Energy Availability and Injuries in Female Football Players

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Abstract

The popularity of women's football has been rising steadily since the first world cup in 1991. As the interest and number of participants grow, so does the need for more focused research on female players.
Football is a sport with a high injury incidence, therefore, one of the key areas of research is in injury prevention. An area of injury prevention that has not received much attention is that of energy availability (EA). Low EA has been linked to numerous negative effects on the physiological systems, including the endocrine, reproductive, metabolic, and adrenal systems. These effects may influence athletic health in many ways including increased risk of illness, decreased strength and coordination, and poor training responses, which may lead to injuries.

This study aimed to address this research gap and contribute to the development of comprehensive injury prevention strategies tailored specifically for women in football by answering the question: is there a relationship between EA and injury risk in the female football player?

Data, including EA from food and exercise diaries, the LEAF-Q questionnaire, injury and illness incidence using the OSTRC-H questionnaire, and body composition on 46 female first-division athletes were collected in collaboration with the KIHU training center over a one year period.
The study found a high prevalence of athletes (77.4%) who had energy availability levels below the recommended threshold and a high incidence of injuries and illness (median: 2). High LEAF-Q scores were associated with increased risk of injuries, and more time off of sport due to injury and illness.

Coaches and athletes need to be educated on the role nutrition plays in athletic performance. This education should include the different fuel sources the body requires, with an emphasis on carbohydrates, as well as how to fuel to match exercise energy demands. The LEAF-Q questionnaire should be used as a screening tool to identify athletes at risk of future injuries and illness, and prevention strategies implemented with the results. Future research on EA should use more objective measures of EA in combination with validated outcome measures.

Keywords/tags (subjects)

Energy Availability, Low energy availability, athletic injuries, injury prevention, football injuries, women's football, female athletes

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1 Introduction

Participation in women’s football has been increasing exponentially since its first official World Cup in China in 1991, which saw 12 teams compete. In 2023, 32 teams are scheduled to participate in Australia and New Zealand, with FIFA reporting in 2019 a whopping 13 million women and girls were playing worldwide (FIFA 2019).

As the interest and popularity in the sport continues to grow, the focus on optimizing the performance and health of the players becomes increasingly important. Football is a contact sport associated with a high injury rate, ranging from 6-9 injuries per 1000 hours (Hägglund & Waldén, 2012). Therefore, research on all aspects of injury prevention is crucial.

Injuries have substantial financial implications for professional players, with the average cost of a one-month-long injury in professional teams reported to be around €500 000 (López-Valenciano et al., 2020). Furthermore, injury rates have been linked to team performance, with lower injury rates associated with a higher league ranking (Hägglund, et al., 2013). From an athlete's perspective, injuries impact not only their career longevity but also their mental health and enjoyment of the game (Koch et al., 2021).

One area of injury prevention that has been relatively unexplored in the football community is energy availability (EA). EA refers to the amount of dietary energy remaining to support body functions after subtracting the energy expended in exercise (Mountjoy, et al., 2018). Inadequate levels, known as low energy availability (LEA) are associated with numerous detrimental health consequences, including a possible increase in injury risk.

The majority of research in EA has focused on endurance sports, and to a lesser extent aesthetic and weight category sports, where the pressure to fit a certain body type or weight is highest. Despite the high training load and energy expenditure, with elite outfielders covering up to 10km in a match (De Sousa et al, 2020) football has not been considered a sport where athletes are at risk of LEA. However, a recent study found 85% of elite female football participants had reduced EA over 5 days (Moss et al, 2020), suggesting the need for more research into EA in football.

This paper aims to address this research gap by examining the relationship between EA and injuries in the female football player and contribute to the development of comprehensive injury prevention strategies tailored specifically for women in football. Understanding the role of EA in injury occurrence and its potential implications for performance and player well-being will not only enhance the overall understanding of the sport but also provide valuable insights for coaches, medical professionals, and athletes themselves.

2 Literature Review

2.1 Energy Availability

Energy availability (EA) is defined as “the amount of dietary energy available to sustain physiological function after subtracting the energetic cost of exercise” (Areta et al, 2021), and it is calculated by using the formula below. It has long been considered the key causative factor in syndromes such as relative energy deficiency in sport (REDs) and the female athlete triad (De Souza et al, 2014, 2019; Mountjoy et al, 2018).

$$Energy\ Availability = \frac{(Energy\ Intake(kcal) - Exercise\ Energy\ Expenditure(kcal)}{Fat - free\ mass\ (kg)}$$

In ideal conditions, the above equation leaves enough energy after exercise to be funneled into the various body systems as needed to sustain optimal physiological function. During starvation/low energy availability (LEA) periods, less energy is allocated to non-essential functions, such as reproduction and growth, to preserve the systems necessary for survival and maintain energy homeostasis (Areta et al, 2021). These systems include thermoregulation, cellular maintenance, and locomotion. (De Souza et al., 2019; Mountjoy et al., 2018).

This energy conservation process leads to a cascade of interrelated physiological impairments, the negative health consequences of which will be explored briefly below.

2.2 Low energy availability

Accurate LEA prevalence data is difficult to get due to discrepancies in the way it is defined and measured. For female endurance and track and field athletes, the estimated range is between 41-51%, with Melin et al (2014) finding that 62.2% of endurance athletes were classified as ‘at risk’ when using the LEAF-Q questionnaire. In team sports such as football, the range is 11-67%, depending on when in the season the measurements are taken (Jagim et al, 2022).

Logue et al. performed a study in 2018 with 833 female athletes from a variety of sports and found that almost 40% of them were at risk of LEA. The risk increased with the level of competition and the time spent participating in exercise.

LEA has historically been classified at 30 kilocalories-per-kilogram of fat-free-mass-per-day (kcal·kg FFM^{-1}·day^{-1}) when measuring EA through the commonly used method of food and exercise logs. However, two recent reviews (De Souza et al, 2019; Logue et al, 2020) recommend that a sliding scale be used instead, with 45kcal·kg FFM^{-1}·day^{-1} being the targetted level of optimal energy balance. This is due to the findings that while EA and the associated negative sequelae (such as menstrual disturbances) are inversely proportional, there is great variability between the levels at which individuals experience adverse health effects, with some participants experiencing menstrual disturbances above the 30kcal·kg FFM^{-1}·day^{-1} mark (Lieberman et al., 2018). Factors such as an athlete's gynaecological age, genetics, sport type, and the composition of macronutrients in their diet all contribute to this variability in LEA thresholds (Melin et al, 2023).

The duration of exposure to LEA also plays a big role, so a smaller energy deficit (that may not be picked up with the above threshold) over a long period of time may have greater consequences than a severe energy deficit over a very short period of time. This interaction has been described as 'LEA dose or load', where the product of the energy deficit and the number of days with LEA is used instead of a threshold (Melin et al, 2023).

Further research has shown that EA can be measured more conveniently with appropriate questionnaires that screen psychological factors (eg. Drive for thinness and disordered eating) and physiological factors (eg. LEAF-Q, RED-S), and more objectively through surrogate markers such as menstrual function, BMD, metabolic hormones or resting metabolic rate (RMR) ratios, especially once laboratory protocols for accurate and consistent RMR measurements are developed. These measures are not only more accurate than the EA obtained from training logs but give a better representation of a person's long-term EA, rather than the few days seen with the food diaries and exercise logs. (Heikura, et al., 2018; Logue et al., 2020; Ihalainen et al, 2021)

2.3 Health consequences of LEA

The health consequences of LEA are numerous and complex, and the extent to which individuals experience these effects depend on the duration and severity of LEA to which they have been exposed. A summary of all the possible effects LEA can have on the body is shown in Figure 3. (While there is growing research on the effects of LEA in the male population, this analysis will focus only on females).

The female athlete triad outlined the effect of decreased EA on bone health and menstrual function (De Souza et al, 2014; 2019), with Figure 1 illustrating the spectrum of the 3 interrelated components, from optimal health to serious health concerns. More recently however, a more

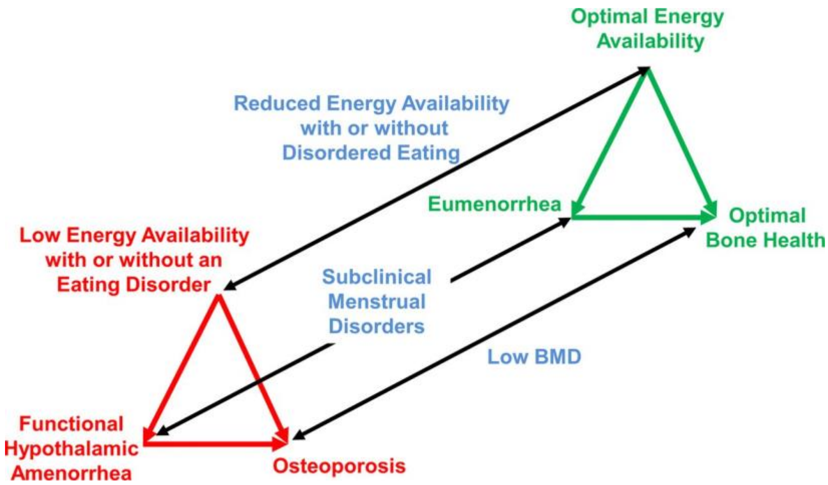

Figure 1. Components of the Female Athlete Triad. (De Souza et al, 2014)

comprehensive, gender-inclusive condition known as REDs has been described by the International Olympic Committee (IOC) consensus statement to include impacts on neuroendocrine function, cardiovascular and gastrointestinal health, metabolic rate, immunity, growth and development, psychological as well as possible performance factors (Mountjoy et al, 2018). These components will be discussed in more detail below.

2.3.1 Endocrine effects

Decreased EA can lead to neuroendocrine changes that are thought to be mediated, at least in part, by the hormone leptin (Chan & Mantzoros, 2005; Boutari et al, 2020). Leptin is primarily secreted by adipose tissue and is responsible for regulating energy homeostasis. As EA decreases, circulating levels of leptin also decrease, indicating an energy-deficient state to the hypothalamic-pituitary axes (Areta et al, 2021).

At the hypothalamic-pituitary-gonadal axis, a decrease in leptin suppresses the release of gonadotropin-releasing hormone(GnRH) through kisspeptin. In females, GnRH is responsible for the release of luteinizing hormone(LH) and follicle-stimulating hormone (FSH), which in turn signals the production and release of estrogen and progesterone. (Areta et al, 2021; Boutari et al, 2020). Depending on the severity of energy deficiency, the decrease in LH, FSH, and estrogen can cause menstrual disturbances, hypothalamic amenorrhea, and infertility. Oestrogen plays a key role in bone remodelling through the inhibition of bone reabsorption as well as the regeneration and repair of muscle tissue, therefore decreased levels contribute to poor bone health and potentially increases the risk of muscular injuries (Dipla et al, 2021; Wasserfurth et al, 2020; Tornberg, et al., 2017).

A decrease in circulating leptin levels can suppress of thyrotropin release hormone at the hypothalamic-pituitary-thyroid axis, which regulates the release of thyroid stimulating hormone and subsequently the synthesis and release of thyroid hormones T3 and T4. Low thyroid hormone levels can result in a myriad of symptoms, including decreased resting metabolic rate, neuromuscular function, decreased muscle strength and recovery, fatigue, cold sensitivity, shortness of breath, and decreased cognition. (Flier et al, 2000; Chaker et al, 2017; Tornberg, et al., 2017; Areta et al, 2021)

And lastly, the hypothalamic-pituitary-adrenal axis. Cortisol, which is a catabolic hormone responsible for numerous things including modulating inflammation and increasing blood glucose levels, is increased with LEA. Increased cortisol levels causes the suppression of inflammatory reactions as well as the suppression of GnRH, which can further exacerbate menstrual disturbances (Dipla et al, 2021). However, cortisol levels are influenced by numerous other factors that athletes regularly encounter, including, poor sleep, increased training load, psychological and emotional stress, and poor mental health (Drew et al, 2017;2018; Mountjoy et al, 2018; Pedlar et al, 2019; Wasserfurth et al, 2020) and more research is needed in this area to know whether the changes in cortisol found in athletes with LEA are as a direct or indirect result of energy restriction.

On the anabolic side, changes are seen in growth hormone (GH), insulin-like growth factor 1 (IGF-1) as well as insulin levels, which all play key roles in muscle and bone growth formation and remodelling. LEA causes GH insensitivity in the liver, leading to a decrease in the production of IGF-1 and an increase in circulating GH. (Dipla et al, 2021; De Souza et al, 2019; Areta et al, 2021)

2.3.2 Skeletal Health

Bone metabolism, or the cycle of bone remodeling, is influenced by nutrition and external load. (Dipla et al, 2021). The strength and mass of bones adapt according to the mechanical load to which they are subjected. In addition, resistance exercise has been found to increase levels of GH, IGF-1, and insulin, further promoting healthy bone metabolism. However, these effects are somewhat inhibited with LEA. As mentioned above, estrogen, IGF-1, and insulin play a key role in activating and regulating bone formation and remodeling. Leptin also acts directly on bone cells, stimulating bone formation and inhibiting degradation. Reduced levels of these hormones decrease rates of bone remodeling, leading to low bone mineral density. (Dipla et al, 2021) Interestingly, bone formation markers appear to be more sensitive to EA changes compared with reabsorption markers, which short-term LEA studies have found to increase only in more severe LEA states (Areta et al, 2021). Untreated, this decrease in bone mineral density leads to long-term consequences for athletes, including stress injuries and osteoporosis.

2.3.3 Reproductive Function

The menstrual disturbances experienced by many female athletes are primarily the result of the hormone changes described above. Studies have shown that it is LEA and not the stress of exercise alone that illicit these changes (Dipla et al, 2020) The extent of menstrual sequelae (including luteal phase defects, anovulation, and oligomenorrhea) is dependent on the size of the energy deficit compared to baseline (Mountjoy et al.,2018).

Studies have shown that restoration of menstrual disturbances through nutritional interventions to increase EA can take between 23 days to 16 months (Ihalainen et al, 2021).

2.3.4 Immune Health

During specific periods of the athletic season, there is an elevated risk of upper respiratory tract infections and decreased immunity among athletes (Walsh, 2018). This heightened susceptibility can be attributed to several factors, as illustrated in Figure 2. These factors include prolonged intense exercise or overtraining, inadequate nutrition, insufficient sleep, psychological stress, and exposure to changing environments or extreme environmental conditions such as high altitude or extreme temperatures. When athletes encounter one or more of these factors, it can trigger the

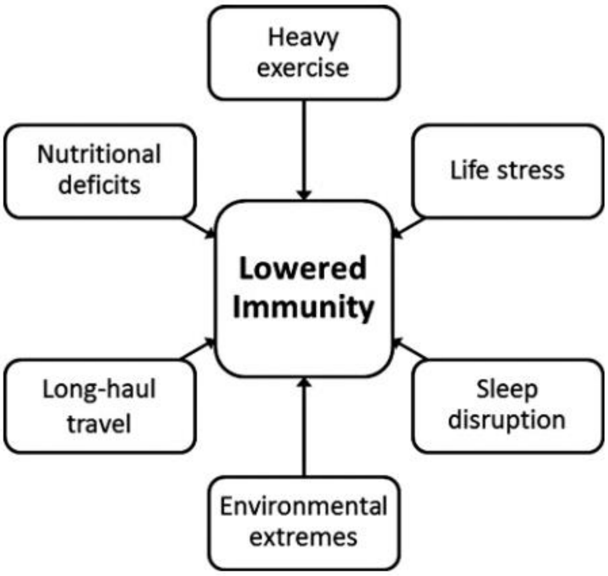

Figure 2. Factor's affecting athlete immunity (Walsh, 2018)

activation of the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system. Consequently, there is an increase in glucocorticoids and circulating catecholamines, which can disrupt the normal functioning of the immune system (Dipla et al., 2021; Walsh, 2018, 2019).

The impact of elevated cortisol on the immune system depends on the duration and extent of exposure. Short-term exposure can potentially enhance immune function, while chronic exposure can lead to glucocorticoid resistance, which compromises the body’s infection resistance capacity, reduces the number of immuno-protective cells, and induces low-grade chronic inflammation (Walsh, 2019).

Regarding poor nutrition, the immune system requires enough energy from various sources (e.g., glucose, amino acids, nucleotides) for optimal function. Without it, the immune system's ability to clear viruses, perform DNA and RNA synthesis, and produce necessary proteins, such as immunoglobulins and immune cells, is reduced (Walsh, 2019). Certain micronutrients, such as iron, zinc, and magnesium, as well as vitamins C and D, which may be lacking in athletes with LEA, also play a vital role in decreasing infection burden and countering exercise-induced oxidative stress (Walsh, 2019). Furthermore, carbohydrate restriction has been found to exacerbate the immunosuppressive stress hormone response to exercise, potentially increasing the "window" for opportunistic infections (Walsh, 2018).

Drew et al. (2018) performed a study on athletes from the 2016 Australian Olympic team. 100% of the athletes reported at least one illness symptom in the month before the study and an association between LEA and illness in female athletes was found. However, this study was done using self-reported questionnaires, and the authors recommended that further research be done on this topic using more objective measures of LEA, illness, and immunity. Logue et al. (2018) also found that athletes with LEA were three times more likely to miss training for more than 22 days due to illness than those without LEA.

More research is needed to determine whether the magnitude of energy deficiency experienced by most female athletes is significant enough to compromise immune health as described above.

2.3.5 Injury and performance

Injuries in professional and amateur sports are highly prevalent, have large financial implications for teams and individuals, and have a big impact on performance (López-Valenciano et al.,2020). Logue et al. (2018) looked at 833 female athletes and reported 62% of participants recorded missed training due to injury over one year. In football specifically, a systematic review of female athletes reported a 55% injury incidence proportion (Mayhew et al., 2021). The average injury rate varies between 6 - 9 injuries /1000 hours in males and females (Hägglund & Waldén, 2012; Hägglund et al, 2013; López-Valenciano et al, 2020) with Larruskain et al. (2018) reporting that while males had a higher incidence of injuries, females had a higher total injury burden and lost 21% more days due to injury than males at 216 days/1000h.

Performance-wise, a study done on track and field athletes showed that athletes who were able to keep their modified training weeks (considered a week where one or more days of training could not be completed as planned and needed adapting due to illness or injury) to less than 20% of total training were 7 times more likely to achieve their performance goals. A 26% decrease in achieving key performance goals was seen for any one week of modified training taken, and there was a 3 fold increase in achieving performance goals for athletes who had less than 2 injuries or illnesses per season, compared to those athletes who had 2 or more episodes (Raysmith & Drew, 2016). Football performance has also been shown to decrease, a study done on UEFA Championship League teams found associations between match availability (squad size multiplied by the number of matches) and lower injury rates, with a higher average score per match and a higher league ranking at the end of the season (Hägglund et al., 2013).

Although the association between bone stress injuries and LEA has been extensively studied, including a recent study that showed a 4.5-fold increase in bone injuries among athletes with menstrual dysfunction compared to eumenorrheic athletes (Heikura et al., 2018), research on the association between musculoskeletal injuries and LEA is limited. Several studies (discussed below) have, however, established an association between LEA and risk factors for injury, such as decreased muscle power and strength, impaired coordination, slower reaction times, and signs of overreaching. These risk factors are significant enough that they form the main focus of injury prevention programs (Lauersen, Andersen, & Andersen, 2018; Vlachas & Paraskevopoulos, 2022).

At the most basic level, the energy deficit from LEA means athletes have less readily available fuel to perform high-intensity exercise. Carbohydrates from skeletal muscle, liver glycogen, as well as blood glucose provide the main fuel for anaerobic and aerobic metabolism in athletes. When these stores become depleted, the body turns to less efficient methods of energy production (Hargreaves & Spriet, 2020). Consequently, over and above the endocrine and physiological effects discussed below, LEA may directly impact performance, and increase the risk of injury simply due to a lack of fuel. (Melin et al.,2023; Logue et al, 2018). Indeed in a study of Polish women, low pre-exercise muscle glycogen levels were associated with impaired football performance (Dobrowolski, Karczemna and Wlodarek 2020) .

Kettunen et al. (2021) found that cross-country skiers with lower carbohydrate intake over a 5-day period had decreased power and muscular performance, and showed more signs of overreaching when compared to those athletes with adequate carbohydrate intake. As the authors noted, not only did this have a direct impact on performance at the training camp, but better nutrition may have enabled those athletes to complete more training at a higher intensity, thereby getting the most out of the training camp and improving future performances. Leg extension power and average jump height (a functional measurement of power) have also been found to be a predictor of a football team’s success and performance (Datson et al.,2014).

Ackerman et al. (2018) conducted a large survey study with self-reported questionnaires and found athletes with LEA reported a higher prevalence of decreased coordination, impaired judgement, poorer concentration, decreased endurance performance and increased irritability than athletes with sufficient EA.

The associated negative endocrine effects from LEA could also play a role in injury risk and decreased performance(Logue et al, 2020). Low estrogen levels have been associated with poor muscular recovery, lower muscle mass and decreased muscle strength (Collins, Laakkonen, & Lowe, 2019; Chidi-Ogbolu & Baar, 2019). While most of these studies have been performed on post-menopausal women, Tornberg et al. (2017) found that elite endurance athletes with menstrual dysfunction (and associated decreases in estrogen and t3 levels, decreased fat-free mass in the leg, and elevated cortisol) showed slower reaction times and poorer neuromuscular performance using isokinetic dynamometry when compared to eumenorrheic athletes.

Fluctuating estrogen levels as seen in a regular menstrual cycle, with periodically higher levels also promote a decrease in tendon stiffness and modulate IGF-1 and IGF binding proteins, which increases tendon collagen synthesis and incorporation, all of which protect both the tendon and associated muscle from injury. Conversely, these high estrogen levels have been linked with ligament injury due to increased ligament laxity (Chidi-Ogbolu & Baar, 2019). This is noteworthy as female athletes incur 2-8 times more ACL ruptures than their male counterparts, and ligament sprains are the most common injury in female football (Mayhew, et al., 2021), with female players being 5 times more likely to suffer a severe joint or ligament injury than males (Larruskain et al, 2018).

Ihalainen et al. (2021) found that female runners with amenorrhea had more injuries, higher LEAF-Q scores and lower total running volume over a season compared to the eumenorrheic athletes. Subsequently, only the eumenorrheic athletes recorded a performance improvement. These findings were consistent with one performed on swimmers, where after a 12-week training period, amenorrheic athletes recorded a drop in performances vs. improvement with eumenorrheic athletes (Vanheest et al, 2014). Gillbanks et al. (2022) conducted a qualitative study on lightweight rowers with REDs symptoms and found that 11/12 of the athletes reported recurrent injuries including stress fractures and generalised joint pain and all 12 of the athletes reportedly believed their performance and recovery were impaired because of LEA.

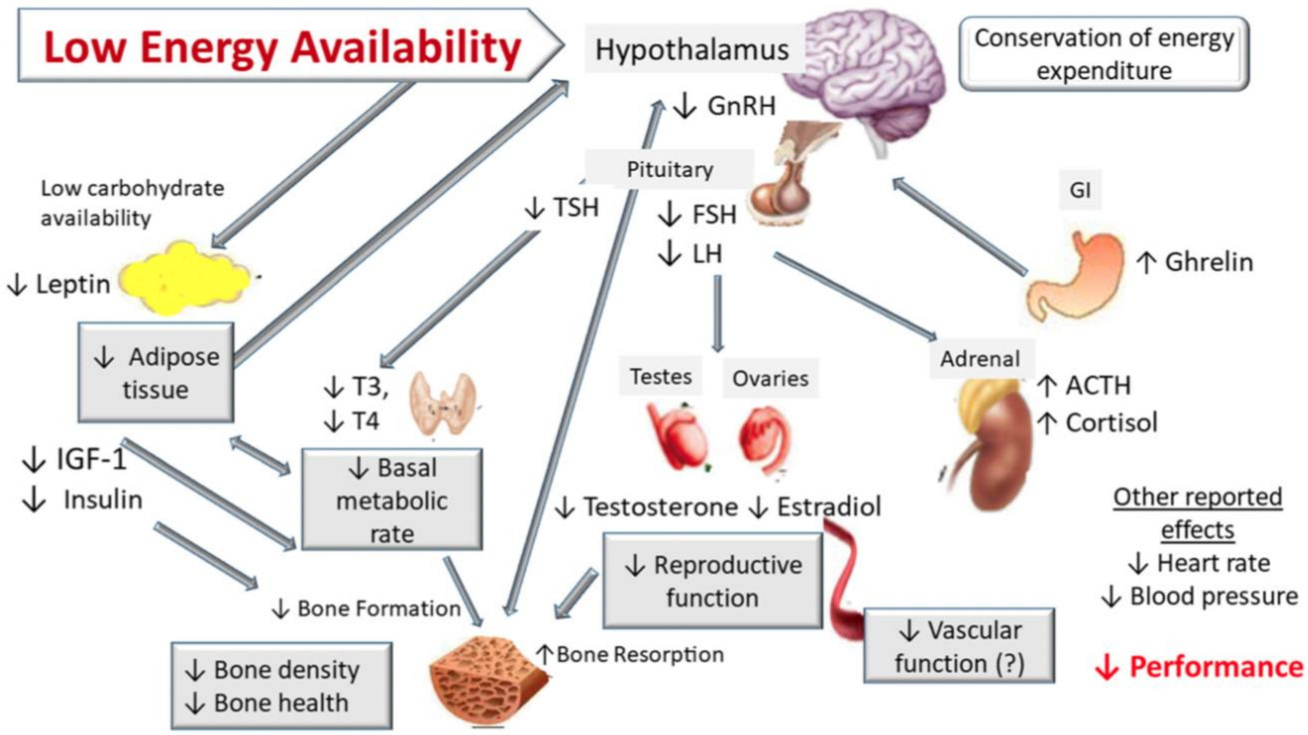

Figure 3. Summarized effects of LEA on the body. (Dipla et al, 2021)

2.3.6 Female football players and LEA

Football can be described as an intermittent hybrid sport (De Sousa et al., 2022), with approximately 80% of the 90-minute game comprising of low-intensity running or walking, (around 8kms) with periods of high-intensity running and sprinting scattered throughout the game (approximately 2 kms). The total distance covered as well as the amount of high-intensity running each player performs is dependent on their level of competition as well as their playing position (Datson et al.,2014), however, on average, players effort levels have been measured at 70 – 80% of VO_2 max (Dobrowolski et al, 2020). During the competition season, elite players usually have 1-2 matches and 5 – 7 training sessions per week. (De Sousa et al., 2022). Given this high training load, nutritional optimization is extremely important not only to ensure optimal adaptation to training and adequate recovery between, but to prevent athletes from accidentally entering in LEA.

Football utilizes large quantities of skeletal muscle and liver glycogen, and studies in female football players have found substantial amounts of type I and II muscle fibers to be empty of glycogen at the end of a game (Krustrup et al., 2022). Carbohydrate availability becomes the limiting factor during prolonged or high-intensity exercise (Dobrowolski et al, 2020) and therefore, carbohydrate consumption plays a key role in maintaining and replenishing these stores prior to and after training. Numerous academic bodies, including The American College of Sports Medicine, Dietitians of Canada and Academy of Nutrition and Dietetics have recommended carbohydrate consumptions of 3 – 5g·kg·day^{-1} for skill-based or low-intensity activities, 5 - 7g·kg·day^{-1} for moderate activity, 6 – 10g·kg·day^{-1} for endurance activities of 1-3 hours in length, and 8 - 12g·kg·day^{-1} for anything longer than 3 hours. These figures were supported by FIFA who released recommendations for female players of 5 - 7g·kg·day^{-1} for low intensity or moderate duration training and 7 – 12g·kg·day^{-1} for moderate to heavy endurance training. (Dobrowolski et al, 2020)

A review by de Sousa et al. in 2020 found 8 studies with a total of 164 athletes, looking at the dietary patterns and energy intake of female football player. Of these studies, only one group of athletes (n = 15) had an average carbohydrate intake within the suggested range during season training, and only just at 5g·kg·day^{-1}, the rest were below this recommendation. As female athletes appear to not be meeting their nutritional needs, it makes sense to study the EA of these athletes, as well as any adverse side effects associated with them.

4 studies were found to reported on EA of female football players. All 4 studies defined LEA as less than 30 kcal·kg FFM^{-1}·day^{-1} with Moss et al. (2020) also including 'reduced EA' as between 30 – 45 kcal·kg FFM^{-1}·day^{-1}, and 'optimal' as anything above 45 kcal·kg FFM^{-1}·day^{-1}.

56 German elite youth division football players were studied over a 7-day period. After excluding over and under-reporters, 32 athletes remained, of which, 53% were classified as LEA. 31% of athletes consumed less than 5 g·kg·day^{-1} carbohydrates and 34% consumed less than the recommended protein intake. (Braun et al, 2018)

Moss et al. (2020) looked at EA of 13 British professional female football players over a 5-day period, which included heavy, light, and no training days. Over the five-day period, 85% of participants had reduced EA, (mean: 36.7 kcal·kg FFM^{-1}·day^{-1}), with 23% being classified as LEA. Interestingly, they found that 69% of players had LEA on heavy training days, vs. only 38% on light training days, and 0% on no training days, suggesting that players aren't adjusting their caloric intake to match their exercise output. In particular, the study found that the athletes carbohydrate intake was not sufficient, with 92% of the participants ($\bar{x}$ of 3.31g·kg·day^{-1}) consuming less than the 5-7g·kg·day^{-1} as per the recommended discussed above. 23% of the participants were also classified as 'at-risk' with the LEAF-Q questionnaire, which matched with the percentage of athletes classified as LEA.

The third study looked at 19 American Division I athletes with EA being measured for 3 consecutive days pre, mid and post season The study found that the mean EA dipped by 19% from pre (43.2 kcal·kg FFM^{-1}·day$^{-1)}$ to mid-season (35.2 kcal·kg FFM^{-1}·day$^{-1)}$, but increased again (by 35%) for post season(44.5 kcal·kg FFM^{-1}·day^{-1}), with 26.3%, 33.3% and 11.8% of participants classified as LEA in those time periods respectively. The authors theorised that LEA risks for football players may therefore be seasonal, which means that for most players any negative sequalae could be reversible in the off-season. However, this was the first study of its kind to examine LEA over a season, with a small sample size, so caution should be taken when inferring this to the rest of the female football population. (Reed et al, 2013).

The final study looked at 51 Norwegian premier and first division players over a 14 day period, and found a LEA prevalence of 36% on match days (mean: 36.7 kcal·kg FFM^{-1}·day^{-1}) and 23% on training days (mean: 37.9 kcal·kg FFM^{-1}·day^{-1}). They had similar findings to Moss et al. (2020) and Braun et al. (2018) with most players not meeting the carbohydrate recommendations, and very little change in energy intake between the match,training and rest days (Dasa, et al., 2023).

Other studies in female football have not looked directly at EA but have looked at various aspects of the female athlete triad or REDs. A study of 220 football players found 1/5 high level athletes have menstrual dysfunction and 19 athletes reported a history of stress fractures despite most of these athletes having an appropriate body mass index (BMI) for their age (Prather et al., 2016).

Although football does not present as the typical sport where LEA is prevalent, given the evidence that female athletes appear to consume too few carbohydrates to match the demands of training, and the studies mentioned above with a fairly large percentage of athletes with LEA and menstrual dysfunction, it appears as though more research needs to be done to discover the extend of the risk for football players. For example, at the time of writing, no research could be found on the associations between EA and injuries or illness in football. Understanding the impact of EA on injury risk is crucial for athletes, coaches, and managers to enhance injury prevention strategies, reduce long term health consequences, and achieve optimal performance goals.

3 Objectives

This paper aims to address this research gap by investigating the correlation between EA and injuries in female football players, while also contributing to the development of comprehensive injury prevention strategies specifically designed for women in football. By exploring the role of EA in injury occurrence and its potential impact on performance and player well-being, this study not only advances the overall understanding of the sport but also provides valuable insights for coaches, medical professionals, and athletes themselves.

The primary research question addressed in this study is: Does energy availability levels play a role in injury occurrence among female football players? Additionally, the study aims to answer secondary questions such as: Is there a connection between energy availability and illnesses in female football players? And what is the prevalence of low energy availability within this particular group of athletes.

4 Implementation

4.1 Methods

4.1.1 Design

This study adopts a prospective cohort design, which involves the examination of distinct groups of people with different levels of a certain characteristic, known as the exposure, over a period of time, to assess the incidence of a particular outcome (Ranganathan and Aggarwal 2019). In this study the exposure of interest was EA, and the outcomes of interest were injuries and illness. Athletes EA was assessed using two outcome measures that are explained below, in December 2019 and February 2020 respectively, and then followed throughout the remainder of the year to monitor injuries and illnesses.

The data from this study was collected in collaboration with the University of Jyväskylä and the Finnish Institute of High-Performance Sport (KIHU) from December 2019 – December 2020 and analyzed in September 2022. A detailed timeline can be seen in Figure 5, that shows when each assessment was carried out.

4.1.2 Participants

Data from 46 first-division female football players between the ages of 15 – 26 were collected for this study. The participants were made up of a senior and a u/18 team from the same club. All team members were asked to participate in the data collection as part of their collaboration with KIHU, however completing all the information was not mandatory. Training consisted of 4 team training sessions, 1 – 2 strength sessions, and 1 – 2 games per week. Table 1 displays the physical characteristics of the players.

N = 42	Mean $\pm$ SD	Range
Age [years]	18.40 $\pm$ 3.1	15 – 26
Height [cm]	169.02 $\pm$ 6.45	153 – 182.20
Weight [kg]	64.36 $\pm$ 9.27	45.30 - 85
Body Mass Index [$kg.m^{-2}$]	22.45 $\pm$ 2.36	16.97 – 27,72
Body Fat [%]	23.31 $\pm$ 4.51	9.05 – 31.86

Table 1. Physical characteristics of the participants

The flowchart of athlete participation can be seen below (Figure 4). 4 participates were excluded from all analysis as they did not return at least one measure of EA (LEAF-Q or food and exercise logs), 1 participant was excluded from LEAF-Q and injury/illness analysis as they did not complete the LEAF-Q questionnaire, 11 participants were excluded from the EA average and illness/injury section of the analysis as they did not complete the food and/or exercise logs.

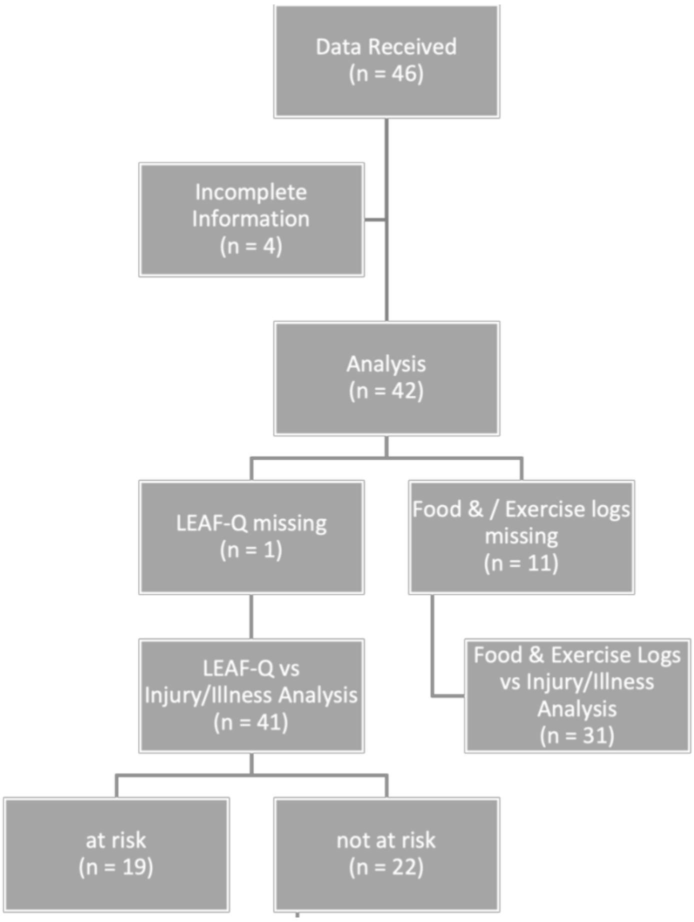

Figure 4. Flowchart of participants

4.1.3 Procedure

Data on body composition, injuries, EA, menstrual function, and exercise logs were collected from the athletes throughout the year (see timeline below).

4.2 Outcome measures

4.2.1 Leaf-Q

The Low Energy Availability in Females Questionnaire (LEAF-Q) is a self-reporting screening tool developed to help identify female athletes at risk of the female athlete triad. It consists of three sections: gastrointestinal symptoms, menstrual health, and injuries. A combined score of ≥ 8 indicates the athlete is at risk (Melin et al.,2014). While this questionnaire was validated with endurance athletes, Roger, et al. (2021) showed that it can be reliably used to rule out athletes who are not at risk (scores of < 8) of LEA in mixed sports. See appendix 3 for a copy of the outcome measure.

The participants in this study filled out a physical copy of the LEAF-Q, which had been translated into Finnish, in December 2019 and were categorized as not at risk (<8) or at risk (≥8) with the results.

4.2.2 OSTRC-H

The athletes completed the Finnish version of the Oslo Sports Trauma Research Centre (OSTRC) on Health problems every week for a full season, December 2019 – December 2020, through the AthleteMonitoring (AthleteMonitoring n.d.) mobile app. Athletes joining the team part way through the season completed the questionnaire from when they joined. This translated version of the OSTRC-H was found to be a reliable and valid measure of athlete health problems. (Virta, 2019).

The OSTRC-H was developed from the OSTRC Overuse Injury Questionnaire as a quick tool to monitor athletes' overall health, including injury and illness patterns (Clarsen et al, 2014). The questionnaire requires one to answer 4 basic questions – and depending on the results, participants were asked further questions to clarify illness symptoms or injury location.

The data from these questionnaires were aggregated, and variables created based off the methods used by the authors of the questionnaire (Clarsen et al, 2014). These variables included the number of unique injuries/illnesses registered per athlete and the number of substantial injuries/illnesses per athlete. A substantial event was defined as an incident that resulted in complete inability to participate in training. The total time lost to injury/illness, the number of modified training weeks, and average cumulative severity were also created. To calculate the average cumulative severity, first the cumulative severity was found, by adding the total score for each week the issue was reported, and then the average was calculated by dividing the cumulative severity score by the number of weeks the health problem was reported. This average cumulative score was used instead of the cumulative score, to account for athletes who did not complete the outcome measure for a full season. See appendix 4 for a copy of the outcome measure.

4.2.3 Body Composition

The dual energy X-ray absorptiometry (DXA) scan, which was originally designed to determine bone mineral density, works by sending two low radiation x-rays through the body. The difference in energy absorption of various tissues makes it possible to determine tissue type and quantity.

Body composition and fat free mass (FFM) was obtained in the morning after an overnight fast. Height was measured with a tape measure to the nearest 1cm. Weight, accurate to the nearest 0.1kg, and fat mass, was measured through the DXA scan. (DXA, LUNAR; GE Healthcare, Chicago, IL, USA) All measurements were done with patients in their underwear.

$$BMI = \frac{Weight}{Height^2}$$

BMI was calculated as weight (kgs) divided by height (m) squared. FFM was calculated as weight minus total fat mass. For athletes who did not have the DXA scan done (n = 10) fat mass was estimated at 25%, based on the average female fat mass.

4.2.4 Energy Availability

EA were determined through the completion of food and exercise diaries. All participants were asked to complete these for 3 days, with 2 days being training days, and one a rest day. The detailed instructions given to the participants can be found in the appendices.

4.2.4.1 Food Diaries

Using the National Food Composition Database in Finland, Fineli, (Finnish institute for health and welfare, n.d.) the results from the food diaries were broken down into individual food components (fats, proteins, carbohydrates, vitamins, and minerals etc.), and then the total energy (kcal) of each item was recorded. The energy from each food item was added together to get the total energy intake (EI) per day.

4.2.4.2 Exercise Logs

The exercise log was completed on the same days as the food diary. Athletes were asked to record their training session length, the type of physical activity and their perceived exertion using the modified Borg Scale. The detailed instructions can be seen in the appendix.

Each participants resting energy expenditure (REE) was calculated using Cunningham's (1991) equation, which is as follows:

$$REE = (22 \ x \ FFM\ ) + 500$$

Exercise energy expenditure (EEE) was then calculated using the metabolic equivalent of task (MET) tables (Ainsworth et al.,2011), with the formula below. 't' represents the duration of exercise in hours.

$$EEE = t \ x \ MET \ x \ \left(\frac{REE}{24}\right) - \left(\frac{REE}{24}\right) x \ t$$

Energy availability was calculated as:

$$\frac{(EI - EEE)}{FFM}$$

4.3 Timeline

As can be seen in the timeline, the translated LEAF-Q questionnaire was filled out in person in December 2019, followed by the food and exercise logs, which were filled out for 3 consecutive

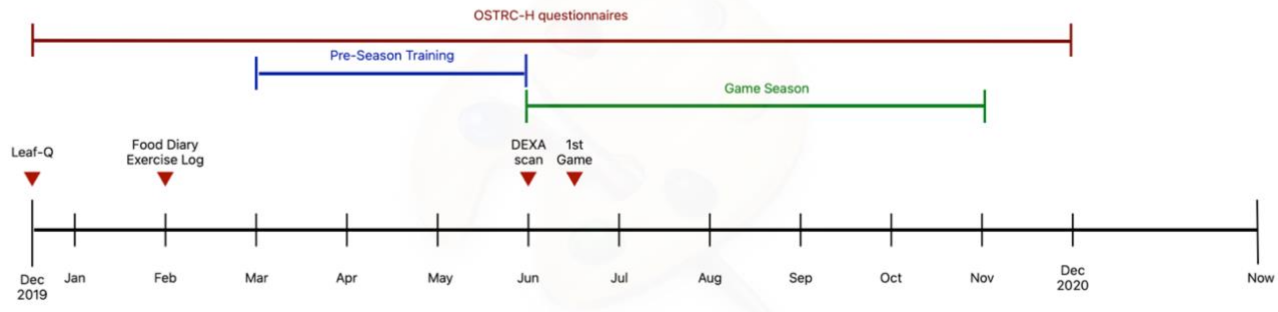

Figure 5. Study Timeline

days of the athletes choosing in February 2020. Body measurements and DXA scans took place at the KIHU training center in June 2020. OSTRC-H data was collected throughout this period from December 2019 – December 2020 via the AthleteMonitoring app. Pre-season training took place from March – June 2020, followed by the game season from June – November 2020. The data was then collated and analyzed in September 2022.

4.4 Data Analysis

The dataset was checked for missing data, and all analyses were performed using IBM SPSS Statistics version 28.0.1.1 (15) (Armonk, NY, USA). Significance was set at $p < 0.05$, two tailed. Normality for all continuous variables was assessed using histograms and the Shapiro-Wilk test. Parametric data are reported as mean and standard deviation (SD), non-parametric data are reported as median and interquartile range (IQR) and categorical data are reported with percentages and counts.

Participants were initially divided into groups based on their LEAF-Q results, and new variables as described above were created. When examining the distribution of these variables, it is apparent that there are extreme outliers. After careful consideration, these outliers were not removed as they were naturally occurring and were not due to input errors, but new variables were created to account for this. The distribution of the original and new variables can be seen in Figure 6.

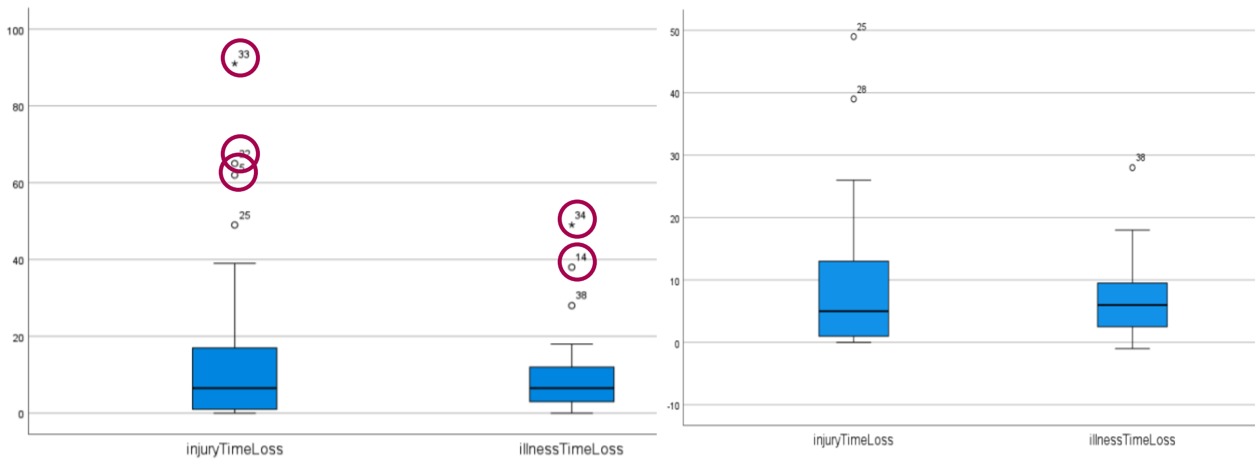

Figure 6. Box plots for time lost to injury and illness with extreme outliers circled (left), and new variables to accommodate for them (right).

The Fisher's exact test was used to identify associations between categorical variables, as some cell counts in the crosstabulation (see Table 3) were less than 5, despite the relatively large sample size. The independent-sample t-test was used for comparison of means in normally distributed data, and the Mann-Whitney U test was used for skewed data.

The data were then analyzed as a whole, using the raw LEAF-Q scores and the average EA from the food and exercise logs. Pearson's correlation coefficient and Spearman rank correlation coefficient were used to test parametric and non-parametric data respectively for associations between continuous variables.

5 Results

5.1 Participants

5.1.1 Energy Availability

31 participants completed their food and exercise logs. The group average was 38.32 kcal·kg FFM^{-1}·day^{-1} (SD 10.72), with a range of 10.64 – 57. Of these participants, 77.4% (n= 24) had an EA below the recommended optimal range (45 kcal·kg FFM^{-1}·day^{-1}), and 14.3 % (n = 6) had averages below 30 kcal·kg FFM^{-1}·day^{-1}.

5.1.2 LEAF-Q

41 participants completed the LEAF-Q questionnaire. The mean score was 7.61 (SD 4.1), with a range of 1 – 20. 46.3% (n = 19) of participants were classified as 'at risk', with scores of 8 or greater, and 53.7% (n = 22) 'not at risk'.

5.1.3 LEAF-Q and EA

Of the participants who had filled out both the LEAF-Q and the training logs, 8 (26.7 %) had EA below the recommended 45 kcal·kg FFM^{-1}·$day^{-1}$and were classified as 'at risk' with the LEAF-Q.

5.1.4 Injuries and Illness

A total of 112 unique injuries (median: 2, IQR: 3), were reported by 39 (92.9%) out of the 42 participants throughout the season. Of those, 71 injuries (median: 1, IQR: 2), were substantial injuries leading to a complete inability to train for at least one day, sustained by 78.6% (33/42) of the participants, which resulted in 575 days missed due to injury (median: 6.5, IQR: 17).

There were also 97 unique incidences of illness (median: 2, IQR: 3) with a total of 367 days missed (median: 6.5, IQR: 10) and 36 (85.7%) of the 42 participants reported an illness. Of these, 87 (median: 2, IQR: 2) lead to missed or modified training, experienced same number of participants.

Together, this led to a total of 431 modified training weeks (median:8, IQR: 14).

5.2 EA and Injuries/Illness

5.2.1 LEAF-Q and Injury/Illness by groups

The Fischer's exact test between LEAF-Q and injury/Illness(yes/no) showed no significant results. The p-value for injury was 1, and 0.191 for illness. See Table 2 for the crosstabulation.

	Injured		TOTAL	**Illness**		TOTAL
LEAF-Q	Yes	No		Yes	No	
Not at risk	20	2	22	17	5	22
At risk	18	1	19	18	1	19
TOTAL	38	3	41	35	6	41

Table 2. Injury/Illness vs LEAF-Q crosstabulation

Table 3 presents the summary of participant outcomes as a whole, and between groups. No significant between group differences were found from the independent samples t-test for age, weight, height, BMI or EA or average cumulative severity for injuries.

	ALL (n = 42)	**not at risk** (n = 22)	**at risk** (n = 19)	**P** (< 0.05)
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	P
Age	18.40 (3.1)	17.91 (2.22)	18.89 (3.97)	0.346
Weight (kg)	64.36 (9.27)	64.15 (7.84)	64.47 (11.13)	0.915
Height (cm)	168.99 (6.45)	169.83 (6.78)	167.93 (6.20)	0.340
Body Mass Index	22.45 (2.36)	22.195 (1.93)	22.76 (2.85)	0.453
Energy Availability	38.32 (10.72)	37.33 (7.65)	39.94 (13.79)	0.538
Average Cumulative injury	45.04 (98)	43.99 (22.1)	44.87 (19.16)	0.894
	Median (IQR)	**Median (IQR)**	**Median (IQR)**	
Body fat (%)	25 (2.8)	24.43 (2.62)	25 (6.81)	
Injury Count	2 (3)	2 (2)	3 (3)	**0.079**
Illness Count	2 (3)	2 (3)	2(3)	0.680
Substantial Injury	1 (2)	1 (2)	2 (2)	0.120
Substantial Illness	2 (2)	2 (3)	2 (2)	0.528
Time Loss due to Injury	6.5 (17)	4.5 (11)	11 (20)	0.216
Time Loss due in Illness	6.5 (10)	4.5 (9)	7 (9)	0.160
Time loss injury outliers	5 (12)	4 (9)	11 (19)	0.321
Time loss illness outliers	6 (8)	4 (7)	7 (9)	**0.16****
Average Cumulative Illness	62.88 (31.8)	56.7 (46)	67.5 (31)	**0.058**
Modified training weeks	8 (14)	6 (14)	9 (12)	**0.082**
Combined average cumulative severity	15.59 (15.40)	9.66 (17.49)	19.18 (21.28)	**0.053**

**** statistically significant**

Table 3. Summary of participants outcomes

Although not statistically significant, the Mann-Whitney U test found the at-risk group had more substantial injuries and spent a greater amount of time off due to injury and illness. The at-risk group also had marginally more total injuries ($z = -1.76$, $p = 0.079$), a higher average cumulative severity for illness ($z = -1.9$, $p = 0.058$) and a higher combined average cumulative severity ($z = -1.935$, $p = 0.053$).The distribution of these variables can be seen in the box plots below. (Figures 7, 8). After adjusting for outliers, the at-risk group had significantly more time off due to illness (z = 0.321, p = 0.016).

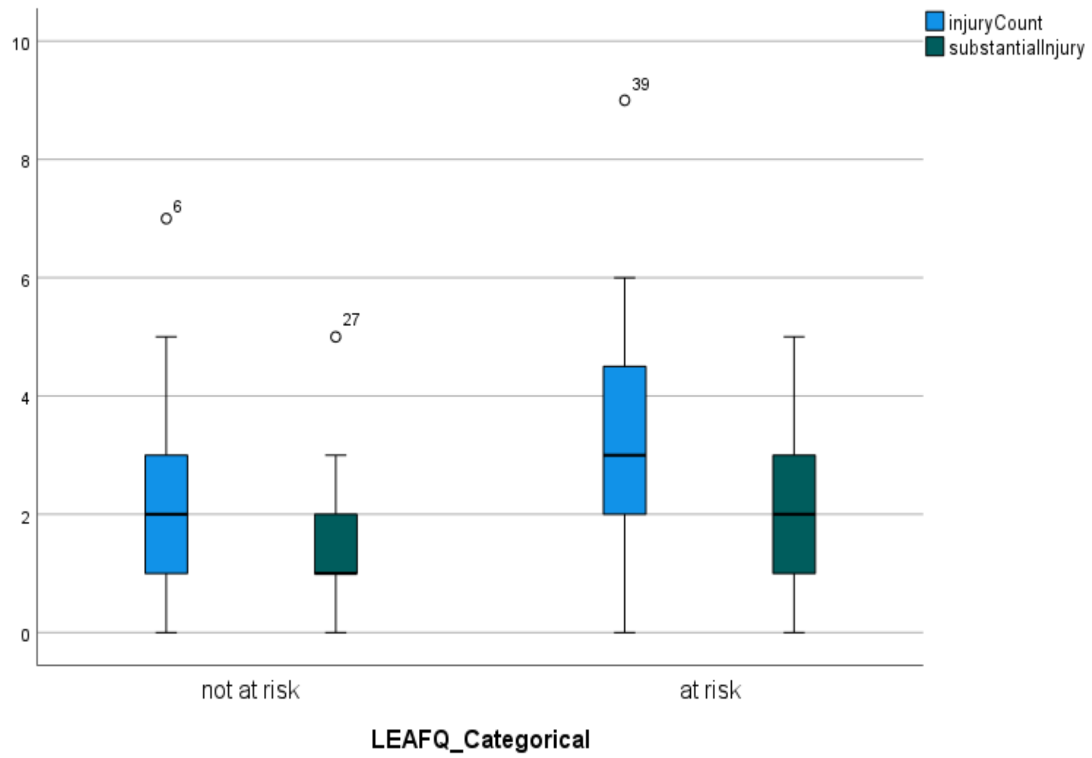

Figure 7. Distribution of total and substantial injuries by LEAF-Q group

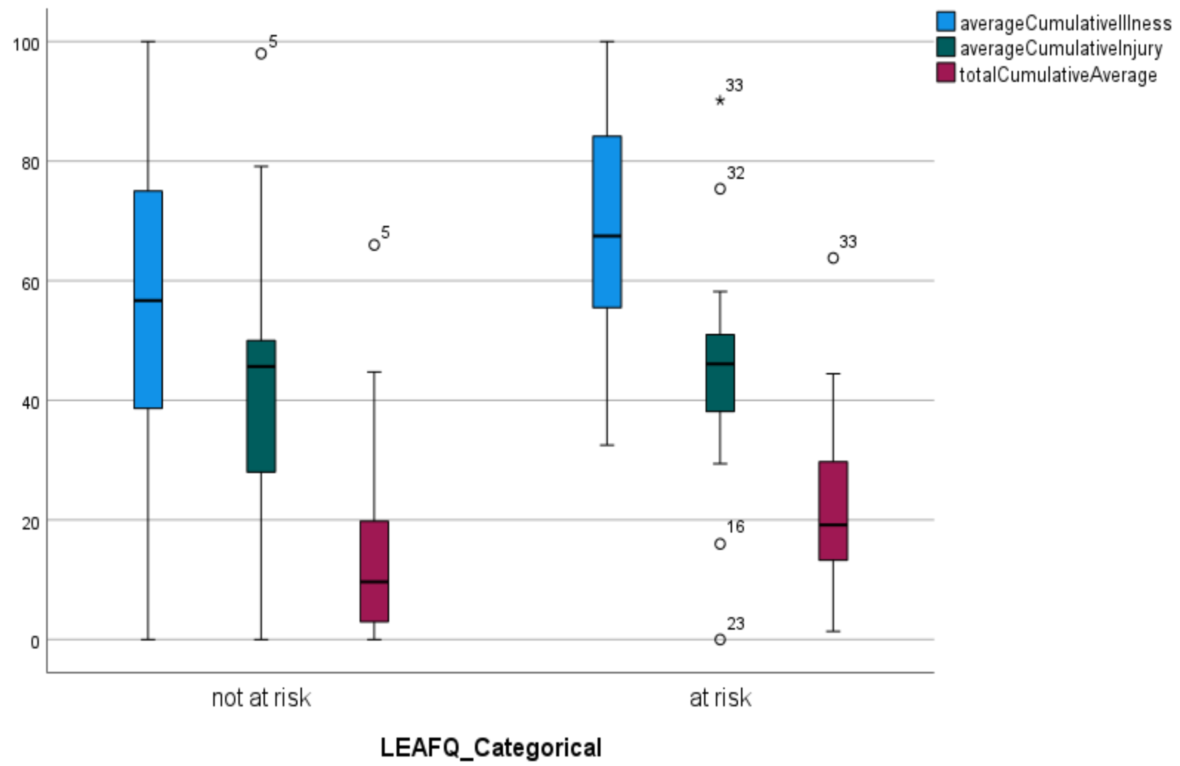

Figure 8. Distribution of average cumulative severity for injuries, illnesses and overall, by LEAF-Q groups

5.2.2 EA and Injuries/Illness grouped as a whole

The Spearman rank correlation was used to assess the relationship between the raw LEAF-Q scores and EA averages and the other variables. Results from the LEAF-Q were positively correlated with injury count (r_s (41) = 0.39, p = 0.013), substantial injury (r_s (41) = 0.44, p = 0.004), time loss due to injury (r_s (41) = 0.34, p = 0.029), time lost due to illness after adjusting for outliers

Figure 10. Heatmap of Spearman's correlation coefficient with significant values circled

(r_s (41) = 0.434, p = 0.005), number of modified training weeks (r_s (41) = 0.448, p = 0.003), and combined average cumulative severity (r_s (41) = 0.44 p = 0.004). Although these relationships are significant, they are weak to moderate associations, as shown in the heatmap in Figure 9.

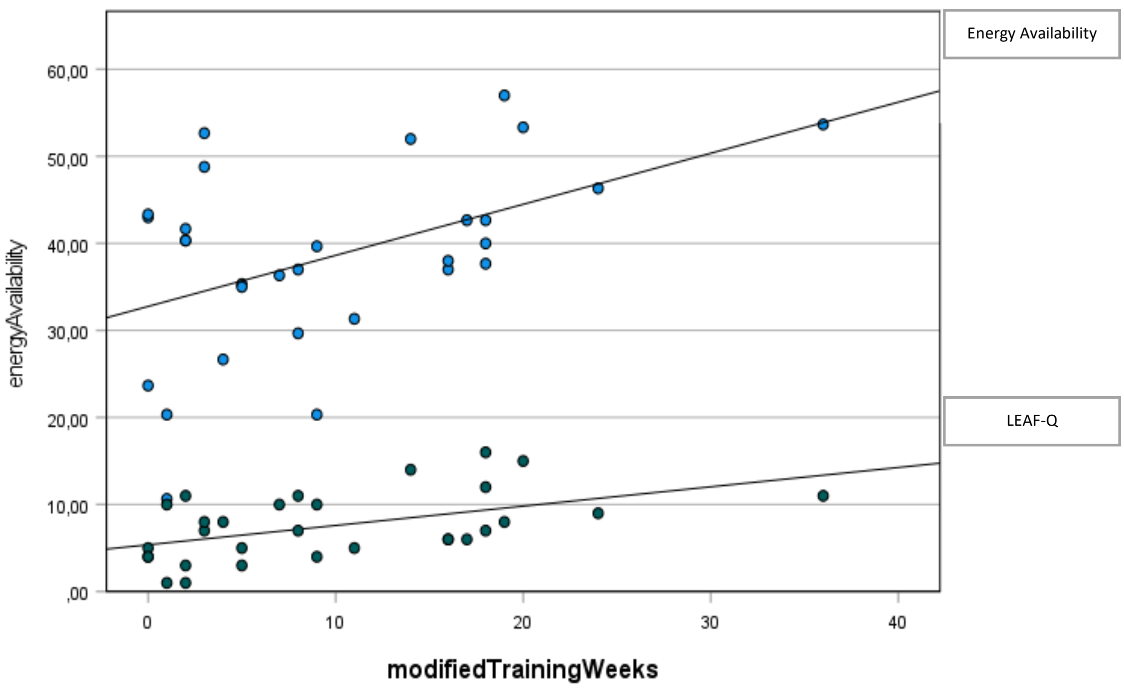

Figure 9. Scatterplot of EA and LEAF-Q by modified training weeks

EA was positively associated with the number of modified training weeks (r_s (31) = 0.369 p = 0.041). It is worth noting that while the other variables had no significant correlation with EA, the Spearman's correlation coefficient, while small, were all positive, suggesting a trend in the opposite direction to what was hypothesized.

The relationship between LEAF-Q, EA and modified training weeks can be seen the scatterplot in figure 10.

5.3 Summary of findings

Prevalence of LEA was 77.4% when using a cutoff of 45 kcal·kg FFM^{-1}·day^{-1}, and 14.3% when using the traditional 30 kcal·kg FFM^{-1}·day^{-1}. 46.3% of participants were classified as 'at risk' of LEA with the LEAF-Q questionnaire.

The median time lost due to injury, and due to illness were both 6.5, with each athlete sustaining on average 2 injuries, and 2 episodes of illness a season, and a median of 8 weeks of modified training per athlete.

After adjusting for outliers, the 'at-risk' group had significantly more time off due to illness than the not at-risk group. There was also a statistical trend indicating the at-risk group had more modified training weeks, more injuries and a higher average cumulative severity for illness compared to the not at-risk group.

The raw LEAF-Q results were positively correlated with injury count, substantial injuries, time lost due to injury, time lost due to illness after adjusting for outliers, the number of modified training weeks, and the combined average cumulative severity. EA was positively correlated with the number of modified training weeks.

6 Discussion

The main objectives of this study were to look at the relationship between EA and injuries and EA and illnesses in female football players. The study also aimed to determine the prevalence of EA within this group of athletes.

6.1 Prevalence of EA

The groups EA average was 38.32 kcal·kg FFM^{-1}·day^{-1}, with 77,4% of players EA below the recommended threshold. These findings were similar to those by Moss et al. (2020), who found an EA average of 36.7, with 85% of players below the recommended threshold, and Dasa et al. (2023) who found an EA average of 37.9. They did not report on the number of participants below 45 kcal·kg FFM^{-1}·day^{-1}.

The present study had a lower percentage of participants with EA below 30 kcal·kg FFM^{-1}·day^{-1}., with only 14.3% of participants falling into this category. In comparison, Moss et al. (2020) reported a prevalence of 23% below this threshold, while Dasa et al. (2023) found rates of 36% on match days and 23% on training days. One potential explanation for this difference could be in the data collection methods used. Both studies mentioned collected EA data over an extended period (5 and 14 days, respectively), ensuring coverage of both match and training days for all participants. In contrast, our study requested participants to collect data on three consecutive days of their choosing, which meant that training or match days were not guaranteed to be included. This approach may have skewed the EA data, potentially leading to an underrepresentation of energy expenditure on those specific days. Notably, Moss et al. (2020) found that none of their athletes exhibited LEA on rest days, further supporting the potential impact of data collection variations on the observed differences in EA prevalence.

In the present study, 46.3% of the participants were categorized as "at-risk" according to the LEAF-Q questionnaire. These results fell between the findings of two previous studies that examined female soccer players with the LEAF-Q, with Moss et al. (2020) reporting a prevalence of 23% and Luszczki et al. (2021) reporting a prevalence of 67.4%. However, our study's findings were consistent with those of Logue et al. (2019), who reported a prevalence of 40% in active females.

These findings suggest that a sizable portion of the team may be at risk of developing LEA. However, it is important to note that this study only provided a brief three-day snapshot of the athletes' season. Previous research has demonstrated that LEA among football players varies during separate phases of the season, including pre-season, regular season, and post-season (Reed et al., 2013). Therefore, to draw conclusive results, a more comprehensive data collection process should be implemented over an extended period, or multiple assessments should be conducted throughout the season. This could involve more rigorous monitoring of EI and EEE, or the use of objective outcome measures such as RMR. Only then can we determine if the observed LEA in this study is a temporary occurrence or a consistent pattern throughout the season. Nevertheless, it is crucial that athletes are educated about proper nutrition, refueling, and the importance of consuming adequate energy, especially carbohydrates, to meet their exercise demands, as even short-term LEA can have minor but significant impacts on performance and overall health.

6.2 Injuries/Illness

78.6 % of participants reported at least one injury over the season that resulted in total inability to participate in training, with an median of 2 injuries a player, 1 of which being classified as substantial. This percentage is much higher than previous studies, which reported between 55% - 62% of participants with an injury resulting in missed or modified training (Logue et al, 2018; Mayhew et al, 2021), however the number of injuries per athlete per season is the same as that reported by Lopez-Valenciano et al, (2020) with 2 per season.

The incidence of illness was slightly lower, but still a median of 2 per athlete, with 85.7% of the players reporting at least one substantial illness, and a median of 6.5 days lost to illness. The number of days lost to illness is higher than previous studies, which found a median of 3 days amongst female senior players (Sprouse et al, 2020). No previous data could be found on the illness incidence in female football players that was measured in the same manner, with the previous study reporting an illness incidence of 0.71/1000h. However, in Clarsen et al. (2014) study of male and female olympic athletes, they reported similar findings of 3.1 illnesses per athlete.

The year in which the data was collected was atypical due to the COVID-19 pandemic and it is possible that this had an effect on the time lost due to illness, as well as the number of injuries the athletes experienced. Despite making every effort to maintain training routines, unavoidable disruptions occurred, including a decreased number of full team practices prior to the start of the match season. These disruptions may have resulted in the athletes being less conditioned and less prepared for the season, consequently increasing their susceptibility to injuries.

6.3 Modified training weeks

When the injury and illness data are combined, it reveals a median total of 8 weeks of modified training per athlete, along with 4 instances of injury or illness. The athlete's season for 2020 was from June – November 2020, comprising of 26 weeks, therefore the median of 8 weeks comprised just under a third (30.7%) of the season. Raysmith and Drew (2016) found that athletes who were able to complete greater than 80% of their training weeks throughout the session, or 5.2 weeks or less of modified training, were 7 times more likely to achieve their performance goals. Given these performance implication or the 3 fold increase in chances of achieving performance goals with 2 or less injuries or incidence per season, teams should be focusing on injury and illness prevention strategies to get the majority of their athletes into this 80% window.

6.4 EA and LEAF-Q

There was no significant correlation between LEAF-Q results and EA which was surprising. The LEAF-Q questionnaire is designed to assess the physiological symptoms associated with LEA, therefore a strong inverse relationship between EA and LEAF-Q scores would be expected. However, when examining the scatterplot of these two variables (see figure 11 below), a weak positive trend is observed, indicating a very weak relationship between variables. There are a few possible explanations for this.

The LEAF-Q questionnaire was completed in December 2019, while the training logs were recorded in February 2020, as indicated in the timeline presented in Figure 5. It is possible that the athletes received counseling or nutritional advice based on their LEAF-Q scores in the intervening months and subsequently adjusted their calorie intake accordingly.

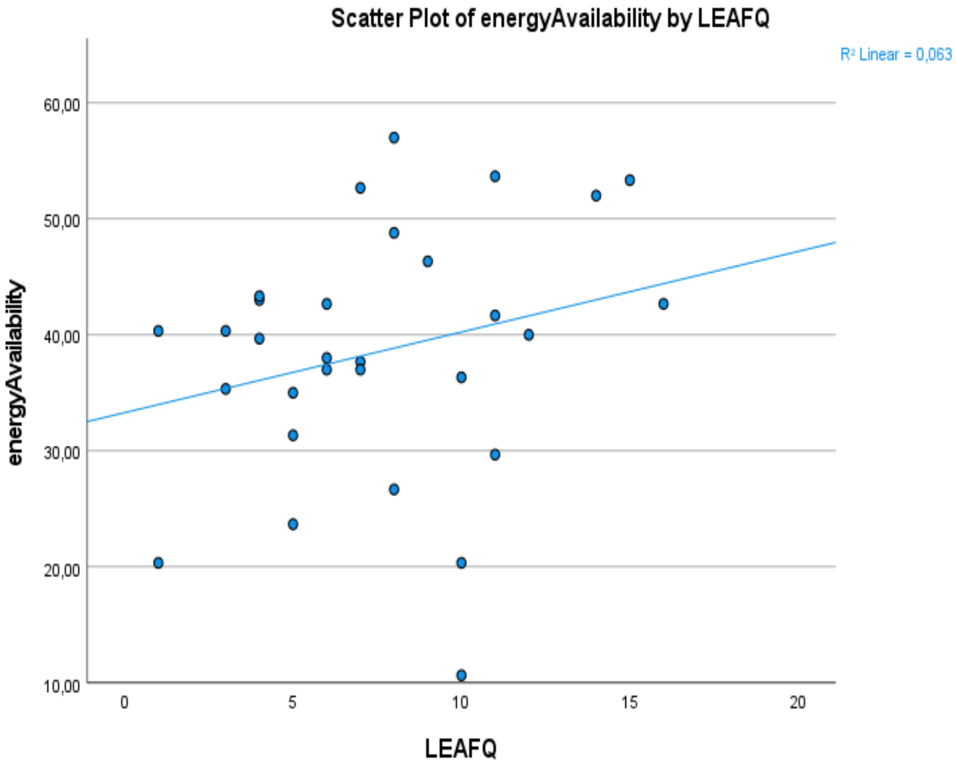

Figure 11. scatterplot of LEAF-Q to Energy Availability

Alternatively, athletes with high LEAF-Q scores had significantly higher injury rates, and more time off of sport due to injury and illness as discussed above, therefore it is also possible that their EA is higher due to the lower energy expenditure during that time. As Moss et al. (2020) reported, football players tend not to adjust their caloric intake to align with their exercise demands meaning that despite less exercise during periods of injury, their EI could have remained the same, skewing the EA data.

Another factor to consider is the inherent challenge of accurately measuring EA using self-reported methods. Under- and over-reporting are common issues associated with this approach. Apart from the possible difficulties athletes may have recalling precise quantities and details of their daily food intake, psychological factors should also be considered. Some athletes may feel embarrassed about their eating habits or be self-conscious about their weight, leading them to underreport their calorie intake. Conversely, athletes with potential disordered eating patterns may attempt to conceal their behaviors and overreport their intake. I

It is also worthwhile remembering that the training logs only provide a 3 day window into dietary and exerise habits, and not a long term view. Studies have suggested that the severity and duration of LEA, or “LEA dose or load” (Melin et al, 2023) is an important consideration. While athletes were asked not to change their dietary and exercise habits over the 3-day period, knowing that they were recording everything, may have subconsciously led to changes that do not reflect the rest of their year’s dietary and exercise habits.

6.5 EA and Injuries/Illness

These explanations may also account for the significant positive correlation seen between EA and modified training weeks. Based on the research presented above, one would expect to see the number of modified training weeks increase as EA decreased, however the opposite was true in this study, as can be seen in the scatterplot of figure 10. While it is of course possible that there is a relationship between high EA and the number of weeks of modified training due to injury or illness, the fact that there were no other significant correlations with EA, including injury and illness rate, or time off due to injury or illness makes the explanations presented above seem more likely. However, a more comprehensive examination of this relationship is recommended to verify these assumptions.

Poor correlations of EA levels measured from training logs and known LEA sequalae have been seen in numerous previous studies. Heikura et al (2018) failed to find any significant correlations with dietary EA in the female participants, despite objective measures of LEA being positive. These findings were similar to those of Ihalainen et al (2021). Both studies, as well as those of Logue et al (2020), and Melin et al (2023) encourage future research to use outcome measures created to measure REDs (such as the LEAF-Q questionnaire) or measure physiological consequences of LEA such as RMR and menstrual dysfunction instead of, or in conjunction with dietary EA as they provide a more accurate and sensitive representation of an athlete’s LEA risk.

6.6 LEAF-Q and Injuries/Illness

The only significant difference between LEAF-Q groups was that the ‘at-risk’ group was associated with time off due to illness, when adjusted for outliers. It is important to interpret this result cautiously since outliers were removed. However, Logue et al. (2018) reported similar findings, indicating that athletes classified as "at risk" using the LEAF-Q were three times more likely to miss training sessions due to illness compared to those not at risk. Likewise, LEA was identified as the primary variable associated with illness among Olympic level athletes (Drew et al, 2018). As was suggested by the same authors, these findings indicate the LEAF-Q questionnaire could be used as a screening tool to help identify athletes at risk of illness in the future and implement prevention strategies.

Modified training weeks had a significant positive correlation with the LEAF-Q scores (refer to figure 10), indicating that those at higher risk of LEA spend more time away from training due to injury and illness. While there are no studies on female football players to compare with, these findings are similar to that by Ihalainen et al. (2021) who found athletes with amenorrhea and higher LEAF-Q scores had a lower running volume and higher injury rates compared to athletes with lower scores as well as findings by Heikura et al (2018).

In addition, the LEAF-Q score was positively associated with injury count and significant injuries, and therefore it was unsurprising that it was also associated with time lost to injury, and higher overall OSTRC-H scores (combined average cumulative severity). These findings show that athletes with high LEAF-Q scores are more at risk of developing severe injuries and illnesses that resulted in more time away from training than athletes with low LEAF-Q scores.

Increased injury rates are consistent with research on athletes with components of REDs/female athlete triad as discussed in the injury section of the literature review (Ihalainen et al, 2020; Logue et al 2019), with Heikura et al (2018) finding athletes with high LEAF-Q scores and amenorrhea to have injury rates 4.5 times higher than eumenorrheic athletes. These results further advocate for the LEAF-Q questionnaire to be used as a screening tool in all sports, not just endurance sports, to help identify athletes who are at risk for injuries, as well as identify possible mechanisms of injury that can be addressed early.

Moss et al. (2020) raises an important question regarding the reliability of using the LEAF-Q as an assessment tool for determining the risk of LEA among football players. The concern stems from the fact that a sizable portion of the LEAF-Q score is derived from the injury subset, which asks athletes about their injury history over the last year. Football, being a contact sport with high injury rates, may introduce bias in the assessment. Although in the current study the completion of the LEAF-Q questionnaire preceded the start of the football season, ensuring that the injuries associated with the LEAF-Q scores did not influence the results, it is still a valid point to consider.

It is widely recognized that prior injuries are a risk factor for future injuries. A study on youth football players conducted by Kucera et al. (2005) revealed a 2.6 times higher injury rate among athletes with a history of injuries compared to those without. Hence it is reasonable to consider that athletes who had high scores in the injury subset of the questionnaire are more susceptible to future injuries as a result of their injury history, rather than due to LEA. Conversely, given the high rates of LEA found in this study, it is also plausible to consider that LEA might have been the contributing risk factor for the initial injury, leading to the subsequent complications. However, without access to the necessary data to analysis, this is just speculation.

Further research is warranted to ascertain whether the correlations with LEA and injury rates observed in the current study using the LEAF-Q are a consequence of LEA or simply due to the nature of football as a high-injury sport. This could involve the incorporation of a combination of the LEAF-Q and more objective measures of EA over an extended period or at periodic intervals throughout the football season. By doing so, we can gain a better understanding of whether the observed correlations genuinely reflect LEA or are primarily driven by the inherent injury risks associated with football.

7 Conclusion

While football athletes are not conventionally associated with having LEA, this study showed a significant number of players exhibited EA levels below the recommended threshold. Additionally, a considerable number of athletes were classified as ‘at-risk’ according to the LEAF-Q questionnaire. These findings emphasize the need to educate coaches, health professionals, and athletes about general nutrition, refueling, and how the body utilizes different energy sources, particularly carbohydrates. In this education, it is essential to emphasize the importance of adapting energy intake to match the demands of exercise.

Furthermore, this study showed that the LEAF-Q questionnaire is a valuable screening tool for identify athletes who are at risk of future injuries and illnesses leading to prolonged absences from sport. By implementing preventative measures that are focused on athletes with elevated scores and utilizing the LEAF-Q responses to identify potential causes, it is possible to mitigate the occurrence of some injuries and illness and decrease the amount of time away from sport.

This study only looked at a brief three-day snapshot of the athletes eating and training habits and further research that examines EA levels periodically throughout pre-season, season, and post season is recommended. These studies should use more objective outcome measures such as menstrual function and RMR, in combination with validated questionnaires (e.g., LEAF-Q). This will provide us with a more comprehensive understanding of the relationship between injuries and illness and EA in female football players.

By expanding the knowledge in this area, future studies can contribute to the development of evidence-based guidelines and tailored interventions that optimize EA, reduce injury and illness risk, and enhance the overall well-being and performance of female football players.

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Appendices

Appendix 1. List of Abbreviations

BMI	Body mass index
DXA	Dual-energy X-ray absorptiometry
EA	Energy availability
EEE	Exercise energy expenditure
EI	Energy intake
FFM	Fat free mass
FSH	Follicle-stimulating hormone
GH	Growth hormone
GnRH	Gonadotropin-releasing hormone
IGF-1	Insulin like growth factor 1
IOC	International Olympic committee
LEA	Low energy availability
LEAF-Q	Low Energy Availability in Females Questionnaire
LH	Luteinizing hormone
MET	Metabolic equivalent.
OSTRC-H	Oslo Sports Trauma Research Centre
REE	Resting energy expenditure.
RMR	Resting metabolic rate
REDs	Relative Energy Deficiency in Sports

Appendix 2. Data Management Plan

1. General description of data

What kinds of data is your research based on? What data will be collected, produced or reused? What file formats will the data be in?

The data in this project was collected in collaboration with the university of Jyväskylä and the KIHU training room and is being re-used here with permission from the data manager (Johanna Ihalainen).
The data used is explained in detail in the material and methods section of the research plan, but includes ratio, nominal and categorical data from in person measurements, individual logbooks as well as survey data collected over a one-year period.
The raw data, which had already been anonymized, was acquired in excel format (.xlxs), and included the responses from survey data in its original format. The data will be cleaned, processed and then analyzed using IBM SPSS (.sav).

How will the consistency and quality of data be controlled?

The original data received from the data manager will be stored as read-only files and backed up on the university's H-Drive. All subsequent changes or analysis made to the files will be saved as a new file and labeled appropriately.
The data manager also holds a master copy, to which only she has access.

2. Ethical and Legal Compliance

What ethical and legal issues are related to your data management, for example, the Data Protection Act and other legislation related to the processing of the data)?

All data received from the data manager has been scrubbed of all direct and indirect identifiers, with all participants just represented with a number. However, the data includes information such as age, height, weight and detailed injury/illness records which could be used to identify athletes if pressed. Therefore, the injury data will only be reported as summaries in the paper.
The participants in the original study gave informed consent for their data to be collected and used in future studies.

How do you manage the rights to the material you use, produce and share? Is the material confidential, are there any copyrights, licenses or other restrictions?

The data is owned by KIHU and the University of Jyväskylä. The use of the data in this project is by permission of these two organizations and cannot be shared with anyone who does not have permission. Once the project is complete, the data will be deleted from the principal investigator's hard drive and online storage.

3. Documentation and metadata

How will you document your data in order to make it findable, accessible, interoperable and re-usable for you and others? The folder containing the excel spreadsheets will also contain:

a readme.txt file that will document the purpose of each file in the datasheet and any data manipulations done
a data dictionary in .xlxs format containing variable names, units of measure, data types and formulas that will be used for calculations pdf copies of the questionnaires used and explanations given to the participants for the exercise and food logs.

4. Storage and backup during the thesis project

Where will your data be stored, and how will it be backed up?

The data will be stored online using JAMK's OneDrive as well as Google Drive, both of which are password protected and backup automatically whenever changes are made, and a master copy is held by the original data manager.

Who will be responsible for controlling access to your data, and how will secured access be controlled?
The principal investigator is the only person who will hold the passwords to access the data shared by the data manager, and it will not be shared with anyone else.

5. Opening, publishing and archiving the data after the thesis project

What part of the data can be made openly available or published? Where and when will the data, or its metadata, be made available?

As the data does not belong to the principal investigator, once the project is completed, it will be removed from all storage areas and not made openly accessible. The original data will still be stored by the original data manager and if deemed necessary, permission could be requested to access it.

Where will data with long-term value be archived, and for how long? The data will be destroyed. See above

6. Data management responsibilities and resources

Who will be responsible for specific tasks of data management during the life cycle of the research project? Estimate the resources.
The principal investigator will oversee all data management during the life cycle of the research project. Nobody else will have access to the data.

Appendix 3. The LEAF-Q

The low energy availability in females questionnaire (LEAF –Q), focuses on physiological symptoms of insufficient energy intake. The following pages contain questions regarding injuries, gastrointestinal and reproductive function. We appreciate you taking the time to fill out the LEAF-Q and the reply will be treated as confidential.

Name: ____

Address: ____

____

E-mail: ____

Cell: ________________

Profession: ____

Education: ____

Age: ________(years)

Height: ________(cm) Weight: ________(kg)

Your highest weight with your present height: ________ (kg)
(excluding pregnancy)

Your lowest weight with your present height: ________ (kg)

Do you smoke? Yes No

Do you use any medication (excluding oral contraceptives)? Yes No

If yes, what kind of medication?____

Your normal amount of training (average) – number of hours per week and what kind of exercise, such as running, swimming, bicycling, strength training, technique training etc.:

____

____

____

Comments or further information regarding exercise:__________________________

____

____

1. Injuries

Mark the response that most accurately describes your situation

A: Have you had absences from your training, or participation in competitions during the last year due to injuries?

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

A1: If yes, for how many days absence from training or participation in competition due to injuries have you had in the last year?

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

A2: If yes, what kind of injuries have you had in the last year? ____________________

____

Comments or further information regarding injuries:____________________

____

____

2. Gastro intestinal function

A: Do you feel gaseous or bloated in the abdomen, also when you do not have your period?

☐ Yes, several times a day ☐ Yes, several times a week

☐ Yes, once or twice a week or more seldom ☐ Rarely or never

B: 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

C: 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

D: How would you describe your normal stool?

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

Comments regarding gastrointestinal function: ______________________________

____

3. Menstrual function and use of contraceptives

3.1 Contraceptives

Mark the response that most accurately describes your situation

A: Do you use oral contraceptives?

☐ Yes ☐ No

A1: If yes, why do you use oral contraceptives?

☐ Contraception ☐ Reduction of menstruation pains ☐ Reduction of bleeding

☐ To regulate the menstrual cycle in relation to performances etc..

☐ Otherwise menstruation stops

☐ Other____

____

A2: If no, have you used oral contraceptives earlier?

☐ Yes ☐ No

A2:1 If yes, when and for how long?____

____

____

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

☐ Yes ☐ No

B1: If yes, what kind?

☐ Hormonal patches ☐ Hormonal ring ☐ Hormonal coil ☐ Hormonal implant ☐ Other

____

3.2 Menstrual function

Mark the response that most accurately describes your situation

A: How old were when you had your first period?

☐ 11 years or younger ☐ 12-14 years ☐ 15 years or older ☐ I don't remember

☐ I have never menstruated (If you have answered "I have never menstruated" there are no further questions to answer)

B: Did your first menstruation come naturally (by itself)?

☐ Yes ☐ No ☐ I don't remember

B1: If no, what kind of treatment was used to start your menstrual cycle?

☐ Hormonal treatment ☐ Weight gain

☐ Reduced amount of exercise ☐ Other

C: Do you have normal menstruation?

☐ Yes ☐ No **(go to question C6)** ☐ I don't know **(go to question C6)**

C1: If yes, when was your last period?

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

C2: If yes, are your periods regular? (Every 28th to 34th day)

☐ Yes, most of the time ☐ No, mostly not

C3: If yes, for how many days do you normally bleed?

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

C4: If yes, have you ever had problems with heavy menstrual bleeding?

☐ Yes ☐ No

C5: If yes, how many periods have you had during the last year?

☐ 12 or more ☐ 9-11 ☐ 6-8 ☐ 3-5 ☐ 0-2

3.2 Menstrual function

Mark the response that most accurately describes your situation

C6: If no or "I don't remember", when did you have your last period?

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

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

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

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

- ☐ Yes
- ☐ No

E1: If yes, how? (Check one or more options)

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

Appendix 4. The OSTRC Questionnaire on Health Problems

The OSTRC Questionnaire on Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1

Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Question 2

To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

To what extent has injury, illness or other health problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4

To what extent have you experienced symptoms/health complaints during the past week?

- ☐ No symptoms/health complaints
- ☐ To a mild extent
- ☐ To a moderate extent
- ☐ To a severe extent

Question 7 - Illness Symptoms

Please check the boxes corresponding to the major symptoms you have experienced during the past 7 days. You may select several alternatives; however, in the case that you have several unrelated illnesses please complete a separate registration of each one.

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache
- ☐ Nausea
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Fainting
- ☐ Rash/itchiness
- ☐ Irregular pulse/arrhythmia
- ☐ Chest pain/angina
- ☐ Abdominal pain
- ☐ Other pain
- ☐ Numbness/pins and needles
- ☐ Anxiety
- ☐ Depression/sadness
- ☐ Irritability
- ☐ Eye symptoms
- ☐ Ear symptoms
- ☐ Symptoms from urinary tract/genitalia
- ☐ Other. *Please specify* ______________________________________

Question 9 - Time loss

Please state the number of days over the past 7-day period that you have had to completely miss training or competition due to this problem?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Question 10 - Reporting

Is this the first time you have registered this problem through this monitoring system?

- ☐ Yes, this is the first time
- ☐ No, I have reported the same problem in one of the previous four weeks
- ☐ No, I have reported the same problem previously, but it was more than four weeks ago

Question 11 - Contact with medical personnel

I have reported this problem to

- ☐ Olympic team doctor
- ☐ Olympic team physiotherapist
- ☐ Other Olympiatoppen doctor
- ☐ Other Olympiatoppen physiotherapist
- ☐ Other doctor or physiotherapist. Please state their name and workplace: ____

Question 12

Please use this field to send additional information about this problem to your Olympic medical team

Question 13

Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

- ☐ Yes
- ☐ No

Appendix 5. Food Diary Instructions

Food Diary

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Urheilijoiden vammojen ja sairastuvuuden monitorointitutkimus – monialaisen intervention käyttökelpoisuuden arviointi (MIIA)

INSTRUCTIONS FOR COMPLETING THE FOOD DIARY

Fill out a food diary for **three days**, one of which is a weekend. Record on the food diary form all the foods you eat during the day and beverages. Despite filling out a diary, try to keep your diet and meal time as normal as possible.

If the form runs out of free space in the middle of the day, continue to the new page, but be sure to write the date on it. Always start a new day with a new form.

For each meal, fill in the time of the meal and the place where the meal took place (eg home, workplace canteen). Follow the instructions below to write each individual food or drink on its own line:

- For example, bread and bread toppings are marked on their own lines.
- Record food and beverages as accurately as possible:
  - Quality. For example, oatmeal cooked in skim milk, filter coffee / pan coffee, tuna (preserved in oil).
  - Product trade name. For example, Ruispalat-bread, Greek yogurt.
  - Record the product manufacturer. For example, Atria, Fazer, Valio, Rainbow.
  - Method of manufacture. For example, potato (boiled), egg (fried; in this case also remember to mark the cooking fat on its own line
  - e.g. Keiju 80%, 1 tbsp), salmon (cooked in the oven).
- Record in own column the size or number of doses accurately estimated or measured as possible.
- Fill in the supplements / additional nutrient you use at the beginning of the form.

Food diary
ID: __________ Additional information: ____

DATE	TIME	PLACE	FOOD, DRINK	AMOUNT
04.08.11	6.45 a.m.	Home	frozen blueberry	150 g
			Valio A+ fatfree natural yogurt	2 dl
			filtter coffee	1 cup
			Valio lactose-free milk (2 % fat)	3 tbsp
			Vaasan ruispalat	2 slice (TAI 55 g)
			Becel 38 %	3 tsp
			Valio Edam 17 %	2 slice
			Cucumber	6 slice
	10.35 a.m.	Amica, at work	salad (cucumber, lettuce, tomato)	1 dl
			salad dressing (sour cream based)	2 tbsp
			potato (boiled, medium)	2 pcs
			salmon (cooked in the oven)	5x10 cm
			Valio lactose-free milk (0 % fat)	2 glasses
	1.05 p.m.	At work	chocolate chip cookies (small; homemade butter used as fat)	2 pcs
			Valio orange juice	2 glasses
	4.15 p.m.	Home	Banana (medium size)	1 pcs
	9.15 p.m.	Home	Atria meat pie	1 pcs
			Atria light snack sausage	3 pcs
			Felix ketchup	2 tbsp
			BonAqua raspberry flavored mineral water (sugar-free)	2 glasses
			Olvi beer	2 bottles

Food diary
ID: __________ Additional information: ____

DATE	TIME	PLACE	FOOD, DRINK	AMOUNT

Appendix 6. Exercise log instructions (in Finnish)

AKTIIVISUUS- JA HARJOITUSPÄIVÄKIRJA

Aktiivisuus- ja harjoituspäiväkirja antavat tietoa päivittäisestä aktiivisuudesta ja kuormituksesta. Yhdessä ruokapäiväkirjan kanssa nämä antavat tietoa siitä, saatko riittävästi energiaa ja energiaravintoaineita tukemaan kehittymistä ja palautumista.

Seurannasta saatava palaute auttaa sinua hahmottamaan ruokavaliosi vahvuuksia sekä kehityskohteita. Palautteeseen kuuluvat myös käytännön vinkit ja neuvot ravitsemuksen ja aktiivisen elämäntyylin yhteensovittamiseen.

Päiväkirjojen täyttäminen vaatii hieman vaivaa. Vaivannäön seurauksena saat kuitenkin todenmukaisen käsityksen siitä, vastaako ravitsemus päivittäisen aktiivisuuden ja harjoittelun asettamiin vaatimuksiin. Mitä tarkemmin päiväkirjat täytät, sitä tarkemman palautteen saat! Muista täyttää päiväkirjoja kolmena peräkkäisenä päivänä, joista yksi on lepopäivä.

Ohjeet aktiivisuuspäiväkirjan täyttöön

Merkitse aktiivisuuspäiväkirjaan mahdollisimman tarkka päivän kulku jokaiselta kolmelta päivältä. Päiväkirjaa kannattaa täyttää samanaikaisesti ruokapäiväkirjan kanssa tai vaihtoehtoisesti muutamaan muuhun itselle sopivaan ajankohtaan jaettuna, jotta tapahtumat ovat tuoreessa muistissa. Muista merkitä päivämäärä.

Merkitse päiväkirjaan uni, arkiaskareet, opiskelu, liikkuminen, ruokailu ja muu päivän aikana tapahtunut toiminta. Älä merkitse ruokailun sisältöä tähän päiväkirjaan. Merkitse tähän päiväkirjaan myös kaikki liikuntaharjoittelu.

Päiväkirjaan merkattu kellonaika viittaa alkavaan tuntiin, esimerkiksi 10 = 10-11. Jos tunnin aikana aktiivisuutesi on vaihdellut suuresti, muista merkata se mahdollisimman selkeästi. Tutustu alla olevaan esimerkkipäivään.

Päivä: 24.5.2021

klo	Aktiivisuus (ruokailu, peseytyminen, liikkuminen, uni, arkiaskareet..)
0	uni
1	uni
2	uni
3	uni
4	uni
5	uni

6	uni
7	herääminen 07:00, aamutoimet, aamiainen 07:30
8	kevyet kotityöt (pyykkien viikkaus, roskien vienti, tiskikoneen purku), 1 km kävely salille (10 min)
9	voimaharjoitus alkaa 9:00
10	voimaharjoitus loppuu 10:20, 1 km kävely kotiin (10 min), suihku, ruoanlaitto
11	lounas, opiskelua
12	pyykinpesu
13	koiran ulkoilutus 1 h
14	välipala, päiväunet
15	opiskelua
16	opiskelua
17	välipala, treenivarusteiden pakkaus, 20 min kävely (2 km) treeneihin
18	lajiharjoitus alkaa 18:00
19	lajiharjoitus loppuu 19:30, autokyyti kotiin, suihku
20	illallinen ja tv:n katsomista
21	tv:n katsomista
22	iltapala, iltatoimet, nukkumaan klo 22:45
23	uni

Ohjeet harjoituspäiväkirjan täyttöön

Kirjaa harjoituspäiväkirjaan **kaikki seurannan aikainen liikuntaharjoittelu** (joukkueharjoitukset + omatoiminen harjoittelu) seuraavien ohjeiden mukaisesti:

1) Merkitse harjoitus, kellonaika ja kesto. (*Esim. Harjoitus 1. 09:00-10:20, 80 minuuttia*)

2) Merkitse harjoituksen tyyppi. (*Esim. Voimaharjoitus*)

3) Merkitse alkulämmittelyn sisältö ja kesto.

(*Esim. Juoksu matolla 9 km/h vauhdilla 5 minuuttia + liikkuvuus- ja aktivointiliikkeet 10 minuuttia*)

4) Merkitse varsinaisen harjoitusosion sisältö ja kesto.

(*Esim. Box-kyykky 4 x 5, lantionnosto 4 x 8.. 50 minuuttia)*

Borgin RPE -taulukko 0-10

RPE	Kuvaus
0	Lepo
1	Hyvin kevyt
2	Kevyt
3	Kohtalaisen rasittava
4	
5	Rasittava
6	-
7	Hyvin rasittava
8	-
9	-
10	Maksimaalinen

5) Merkitse loppujäähdyttelyn sisältö ja kesto. (*Esim. Juoksu matolla 8 km/h vauhdilla 10 minuuttia + venyttely 5 minuuttia*)

6) Merkitse koettu kuormittuneisuus eli RPE asteikolla 0-10 (ks. yllä oleva kuva) jokaisen harjoitusosion (alkulämmittely, varsinainen harjoitus, loppujäähdyttely) osalta.

7) Jos käytössäsi on sykemittari/aktiivisuusmittari, voit kirjata Lisätiedot-kohtaan tiedot keskisykkeestä, harjoituksen energiankulutuksesta ja sykealueesta. Sivun loppuun voit myös vapaasti kirjata päivän harjoituksen laatua ja tuntemuksia. Jos mahdollista, kirjaa myös varsinaisen harjoitusosion keskisyke (katso esimerkki 25.5.2021). Nämä tiedot antavat kallisarvoista lisätietoa analyysia varten.

Pyri kirjaamaan harjoitukset mahdollisimman tarkasti. Kirjaa kestävyysliikunnan osalta kuljettu matka (esim. 4 km hölkkä 30 min) jos mahdollista – muussa tapauksessa voit kirjata ylös kuvauksen tehosta (esim. kevyt hölkkä 30 min). Tutustu vielä alla oleviin esimerkkikirjauksiin ennen harjoituspäiväkirjan täyttöä. **Jos pohdit, miten jokin harjoitus tulisi kirjata, älä epäröi ottaa yhteyttä puhelimitse tai sähköpostitse**.

Päivä: 24.5.2021

Harjoitus, kellonaika ja kesto	Harjoitus 1. 09:00-10:20, kesto 80 min.	Harjoitus 2. 18:00-19:30, kesto 90 min.
Harjoituksen tyyppi	Voimaharjoitus	Lajiharjoitus
Alkulämmittelyn sisältö ja kesto	Juoksu matolla (vauhti 9 km/h) 5 min Liikkuvuus- ja aktivointiliikkeet 10 min	Kevyt hölkkä n. 10 min Liikkuvuus- ja keskivartaloliikkeet 10 min
Alkulämmittely RPE (koettu kuormittuneisuus 0-10)	2	2
Varsinaisen harjoituksen sisältö ja kesto	Box-kyykky 4 x 5 Lantionnosto 4 x 8 Yhden jalan prässi 3 x 10 Askelkyykkykävely 3 x 12 Nordic hamstring curl kuminauhalla 3 x 10 50 min	Tekniikkaa, pallonhallintaa, syöttöjä 15 min Pienpelit 15 min Peli kahteen maaliin 30 min 60 min
Varsinainen harjoitus RPE (koettu kuormittuneisuus 0-10)	7	6
Loppujäähdyttelyn sisältö ja kesto	Juoksu matolla (vauhti 8 km/h) 10 min Venyttely 5 min	Kävely/Hölkkä 5 min Venyttely 5 min
Loppujäähdyttely RPE (koettu kuormittuneisuus 0-10)	2	1
Lisätiedot	Keskisyke 130. Kulutus 600 kcal.	Keskisyke 150. Kulutus 750 kcal.

Päivä: 25.5.2021

Harjoitus, kellonaika ja kesto	Harjoitus 1. 10:00-11:35, kesto 95 min.	
Harjoituksen tyyppi	Juoksuharjoitus	
Alkulämmittelyn sisältö ja kesto	Kävely 1 km/10 min Liikkuvuusliikkeet 10 min	
Alkulämmittely RPE (koettu kuormittuneisuus 0-10)	1	
Varsinaisen harjoituksen sisältö ja kesto	Juoksu 9 km 60 min	
Varsinainen harjoitus RPE (koettu kuormittuneisuus 0-10)	4	
Loppujäähdyttelyn sisältö ja kesto	Kävely 1 km/10 min Venyttely 5 min	
Loppujäähdyttely RPE (koettu kuormittuneisuus 0-10)	1	
Lisätiedot	Harjoituksen keskisyke 125 (juoksussa keskisyke 135 ja 65 % maksimisykkeestä). Kulutus 780 kcal. *Perinteinen peruskuntolenkki, kevyttä!*	

AKTIIVISUUSPÄIVÄKIRJA

Päivä:

klo	Aktiivisuus (ruokailu, peseytyminen, liikkuminen, uni, arkiaskareet..)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	