Mid distances (10-15km)	☐
Long distances (16-20.1km)	☐
Super long distances (21.1-42.2km)	☐
Ultra distances (42.3km+)	☐
100km	☐
100 miler	☐
Skyrunning	☐
24-hour races	☐
Ultra relays	☐
Other	☐

Q12 What is the longest distance you've ever completed in a trail event?
*Please type event distance in km (e.g. 100)*_________________________

Q13 When was this event completed?
Please type event year (e.g. 2018) ________________________________

Q14 Do you currently follow any specific dietary pattern(s)?

	Select all that apply
No, I don't follow any specific dietary pattern	☐
Vegetarian or vegan	☐
Gluten or wheat-free	☐
Dairy-free or low lactose	☐
Low FODMAP	☐
Diabetic diet or low glycemic index (GI)	☐
Intermittent fasting	☐
Paleo	☐
High fat/ low carb (i.e. ketogenic diet)	☐
Other	☐

Q15 Do you currently diet or restrict your food intake in order to make weight or achieve your body composition goals? *Choose the answer that best suits your situation*

- O No, I eat as much as I like/need most of the time
- O Yes, I watch what I eat but I can still eat freely
- O Yes, I am actively trying to lose weight/body fat to achieve a target
- O Yes, I restrict what I eat most of the time to manage my body weight/composition

Q15 Do you smoke?

- O No
- O Yes

Q16 Do you currently use any medications, vitamins and/or supplements (including oral contraceptives and Hormone Replacement Therapy/Menopausal Hormone Therapy)?

- O No
- O Yes

Display This Question:
If Do you currently use any medications, vitamins and/or supplements (including oral contraceptives... = Yes

Q17 What kind of medications, vitamins and/or supplements do you use? *(please list all that apply)* ____
____

Q18 Do you have any chronic illness (e.g. diabetes, Crohn’s Disease)?

- O Yes
- O No

Display This Question:
If Do you have any chronic illness (e.g. diabetes, Crohn’s Disease)? = Yes

Q19 Which one(s)? *(please give details)*____

Q20 Do you have any food allergy or intolerance (e.g. nut allergy, coeliac disease, lactose intolerance)?

- O Yes
- O No

Display This Question:
If Do you have any food allergy or intolerance (e.g. nut allergy, coeliac disease, lactose intoleran... = Yes

Q21 Which one(s)? *(please give details)*____

Q30 What biological sex are you?

- O Female
- O Male

End of Block: Trail running questions and demographics

Start of Block: LEAF-Q

This section will ask you questions about injuries, gastrointestinal function, menstrual function and use of contraceptives.

(NB – notes in blue refer to wording of original LEAF-Q where minor changes were made to enhance readability and understanding for participants)

INJURIES

For each question, select the option that most accurately describes your situation

Q1 Have you had any periods of absence from training or competition due to injuries in the last year? *(Have you had any absences from your training, or participation in competitions during the last year due to injuries?)*

- O No not at all
- O Yes, once or twice
- O Yes, three or four times
- O Yes, five times or more

Skip To: S2 If Have you had any periods of absence from training or competition due to injuries in the last year? = No not at all

Q2 How many days absence from training or competition due to injuries have you had in the last year? *(If yes, for how many days absence from training or participation in competition due to injuries have you had in the last year?)*

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

Q3 What kind of injuries have you had in the last year?____

Q4 Any additional comments or further information regarding injuries:____

GASTROINTESTINAL FUNCTION

For each question, select the option that most accurately describes your situation

Q5 Do you feel gaseous or bloated in the abdomen? *(Please only answer for times when you do not have your period)* *(Do you feel gaseous or bloated in the abdomen, also when you do not have your period?)*

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

Q6 Do you get cramps or stomach ache? *(Please only answer for times when you do not have your period)* *(Do you get cramps or stomach ache which cannot be related to your menstruation?)*

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

Display This Question:
If Do you feel gaseous or bloated in the abdomen? (Please only answer for times when you do not have... != Rarely or never
Or Do you get cramps or stomach ache? (Please only answer for times when you do not have your period) != Rarely or never

Q7 Please provide more detail around when you experience these gastrointestinal issues (i.e. is it mainly around eating or while running)____________________________________

Q8 On average, how often do you have bowel movements? *(How often do you have bowel movements on average?)*

- Several times a day
- Once a day
- Every second day
- Twice a week
- Once a week or more rarely

Q9 How would you describe your normal stool?

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

Q10 Any additional comments or further information regarding gastrointestinal function:

____

MENSTRUAL FUNCTION AND USE OF CONTRACEPTIVES

For each question, select the option that most accurately describes your situation

CONTRACEPTIVES

Q11 Do you use oral contraceptives?

- Yes
- No

Skip To: Q13 If Do you use oral contraceptives? = No

Q12 Why do you use oral contraceptives? *(Select the option that best describes your situation)*

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

Display This Question:
If Do you use oral contraceptives? = No

Q13 Have you used oral contraceptives in the past? *(If no, have you used oral contraceptives earlier?)*

- O Yes
- O No

Skip To: Q16 If Have you used oral contraceptives in the past? = No
Display This Question:
If Have you used oral contraceptives in the past? = Yes

Q14 When did you use oral contraceptives? ________________________________

Display This Question:
If Have you used oral contraceptives in the past? = Yes

Q15 For how long did you use oral contraceptives?________________________________

Q16 Do you use any other kind of hormonal contraceptives? *(e.g. hormonal IUD (Mirena), hormonal implant (Jadelle) or injection (Depo Provera))*

- O Yes
- O No

Display This Question:
If Do you use any other kind of hormonal contraceptives? (e.g. hormonal IUD (Mirena), hormonal impla... = Yes

Q17 What kind of hormonal contraception do you use? *(the following options were changed in this study to specifically include New Zealand brands)*

- O Hormonal IUD e.g. Mirena and Jaydess
- O Hormonal implant e.g. Jadelle
- O Hormonal injection e.g. Depo Provera
- O Other ________________________

MENSTRUAL FUNCTION

Q18 How old were when you had your first period?

- O 11 years or younger
- O 12-14 years
- O 15 years or older
- O I don’t remember
- O I have never menstruated

Skip To: End of Block If How old were when you had your first period? = I have never menstruated

Q19 Did your first menstruation come naturally (by itself)?

- O Yes
- O No
- O I don't remember

Skip To: Q21 If Did your first menstruation come naturally (by itself)? = I don't remember
Skip To: Q21 If Did your first menstruation come naturally (by itself)? = Yes
Display This Question:
If Did your first menstruation come naturally (by itself)? = No

Q20 If no, what kind of treatment was used to start your menstrual cycle?

	Select all that apply
Hormonal treatment	☐
Weight gain	☐
Reduced amount of exercise	☐
Other	☐

Display This Question:
If Do you use oral contraceptives? = No

Q21 At present do you have normal menstruation – (regular monthly period)? *(Do you have normal menstruation?)*

- O Yes
- O No
- O I don't know

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? = Yes

Q22 When was your last period?

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

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? = Yes

Q23 Are your periods regular? (A 21 to 35 day cycle) *(every 28th to 34th day)*

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

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? = Yes

Q24 For how many days do you normally bleed?

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

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? = Yes

Q25 Have you ever had problems with heavy menstrual bleeding?

- O Yes
- O No

Display This Question:
If Have you ever had problems with heavy menstrual bleeding? = Yes

Q26 Can you provide details on the problem experienced with heavy menstrual bleeding?____

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? = Yes

Q27 How many periods have you had during the last year?

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

Display This Question: If At present do you have normal menstruation – (regular monthly period)? != Yes
And Do you use oral contraceptives? = No

MENSTRUAL FUNCTION

Display This Question:
If At present do you have normal menstruation – (regular monthly period)? != Yes
And Do you use oral contraceptives? = No

Q28 When did you have your last period? *(the last two options were added to this study to account for older age groups)*

- O 2-3 months ago
- O 4-5 months ago
- O 6 months ago or more
- O I'm pregnant and therefore don't menstruate
- O I'm going through early menopause and have irregular menstrual patterns
- O I'm postmenopausal and therefore don't menstruate

Skip To: End of Block If When did you have your last period? = I'm pregnant and therefore don't menstruate
Skip To: End of Block If When did you have your last period? = I'm postmenopausal and therefore don't menstruate

Display This Question:
If Do you use oral contraceptives? = No
And At present do you have normal menstruation – (regular monthly period)? != Yes

Q29 Have your periods ever stopped for 3 consecutive months or longer (besides pregnancy)?

- O No, never
- O Yes, it has happened before
- O Yes, that's the situation now

Display This Question:
If Do you use oral contraceptives? = No
And At present do you have normal menstruation – (regular monthly period)? != Yes

Q30 Do you experience that your menstruation changes when you increase your exercise intensity, frequency or duration?

- O Yes
- O No

Display This Question: If Do you experience that your menstruation changes when you increase your exercise intensity, frequ... = Yes

Q31 How does your menstruation change?	*Select all that apply*
I bleed less	☐
I bleed fewer days	☐
My menstruation stops	☐
I bleed more	☐
I bleed more days	☐

End of Block: LEAF-Q

Start of Block: LEAM-Q

This section will ask you questions about dizziness, gastrointestinal function, injuries, fatigue, fitness, recovery, energy levels and sex drive.

DIZZINESS
For each question, select the option that most accurately describes your situation

Q1 Do you feel dizzy or lightheaded when you rise quickly?
- O Yes, several times a day
- O Yes, several times a week
- O Yes, once or twice a week or more seldom
- O Rarely or never

Q2 Do you experience problems with vision (blurring, seeing spots, tunnel vision, etc.)?
- O Yes, several times a day
- O Yes, several times a week
- O Yes, once or twice a week or more seldom
- O Rarely or never

GASTROINTESTINAL FUNCTION
For each question, select the option that most accurately describes your situation

Q3 Do you feel gaseous or bloated in the abdomen?
- O Yes, several times a day
- O Yes, several times a week
- O Yes, once or twice a week or more seldom
- O Rarely or never

Q4 Do you get cramps or stomach ache?
- O Yes, several times a day
- O Yes, several times a week
- O Yes, once or twice a week or more seldom
- O Rarely or never

Q5 On average, how often do you have bowel movements?

- O Several times a day
- O Once a day
- O Every second day
- O Twice a week
- O Once a week or more rarely

Q6 How would you describe your normal stool?

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

Q7 Any additional comments or further information regarding gastrointestinal function:____

HEALTH PROBLEM INTERFERING WITH TRAINING OR COMPETITION PLANS

In the following we will ask you some question regarding how often, during the last 6 month you have had to change plans concerning training or competition or not been able to perform your maximal during training due to a sport injury or illness. An acute injury appears suddenly for an obvious reason at a specific time (e.g. a sprain). An injury due to overload develops gradually (e.g. shin or Achilles, stress fracture).

Q10 How many acute injuries have you had during the past 6 months?

- O Number of acute injuries____________________________________

Q11 How many overload injuries (the same reoccurring overload injury, counts as a new injury for every new period) have you had during the past 6 months?

- O Number of overload injuries_________________________________

Q12 How many breaks in training have you had due to illness during the past 6 months?

- O Number of training breaks due to illness ______________________

Q13 During the last 6 months, how many days in a row, at the most, have you been absent from training/competition or not been able to perform optimally at training/competition due to an injury (acute/overload) or illness?

	None	1-7 days	8-14 days	15-21 days	22 days or more
Acute injury	C	O	O	O	O
Overload injury	C	O	O	O	O
Illness	C	O	O	O	O

Q14 Any additional comments or further information concerning your injuries:____

Q15 Any additional comments or further information concerning your illnesses:____

WELL-BEING AND RECOVERY

For each question, select the option that most accurately describes your situation

FATIGUE

Q16 I feel tired from work/school

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

Q17 I feel overtired

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

Q18 I'm unable to concentrate well

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

Q19 I feel lethargic

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

Q20 I put off making decisions

- Yes, always
- Yes, often
- Yes, sometimes
- Rarely or never

FITNESS

Q21 Parts of my body are aching

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

Q22 My muscle feels stiff or tense during training

- Yes, almost every training session
- Yes, often
- Yes, sometimes
- Rarely or never

Q23 I have muscle pain after performance

- Yes, almost after every training session
- Yes, often
- Yes, sometimes
- Rarely or never

Q24 I feel vulnerable to injuries

- Yes, always
- Yes, in most training periods
- Yes, in some training periods
- Rarely or never

Q25 I have a headache

- Yes, almost daily
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q26 I feel physically exhausted

- Yes, almost daily
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q27 I feel strong and am making good progress with my strength training

- Yes, always
- Yes, in most training periods
- Yes, in some training periods
- Rarely or never

RECOVERY

Q34 I recover well physically

- Yes, after almost all training sessions
- Yes, often
- Yes, sometimes
- Rarely or never

Q35 I'm in good physical shape

- Yes, always
- Yes, mostly
- Yes, sometimes
- Rarely or never

Q36 I feel I'm achieving the progress in training and competition that I deserve

- Yes, always
- Yes, in most training periods
- Yes, in some training periods
- Rarely or never

Q37 My body feels strong

- Yes, almost every day
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

ENERGY LEVELS

Q38 I feel very energetic in general

- Yes, almost every day
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q39 I feel invigorated for training sessions and ready to perform well

- Yes, almost every day
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q40 I feel happy and on top of my life outside sport

- Yes, almost every day
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q41 I feel down and less happy than I used to feel or would like to feel

- Yes, almost every day
- Yes, several days a week
- Yes, once or twice a week or more seldom
- Rarely or never

SEX DRIVE

Your sex drive can be a marker of the balance between training, rest and nutrition.

Q42 In general I would rate my sex drive as:

- High
- Moderate
- Low
- I don’t have much interest in sex

Q43 Over the last month I would rate my sex drive as:

- Stronger than usual
- About the same as usual
- A little less than usual
- Much less than usual

Q44 It is common to wake in the morning with an erection.
Over the last month, has this happened:

- 5-7 x per week
- 3-4 x a week
- 1-2 x a week
- Rarely or never

Q45 Compared to what you would consider is normal for you is this:

- More often
- About the same
- A little less often
- Much less often

End of Block: LEAM-Q

Start of Block: Important info - survey link

Important information!

Thank you for completing Part 1 of our Trail NZ survey. To access Part 2 (Nutrition Knowledge Survey) – please first copy the following Survey ID (this is your unique identifier):

Your ID number: **TrailNZ**

Then click the **'Next Button'** below which will redirect you to the Nutrition Knowledge Survey.

You will then need to paste (ctrl + V) or type in this unique Survey ID (TrailNZ) into the question that asks "Please enter a survey ID" (this is the first question in Part 2).

By correctly entering your unique Survey ID it will allow us to link the two surveys we are using in the study, ensuring that the data we collect is both reliable and valid. Please take extra care to ensure this Survey ID is correctly entered.

Data for Part 1 is collected by the research team at Massey University. Data for Part 2 is collected by the research team at the University of Sydney and then sent to the research team at Massey to combine and analyse the full dataset.

In Part 2, there is also a question that will ask you to indicate which sporting institution, organisation or research study you belong to – please select "Massey University".

At the start of Part 2, you can also add your email address to receive an individualised summary report of your nutrition knowledge scores.

We hope you enjoy the survey. Thank you in advance!

Appendix C: Survey Part 2

Platform to Evaluate Athlete Knowledge of Sports Nutrition Questionnaire (PEAKS-NQ)
Available at: sportsnutritionassessment.com/peaks-nq/

Designed at The University of Sydney in collaboration with Massey University

Before you start:
Please enter a survey ID.
You may choose to use an ID number (athlete ID) provided to you by your sporting institution. Otherwise, enter an anonymised ID of your choice. ___________________

Are you:

- O Over 16 years of age
- O Under 16 years of age

Are you completing this as:

- O An athlete
- O A nutritionist or dietitian
- O Athlete support staff (e.g. coach, strength and conditioning coach)
- O University student (nutrition, exercise science etc.)
- O Other _____________________________________

Display This Question:

If Are you: = Over 16 years of age

The PEAKS-NQ survey will ask for a small amount of information about your health and fitness. It will also ask about the sports you participate in and the country you live in. It will then ask you a series of questions about your sports nutrition knowledge. This information will be used to give you a summary report to show you which areas of nutrition you understand well, and those where you need further improvement. You can choose to share your survey results with your dietitian, who can help you to build your nutrition knowledge. If you complete the PEAKS-NQ survey, your deidentified results will also be used by authorised researchers at the University of Sydney to improve knowledge of and support for improved sports nutrition. The University will securely store your survey data in its Qualtrics servers and its secure data storage repository, hosted in Australia. These environments have security monitoring and regular security audits and testing. We respect your trust and protect your privacy and will never share your data with third parties without your consent except where required or authorised by law. If you have any questions or concerns please use the Contact Us page available on our website. The full Privacy Policy explains how your personal information will be used, protected and stored. By providing consent you are acknowledging that you have read and understood the Privacy Policy .

- ☐ I understand that the data collected from me in this study will be preserved and made available with all direct identifiers removed, so that they can be consulted and re-used by others.

Display This Question:

If Are you: = Over 16 years of age

Your deidentified data may be used to inform future research projects and/or improvements to the PEAKS-NQ. Please select one of the following:

- O I give consent for my my data with all direct identifiers removed to be used in future research projects.
- O I do not give consent for my data with all direct identifiers removed to be used in future research projects.

Display This Question:

If Are you: = Under 16 years of age

The PEAKS-NQ survey will ask for a small amount of information about your health and fitness. It will also ask about the sports you participate in and the country you live in. It will then ask you a series of questions about your sports nutrition knowledge. This information will be used to give you a summary report to show you which areas of nutrition you understand well, and those where you need further improvement. You can choose to share your survey results with your dietitian, who can help you to build your nutrition knowledge. If you complete the PEAKS-NQ survey, your deidentified results will also be used by authorised researchers at the University of Sydney to improve knowledge of and support for improved sports nutrition. The University will securely store your survey data in its Qualtrics servers and its secure data storage repository, hosted in Australia. These environments have security monitoring and regular security audits and testing. We respect your trust and protect your privacy and will never share your data with third parties without your consent except where required or authorised by law. If you have any questions or concerns, contact info@asnap.com.au. The full Privacy Policy explains how your personal information will be used, protected and stored. By providing consent you are acknowledging that you have read and understood the Privacy Policy .

- ☐ My parents/guardian and myself understand that the data collected from me in this study will be preserved and made available with all direct identifiers removed, so that they can be consulted and re-used by others

Display This Question:

If Are you: = Under 16 years of age

Please check the box below to confirm that you have your parent/guardian's permission to complete this survey.

- ☐ I have my parent/guardian's permission to complete this survey.

Display This Question:

If Are you: = Under 16 years of age

Your deidentified data may be used to inform future research projects and/or improvements to the PEAKS-NQ. Please select one of the following:

- O I give consent for my data with all direct identifiers removed to be used in future research projects.
- O I do not give consent for my data with all direct identifiers removed to be used in future research projects.

Display This Question:

If groupq = 1

Please indicate which sporting institution, organisation or research study you belong to. Your results will be shared with your respective choice.

- O Australian Institute of Sport
- O High Performance Sport New Zealand
- O I don't belong to any sporting institution or organisation
- O TrailNZ Study (Massey University)
- O Other ____

Display This Question:

If emailq = 1

If you like you would like to receive an individualised summary report, please enter **your email address**. ____

Display This Question:

If dietitianq = 1

Who is your regular sports dietitian (if applicable)? Please enter their **email address** if you would like them to receive a copy of your results. _______________________________________

It is your responsibility to confirm with your dietitian that they consent to you providing their email address, and that the email address you provide for them is accurate.

By providing your dietitian’s email address, your dietitian will receive a copy of your results, your ID number and email address for the purpose of identifying your final results.

- ☐ I consent to my results, ID number and email address being shared with the email entered above.

In what country do you currently live or spend the most time?

- O Australia
- O New Zealand
- O United States
- O United Kingdom
- O Other

Display This Question:

If Country = Other

What country do you currently live or spend the most time? ___________________________

What is your age in years? (Enter numbers only) _____________

What is your height? (Enter height in centimetres e.g. 160) __________

What is your weight? (Enter weight in kilos) ____________

What sport do you spend most time training and competing in?

▼ Archery, Athletics (endurance), Athletics (power) ... Wheelchair sport (e.g. rugby, basketball, tennis), Wrestling, Winter sport (e.g. cross country skiing, skating, downhill skiing, snowboarding, ice hockey)

Has your weight changed in the last 6 months?

- O Yes
- O No

Display This Question:

If NZ Weight Change = Yes

If you gained or lost weight in the past 6 months, was this weight change intentional?

- O Yes
- O No

Do you alter your bodyweight for training or competition on a regular basis? (e.g. weight or class restrictions for certain sports)

- O Yes
- O No
- O Sometimes

What is your gender?

- O Male
- O Female

What language do you mostly speak at home?

- O English
- O Other - please specify ______________________

What is your ethnicity? *(Pick up to 2 that most apply)*

- ☐ New Zealand European
- ☐ Māori
- ☐ Pacific Islander

☐ Indian
☐ Middle Eastern/Latin American/African
☐ Chinese
☐ Other - please specify ________________

What is the highest level of education you have completed?

- ○ Year 10 or lower
- ○ Year 11, 12 or 13
- ○ Polytechnic
- ○ University
- ○ Other - please specify ____________________

What is the highest level you have competed at for your sport?

- ○ Recreational
- ○ School
- ○ Regional
- ○ University/Collegiate
- ○ National
- ○ Junior International
- ○ Age Group International
- ○ Open International

Have you previously received any nutrition education (from a health professional, school, sporting institute or similar)?

- ○ Yes
- ○ No

Display This Question:

If NZ Previous Nutrition Education = Yes

Please indicate where you received your nutrition education from? *Select all that apply:*

- ○ Naturopath
- ○ Group education from Sports Dietitian/Nutritionist
- ○ Individual education from Sports Dietitian/Nutritionist
- ○ Sporting program from athlete support staff
- ○ Strength and conditioning coach
- ○ Personal trainer
- ○ School e.g. Physical education/health subject
- ○ Other - please specify _____________________

What is your usual occupation? ______________________________________

Please indicate your current employment status:

- Full time
- Part time
- Casual
- Shift worker
- Contractor
- Trainee
- Student
- Volunteer
- Self-employed

SECTION 1: GENERAL NUTRITION KNOWLEDGE

Which food group does the following food belong to? **Pasta**

- Vegetables
- Fats and oils
- Fruit
- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Which food group does the following food belong to? **Energy drink**

- Vegetables
- Fats and oils
- Fruit
- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Which food group does the following food belong to? **Butter**

- Vegetables
- Fats and oils
- Fruit
- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Which food group does the following food belong to? **Mushrooms**

- Vegetables
- Fats and oils
- Fruit

- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Which food group does the following food belong to? **Fish**

- Vegetables
- Fats and oils
- Fruit
- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Which food group does the following food belong to? **Peach**

- Vegetables
- Fats and oils
- Fruit
- Meat and meat alternatives
- Grains (cereals)
- 'Sometimes' and 'treat' foods (discretionary)
- Dairy and dairy alternatives
- I'm not sure

Do these foods contain mainly protein, fat or carbohydrate?

	Please select 1 option per food option			
	Protein	Fat	Carbohydrate	Not sure
Orange juice	O	O	O	O
Tofu	O	O	O	O
Avocado	O	O	O	O
Salmon	O	O	O	O

Do these foods contain mainly protein, fat or carbohydrate?

	Please select 1 option per food option			
	Protein	Fat	Carbohydrate	Not sure
Kidney beans	O	O	O	O
Cashews	O	O	O	O
Soft drink	O	O	O	O
Prawn	O	O	O	O

For each nutrient, choose the most important role in the body. *Select the most correct option for each nutrient*.

Protein

- O An important fuel for exercise during moderate to high intensities
- O An important fuel for exercise during low to moderate intensities
- O Muscle growth and repair
- O A healthy digestive system
- O Hydration
- O Not sure

Carbohydrate

- O An important fuel for exercise during moderate to high intensities
- O An important fuel for exercise during low to moderate intensities
- O Muscle growth and repair
- O A healthy digestive system
- O Hydration
- O Not sure

Fat

- O An important fuel for exercise during moderate to high intensities
- O An important fuel for exercise during low to moderate intensities
- O Muscle growth and repair
- O A healthy digestive system
- O Hydration
- O Not sure

Fibre

- O An important fuel for exercise during moderate to high intensities
- O An important fuel for exercise during low to moderate intensities
- O Muscle growth and repair
- O A healthy digestive system
- O Hydration
- O Not sure

Water

- O An important fuel for exercise during moderate to high intensities
- O An important fuel for exercise during low to moderate intensities
- O Muscle growth and repair
- O A healthy digestive system
- O Hydration
- O Not sure

Calcium

- O Strong bones and teeth
- O Immune function
- O Delivery of oxygen to muscles
- O Not sure

Iron

- O Strong bones and teeth
- O Muscle contraction
- O Delivery of oxygen to muscles
- O Not sure

Which of these foods contain mostly healthy fats? *Select all that apply.*

- ☐ Butter
- ☐ Olive oil
- ☐ Salami
- ☐ Salmon
- ☐ Cream
- ☐ Coconut oil
- ☐ Avocado
- ☐ Almonds
- ☐ Not sure

Fats
Athletes should:
Select all the answers that are true. You may select more than one answer.

- ☐ Eat between 20%-35% of total energy intake from fat
- ☐ Aim to increase saturated fat intake
- ☐ Include dietary fats to provide water soluble vitamins
- ☐ Avoid all types of dietary fat
- ☐ Eat a high fat diet (>80% of total energy) to fuel sprint activities
- ☐ Include dietary fats to provide essential fatty acids
- ☐ Not sure

Which of the following foods has the most iron?

- O ½ cup (60g) cooked spinach
- O 1 cup (190g) cooked rice
- O 100g lean grilled steak (trimmed)
- O Not sure

Which of the following foods has the most iron?

- O ½ cup (50g) cooked kidney beans
- O 1 boiled egg
- O 1 cup (260g) cooked porridge (made with full fat milk)
- O Not sure

You have eaten chickpeas at lunch. What foods would you add to improve the iron absorption of your meal? *Select all answers below that apply*:

- ☐ Citrus fruits (e.g. oranges, mandarins)
- ☐ Tea and coffee
- ☐ Dairy products
- ☐ Red meat
- ☐ Spinach
- ☐ Not sure

Which of the following foods has the most calcium?

- O 1 banana
- O 1 cup (200g) cooked broccoli
- O 1 cup (250ml) reduced fat (light) milk
- O Not sure

Which of the following foods has the most calcium?

- O ½ cup (70g) peanuts
- O Tofu (100g)
- O ½ cup (20g) raw spinach
- O Not sure

Which of the following foods has the most dietary fibre?

- O ½ cup (40g) raw oats
- O 1 handful (30g) of peanuts
- O 2 slices of watermelon
- O Not sure

SECTION 2: SPORTS NUTRITION

Which option would be best to refuel the muscles after a weight training session?

- O 1 banana + 1 cup (250ml) reduced fat (light) milk + 1 nut bar
- O Large chicken salad + olive oil and balsamic vinegar dressing
- O Not sure

Which option would be best to refuel the muscles after 1 hour of sprint or high intensity exercise?

- O 1 tuna and salad sandwich + 1 glass (350ml) chocolate milk
- O 30g almonds, 250ml glass of water, 250g chicken breast and 2 cups (320g) steamed vegetables
- O Not sure

Immediately after exercise, which of the following are helpful for recovery from a high intensity/sprint session? *Select all that apply:*

- ☐ Alcohol - e.g. beer
- ☐ Protein - e.g. milk
- ☐ Carbohydrates - e.g. rice
- ☐ Fluid - e.g. water
- ☐ Not sure

You are training twice in one day, at 9am and 3pm. How soon after the morning session should you eat to start getting ready for the evening session?

- O Within 45 minutes after the morning session
- O Within 2 hours after the morning session
- O Within 3 hours after the morning session
- O Within 4 hours after the morning session
- O Not sure

If an athlete does not eat or drink enough carbohydrate before and/or after exercise, they may have: *Select all that apply*.

- ☐ Decreased performance
- ☐ Faster recovery
- ☐ More fatigue (tired)
- ☐ Increased muscle glycogen (carbohydrate)
- ☐ Light-headedness
- ☐ Better sprinting ability
- ☐ Dizziness during exercise
- ☐ Not sure

What proportions of food is best if you are trying to change body fat levels?

- ○ Plate 1 (20% non-starchy vegetables, 40% starchy vegetables, 40% lean protein)
- ○ Plate 2 (25% lean protein, 25% starchy carbohydrate, 50% non-starchy vegetables)
- ○ Plate 3 (25% lean protein, 25% non-starchy carbohydrate, 50% starchy vegetables)
- ○ Not sure

When an athlete is trying to change body fat levels, which of the following would be recommended to be helpful while maintaining the quality of training? *Select all that apply:*

- ☐ Cutting out all carbohydrate foods from the diet
- ☐ Eating more vegetables
- ☐ Skipping meals
- ☐ Reducing drinks containing sugar
- ☐ Not sure

When an athlete is trying to change body fat levels, which of the following would be recommended to be helpful while maintaining quality of training? *Select all that apply:*

- ☐ Avoiding carbohydrates after breakfast
- ☐ Reducing portion sizes at meals and snacks
- ☐ Cutting out all dairy foods from the diet
- ☐ Eating less 'treat' or 'sometimes' foods
- ☐ Not sure

When an athlete is trying to gain lean mass, which of the following would be recommended (helpful)? *Select all that apply:*

- ☐ Eating more energy (kilojoules/calories) than they use each day
- ☐ Eating less energy (kilojoules/calories) than they use each day
- ☐ Taking a multivitamin supplement
- ☐ Eating a protein-rich food after resistance training sessions
- ☐ Not sure

When an athlete is trying to gain lean mass, which of the following would be recommended (helpful)? *Select all that apply:*

- ☐ Eating regularly and including snacks between meals
- ☐ Spacing protein intake evenly throughout the day
- ☐ Increasing vegetable intake
- ☐ Drinking more water
- ☐ Not sure

How much protein does an athlete need compared to a non-athlete?

- ○ The same amount of protein
- ○ Up to double (2x) the amount of protein
- ○ 3-4 times the amount of protein
- ○ 5 times the amount of protein
- ○ Not sure

Which of the following would be appropriate to fuel an athlete during continuous competition lasting more than 1 hour? *Select all that apply:*

- ☐ Macadamia nuts
- ☐ Protein bar (low carb)
- ☐ Muesli bar
- ☐ Water
- ☐ Sports drinks
- ☐ Not sure

Which of the statements about hydration are true? *Select all options that are true:*

- ☐ During exercise, athletes should only drink when feeling thirsty
- ☐ Change in body weight over an exercise session can be used to assess hydration
- ☐ The colour of urine can be an indicator of hydration
- ☐ It is impossible to drink too much water during exercise
- ☐ Athletes should drink enough fluid to keep change in body weight to less than 2-3% of body weight during exercise
- ☐ Athletes should aim to finish exercising weighing more than when they started exercise
- ☐ Athletes should drink less when training in cooler, less humid conditions
- ☐ Not sure

Which of the following drinks are recommended as the main source of fluid replacement during most types of training and competition involving 90 minutes of hard exercise? *Select all the options that are true*.

- ☐ Water
- ☐ Coffee
- ☐ Fruit juice
- ☐ Soft drinks
- ☐ Milk
- ☐ Cordial
- ☐ Sports (carbohydrate-electrolyte) drinks
- ☐ Energy drinks
- ☐ Not sure

An athlete loses 1kg during an event. How much fluid should the athlete aim to drink to rehydrate afterwards?

- ○ 500ml (0.5L) of fluid
- ○ 1000ml (1L) of fluid
- ○ 1500ml (1.5L) of fluid
- ○ 2000ml (2L) of fluid
- ○ Not sure

Which of the following statements about vitamins and minerals are true? *Select all the statements that are true.*

- ☐ All athletes should use vitamins and mineral supplements
- ☐ Athlete should seek guidance from a doctor or sports dietitian/ nutritionist before taking vitamins and minerals
- ☐ Eating a wide range of foods provides most athletes the vitamins and minerals they need
- ☐ It is not possible to consume too much of a vitamin or mineral from a supplement
- ☐ Not sure

Which of the following statements about vitamins and minerals are true? *Select all the statements that are true.*

- ☐ Vegetarians and vegans are not at risk of vitamin and mineral deficiencies
- ☐ Vitamins and mineral supplements are safe for all athletes
- ☐ Vitamins and mineral supplements can assist athletes to correct a deficiency diagnosed by a medical professional
- ☐ Vitamins and minerals may sometimes be recommended when travelling to competition where there is limited food variety
- ☐ Not sure

If you are considering a new dietary supplement, you should: *Select all the statements that are true.*

- ☐ Only use supplements used by well known athletes
- ☐ Check with staff at a supplement store
- ☐ Check with a naturopath or herbalist
- ☐ Pick supplements that have had additional (third party) testing
- ☐ Check with a sports dietitian or nutritionist
- ☐ Check with a team mate to get their opinion
- ☐ Not sure

An athlete eats less food to reduce body fat over many months. The amount of energy (calories/kilojoules) is not enough to support their training. What symptoms might the athlete experience? *Select all the statements that are true.*

- ☐ Poor performance
- ☐ Stress fractures
- ☐ High energy levels
- ☐ Increased bone strength
- ☐ Low male hormone levels / Irregular periods
- ☐ Increased metabolism
- ☐ Increased chance of micronutrient (vitamin/mineral) deficiency
- ☐ Not sure

In high altitude and extreme environments, which of the following statements are true? *Select all the options that are true.*

- ☐ Symptoms of heat exhaustion can include anxiety, dizziness and fainting
- ☐ Pre-cooling the body prior to exercise in hot environments reduces exercise performance
- ☐ Athletes should prioritise reducing skin temperature, and minimising fluid loss in hot environments
- ☐ Athletes can't get heat stroke in cool environments
- ☐ Not sure

Thank you for completing the PEAKS-NQ!