



TEELE PUHLOV

Female Athlete Triad

A systematized literature review on what is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad

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<p>Title of publication Female Athlete Triad A systematized literature review on what is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad</p>		
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<p>Abstract</p> <p>The aim of this thesis is to increase knowledge about physiotherapy process in Female Athlete Triad. The objective of this thesis is to search for evidence for physiotherapy process in Female Athlete Triad using systematized literature review. The systematized literature review will focus on the following question: What is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad?</p> <p>This thesis will provide an overview on what the evidence-based recommendations exist for physiotherapist process regarding Female Athlete Triad. This thesis could be used as educational material in the faculty of health and welfare to educate physiotherapy and or nursing students about the Female Athlete Triad syndrome and its potential negative health consequences</p> <p>Despite the low level of evidence, the role of physiotherapy is manifold. Physiotherapists play a part in pre-seasonal examinations and evaluations, assessments of movement and strength, preventing injuries and rehabilitation of injuries. Physiotherapists provide their expertise in biomechanical analysis of basic movements and technique used by the athlete. They help modify training programs and give their own input for rest and recovery ratios. Physiotherapists refer their clients to other specialists for further counselling or for diagnosis if necessary.</p> <p>The primary role of physiotherapists is in education and prevention together with other members of the multidisciplinary team. All members of the multidisciplinary team represent a unified front and work in unison to provide best possible care for the athlete.</p>		
<p><u>Key words</u> Physiotherapy, Physical therapy, Female Athlete Triad, Energy deficiency, Menstrual dysfunction, Low bone mineral density</p>		

FOREWORD

“It has taken decades to learn that important sex differences exist in male and female physiology, and we should not repeat previous mistakes by establishing clinical guidelines for both sexes when there are data primarily only for one sex.” (De Souza et al., 2014, pp. 1461-1465).

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LIST OF SYMBOLS AND TERMS

ACSM – American College of Sport Medicine

BMD – Bone mineral density

DE – Disordered eating

DIT – Dietary induced thermogenesis

DXA or DEXA - Dual-energy x-ray absorptiometry

E2 - 17 β -estradiol

EA – Energy availability

EAT – Exercise activity thermogenesis

ED¹ – Energy deficiency

ED² – Eating disorder

EEE - Exercise energy expenditure

EBP – Evidence based practice

FFM – Fat free mass

FHA – Functional hypothalamic amenorrhea

HPG - hypothalamic-pituitary-gonadal axis

IOC – International Olympic Committee

LBMD – Low bone mineral density

LEA – Low Energy Availability

LH – Luteinizing hormone

MD – Menstrual dysfunction

NEAT – non-exercise activity thermogenesis

PT – Physiotherapist or Physical therapist

REE – Resting metabolic rate

RED-S – Relative Energy Deficiency in Sports

RMR – Resting metabolic rate

SCI – Spinal cord injury

TEF – Thermic effect of food

The Triad/ The Athletes Triad – Female Athlete Triad

WHO – World Health Organization

1 INTRODUCTION

The basic formula for a healthy lifestyle lies in the standard advice given by many: eat well, exercise, drink plenty of water and get plenty of sleep. In this day of age there is no doubt that benefits of exercise and regular physical activity far outweigh the risks caused by sedentary lifestyle. Exercise does more than effect our body composition. In adult population, aged 18-64, regular physical activity improved cognitive health and sleep, reduced symptoms of anxiety and depression and decreased the risk of cardiovascular diseases, hypertension, and type-2 diabetes. (WHO, 2021.)

Participating in sport has always been a wonderful motivator for staying healthy. Women's path to physical activity and professional sport has had its obstacles. In 1972 Title IX was passed in USA which stated that no person shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination based on sex under any education program or activity receiving federal financial assistance. Since the passing of Title IX, more girls and women of all age groups participate in competitive sports. This is a positive development due to all the potential health benefits of sport, exercise, and regular physical activity, however sport does not come without its health risks. (Women's Sport Foundation, 2021.)

One of those health risks among female athletes is known as Female Athlete Triad. Weigh-sensitive sports, such as those emphasizing leanness and or aesthetics, those where weighing less gives a performance advantage or those which require an athlete to be in a certain weigh class to compete, could lead to chronic energy deficiency by either restring dietary intake, by excessive exercising or by both. (The Female and Male Athlete Triad Coalition, 2021.)

Female Athlete Triad has never been entirely unique to female athletes only, however its manifestation in women is far more severe than in male counterparts due to female physiology – metabolic and reproductive. Published since the early 90s, Female

Athlete Triad has 30 plus years of substantial evidence to support its existence. (De Souza et al., 2014, pp. 1461-1465.)

2 SEX-BASED DIFFERENCES IN PHYSIOLOGY

There is no denying that biological sex plays a role in sport and performance. The differences go far beyond just height and weight. The differences not only exist in normal physiology but also in epidemiology and pathophysiology of diseases. The foundation for sex-based differences can be found in genetics – X and Y chromosomes, which affects sex steroid hormone production throughout one's life. Despite the importance of sex-based differences in physiology and despite the amount of literature available today, sex-based differences are not extensively taught in professions other than those involved with reproductive physiology, nor does it get the attention it deserves in majority of health-care curriculums or physiology textbooks. (Blair, 2007, pp. 23-25.)

Anatomically differences in size and shape not only exist between sexes but also between same sex people. Bones of male skeleton are typically larger and heavier. They have larger surface markers compared to women. Female pelvis is broader compared to males, and as a result the angle of convergence of femoral shaft is larger in women. (Tortora & Derrickson, 2017, pp. 213-215.) These differences in anatomy affect biomechanical alignment and therefore also function (Physiopedia, 2021).

A gait analysis on 20 men and 20 women revealed that female recreational runners showed differences in lower extremity mechanics compared to their male counterparts. Specifically in peak hip adduction, hip internal rotation and in knee abduction angles. (Ferber, Davis & Williams, 2003, pp.350-357.) Another study investigated landing strategies in men and women and found that although both sexes used knees as primary shock absorbers, the second largest muscle group used in energy absorption in women were plantar-flexors and hip extensor muscles in men. The same study noted that

women also had a more upright landing posture. This landing strategy may put women in a greater risk for ACL injuries. (Decker et al., 2003, pp. 662-669.)

When discussing sex-based differences, female reproductive system, and hormonal differences, specifically estrogen comes to mind. It is not just estrogen. Hormones in question: estrogen, progesterone, and luteinizing hormone (LH), fluctuate during the monthly cycle, every month, during reproductive years. This divides the menstrual cycle into two distinct phases: follicular phase and luteal phase, between which ovulation occurs. (Tortora & Derrickson, 2017, pp. 942-947.) This monthly fluctuation in hormones affects number of organ systems in the human body because receptors of sex steroid hormones: androgens, estrogens, and progestins, can be found in a variety of nonreproductive tissues, such as heart, bone, skeletal muscle, ligaments, and tendons, even in the brain. (Blair, 2007, pp. 23-25.)

A study done in 2020, found that not only were there significant differences between sexes in lower limb proprioception and mechanical function, but the study demonstrated that during ovulatory and luteal phases women had better lower limb proprioception compared to follicular phase. (Hu, Li & Wang, 2020, 571-587.) On the other hand, a systematic review on the effects of menstrual cycle on lower limbs showed strong evidence that ACL injury risk is greater in the pre-ovulatory phase and that greater ACL laxity in pre-ovulatory phase leads to greater knee valgus and greater tibial external rotation during functional activities. (Balachandar et al., 2017, pp. 136-146.)

Biological sex affects myriad of physiological functions which reflect in clinical manifestations, in symptoms and in outcomes and management of pathology. These differences influence prevention strategies, management, and therapeutic treatment. This would make personalized health care more efficient and holistic for patients. (Regitz-Zagrosek, 2012, pp. 596-603.)

3 FEMALE ATHLETE TRIAD

Condition known as Female Athlete Triad became known to a wider audience when American College of Sport Medicine (ACSM) first introduced it in 1992 in a consensus conference called The Task Force on Women's Issues. The focus of this conference was on the relationship between disordered eating (DE), amenorrhea, and osteoporosis among female athletes. (Otis et al., 1997, pp. i-ix; Nattiv et al., 2007, pp. 1867-1882.)

Today Female Athlete Triad, also known as the Triad (Figure 1), is defined as a condition of three interrelated components (Figure 2) that exist on a continuum of severity (Figure 3), including: energy deficiency (ED¹), menstrual dysfunction (MD), and impaired bone health. (The Female and Male Athlete Triad Coalition, 2020.)

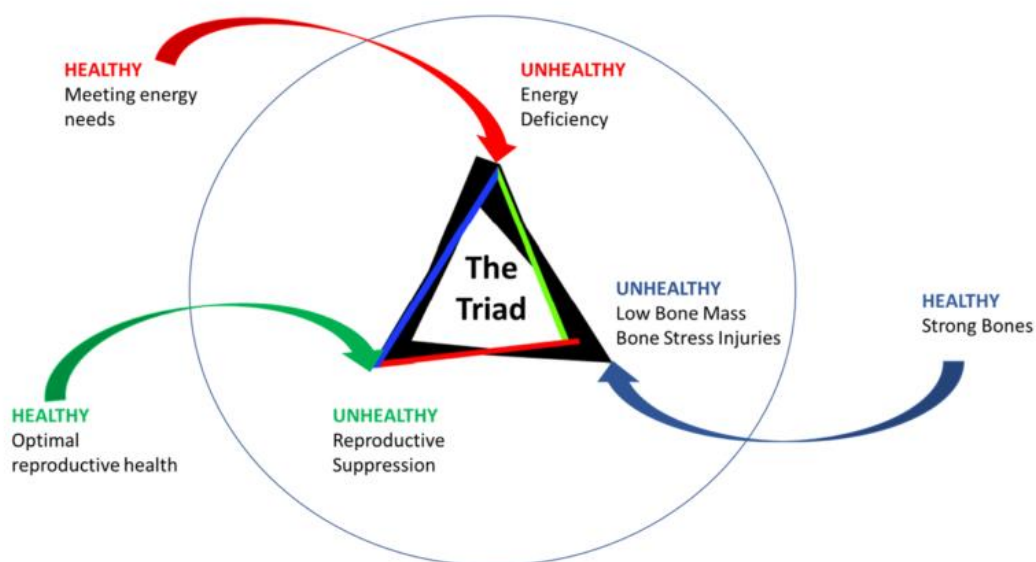


Figure 1 The Female and Male Athlete Triad Model. The Female and Male Athlete Triad Coalition, 2020.

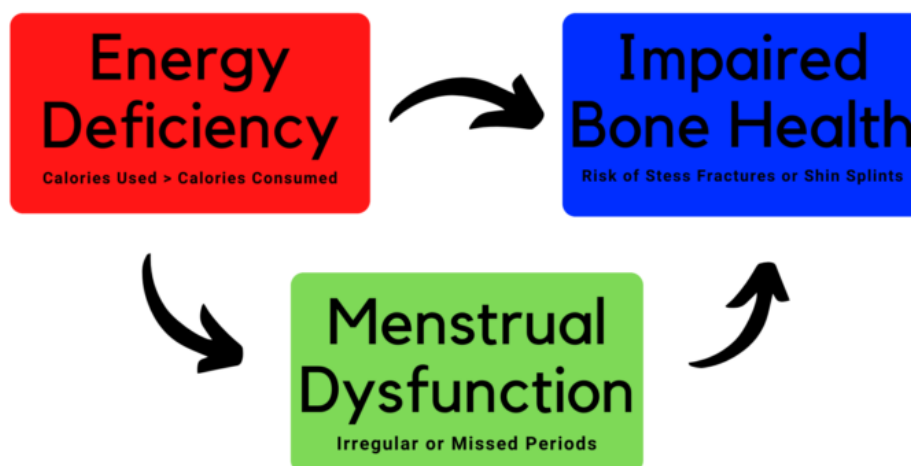


Figure 2 The components of Female Athlete Triad. The Female and Male Athlete Triad Coalition, 2020.

Energy deficiency, with or without DE, menstrual dysfunction, and impaired bone health could all lead to serious health problems on their own, but it is the complex relationship that exists with one another that lays the foundation for the Triad. (Nattiv et al., 2007, pp. 1867-1882.)

The definition of the Triad introduced in the 90's focused on the severe end results of each Triad component, but the ACSM second position stand (2007) on the topic introduced the spectrum idea to better describe and understand the condition (Figure 3) and draw attention to athletes who show subclinical abnormalities. (De Souza et al., 2014, p. 289.) Each component of a Triad exists on a spectrum ranging from healthy (green triangle in Figure 3) to unhealthy (red triangle in Figure 3). Each component moves along their own imaginary line at their own speed (black lines in Figure 3) and each component could move in either direction. (Nattiv et al., 2007, pp. 1867-1882.)

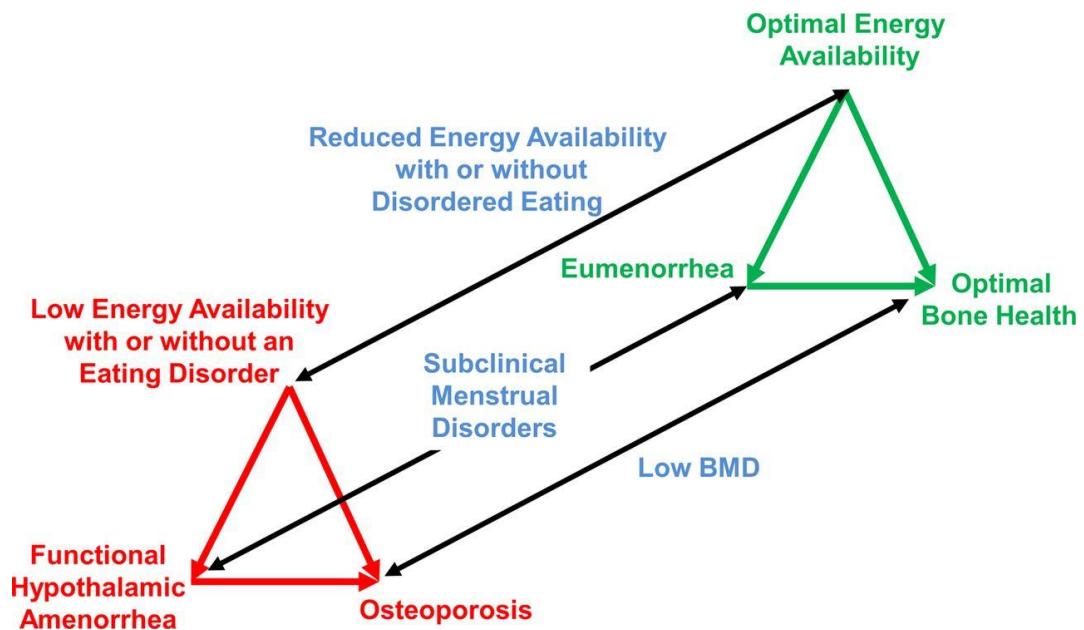


Figure 3 Female Athlete Triad spectrum. De Souza et al., 2014, p. 289.

All three components of the Triad do not have to be present in an athlete simultaneously to be affected by the condition or to be diagnosed with it. In fact, manifestation of only one component is enough to justify further examination for a conclusive diagnosis. (Female and Male athlete Triad Coalition, 2020; Women’s Sport Foundation 2020.)

3.1 Energy deficiency

Female Athlete Triad starts because of low energy availability (LEA) also known in the literature as energy deficiency (The Female and Male Athlete Triad Coalition, 2020). The spectrum for energy availability (EA) ranges from optimal energy availability to low energy availability. EA is the amount of energy that is left once exercise energy expenditure (EEE) is subtracted from dietary energy intake (EI) and normalized to fat free mass, which is metabolically the most active tissue in the human body. Equation used to calculate EA is displayed in Figure 4 and its unit of measure is kcal/kg FFM/day. (Wasserfurth et al., 2020.)

$$EA = \frac{\text{Dietary energy intake (kcal)} - \text{Exercise energy expenditure (kcal)}}{\text{Fat Free Mass (kg)}}$$

Figure 4 Equation for energy availability. Wasserfurth et al., 2020.

All systems in the human body require energy to work optimally. The demand for energy is even higher amongst athletes because of higher energy expenditure demands, which is why daily dietary intake should cover all athletes' daily needs. This is known as energy balance – a state where daily dietary energy intake, i.e., the total number of calories consumed in a day equals total daily energy expenditure, i.e., the total number of calories used in the same day (Figure 5). (Wasserfurth et al., 2020.)

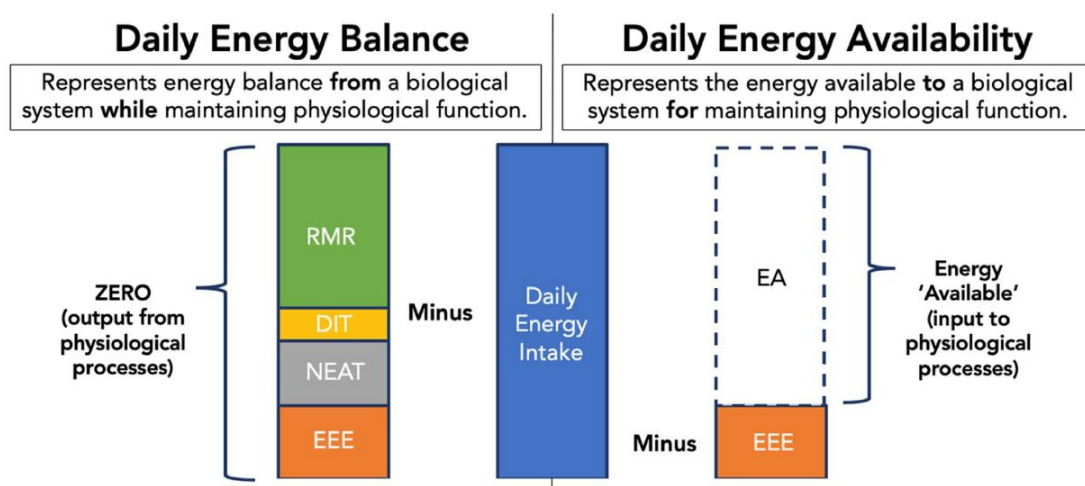


Figure 5 Energy/Caloric balance vs Energy availability. Areta, Taylor & Koehler, 2021.

Figure 5 shows how daily energy balance is generally divided in the literature. Resting metabolic rate (RMR) also called basal metabolic rate (BMR) or resting energy expenditure (REE) makes up roughly 60-70% of total daily energy expenditure. Components such as exercise energy expenditure (EEE) also known as exercise activity thermogenesis (EAT), non-exercise activity thermogenesis (NEAT) and thermic effect of food (TEF) make up the rest 40-30%. EEE, NEAT and TEF could also collectively be called non-resting energy expenditure (NREE). (Wasserfurth et al., 2020.)

Determining LEA accurately is difficult as there is no agreed upon guidelines for optimal EA for elite athletes (Wasserfurth et al., 2020). Additionally, daily dietary intake can be altered by the athlete by underreporting and or modifying food intake or

imprecise recording of portion sizes and or calories. Measuring EA requires honesty and compliance from the athlete. (De Souza et al., 2014, pp. 1-20.)

A threshold for LEA has been established and is currently recognized as $< 30\text{kcal/kg FFM/day}$. Numerous short-term laboratory experiments have shown this to be the starting point of severe health implications, for example amenorrhea. (ACSM position stand, 2007; Wasserfurth et al, 2020.) EA around $45\text{ kcal/kg FFM/day}$ is currently considered healthy for athletes (ACSM, 2019).

There are numerous reasons why an athlete might have energy deficit, however four distinct pathways are recognized. Those four pathways are, clinical eating disorders (ED²), disordered eating (DE) patterns, inadvertent undereating due to for example high energy expenditure sports or intentional weight loss. (Wasserfurth et al., 2020; the Female and Male Athlete Triad Coalition, 2020.)

ED² are defined as mental disorders with persistent patterns of unhealthy eating or dieting behavior which can cause health impairment. The two most common ED²-s are anorexia nervosa and bulimia nervosa. Anorexia nervosa is characterized by a relentless pursuit of thinness, a morbid fear of obesity, a distorted body image, and restriction of intake relative to requirements, leading to a significantly low body weight. Bulimia nervosa is characterized by a cycle of bingeing and compensatory behaviors to undo or compensate for the effects of binge eating. (NEDC, 2021; AED, 2020; NEDA, 2021.)

DE is a change in eating behaviors or patterns that by themselves, do not warrant a diagnosis of an ED². DE is a descriptive phrase and not a diagnosis. DE patterns are also seen as sub-clinical issues which if persistent can lead to ED²-s. (NEDA, 2021; AED, 2020.) This is one of the most common pathways seen in female athletes. Dietary cognitive restraints to deliberately reduce food intake or because of high drive for thinness. (ACSM, 2019.)

Inadvertent undereating is used to describe athletes or physically active girls and women who fail to consume enough calories unintentionally. For example, high energy expenditure sports, such as running, rowing, and cycling could lead to

unintentional energy deficit. Athletes engaged in these sports may not even be aware of their energy deficit. In addition to high energy expenditure, training volume fluctuates during competitive season and if dietary intake is not addressed, energy deficit can quickly appear. (Wasserfurth et al., 2020.)

Student-athletes may find themselves not having enough time to make food and or eat between school and training or may be lacking financial means to afford enough food. Even inadequate cooking skills or loss of appetite before or after training could lead to LEA. In these cases, athletes are not consciously trying to decrease their daily intake but may find themselves dealing with the negative effects of LEA regardless. (Wasserfurth et al., 2020.)

Intentional weight loss can also lead to LEA if athletes themselves, parents of young athletes, or coaches lack proper nutritional knowledge. (The Female and Male Athlete Triad Coalition, 2020.) Wasserfurth et al. (2020) draws attention to evidence which shows that general sport nutrition is poor among athletes and coaches.

When LEA becomes chronic, physiological adaptations to conserve fuel take place for survival. These adaptations happen all over the body in all systems. The two responsible for Female Athlete Triad are metabolic suppression and reproductive suppression which in consequence lead to skeletal health problems. Additionally, LEA can affect bone health directly. (ACSM, 2019.)

Despite the pathways which lead to LEA it is important to note, that LEA does not always manifest itself in low body weight or reduced BMI. If LEA continues, physiological processes get downregulated. This downregulation means that physiological processes use less calories overall for their functioning which means that body weight remains unchanged. This is often seen in athletes who have not been in LEA for long. (ACSM, 2019.)

3.2 Menstrual dysfunction

Menstrual function in Female Athlete Triad ranges from eumenorrhea to amenorrhea. Eumenorrhea refers to normal or regular menstrual cycle which on average lasts 28 ± 7 days for women. Amenorrhea refers to absence of menstrual cycle and can be divided into two types: primary amenorrhea and secondary amenorrhea. When a girl has not started her first period by the age of 15 it is referred to as primary amenorrhea. Secondary amenorrhea is when menstrual periods are absent for 3 months or 90 days. (Nattiv et al., 2007, pp. 1867-1882; American College of Obstetrician and Gynecologists, 2021.)

Within this spectrum oligomenorrhea, luteal deficiency and anovulation can also occur (Nattiv et al., 2007, pp. 1867-1882). Oligomenorrhea refers to irregular and inconsistent menstrual blood flow in women. Some changes in menstrual periods are considered normal among young girls for two years following menarche, in postpartum women and in perimenopausal women. (Riaz & Parekh, 2021.) Luteal deficiency or luteal suppression is when the luteal phase of the menstrual cycle is shorter than 11 days or with low concentration of progesterone. Anovulation is a menstrual cycle without ovulation. (Nattiv et al, 2007, 1867-1882.) These conditions are described as subclinical menstrual disturbances and can exist without detectible symptoms and therefore can go unnoticed among athletes who are at risk. (De Souza et al., 2014, pp. 1-20.)

The system that regulates reproduction is known as hypothalamic-pituitary-gonadal (HPG) axis and as the name suggests consists of three endocrine glands – hypothalamus, pituitary gland, and gonadal gland. Each gland is responsible for the production of certain hormones (Figure 6). (Vadakkadath Meethal & Atwood, 2005, pp.257-270.)

Table 1 – Major hormones of the HPG axis		
Hormone	Source	Action
GnRH	Hypothalamus	Stimulates release of LH and FSH
FSH	Anterior pituitary	Stimulates E2 release
LH	Anterior pituitary	Stimulates ovulation
E2	Ovary	Follicular development, uterine lining
Progesterone	Ovary (minor source), corpus luteum, placenta	Maintains uterine lining

HPG, hypothalamic-pituitary-gonadal; GnRH, gonadotropin-releasing hormone; LH, luteinizing hormone; FSH, follicle-stimulating hormone; E2, estradiol.

Figure 6 Hormone production of HPG axis. Gordon-Elliott et al., 2017.

In women HPG axis is responsible for regulating the menstrual cycle and ovarian cycle (Gordon-Elliott et al., 2017). Hormones such as estrogen, progesterone and luteinizing hormone fluctuate throughout the cycle to prepare the reproductive system for various stages of the cycle (Tortora & Derrickson, 2017, pp. 942-947). LEA causes HPG axis to downregulate even to the point of deactivating if LEA is severe enough to conserve energy (Logue et al., 2020).

Functional hypothalamic amenorrhea (FHA) is a type of secondary amenorrhea which is caused by suppression of the HPG axis, specifically hypoestrogenism resulting in cessation of menstrual periods. Three different components can lead to HPG suppression: psychological stress, intense exercise, and or disordered eating. (Shufelt, Torbati & Dutra, 2017, pp. 256-262.)

Sex hormones, i.e., estrogen and testosterone, have an important role in bone growth and remodeling. Both hormones are responsible for increased osteoblast activity, synthesis of bone extracellular matrix, and pubertal “growth spurt” during teenage years. Estrogen stops epiphyseal plates from growing, giving us our height. During adulthood, estrogen plays an important role in bone reabsorption, by influencing apoptosis in osteoclasts. (Tortora & Derrickson, 2017, pp. 147-166.)

Four different estrogens have been identified so far: 17 β -estradiol (E2), estrone (E1), estriol (E3), and estetrol (E4). E2 is the estrogen we mean when we talk about estrogen levels in women during their fertile years. E2 is synthesized in the ovaries and

produced from puberty until menopause. Figure 7 demonstrates the role of E2 in men and women throughout their life. (Noirrit-Esclassan et al., 2021, pp.1-18.)

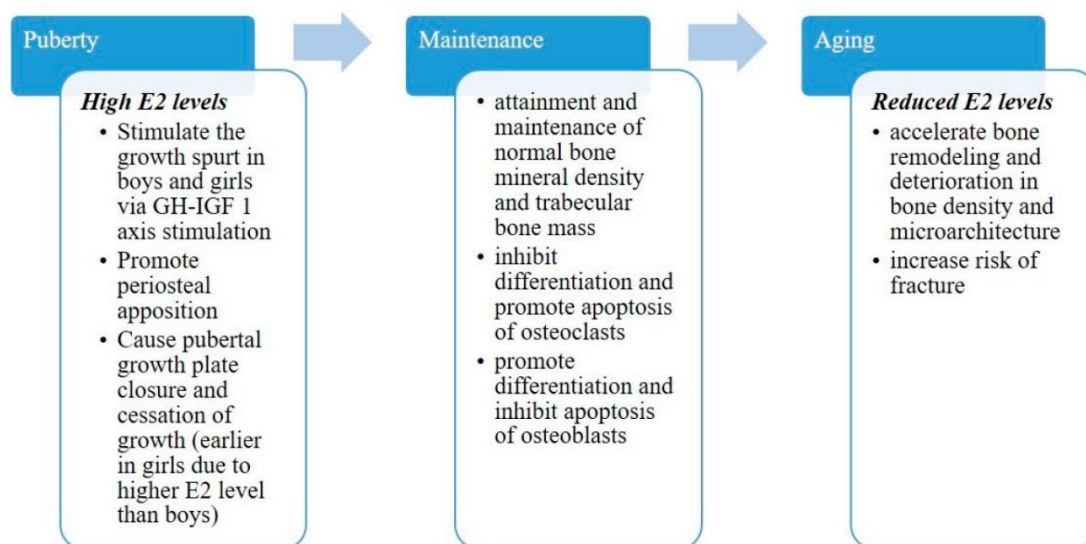


Figure 7 The role of E2 in a person's life. Noirrit-Esclassan et al., 2021, p. 1568.

Maintaining eumenorrhea should be high up in the priority list for exercising individuals. It can be used as a clinical marker to assess female athletes' health however, first and foremost it has an important role in the health of the reproductive system which consequently affect bone health. (Female and Male Athlete Triad Coalition, 2020.)

3.3 Impaired bone health

On the Triad spectrum, bone health ranges from optimal health to osteoporosis (Nattiv, et al., 2007, pp. 1867-1882). World Health Organization (WHO) defines osteoporosis as a systemic skeletal disease characterized by low bone density and microarchitectural deterioration of bone tissue with consequent increase in bone fragility (WHO Scientific Group, p. 2). Osteoporosis can develop as a primary disorder or as a secondary disorder due to other factors or diseases. Less than 5% of osteoporosis accounts for secondary osteoporosis in women. (Merck Sharp & Dohme Corp., 2021.)

The formation and reabsorption of bone tissue is a continuous process throughout a person's lifetime. It is a balanced process in healthy individuals but both formation

and absorption rates are affected by aging, estrogen levels, vitamin D and calcium intake. (Tortora & Derrickson, 2017, pp. 147-166.) Bone reabsorption and formation are for the most part balanced with the exceptions during puberty, when bone formation exceeds bone reabsorption and during menopause when the opposite occurs – bone absorption exceeds bone formation (Merck Sharp & Dohme Corp., 2021).

Bone is made up of two materials: collagenous material combined with mineral crystals. Minerals give bone its stiffness and collagen toughness. This makes bone strong enough to withstand mechanical load without deforming or breaking. (Turner, 2006, pp. 429-446.) There is a significantly higher strain on bone tissue among elite athletes due to their training volume and loads.

Dual-energy x-ray absorptiometry (DXA) is used to measure BMD. WHO recommends using T-scores which are based upon average peak of Caucasian adults BMD. T-score is considered healthy if it is between +1 and -1. T-score indicates osteopenia or low bone mineral density if it falls between -1 and -2,5 and osteoporosis if T-score is less or equal to -2,5. T-scores less or equal to -2,5 with a history of one or more osteoporotic bone fracture gives a diagnosis on severe osteoporosis. (WHO Scientific Group, p. 57.)

Z-scores, introduced by International Society for Clinical Densitometry (ISCD), compares individuals with age and sex-matched controls, making it more reliable among children, adolescent, and premenopausal women. Z-scores lower than -2.0 are labeled as “low” for the persons age and sex. ISCD also recommends using low bone mineral density instead of osteopenia in diagnosis and that osteoporosis as a diagnosis should be used if secondary risk factors are present. (Nattiv et al., 2014, pp. 1867-1882; International Society for Clinical Densitometry, 2021.)

4 HEALTH CONSEQUENCES

The far end of the Triad spectrum gives a terrifying warning for what the possible long-term health consequences of Female Athlete Triad are if it goes untreated. Each component of the Triad has their own spectrum with their own health consequences. However, the list does not end there. Medical consequences of Female Athlete Triad could reach other systems such as endocrine, gastrointestinal, renal, neuropsychiatric, musculoskeletal, and cardiovascular. (De Souza et al., 2014, pp. 1-20; National Eating Disorders Association, 2021.)

Persistent amenorrhea or luteal deficiency leaves women infertile since there is no follicular development, ovulation, or luteal function. With every missed menstrual cycle BMD not only declines but also may become irreversible. Osteoporosis makes bones more fragile and more prone for fracture. Consequently, this could lead to additional problems. (Nattiv et al., 2007, pp. 1867-1882.)

Effects on bones, is the biggest worry according to experts. Bone stress injuries ranging from different types of stress reactions to stress fractures, not only affect health but also performance (De Souza et al., 2014, pp. 1-20).

5 RISK FACTORS

The primary cause of Female Athlete Triad is LEA. Athletes can knowingly or unknowingly alter two components of EA: daily dietary energy intake or daily exercise energy expenditure. (ACSM, 2019.) Anything that alters, more specifically reduces, daily dietary energy intake has a potential of becoming a risk factor for developing LEA. Factors affecting dietary intake are manifold: ED²-s, DE behaviors, food intolerances or allergies, beliefs, pressure from coaches, family or peers, low self-esteem, biological and genetic factors and in this day of age also social media platforms. (Nattiv et al., 2007, pp. 1867-1882.)

Chronic under-fueling causes reregulation of organ systems in order to conserve energy for more vital processes (Female and Male Athlete Triad Coalition, 2020; Nattiv et al., 2007, pp. 1867-1882).

Female Athlete Triad may occur in any sport, regardless of athletic level, regardless of age, however sports which emphasize aesthetics, and are often subjectively judged, that require an athlete to be in a certain weight class, or sports where weighing less gives a performance advantage. For example, dancing, diving, gymnastics, and ice skating belong in a group of sports that emphasized leanness and are subjectively judged. Wrestling, boxing, and rowing belong in weight class sports. Running, ski jumping, high jump and cycling belong to a group of gravitational sports, where leanness gives a performance advantage. (Female and Male Athlete Triad Coalition, 2020.)

Sports with high energy expenditure, such as rowing and cycling, or even increased training volume can cause LEA (ACSM, 2019; Wasserfurth et al., 2020.). Study with 833 participants by Logue et al. (2018) revealed that for each additional hour of exercising per week participants in the study were 1,06 times more likely to be considered at risk of LEA.

6 TREATMENT OF FEMALE ATHLETE TRIAD

Female Athlete Triad is a complicated condition. Each component has their own spectrum with their own health consequences. Each component can exist alone or in combination and each component could be a consequence of a disorder not related to Female Athlete Triad at all. (Female and Male Athlete Triad Coalition, 2021.)

6.1 Screening and diagnosis

What is the difference between screening and assessment? The difference lies in the purpose. Screening is a process, where the purpose is to determine whether an individual needs further, more detailed, assessment for a particular problem. Many screening instruments, e.g., questionnaires, require little to no special training for usage. Assessment is a process where the nature of the problem is defined, a diagnosis is determined, and a treatment for the problem or a diagnosis is proposed. (SAMHSA, 2015, p. 58.)

One of the most crucial elements is prevention. Early recognition of Triad symptoms leads to early diagnosis and early treatment. Prevention happens through education. Coaches and the surrounding team together with the athlete should educate themselves about the condition and how its components effect on one another. Furthermore, why each component is important in the context of sport and performance. (Nattiv et al., 2007, pp. 1867-1882.) For the prevention to be successful, all members of the team need to represent a unified front because “mixed-messages” or inconsistent information could lead to lack of trust and frustration (Thein-Nissenbaum & Hammer, 2017, pp. 85-95).

Early detection for Female Athlete Triad is crucial. Regular screening leads to earlier diagnosis which in turn could lead to better outcomes. Screening for Triad can be complicated because it is largely dependent on the openness and cooperativeness of the client. Additionally, number of symptoms can be subclinical and therefore not always apparent to the client, the parents, or the surrounding team. Screening should be part of the pre-participation evaluation and should involve questions to address all aspects of the Triad. (De Souza et al., 2014, pp. 1-20.) Screening requires understanding the components of the Triad and their interrelationship (Nattiv et al., 2007, pp. 1867-1882). The Female and Male Athlete Triad Coalition recommends making screening for the Triad as part of pre-participation physical examination for girls and women. The Triad Coalition recommends using Triad-specific questionnaire annually to see if more in depth screening is needed. (De Souza et al., 2014, pp. 1-20.) The Triad specific screening questions could be found in Appendix 2.

Every screening starts with proper patient history. Gathering general information about energy intake and energy expenditure, before digging deeper into dietary practices and sport specific training. To understand where on the Triad spectrum the individual is and in which direction on the spectrum they are moving, it is necessary to evaluate each component of the Triad: LEA, menstrual dysfunction, and bone health. All position stands and coalition statements, mention that if the athlete should have a more in-depth evaluation by a licensed practitioner if the individual is at risk for any of the Triad components. (De Souza et al., 2014, pp. 1-20; Nattiv et al., 2007, pp. 1867-1882.)

Female Athlete Triad Coalition Consensus statement recommends using the screening tool on younger athletes as well. It is especially important to detect any component of the Triad among young athletes because 90% of bone mass growth happens during teenage years. Early detection and intervention provide an opportunity for optimizing bone health. (De Souza et al., 2014, pp. 1-20.)

If patient history suggest high risk for any of the components of the Triad physical examination should be performed by a health-care provider. Symptoms of eating disorders, height and weight and vital signs should be obtained. Similarly, to patient history screening, physical examination should look at each component separately by a professional to accurately analyze where on the spectrum the athlete is and in which direction they are moving along the spectrum. (Nattiv et al., 2007, pp. 1867-1882.)

Sometimes laboratory tests are needed to exclude other conditions. Laboratory tests can help give a more specific chemical profile of the individual which in turn could help eliminate other possible causes for Triad symptoms. For example, pregnancy, PCOS or tumors. (Nattiv et al., 2007, pp. 1867-1882.)

Bone mineral density testing is necessary if there is a cumulative history of 6 months or more of hypoestrogenism, disordered eating or eating disorders with or without a history of stress fractures or fractures from minimal trauma. Dual-energy X-ray absorptiometry (DXA or DEXA) is used to evaluate BMD on specific areas in the body. (Nattiv et al., 2007, pp. 1867-1882.)

6.2 Treatment and management

First line of treatment is addressing the elements that cause LEA and the restoring normal energy balance. It is necessary to optimize either daily dietary energy intake, exercise energy expenditure or both to stop and then reverse the movement direction on the spectrum. Additional attention should be given to children and young adults, as they are still growing and putting on bone mass during puberty. (Nattiv et al., 2007, pp. 1867-1882.)

The pathway leading to LEA dictates the recovery recommendations. Clinical ED² warrants a referral to a mental health practitioner and or a sport dietician whereas inadvertent undereating, intentional weight loss and disordered eating will most likely benefit from a sport dietitian or nutritional educator only. (ACSM, 2019.)

Restoring or normalizing the athlete's bodyweight addresses both the menstrual function and bone health. Female and Male Athlete Triad Coalition recommends increasing dietary intake in small steps to keep athletes' adherence strong. It is a general recommendation that dietary intervention should take a year. If dietary intervention fails, the pharmacological intervention is considered. (ACSM, 2019.)

Time course of recovery for each component of Female Athlete Triad differs significantly (Figure 8). Energy availability can be restored relatively quickly. Correcting dietary intake recovers energy status in days or weeks. Depending on the severity of LEA, dietary intake is corrected in small quantities. This guarantees better adherence from the athlete. (ACSM, 2019.)

Recovery of a menstrual cycle and bone health take longer. Menstrual cycle usually takes months to recover. It is advised for the athlete to have three consecutive menstrual periods during for it to be declared to be normal. Recovery of bone mineral density takes the longest which is why adherence to positive energy balance is key. It is not currently known if bone health could recover completely. (ACSM, 2019.)

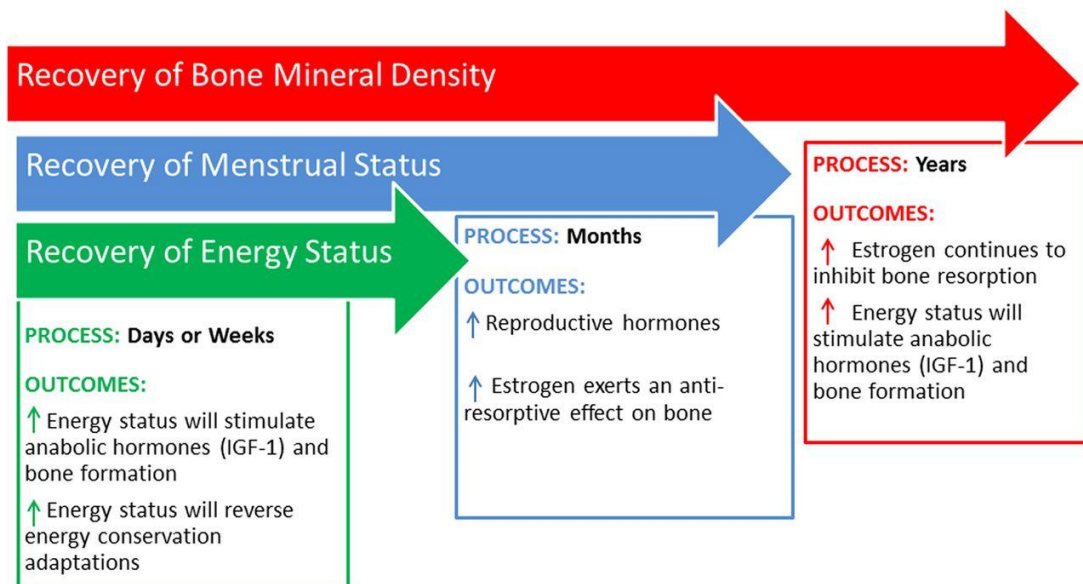


Figure 8 Recovery time of each Female Athlete Triad component

Some pharmacological intervention might be needed if the athlete suffers from ED²s, for example, antidepressants. Oral contraceptive pills might be considered once the athlete over 16 years of age continues to lose BMD despite having adequate nutritional intake and weight. (Nattiv et al., 2007, pp. 1867-1882.)

Regular weightbearing exercises should also be considered both as a preventive measure or as a management option among all sports (Nattiv et al., 2007, pp. 1867-1882). Bone is a dynamic, living tissue and it adapts to the stimulus it is given. Weightbearing exercises are shown to have a positive effect on bone health in certain structures. A meta-analysis of RCT's investigated effects of exercise in BMD in femoral neck and lumbar spine and found that exercise has positive effects in premenopausal women BMD. (Kelley, Kelley & Kohrt, 2013)

Because bone recovery is a slow process and is successful only if restoring energy balance is adhered to, clearance and return to play must be as structured as the treatment of Female Athlete Triad. It is the team physician who assess if and when it is safe to return the athlete back to training or even competition. The Female and Male Athlete Triad Coalition recommends physicians to use both a risk stratification protocol (Appendix 3) and return-to-play (Appendix 4) in their decision making. (De Souza et al., 2014, pp. 1-20.)

7 RELATIVE ENERGY DEFICIENCY IN SPORT (RED-S)

IOC has produced three consensus statements related to Female Athlete Triad – in 2005, in 2014, and in 2018 (International Olympic Committee, 2021). The 2005 IOC statement defined Female Athlete Triad as a condition consisting of disordered eating and irregular menstrual cycles which in combination led to low bone mineral density (LBMD) due to decreased endogenous estrogen and other hormones. (Mountjoy et al., 2014, pp. 491-497.)

In 2014, 7 years after ACSM redefined Female Athlete Triad to how it is understood today, IOC introduced an updated consensus statement: beyond Female Athlete Triad – Relative Energy Deficiency in Sport (RED-S) which served as an update and was supposed to replace IOC's previous 2005 position stand. The new statement introduced a new term Relative Energy Deficiency in Sport or RED-S for short and offered guidelines for better risk assessment, treatment and return-to-play decision making. The new term, RED-S was supposed to replace Female Athlete Triad because of two main reasons. Firstly, RED-S shows the complex nature of energy deficiency and secondly, non-menstrual symptoms also affect male athletes, thus reasoning IOC's request for a term that would be broader and more comprehensive. (Mountjoy et al., 2014, pp. 491-497.)

Mountjoy et al., (2014, pp. 491-497) has defined Relative Energy Deficiency in Sport (Figure 9) as impaired physiological function including, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular health caused by relative energy deficiency. Figure 10 shows some of the potential performance and health consequences of RED-S.

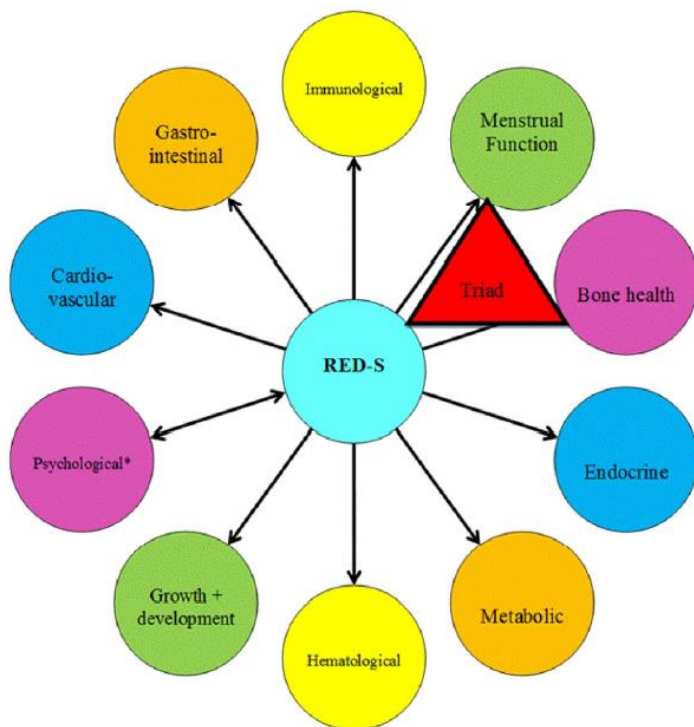


Figure 9 Visual representation of Relative Energy Deficiency in Sport the organ systems it effects. Mountjoy et al., 2014, pp. 491-497.

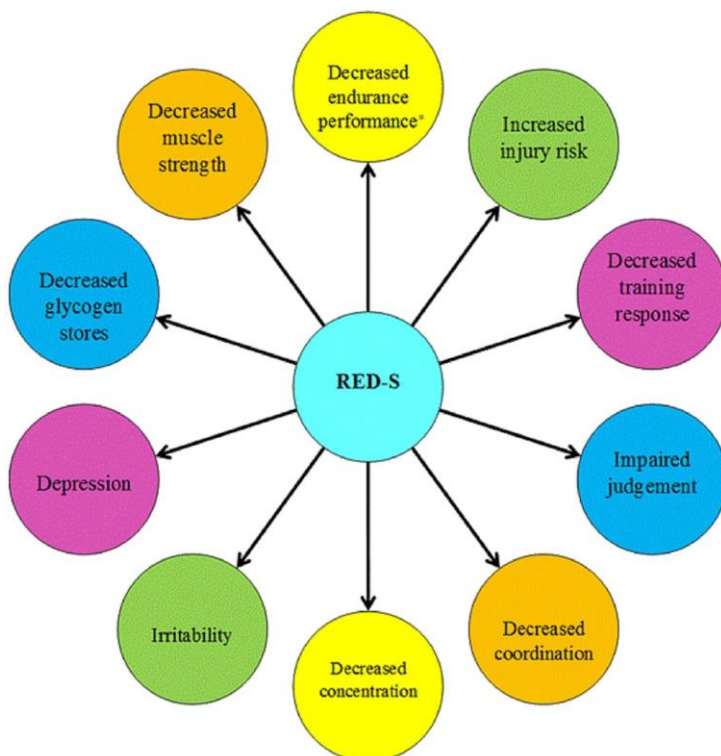


Figure 10 Potential performance and health consequences of RED-S. Mountjoy et al., 2014, pp. 491-497.

The 2014 IOC consensus statement caused controversy among scientific communities. De Souza et al., (2014) in the paper *Misunderstanding the Female Athlete Triad: Refuting the IOC Consensus statement on Relative Energy Deficiency in Sport (RED-S)*, expressed dissatisfaction and concern for the papers' insufficient evidence for many of its claims. "The IOC paper is fraught with fundamental errors and misinterpretation of the literature" (De Souza et al., 2014, pp. 1461-1465)

In 2018, IOC updated their consensus statement on RED-S. The purpose of this document was to provide an updated summary of RED-S and draw attention to the knowledge gaps that currently exist and stimulate scientific activity to address those gaps in knowledge. (Mountjoy et al., 2018, pp. 687-697.)

7.1 Male athlete triad

Position stands produced by ACSM in 1997 and in 2007 both recognized that male athletes are also at risk of developing disordered eating behaviors and or eating disorders and that together with extensive exercise could lead to hypogonadism and osteoporosis. (De Souza et al., 2014, pp. 1-20.)

IOC consensus statements, 2014 and 2018, on RED-S expressed concerns for gaps that exist in the knowledge of understanding LEA in male athletes. Based on the evidence stated in those documents, male athletes competing in endurance sports, e.g., running, cycling, gravitational sports, e.g., ski jumping, jockeys, and weight class sports, e.g., combat sports, are at higher risk for developing LEA. (Mountjoy et al, 2014, pp. 491-497; Mountjoy et al., 2018, pp. 687-697.)

Female and Male Athlete Triad Coalition organized an annual meeting in Denver, Colorado on May 30th, 2017, to develop Male Athlete Triad model. The Male Athlete Triad model was developed by a diverse group of clinicians, basic scientists and recognized national and international scientific experts in physiology, kinesiology, nutrition, women's and men's health, exercise physiology, pediatric and adult medical endocrinology, bone health, reproductive medicine, clinical sports medicine, and epidemiology. (Fredericson et al., 2021, pp. 335-348.)

Similarly, to Female Athlete Triad, Male Athlete Triad consists of the same three interrelated components: energy deficiency/LEA, reproductive suppression, and impaired bone health. LEA, with or without DE/ED², can lead to multiple compensatory metabolic adaptations, e.g., resting metabolic rate (RMR) suppression, low body mass index (BMI) etc. Reproductive suppression, more specifically hypothalamic-pituitary-gonadal (HPG) axis suppression, has shown some outcomes such as hypogonadotropic hypogonadism, oligospermia and decreased libido. And similarly in females, Male Athlete Triad could lead to osteoporosis with or without bone stress injuries. (Fredericson et al., 2021, pp. 335-348.)

Components of Male Athlete Triad also exist on a continuum ranging from healthy to unhealthy and are for the most part reversible (Figure 11). The line for reversal of bone mineral density is a dashed line with a question mark at the end in Figure 11, because research is unclear in what capacity it can be reversed, if at all. (Fredericson et al., 2021, pp. 335-348.)

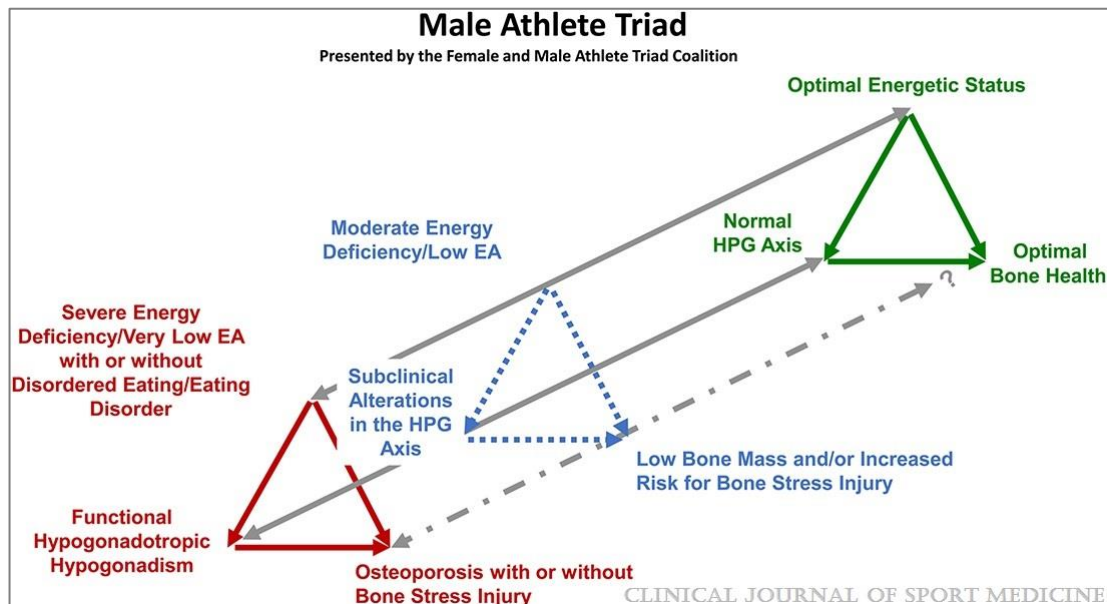


Figure 11 Model of the Male Athlete Triad. Fredericson et al., 2021, pp. 335-348.

7.2 Para-athletes

It is no surprise that athletes, regardless of their athletic level or functional ability, need to train on a regular basis to maintain and improve their skills. In addition to sport specific training demands, athletes' condition plays a role in EA. Condition such as cerebral palsy which often produce involuntary movements, or athletes with amputations, who may use multiple assistive devices in everyday life, may have higher daily energy demands due to their conditions. The opposite happens among athletes who use wheelchair on daily basis and may have lower baseline needs. Additionally, there are conditions, such as Spinal Cord Injury (SCI), which already increases the risk for impaired bone health, because of lack of bodyweight loading. (Mountjoy et al., 2018, pp. 687-697.)

Research regarding the Athletes Triad, RED-S or even LEA in para-athletes is in short supply despite the growing number of para-athletes in the worlds. The variety of disabilities represented in the Paralympic games and the levels at which the athletes train and compete demands better overall understanding of nutrition, energy expenditure and basic values for EA in para-athletes. (Pritchett et al., 2021; Egger & Flueck, 2020.)

7.3 Ethnicity and race

Whether ethnicity or race plays a role in developing RED-S is unclear. Research from non-athletic groups rises some speculation about possibility of LEA among non-Caucasian athletes. For example, National Eating Disorders Association (2021) states on their webpage that bulimic behavior is twice as likely to occur in black teenagers than in whites and that binge eating has higher occurrence among all minority groups. (NEDA, 2021.)

A study on sport nutrition knowledge, behaviors, and beliefs in high school soccer players discovered that among high school soccer players the overall nutritional knowledge is lower than in adolescent athletes. Worryingly, girls and those who

participate in National School Lunch Programs (NSLP) are more likely to skip breakfast. (Manore et al., 2017.)

Little research can be found on if, how and in what capacity race and ethnicity play a role in RED-S development among athletic population. Therefore, the need for more diverse athletic pool for research is evident not only for elite level athletes' wellbeing, but also for high school and college level athletes. (Mountjoy et al., 2018, pp. 687-697.)

8 AIM AND OBJECTIVE

The aim of this thesis is to increase knowledge about physiotherapy process in Female Athlete Triad. The objective of this thesis is to search for evidence for physiotherapy process in Female Athlete Triad using systematized literature review. The systematized literature review will focus on the following question: What is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad?

This thesis will provide an overview on what the evidence-based recommendations exist for physiotherapist process regarding Female Athlete Triad. This thesis could be used as educational material in the faculty of health and welfare to educate physiotherapy and or nursing students about the Female Athlete Triad syndrome and its potential negative health consequences.

9 SYSTEMATIZED LITERATURE REVIEW

The systematized literature review attempts to give structure to the research review similarly to systematic review without adhering to all the given guidelines.

Systematized literature review includes minimum of one element of systematic literature review. (Grant & Booth, 2009, pp. 91-108.)

A systematized literature review in this paper will focus on the question: what is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad? A systematized approach will help identify evidence-based literature which will then be gathered and analyzed to give outcome to the above-mentioned research question.

9.1 Search strategy

Research term and concept selection was guided by the research question and information gathered from the literature review of Female Athlete Triad in the first half of the thesis. It was necessary to include both “physiotherapy” and “physical therapy” in the key-term search because they are used interchangeably across the world to refer to the profession. “Physical therapy” is the preferred term in USA and “physiotherapy” is a preferred term in European countries. Secondly, Relative Energy Deficiency in Sport concept originates from Female Athlete Triad. Therefore, using Relative Energy Deficiency in Sport, or RED-S for short, increases the scope of this systematic research. Thirdly, all fundamental documents describing Female Athlete Triad mentioned the four key approaches for care: prevention, screening, treating and, management of the Triad.

Database used in this paper was PubMed. The choice to use single database is based on several factors. It is sufficient to have a single database for bachelor level thesis and for systematized literature review, the research question changed during writing of this thesis, and a meeting with SAMK’s librarian in February 2021 revealed that the initial key-term search for Female Athlete Triad in various databases ultimately refers to papers published in PubMed or PubMed Central online archive.

The database search was conducted on 1st of October 2021. The terms used were: (Physiotherapy OR physical therapy) AND Female Athlete Triad; (Physiotherapy OR physical therapy) AND (Relative energy Deficiency in Sport OR RED-S); Female

Athlete Triad AND (treatment OR prevention OR screening OR management); Relative Energy Deficiency in Sport AND (treatment OR prevention OR screening OR management); RED-S [MeSH] AND (treatment OR prevention OR screening OR management). Result for PubMed database research can be found in Table 1.

Table 1 Key-term and key-concept research results from PubMed database.

Entry terms	PubMed
(Physiotherapy OR physical therapy) AND Female Athlete Triad	47
(Physiotherapy OR physical therapy) AND (Relative Energy Deficiency in Sport OR RED-S)	46
Female Athlete Triad AND (treatment OR prevention OR screening OR management)	347
Relative energy deficiency in sport AND (treatment OR prevention OR screening OR management)	212
RED-S [MeSH] AND (treatment OR prevention OR screening OR management)	164
Results	816

9.2 Study selection

The key-term and key-concept search yielded a total of 816 results. Two filters in PubMed database were applied to narrow down the search results. Text availability was set to free full text and publication date was set to 10 years, i.e., 2011-2021. This excluded a total 663 papers leaving 153 papers of which 72 duplicates were removed, leaving a total of 81 papers for further examination and inclusion-exclusion criteria (Table 2).

Table 2 Inclusion-exclusion criteria for study selection

Inclusion Criteria	Exclusion Criteria
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Female athletes (regardless of age, sport, or level)	In language other than English
Related to Female Athlete Triad	Male participants
Role of physiotherapy was stated	Non-human participants
Clinical implications for physiotherapists for either prevention, screening, treatment, and or management of Female Athlete Triad	Books/e-books

In the initial examination of abstracts, all papers reporting multidisciplinary team approach (16 papers) for screening, prevention, treatment, and or management were set aside initially to be further examined later, to determine if they contain anything of value for good physiotherapy practice. One paper met the inclusion criteria from those sixteen papers and was relevant for answering the systematized literature research question. One paper met the inclusion-exclusion criteria in the main study selection. Leaving a total of two papers.

In the end, a total of three papers were identified as relevant for the purpose of this thesis. An additional paper from 2003 was added because it fit the inclusion-exclusion criteria and seems to be the earliest paper which explains the role of physiotherapy in Female Athlete Triad. Figure 12 illustrates the entire study selection process.

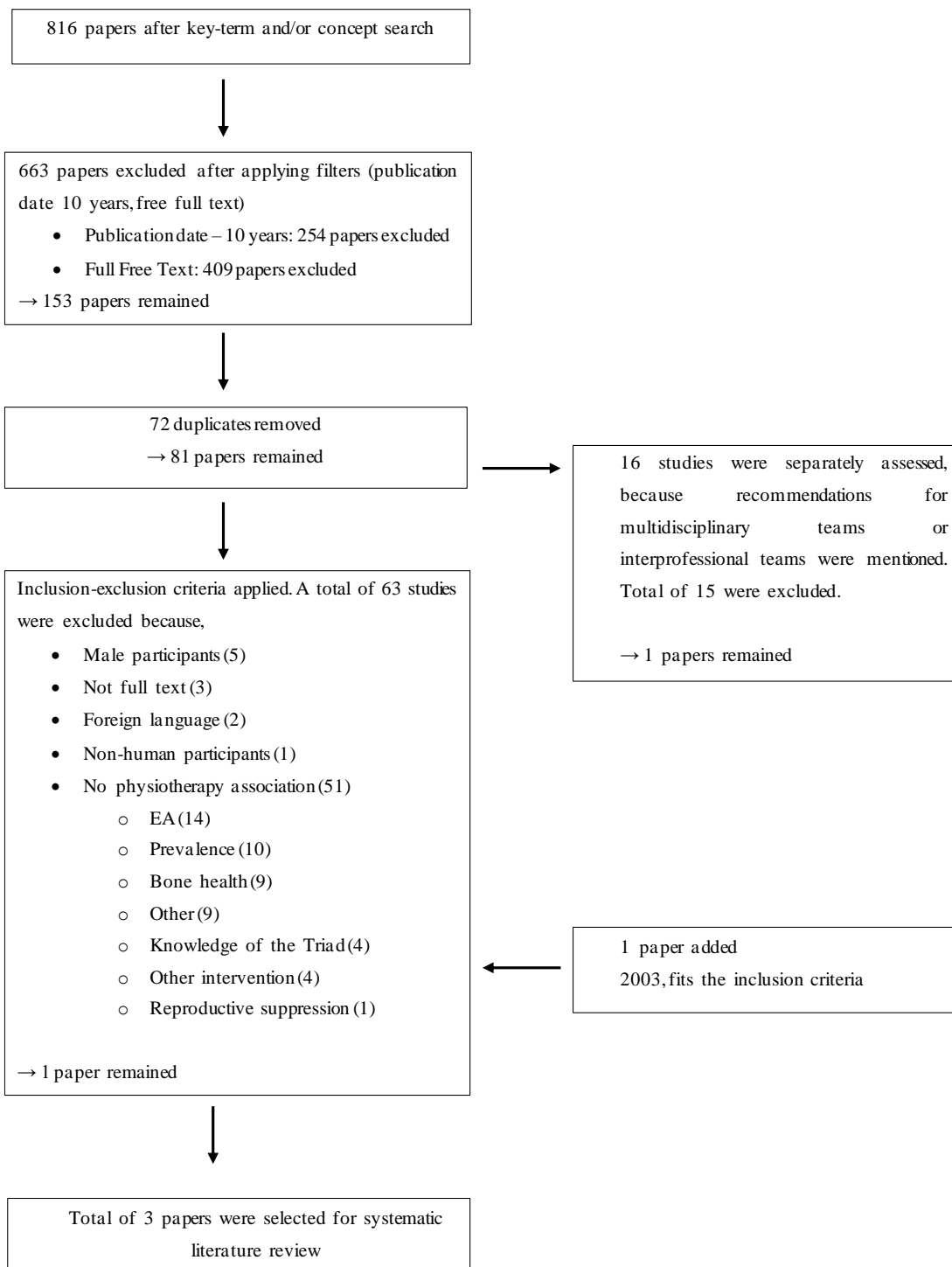


Figure 12 Systematized literature review study selection process

Table 3 Summary of articles

Author(s), year of publication	Aim of the paper	Design, level of evidence	Results/Conclusion	Limitations
Thein-Nissenbaum & Hammer, 2017	Provide an overview of the current terminology used in describing Female Athlete Triad. Review examination and diagnosis of the triad. Provide latest evidence for members of the multidisciplinary team who provide health care for adolescent female athlete.	Narrative review, n/a.	<ul style="list-style-type: none"> • Components of Female Athlete Triad are low EA, MD, and low BMD. • The surrounding multidisciplinary team and fellow teammates should be aware of signs and symptoms of the Triad. • Screening for Triad should be part of preparticipation 	Not high level of evidence

			<p>examination if Triad is suspected</p> <ul style="list-style-type: none"> • Multidisciplinary team must work closely together to provide optimal care • Non-pharmacological treatment first. • Athlete needs to feel her feelings, thoughts, and opinions are valued. 	
<p>Stickler, Hoogenboom & Smith, 2015</p>	<p>To identify and describe essential knowledge in for physical therapists about management of Female Athlete Triad, identify the role of physical therapists in the multidisciplinary</p>	<p>Clinical commentary, level 5</p>	<ul style="list-style-type: none"> • Female athlete has unique traits and demands which place her at risk for the Triad • PTs should know and be able to identify the 	<p>Not high level of evidence</p>

	team and provide resources for physical therapists.		<p>components of the Triad.</p> <ul style="list-style-type: none"> • PTs should be able to screen for components of the Triad. • PTs should have pre-identified strategies for referral and management • PTs should be able to assess for key energy-related requirements. • PT's play a role in educating athletes and the surrounding team 	
Papanek, 2003	Summarize the components of the Female Athlete Triad and their linkage. Provide	Clinical commentary, n/a	<ul style="list-style-type: none"> • Athletes in all sports are at risk. • Highest prevalence is seen in sports with 	Not high level of evidence

	information about the role of physical therapy in prevention, assessment, and intervention of Female Athlete Triad		weight classes, subjective judging, or heavy training schedule <ul style="list-style-type: none">• Prevention is key• Multidisciplinary team is important• Physiotherapy has impact on the health of female athletes	
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10 RESULTS

One of the main roles of physiotherapists is in prevention of Female Athlete Triad. Prevention is often better understood and followed than treatment, but it requires knowledge about the condition. Physiotherapists working with female athletes or physically active girls, and women should first and foremost educate themselves about Female Athlete Triad, its components, and their interrelationship with one another. (Stickler, Hoogenboom & Smith, 2015, pp. 563-571.)

One of the main tools used by physiotherapists, regardless of where or with whom they work, is patient education. Education is the number one tool for prevention. Educating female athletes, physically active girls, and women, and all those who are involved, is the responsibility of the physical therapists, because it promotes health and well-being of their client. Physiotherapists could easily add questions (Appendix 2) regarding Female Athlete Triad into initial examinations during pre-season or into regular physiotherapy sessions to screen for Triad components. (Stickler, Hoogenboom & Smith, 2015, pp. 563-571.)

A huge part of a sport physiotherapists time goes into preventing injuries from happening in the first place. Overseeing injury rehabilitation and management remains an integral part of everyday physiotherapy work. Assessing anatomical differences, e.g., foot type, long bone length, loading lines, techniques used in jumping, landing, running etc., neuromuscular control and muscle strength are an important part of risk assessment and injury management. Screening for movement dysfunction could identify areas at risk for injuries such as stress fractures, stress reactions and overuse injuries (Stickler, Hoogenboom & Smith, 2015, pp. 563-571; Thein-Nissenbaum & Hammer, 2017, pp. 85-95.)

Papanek (2003) mentions promoting age-related restrictions and limitations of participation for childhood and adolescent sports. Early specialization has almost entirely abolished multisport athlete which could be the reason for high number of overuse injuries. Furthermore, promoting adequate rest by decreasing number of competitions or working hours helps maintain the health of an athlete. Providing enough rest and cross-training opportunities may increase performance by decreasing burnout and frustration in athletes. (Papanek, 2003, pp. 594-614.)

In addition to physiotherapists expertise of athletic and orthopedic injuries, knowledge of exercise metabolism, training adaptations, biomechanics and exercise prescription are valuable when designing training programs. (Papanek, 2003, pp. 594-614.)

If the overseeing physician gives permission for the athlete to return to training, physiotherapist either alone or together with athletic trainers' design athlete's training program. This training program needs to suit the athletes needs and the sport they are in. Regardless of the sport, or influences from coaches, parents or peers, the training program must maintain positive energy balance. Dietary intake and the training program mirror one another. If one changes so must the other because positive energy balance is the main treatment for Female Athlete Triad. (Thein-Nissenbaum & Hammer, 2017, pp. 85-95.)

Weight-bearing and resistance training exercise are especially beneficial for bone acquisition as they stimulate osteoblastic activity. Osteoblasts are responsible for bone formation, but also bone remodeling, especially in site-specific areas under load. (Papanek, 2003, pp. 594-614; Thein-Nissenbaum & Hammer, 2017, pp. 85-95.) Available physiotherapy guidelines for osteoporosis treatment and clinical expertise from physical therapists treating clients with osteoporosis serves as a starting point for bone recovery in Female Athlete Triad patients (Papanek, 2003, pp. 594-614).

Stickler, Hoogenboom & Smith (2015) emphasizes where physical therapy knowledge is insufficient and where the authority ends. Physical therapists are not sufficiently trained to diagnose all aspects of the Triad. Elements such as assessment of energy availability or nutritional counseling, menstrual disturbances, bone health or

physiological issues should be left for licensed professionals. (Stickler, Hoogenboom & Smith, 2015, pp. 563-571.)

Female Athlete Triad is a complex and multifactorial which is why the treatment needs to be the same. Every expert brings their own expertise which helps solve the problem and helps represent a unified front. All team members must work together and provide consistent and uniformed messages about the treatment for the athlete for best possible outcome. (Thein-Nissenbaum & Hammer, 2017, pp. 85-95.)

11 CONCLUSION

Despite the low level of evidence, the role of physiotherapy in the treatment and management of Female Athlete Triad is clear. Physiotherapists play a part in pre-seasonal examinations and evaluations, assessments of movement and strength, preventing injuries and rehabilitation of injuries. Physiotherapists provide their expertise in biomechanical analysis of basic movements and technique used by the athlete. They help modify training programs and give their own input for rest and recovery ratios.

The primary role of physiotherapists is in education and prevention. Educating athletes, parents, coaches, other team members and the public about Female Athlete Triad, its components, possible health, and performance consequences.

Physiotherapists refer their clients to other specialists for further counselling or diagnosis if necessary.

Physiotherapists are a part of a multidisciplinary team which represents a unified front. All team members of the teamwork in unison to provide best possible care for the athlete.

12 DISCUSSION

The work of researchers across the world and fields looking into female physiology in sport, in training, and in recovery is still gaining momentum and is far behind of what is known about men. Syndromes like Female Athlete Triad and its components draw attention to the importance of understanding not only basic physiology but also sex-based differences in physiology. The author of this thesis finds this to be one of the important learning experiences gained during writing of this thesis.

The topic of this thesis – Female Athlete Triad, came about by accident by following journals in social media platforms. A single post caught the authors' eye which then led to diving headfirst into something which seemed so far from the future profession of physiotherapy. The author was most definitely proved wrong and hopefully the same fate awaits the future readers of this thesis.

Once the topic was decided finding literature was somewhat challenging, because of the newer RED-S model, first introduced in 2014 by IOC. For someone looking into this topic for the first time, this model caused confusion. After getting familiar with foundational documents of Female Athlete Triad, its history and progression, its content and difference between the two made progressing with the thesis significantly easier.

The systematized literature review question changed from short- and long- term effects of Female Athlete Triad to what is the current evidence for physiotherapy process in the treatment and management of Female Athlete Triad? Discussion with the supervisor led to this change to better link the paper to physiotherapy profession. The systematized literature review searched a free PubMed database and the key-concept search yielded in numerous results. The study selection process narrowed the result down to three papers.

Papers reviewed for systematized literature review were of low level of evidence – two clinical commentaries and one narrative review. Despite low levels of evidence, the selected papers answered the research question. The author finds the result of

systematized literature review to be important as it makes a crucial point. Physiotherapy process does not change in regard to Female Athlete Triad, however effective physiotherapy care requires understanding this syndrome, its changing components and their interrelationship. The author finds this to be one of the strengths of her thesis.

Physiotherapy does not play the main role in Female Athlete Triad treatment. However, physiotherapy plays a supporting role by being part of pre-seasonal examinations and evaluations, assessments of movement and strength, preventing injuries and rehabilitation of injuries. Providing expertise in biomechanical analysis of basic movements and technique used by the athlete. Helping modify training programs and give input for rest and recovery ratios. Physiotherapy does not change, but rather must tailor itself to fit the athletes needs at a given point in time.

The limitation of this paper is the systematized literature review. The review used a single database, papers did not go through a quality assessment and as a result only produced three papers with low level evidence. The added paper which seems to be the first of its kind in answering the systematized literature review research question was 18 years old.

Based on limitations of this systematized literature review and on other insights presented in this thesis, future research in the physiotherapy profession should focus on:

1. Better understand short and long-term effects of Female Athlete Triad, to better tailor rehabilitation programs for athletes.
2. Health consequences of LEA among different athletic groups, because of numerous whole body health consequences.
3. Specific physiotherapeutic interventions for bone health in Triad athletes.

All in all, this thesis provides a comprehensive overview of Female Athlete Triad. This thesis could be used in the faculty of Health and Welfare in SAMK as an educational material to students of all levels and professions about the Female Athlete Triad, its potential negative health consequences, its treatment, management and most importantly its prevention.

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APPENDIX 1

Glossary of Terms

Amenorrhea	Absence of menstrual cycles lasting more than three months or 90 days
Anovulation	A menstrual cycle without ovulation
Bone mineral density (BMD)	A numerical measurement showing how much calcium and other types of minerals are in a specific area of your bone.
Disordered eating	A change in eating behaviors/patterns that, by themselves, do not warrant diagnosis of an eating disorder
Energy availability (EA)	Dietary energy intake (EI) minus exercise energy expenditure (EEE) normalized to fat free mass (FFM), i.e., $EA = (EI - EEE) / FFM$.
Energy balance	The state at which the number of calories eaten equals the number of calories used.
Energy deficiency (ED ¹)	Imbalance between the amount of energy consumed and the amount of energy expended during exercise.
Eating disorder (ED ²)	A mental disorder with persistent pattern of unhealthy eating or dieting behaviour that can cause health impairment
Energy intake	The amount of energy produced by an individual taken in from food consumption; this is typically measured in calories (kcal).
Estrogen (E2)	Female sex hormone which is synthesized in the ovaries and produced from puberty until menopause
Eumenorrhea	Normal menstrual cycle. In healthy females 28 days \pm 7 days.
Exercise associated amenorrhea/ athletic amenorrhea	Medical condition in which physically active female experiences absence of menstrual periods due to heavy training
Exercise energy expenditure (EEE)	Energy expended during exercise training
Fat free mass (FFM)	Also known as lean body mass. Refers to all of body components (vital organs, bones, connective tissue etc.) except fat.
Female Athlete Triad	A condition of three interrelated components that exist on a continuum of severity, including: energy deficiency (ED ¹), menstrual dysfunction, and impaired bone health.
Hypothalamic-pituitary-gonadal axis (HPG)	A system consists of three endocrine glands – hypothalamus, pituitary gland, and gonadal gland, that regulates reproduction.

Low energy availability (LEA)/ Energy deficiency (ED ¹)	A state in which the body does not have enough energy left to support all physiological functions needed to maintain optimal health. EA < 30 kcal/kg FFM
Low bone mineral density (LBMD)	Refers to bone density that is lower than the normal peak density but not low enough to be classified as osteoporosis. Bone mineral density Z-score between -1.0 and -2.0 Also known as osteopenia however LBMD is the preferred term among athletes
Menarche	First menstrual period. Usually starts between ages 11-14.
Oligomenorrhea	Medical term for infrequent menstrual periods. Intervals longer than 35 days.
Osteoporosis	A systemic skeletal disorder characterized by low bone mass, micro-architectural deterioration of bone tissue leading to bone fragility, and consequent increase in fracture risk. Bone mineral density Z-score \leq -2.0 together with secondary risk factors for fracture
Primary amenorrhea	Delay in the age (15 y.o) of menarche.
Progesterone	An endogenous steroid and progestogen sex hormone involved in the menstrual cycle, pregnancy, and embryogenesis of humans
Secondary amenorrhea	Amenorrhea beginning after menarche
Z-score	Compares bone mineral density of an individual to those of age, race, and sex-matched controls

APPENDIX 2

Box 1 Triad Consensus Panel Screening Questions*

- Have you ever had a menstrual period?
- How old were you when you had your first menstrual period?
- When was your most recent menstrual period?
- How many periods have you had in the past 12 months?
- Are you presently taking any female hormones (oestrogen, progesterone, birth control pills)?
- Do you worry about your weight?
- Are you trying to or has anyone recommended that you gain or lose weight?
- Are you on a special diet or do you avoid certain types of foods or food groups?
- Have you ever had an eating disorder?
- Have you ever had a stress fracture?
- Have you ever been told you have low bone density (osteopenia or osteoporosis)?

*The Triad Consensus Panel recommends asking these screening questions at the time of the sport preparticipation evaluation.

APPENDIX 3

Risk Factors	Magnitude of Risk		
	Low Risk = 0 points each	Moderate Risk = 1 point each	High Risk = 2 points each
<i>Low EA with or without DE/ED</i>	<input type="checkbox"/> No dietary restriction	<input type="checkbox"/> Some dietary restriction‡; current/past history of DE;	<input type="checkbox"/> Meets DSM-V criteria for ED*
<i>Low BMI</i>	<input type="checkbox"/> BMI ≥ 18.5 or ≥ 90% EW** or weight stable	<input type="checkbox"/> BMI 17.5 < 18.5 or < 90% EW or 5 to < 10% weight loss/month	<input type="checkbox"/> BMI ≤ 17.5 or < 85% EW or ≥ 10% weight loss/month
<i>Delayed Menarche</i>	<input type="checkbox"/> Menarche < 15 years	<input type="checkbox"/> Menarche 15 to < 16 years	<input type="checkbox"/> Menarche ≥ 16 years
<i>Oligomenorrhea and/or Amenorrhea</i>	<input type="checkbox"/> > 9 menses in 12 months*	<input type="checkbox"/> 6-9 menses in 12 months*	<input type="checkbox"/> < 6 menses in 12 months*
<i>Low BMD</i>	<input type="checkbox"/> Z-score ≥ -1.0	<input type="checkbox"/> Z-score -1.0*** < - 2.0	<input type="checkbox"/> Z-score ≤ -2.0
<i>Stress Reaction/Fracture</i>	<input type="checkbox"/> None	<input type="checkbox"/> 1	<input type="checkbox"/> ≥ 2; ≥ 1 high risk or of trabecular bone sites†
Cumulative Risk (total each column, then add for total score)	___ points +	___ points +	___ points = ___ Total Score

	Cumulative Risk Score*	Low Risk	Moderate Risk	High Risk
<i>Full Clearance</i>	0 – 1 point	<input type="checkbox"/>		
<i>Provisional/Limited Clearance</i>	2 – 5 points		<input type="checkbox"/> Provisional Clearance <input type="checkbox"/> Limited Clearance	
<i>Restricted from Training and Competition</i>	≥ 6 points			<input type="checkbox"/> Restricted from Training/ Competition-Provisional <input type="checkbox"/> Disqualified

