FACTA UNIVERSITATIS
Series: **Physical Education and Sport**, Vol. 18, No 1, 2020, pp. 37 - 48
https://doi.org/10.22190/FUPES191019005P

Review article

DOES THE FEMALE ATHLETE TRIAD REALLY EXIST?

UDC 615:-004
796.01

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Abstract. *The Female Athlete Triad (Triad) is a medical condition of female athletes consisting of three components: low energy availability (EA), menstrual dysfunction (MD), and low bone mineral density (BMD). The prevalence of all three components of the Triad ranges from 1-14%. In last ten years, it has ranged from 1.3% up to 23% with 78% of female athletes having at least one of the three components of the Triad. The aim of this systematic review is to collect and analyze recent studies of the Female Athlete Triad. Based on an analysis of electronic databases and the inclusion criteria set, 20 studies were included in the analysis. The following conclusions are proposed based on their analysis: MD was the most prevalent among endurance athletes with ranges from 35.5% to 60.7%, with the presence of secondary amenorrhea and oligomenorrhea, 30% to 64.0% and 18% to 27.0% and with a very high level of cases with irregular menorrhea, 72.3%. Low/negative EA ranges from 19.8% among non-leanness athletes and up to 77%. The greatest proportion of athletes in moderate- and high-risk categories for expressing the Triad participated in sports that emphasize leanness, including cross-country, gymnastics running, and lacrosse. A recommendation for future research is that they should focus on enhanced monitoring of physically active women, and the prevention of the Triad, stress fractures and osteoporosis.*

Key words: *Female Athlete Triad, Stress Fracture, Energy Availability, Menstrual Disorders, Amenorrhea, Bone Mineral Density*

INTRODUCTION

The Female Athlete Triad (Triad) is a medical condition of female athletes consisting of three components: low energy availability (EA) with or without disordered eating, menstrual dysfunction, and low bone mineral density-BMD (Nattiv et al., 2007; de Souza et al., 2014; Joy et al., 2014). This problem was first recognized and defined as the Triad

Received October 17, 2019/ Accepted April 24, 2020
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in 1992 by the American College of Sport Medicine (Nattiv, Agostini, Yeager, & Drinkwater, 1993; Yeager, Agostini, Nattiv, & Drinkwater, 1993). In 2014, the ACSM constructed the Coalition guidelines for determining the level of risk for the Triad (de Souza et al., 2014). Despite that, the fact that the presence of all the components of the triad is still present at a high level among women is devastating. The prevalence of all three components of the Triad ranges from 1-14%. In last ten years, it has ranged from 1.3% (Schtscherbyna, Soares, de Oliveira, & Ribeiro, 2009), 3.3% (Micklesfield, Hugo, Johnson, Noakes, & Lambert, 2007), 5.4% (Movaseghi et al., 2012) up to 23% (Hoch et al., 2011; Melin et al., 2015), with 78% of female athletes having at least one of the three components of the Triad (Bubanj & Obradović, 2002; Cobb et al., 2003; Torstveit & Sundgot-Borgen, 2005; Beals & Hill, 2006; Nichols, Rauh, Lawson, & Barkai, 2006; Schtscherbyna et al., 2009; Hoch et al., 2009; Hoch et al., 2011).

Of the three components, menstrual dysfunction (MD) has exhibited the strongest relationship to injury, showing positive associations with increased risk of stress fractures (SF) among collegiate athletes (Myburgh, Hutchins, Fataar, Hough, & Noakes, 1990; Kelsey et al., 2007), competitive club track-and-field athletes (Bennell & Crossley, 1996; Beachy, Akau, Martinson, & Olderr, 1997), adult recreational runners or athletes (Kelsey et al., 2007; Nattiv et al., 2007) and military recruit populations (Henriksson, Schnell, & Hirschberg, 2000; Austin, Reinking, & Hayes, 2009). MD is common among female athletes, but is often ignored and regarded as a natural result of intense training, despite the fact that negative health consequences exist (Nattiv et al., 2007).

One of the primary causes for developing MD is reduced EA, actually low EA, which is the product of high intensity training and disordered eating (DE), or its associated conditions. Low EA brings a short luteal phase defect (LPD) in females with eumenorrhea and with oligomenorrhea/functional hypothalamic amenorrhea (FHA), which further turns good bone health into low BMD that can lead to injuries, loss of competition, and early onset of osteoporosis with Z-score <-2 (Nattiv et al., 2007). Everything mentioned is usually followed with secondary risk factors for stress fractures (SF) (Bachrach, 2001; Weaver, 2002; Nichols et al., 2006; Nattiv et al., 2007; Baxter-Jones, Faulkner, Forwood, Mirwald, & Bailey, 2011). Some other studies state the theory that SF are common overuse injuries among athletes (Bennell & Brunker, 2005) and related to a sudden increase in training (Sullivan, Warren, Pavlov, & Kelman, 1984) and that the components of the Triad play a minor role in the development of SF (Cosman et al., 2013).

Based on the above mentioned, the aim of this paper is to analyze recent research that examined the existence of the Triad and try to answer the question if it really exists.

METHODS

Research strategy

For the collection of relevant research papers, the following electronic databases were used: *DOAJ*, *PEDro* and *PubMed*. For the purpose of closer search and selection of research papers, the search was limited to using key words that are related to the problem of this research: the female athlete triad, stress fracture, eating disorder, disordered eating, menstrual dysfunctions, amenorrhea, bone density.

Selection strategy

The final analysis includes all available studies published during the last 10 years, namely between 2010 and 2019, which determined the relationship between the components of the Female Athlete Triad.

Inclusion criteria

The review included journal articles written in English and published during the last 10 years. To be included in the analysis, the articles were required to include the existence of some of the components related to FAT: menstrual dysfunction, low energy availability and physical intensity.

Exclusion criteria

The exclusion criteria were as follows: (1) studies without any of the Triad components; (2) studies without female samples and (3) studies written in languages other than English.

Data analysis

Table 1 provides an overview of close analyses of 20 studies that met the set criteria. Following the conventions for systematic reviews, the table presents the following parameters: reference, population group, sample of participants (gender, number and age), body composition parameters (body mass index - BMI, percentage of body fat - %BF, lean body mass - LBM), health status (menarche age, year cycles, menstrual irregularity, bone stress injury) and weekly training frequency, the results and conclusion.

Table 1 Summary of characteristics of all studies meeting the inclusion criteria

Ref.	Population group	Sample (gender, number and age)	BMI (kg/m²), BF (%), LBM (kcal/kg/LBM), T (h/week)	Health status (Menarche age (year); year cycles, menstrual irregularity, bone stress injury (%))	Results (M±SD)	Conclusion
Yang et al. (2010)	Secondary school dancers (E); secondary school healthy controls (C).	F: 133 (E: 60, C: 77); Y: (E) 16.5±0.7; (C) 16.4±0.6	BMI: (E) 18.3±1.4; (C) 21.7±3.1; BF: (E) 25.0±0.5; (C) 34.0±0.4 T (h/w): E: 26.5±5.2; C: /	MA: (E) 14.0±0.9; (C) 13.0±1.3 MI: SA: (E) 26.5%; (C) 14.3%; PA: (E) 19.0%; (C) 0%; IM: (E) 72.3%, (C) 27.3%	BMI, MA, PA, MI dancers ↑(p<.05); SA dancers ↑(p<.01) %BF controls ↑(p<.01) BMD at total body and legs dancers ↑(p<.05); BMC ↑(p<.01)	Bone mass status is a combined result of nutritional status, intensive exercise, menstrual irregularity and systemic hormone decrease. Disordered eating, especially low energy intake, might be the pivotal negative factor of the Triad.
Rauh et al. (2010)	High school competitive athletes	F: 163 (I: 61, U: 102); Y: 15.7±1.3 I, injured; U, uninjured.	BMI: (I) 21.4±2.6; (U) 21.8±2.9 BF: (I) 26.0±6.1; (U) 26.3±7.3 LBM: (I) 39.7±4.6; (U) 39.7±4.7	MA: (I) 12.6±1.2; (U) 12.6±1.2 YC: (I) 10.9±2.1; (U) 11.0±2.4	MA with O/A older than normal menses (p<.001) Injured had ↓ score BMD spine (p=.03), BMD z score spine (p=.02) and BMD total body (p=.05) O/A ↑ injuries (p=.004) DE ↑ injuries (p=.04) or dietary restraint behavior (p=.04)	Disorder eating, oligomenorrhea/amenorrhea, and low BMD were associated with musculoskeletal injuries.

Hoch et al. (2011)	Professional ballet dancers	F: 22 Y: 23.2±4.7	BMI: 19.29±1.1; BF: 16.7±4.9	MA: 13.6±1.8 MI: SA: 64.0%, (C) 14.3%; PA: 18.0%; O: 27.0%	77% with low/negative EA 32% EDE-Q scores>4.0 23% sig. ↓ One (36%), two (14%) three (23%) or four (14%) of the triad components ($p<.05$)	Prevalence of the 4 components (triad and reduced endothelial function) was correlated with reduced BMD and is high in professional dancers.
Movaseghi et al. (2012)	Elite female athletes and athletes on national teams	F: 786 Y: 21.1±4.5	BMI: Low-risk sports: 21.2±2.9; High-risk sports: 20.6±1.5 T (h/w): Low-risk sports: 12.7±10.7; High-risk sports: 14.8±10.4	MA: 13.7±1.6 MI: Total population: 9.2%; Low-risk Sports: 7.7%; High-risk Sports: 11.7% BSI: 2% (Low-risk sports: 6; High-risk sports: 11)	One (58.9%), two (35.7%) or three (5.4%) of the triad components ($p<.05$)	Athletes in the high-risk group had significantly more stress fractures than those in the low-risk group.
Cosman et al. (2013)	Athletes and military recruits	N: 891 (M: 755, F: 136); Y: (M) 18.7; (F) 18.4	BMI: Mw/SFvsNoSF: 24±4 vs 25±3; Fw/SFvsNoSF: 23±3 vs 23±2 BF: Mw/SFvsNoSF: 9±3 vs 9±3; Fw/SFvsNoSF: 20±3 vs 21±3 SF, stress fracture, NoSF, no stress fracture T (h/w): Mw/SFvsNoSF: <7 (19±44 vs 173±24) ≥7 (24±56 vs 536±75); Fw/SFvsNoSF: <7 (7±27 vs 23±22) ≥7 (19 ± 73 vs 85±78)	MA: Fw/SFvsNoSF: 4.9±1.2 vs 5.8±1.4 YC: Fw/SFvsNoSF: 0-6 cycles/% 1±4 vs 12±12; 7-9 cycles/% 4±16 vs 12±12; 10-12 cycles/% 21±80 vs 82±76 BSI: Prior fracture (%): Mw/SFvsNoSF: 16±37 vs 353±50; Fw/SFvsNoSF: 8 ± 31 vs 47±44 History of prior fracture: Mw/SFvsNoSF: 13±30 vs 158±22; Fw/SFvsNoSF: 5±19 vs 12±11	More than 50% of the stress fracture occurred within the first 3 months of matriculation to the USMA 58% of cases were metatarsal fractures and 29% tibia fractures Mean age in Fw/SF sig. ↓ vs Fw/NoSF Males who exercised less than 7 h/w the year before entering the academy (44% w/SF vs 24% w/NoSF) ($p<.004$) F w/SF later had MA ($p<.01$)	Intrinsic factors (physical training in men, length of prior estrogen exposure in women and leg bone dimensions in both genders) play a little role in affecting the risk of stress fracture (explaining less than 10% of the risk).
Barrack et al. (2014)	Cohort study in exercising women with menstrual disturbances (E) vs exercising women with regular ovulatory menstrual cycles (C)	F: 259 (BSI: 28; NI: 231) Y: 18.1±0.3 (BSI: 17.5±0.6; NI: 18.2±0.3) BSI, bone stress Injury; NI, not injured	BMI: 21.5±0.2 (BSI vs NI: 20.7±0.4 vs 22.6±0.2) BF: 25.4±0.4 (BSI vs NI: 22.6±1.4 vs 25.8±0.4) LBM (kg): 40.6±0.3 (BSI vs NI: 41.2±0.9 vs 40.5±0.3) T (h/w): ≥12 h/w 65.6 (BSI vs NI: 89.3 vs 62.8)	MA: 12.8±0.1 (BSI vs NI: 12.7±0.3 vs 12.8±0.1) MI: O/A: 35.5 (BSI vs NI: 35.7 vs 35.5) BSI: 10.8% (tibia: 67.9%, metatarsals: 14.3%, femur: 7.1%, sesamoid: 7.1%, sacrum: 3.6%)	Sport development of SF: Endurance running 64.3%; Track and field 32.1%; Dance 3.6%. Participants w ↑%SF exercised ≥12 h/w, exhibited BMI<21.0 kg/m² and had BMD Z scores <-1.0 and ≤-2.0.	The study observed a sig. relationship between those meeting criteria for an increasing number of Triad-related risk factor variables and the development of prospective bone stress injuries. Single and combined risk factor variables exhibiting the strongest association with injury incidence included elevated exercise training and low BMD (Z score <.1.0). The risk of BSIs increased from approximately 15% to 20% for a significant single risk factor to 30% to 50% for sig. combined female athlete triad-related risk factor variables.

Brown et al. (2014)	High school athletes	F: 240 Y: 14±18	BMI: 20.88±2.7	MA: 12.86±1.29 MI: 152 (No achieved menarche: 12; SA: 1, w/history 39; PA: 4) BSI: 17%	Girls who had reached menarche in ≥ previous 2 years had 3.96 times higher odds of having MI than girls with more recent menarche (p=.014) 42% of athletes had 2 or more of the risk factors: history of amenorrhea and stress fracture, self-reported insufficient eating, underweight, pressure to be a certain weight and wanting to lose >10 pounds.	Menstrual irregularity and stress fracture incidence were relatively common among this population of female high school athletes.
Rauh et al. (2014)	Interscholastic cross-country and track runners	F: 89 Y: 15.5±1.3	BMI: 21.6±2.7 BF: 26.0±6.8 (BSI vs NI: 26.7±6.2 vs 25.5±7.2 LBM (kg): 38.9±4.3	MA: 12.3±1.1 MI: 21.3% YC: 10.9±2.3 (BSI vs NI: 11.1±2.0 vs 10.8±2.5) BSI: 42.7%* (shin/calf 46.2%; knee 15.4%; hip 15.4%; foot 12.3%) *musculoskeletal injuries	O/A runners had older MA than normal menses (p=.001) Injured runners had ↓BMD of the spine (p=.009), total hip (p=.03), and whole-body (p=.04) O/A correlated sig. with ↑ musculoskeletal injury occurrence	Oligo/amenorrhea and low BMD were associated with musculoskeletal injuries among female interscholastic cross-country and track runners.
Ackerman et al. (2015)	Runners and weight-bearing aerobic activity	F: 175 (O: 100; E: 35 & Non-athletes: 40) Y: 14–25	BMI: 20.4±2.3 (O); 22±2.3 (E); 22±2.3 (Non-athletes) T (h/w): 20	MA: 13.8±1.9 (O); 12.5±1.5 (E); 12.4±1.2 (Non-athletes) BSI: 47 % (O); 25.7 % (E); 12.5 %(Non-athletes)	BMD Z-scores were lower in AA (p≤0.001) In AA, those who had 2 stress fractures had lower BMD Z scores (p≤0.05)	Weight-bearing athletic activity increases BMD, but may increase stress fracture risk in those with menstrual dysfunction.
Duckham et al. (2015)	Endurance athletes	F: 70 (61, 9 withdrew) Y: 25.3±7.3	BMI: 19.8±1.5 BF: 17.0±5.1 T (h/w): Case 1: 9.5; Case 2: 19.5; Nl: 12.5±1.3	MA: 14.0±0.2 MI: Current O/A: 47.5%; History A: 60.7 BSI: 17±28.8; Injured over last 12 months: 2 (Case1 and Case2)	%BF ↓ in Case 1 and Case 2 than the group. Case 1 was smaller and lighter than the controls, with ↑ EI and low EPS Case 2 had a late age at menarche (16yr), ↑ BMI and ↓ EI	These findings could not be explained by awareness of Triads; there was a high prevalence of menstrual dysfunction, which could reflect changes in athlete behavior or training practices.
Melin et al. (2015)	Elite endurance athletes	F: 40 Y: 26.3±5.7	BMI: 20.5±1.9 BF: 11.9±3.2 T (h/w): 11.4±4.5	MI: 60% (O: 6; SA: 14, w/history 39; PA: 4) BSI: 17.2% (45% impaired bone health)	63% had low/reduced EA, 25% ED. Low EA group ↑ WF than optimal EA (p=.06) 25% w/O had DE/ED and 67% had low/reduced current EA. 67% w/impaired bone health had O, 33% had DE/ED One (35%), two (32%) or three (23%) of the triad components	Athletes with low/reduced EA and/or MD had lowered RMR. Triad-associated conditions were common in this group of athletes, despite a normal BMI range.
Tenforde et al. (2015)	Runners	G: F: 94; M: 42 Y: 16.9±1.3 (F); 16.3±1.3 (M)	BMI: 20.4±2.4 (F); 20.1±2.0 (M) FM: 14.2±5.2 (F); 8.8±3.4 (M) T (km/w): 27.4 ± 19.2	MA: 12.9±1.5 MI: Current O/A: 35%; History A: 43% BSI: Low bone mass: 14% (F), 21% (M)	Current MI & BSI: (all P<.01) MAage, low lean mass & Z-score (p<.01) <17.5 kg/m^2 & MI ↓ Low bone mass; SF: 24%	Both female and male adolescent runners are at risk for impaired BMD
Nieves et al. (2016)	Elite military cadets	F: 91 Y: 18.4±0.8	BMI: 22.8±2.2 BF: 20.9±3.0	MA: Years from 5.6±1.4 YC: (10-12 cycles) 66; (0-9 cycles) 25	50% of the women had bone loss in at least one: the spine, hip, calcaneus. Bone loss occurred at the spine and hip in those with menstrual dysfunction (p<.05) Hip and calcaneus BMD ↓ with weight loss (p<.05)	Risk factors including subclinical eating disorders, weight loss and menstrual dysfunction can have sig. detrimental effects on BMD in young healthy physically active women.

Prather et al. (2016)	Elite female soccer athletes	F: 220 (34% grade/middle school; 36.8% high school; 12.7% collegiate; 16.3% professional) Y: 16.4±4	BMI: 20.8±2 T (h/w): 9.5±6	MA: 13.0±1.0 (64% not yet reached menarche) MI: 19.3% (19% High school, 17.9% collegiate, 19.4% professional) BSI: 8.6% (19SF of the lower extremity)	8.1% were considered at risk for an eating disorder Athletes w EAT-26 score ≥10 points had a significantly higher prevalence of MI (p=.02) Two of the athletes w EAT-26 score ≥10 had a history of lower extremity SF.	Elite female soccer athletes are susceptible to stress fractures and menstrual dysfunction and have delayed onset of menarche despite normal BMI and appropriate body perception and attitudes towards eating.
Thralls et al. (2016)	High school athletes	F: 320 (70% endurance runners) Y: 15.9±1.2	BMI: 21.1±2.7 BF: 24.6±6.9 LBM (kg): 39.5±4.4	MI: 30% YC: 10.2±3.2	Dietary restriction (DR) 10.9% IBW ≤85% were nearly 4 times more likely to report MI and had low BMD <5th percentile BMI were 9 times more likely to report MI and had low BMD Athletes w/ ↑ %BF were almost 3 times more likely to report DR	Low age-adjusted BMI and low IBW may serve as evidence-based clinical indicators that may be practically evaluated in the field, predicting MI and low BMD in adolescents.
Tenforde et al. (2017)	University athletes	F: 323 Y: 20.0±1.3	BMI: 22.9±2.7	MA: delayed 11.8% (15-<16y); 10.8% (≥16y) MI: O: 11.1%; A: 8.7 BSI: 15.8%	Gymnastics, lacrosse and cross-country athletes were moderate- or high-risk ↓BMI and ↑BSI cross-country runners: 22.9% had a history of delayed menarche and the majority of athletes with delayed menarche were lean-sport athletes O/A and SF were independent predictors for subsequently sustained BSI	29% of female collegiate athletes in this study were classified as moderate- or high-risk categories using the Triad Cumulative Risk Assessment Score. Moderate- and high-risk athletes were more likely to subsequently sustain a BSI.
Tenforde et al. (2018)	Collegiate sports	F: 239 Y: 19.9±1.2	BMI: 22.9±2.8 BF: 24.9±5.8	/	BMD Z-score↓: Synchronized swimming, swimming/diving; crew 7 rowing, cross country. Triad risk factors associated/BMD Z-score (p<.05) BMI associated/ oligomenorrhea/amenorrhea (p<.05)	Athletes with low BMI and oligomenorrhea/amenorrhea are at the highest risk for reduced BMD
Clark et al. (2018)	NCAA Division I Student-Athletes	F: 15 Y: 19-22	Clinical vs. reported MD BMI: 20.5±1.6; 20.9±2.0 BF: 19.6±2.5 19.8±5.3	MI: 40% current; 53% history (A: 60%) BSI: 33% (clinical MD); 11% (reported MD)	MD: 40% EA↓: 53% MD→EA↑	The association between menstrual function and low energy is big; menstrual status was not associated with dyslipidemia.
Brook et al. (2019)	Elite para athletes	G: F: 110; M: 150 Y: 31.7±11.5	BMI: ≤17.5 (4.3%); 7.6-18.4 (3.1)	MA:.9% (<16y); 5% (≥16y) MI: O: 24%; A: 20% BSI: 5% (1 bone stress); 4.2% (2 bone stress); Low BMD: 8.5%	ED: 3.1%	Factors associated with the Triad are present in an elite para athlete population, regardless of sex or sport type.
Tosi et al. (2019)	Figure skaters (FS), dancers (D), and runners (R)	F: 712 (FS: 60%; D: 28%; R: 12%) Y: ≤17 (78%), 18-25 (22%)	BMI: /	MI: O: 25% BSI: 34%	Knowledge of the Triad (HN): 7% Young adults vs. adolescents: R=1.88 (p<.05) D vs. FS: R=0.43 (p<.001) D vs. R: R=0.49 (p<.05) HN: R = 2.43=.05 (p<.05)	Most athletes were at risk of the Triad but few knew about it. Dancers were at a higher risk compared to figure skaters and runners.

Legend: M – male; F – female; Y – age; BMI – body mass index; %BF – percentage of the body fat; LBM – lean body mass; MA – menarche age; YC – year cycles; MI – menstrual irregularity; BSI – bone stress injury; SF – sessions frequency; WF – weekly frequency; TD – training duration; TY – training years; AN – anorexia nervosa; BN – bulimia nervosa; ED – eating disorders; A – amenorrhea; SA – secondary amenorrhea; PA – primary amenorrhea; O – oligomenorrhea; E – eumenorrhea; PCOS – oligomenorrhea including polycystic ovary syndrome; IM, irregular menorrhea; EPS, eating psychopathology score, EI, energy intake; IBW – ideal body weight; RMR – low resting metabolic rate; ↑- high; ↓ - low.

RESULTS

Database searches returned 243 studies. After eliminating all duplicate articles, analyzing titles and screening abstracts, 37 studies entered the next stage of analysis. Only the studies that had included relevant outcomes were considered. The final number of studies included in the analysis was 20.

All the studies that met the inclusion criteria were published in the English language between 2010 and 2019. The pooled sample size of the 20 studies is 5184, whereas a typical size of individual studies ranged from 15 in the research of Clark, Dellogono, Mangano & Wilson (2018) to 891 participants per group in the research of Cosman et al. (2013). The first study in this group was published in 2010 (Yang et al., 2010), and the last in 2019 (Tosi, Maslyanskaya, Dodson, & Coupey, 2019). The participants mostly belonged to the age group 14±18 in the research Brown, Wengreen, & Beals (2014) to 31.7±11.5 year-old participants in the research of Brook et al. (2019). Genderwise, females were the most represented group, with 17 studies including only female participants and three including both sexes (Cosman et al., 2013; Tenforde, Fredericson, Sayres, Cutti & Sainani, 2015; Brook et al., 2019). All the participants belonged to a healthy and active group of people, all of which took part in some sport activities, recreational, national or professional (Hoch et al., 2011; Movaseghi et al., 2012; Ackerman et al., 2015; Melin et al., 2015; Prather et al., 2016; Brook et al., 2019), competitive (Barrack et al., 2014), high school and collegiate athletes (Yang et al., 2010; Rauh, Nichols, & Barrack, 2010; Brown et al., 2014; Rauh, Barrack, & Nichols, 2014; Thralls, Nichols, Barrack, Kern, & Rauh, 2016; Tenforde et al., 2017; Tenforde et al., 2018) and military organization athletes (Cosman et al., 2013; Nieves et al., 2016) in the following sports: endurance running (Rauh et al., 2014; Duckham, Brooke-Wavell, Summers, Cameron, & Peirce, 2015; Melin et al., 2015), dance (Yang et al., 2010; Hoch et al., 2011; Tosi et al., 2019), soccer (Prather et al., 2016). The amount of BMI ranges from ≤17.5 in the study Brook et al. (2019) to 25±3 in the study Cosman et al. (2013).

DISCUSSION

The number of physically active women has grown over the years and they are involved in various types of sports activities, recreational and professional. Under the influence of the environment, ambitions, expectations, they are expected to achieve better results in competitions, look better, and have a lower percentage of body fat. Since 1992 (Nattiv et al., 1993), the number of cases exhibiting the Triad has not diminished. Tenforde et al. (2017) in their research using the 2014 Female Athlete Triad Coalition guidelines (de Souza et al., 2014) identified that 29% of athletes were classified as having moderate or high risk of having all three of the components of the Triad. Those athletes belonging to the higher risk categories had a significantly increased risk of sustaining a subsequent SF. In the research Melin et al. (2015), 50% of cases had one of the conditions of the Triad, 25% two and one had all three components, while in the research of Rauh et al. (2014) there were 23% cases with a history of all three components, with one (35%), two (32%) and three (23%) components. Brown et al. (2014) presented 5.4% cases with three, 35.7% two and 58.9% one of the components, which has drastically increased compared to previous years where in 2008, Torstveit, Rosenvinge, and Sundgot-Borgen presented 2.3% having all three components among long distance running athletes (3.3% among ultra-marathons and 1.5% among half-marathoners), two 21% and 12%, one 40% and 50% respectively. In the research of Micklesfield et al. (2007) 23% cases of elite dancers had all three components, 14% two, 36% one and 14% met the criteria for all three components and reduced MD. The greatest proportion of athletes in the moderate- and high-risk categories for expressing FAT took part in sports emphasizing leanness, including cross-country, gymnastics, and lacrosse (Tenforde et al., 2017), while ultra-marathoners are at a higher risk than half-marathoners (Micklesfield et al., 2007).

The first component of the Triad, where the effect of unbalanced nutrition and exercise is reflected, is MD. MD is mostly affected by energy deficiency (DE), low EA, caused by higher energy consumption or DE. MD was the most prevalent risk factor identified among the endurance athlete population, and oligomenorrhea/amenorrhea were seen among a large number of lean-sport athletes, with ranges from 35.5% to 60.7% (Barrack et al., 2014; Ackerman et al., 2015; Melin et al., 2015; Duckham et al., 2015; Tenforde et al., 2017; Clark et al., 2018; Brook et al, 2019; Tosi et al., 2019), where the presence of secondary amenorrhea was found in 18% to 27%, and oligomenorrhea, 30% to 64.0% (Hoch et al., 2011; Ackerman et al., 2015; Brook et al, 2019; Tosi et al., 2019), with a very high level of cases having irregular menorrhea, 72.3% (Yang et al., 2010; Duckham et al., 2015; Melin et al., 2015; Tenforde et al., 2015; Clark et al., 2018).

EA is shown to appear as a problem when having difficulties in eating enough during periods of high-intensity training or food restriction in order to obtain low body weight (Nattiv et al., 2007). Uncontrolled EA as a second component of the Triad in healthy young female adults, when EA drops under 30 kcal/kg FFM/day, has shown that within five days it can reduce blood glucose levels and hypothalamic-pituitary-axis hormones, and the luteal hormone (LH), which elevates cortisol (Loucks & Thuma, 2003). On the other hand, athletes with MD have shown an unfavorable lipid profile caused by low production of estrogen which effects lipid metabolism by decreasing LDL cholesterol and increasing HDL cholesterol (Schnaper, McGuire, Runyan, & Hubchak, 2000; Rickenlund, Eriksson, Schenck-Gustafsson, & Hirschberg, 2005). In the research of Melin et al. (2015) 25% of athletes had hypercholesterolemia, but with normal LDL/HDL ratio, and 38% of athletes had total cholesterol (TC) ≥5mmol/L. Some authors also found this relationship between high TC and patients with anorexia nervosa (Meczekalski, Podfigurna-Stopa, & Katulski, 2013), and a decrease of TC after weight gain (Ohwada, Hotta, Oikawa, & Takano, 2006). In the study of Melin et al. (2015) participants with increased TC had current low or reduced EA and/or DE (73%), while 33% were still eumenorrheic, suggesting that alterations and cholesterol synthesis might be triggered by low EA, despite normal weight and eumenorrhea. In the research of Clark et al. (2018) menstrual status was not associated with dyslipidemia. Dancers with amenorrhea and oligomenorrhoea consumed less energy than the eumenorrheic dancers (Yang et al., 2010), also low EA has been suggested to exist more commonly among athletes in endurance sports because of the metabolic demands of the sport (Melin et al., 2015; Clark et al., 2018) where this number of low/negative EA is even higher, 77%, found in professional dancers (Hoch et al., 2011), while in elite endurance athletes were 63% (Melin et al., 2015). Clinical EDs were conducted in leanness (46.7%) and non-leanness (19.8%) sports with a significantly high prevalence in leanness sports ($p<.001$) (Movaseghi et al., 2012).

In connection with the above mention, as the third group of components of the Triad, previous research showed a fast loss of bone in women with low plasma estrogen due to a decrease in bone formation and an increase in bone reapportion. Low plasma estrogen levels during the period of bone deposition may damage the peak of bone mass after a certain age. These athletes may not reach the expected peak of bone mass and may precociously develop osteoporosis, even after the resumption of menstrual cycles (Warren & Stiehl, 1999), which increases the risk of SF. Previous research confirmed this theory that a higher percentage of lean body mass positive correlates with higher BMD of the spine and total body among elite swimmers ($p<.05$) (Schtscherbyna et al., 2009) and that is not related only with athletes but also with sedentary individuals, where Hoch et al. (2009) were reported that low BMD was even at a higher percentage among sedentary women with 16% of athletes vs. 30% of their controls having low BMD. The authors explain this by the theory that exercise for strengthening muscles increases bone density that is common for non-leanness sports (Dadgostar, Razi, Aleyasin, Alenabi, & Dahaghin, 2009). In the research included in this study, Yang et al. (2010) explained that BMD among female dancers was relatively high, probably caused by high levels of weight-bearing physical activity. Whether they involving athletes or sedentary individuals, a positive correlation between MD and low BMD was indicated in previous (Øyen, Torstveit, & Sundgot-Borgen, 2009) and in current studies (Rauh et al., 2014; Melin et al., 2015; Nieves et al., 2016) and EA and low BMD (Nieves et al., 2016; Thralls et al., 2016). But, in their research Øyen et al. (2009) reported that women with < 5th percentile BMI were nine times more likely to report MD and have low BMD, and SF significantly correlated with athletes ($p<.001$). On the other hand, Rauh et al. (2010) reported that BMD does not necessarily correlate with SF, whereas in the same research authors also report that injured runners had low BMD of the spine ($p=.009$), total hip ($p=.03$), and whole-body ($p=.04$) compared to non-injured runners. Cases of SFs include as many as 47% of those focusing on running and weight bearing activities (Ackerman et al., 2015).

Since the first announcement of the American College of Sport Medicine in 1992 about a possible existence of the Triad (Nattiv et al., 1993; Yeager et al., 1993) until today, the awareness of the existence of the problem has stagnated (Brown et al., 2014). Brown et al. (Ibid.) studied the knowledge of the Triad by using current ACSM guidelines. The result showed that knowledge and awareness among athletes were very low (score: 2.79 ± 1.61 out of 8) and among coaches were low, which gradually leads to the possibility that this problem may reach even more cases experiencing all of the components of the Triad. This low level of knowledge is confirmed in recent research published in 2019, with only 7% of the participants having heard of the components of the Triad (Tosi et al., 2019). This points to the lack of a solution to the problem during all these years which confirms the results of reviewed research in this study, where cross-country runners had the greatest proportion of bone stress injuries compared to other athletes (Joy et al. 2014; Tenforde et al., 2017) and endurance runners in 64.3% of the cases, then track and field runners in 32.1% and dancers in 3.6% of the cases (Barrack et al., 2014) which is far more than previously reported, 17% in marathoners (Torstveit et al., 2008).

CONCLUSION

Every exercise that leads an individual out of their comfort zone and professional monitoring bring risks of exhibiting some of the components of the Triad or all of them among the female population. In leanless sports there are more cases of experiencing these components than in non-leanless sports. Due to this, it is necessary to increase monitoring physically active women and in case of the appearance of some of the risks, act on the suppression of the lancet trace which leads to identifying all of the components of the Triad and experienced secondary indicators such as stress fractures and osteoporosis.

Acknowledgements: *This study is a part of the project OI179024 "The differences and the influences of the maximum muscle strength on the bone mineral density between athletes and non-athletes of high school population", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

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DA LI ŽENSKA TRIJADA ZAISTA POSTOJI?

Trijada sportista (Trijada) je zdravstveno stanje sportista i odlikuju je tri komponente: nizak nivo energije (EA), menstrualna disfunkcija (MD) i niska koštano mineralna gustina (BMD). Prevalenca sve tri komponente Trijade kreće se od 1-14%. U poslednjih deset godina prevalenca se kretala u rasponu od 1.3% do 23% i kod 78% sportistkinja je utvrđena bar jedna od tri komponente Trijade. Cilj ovog sistematskog preglednog istraživanja je prikupljanje i analiza nedavnih studija o sportiskinjama sa Trijadom. Na osnovu analize elektronskih baza podataka i postavljenih kriterijuma za uključivanje, analizirano je 20 studija. Na osnovu analize izvedeni su sledeći zaključci: MD je bio najrasprostranjenija među sportistkinjama izdržljivosti u rasponu od 35.5% do 60.7%, uz prisustvo sekundarne amenoreje i oligomenoreje, 30% do 64.0% i 18% do 27.0% i vrlo visoke učestalosti neredovne menoreje (72.3%). Nizak/negativan EA se kreće od 19.8% za sportiste sa nižim nivoom bezmasne komponente do 77%. Sportovi u kojima je izražena mršavost, uključujući trčanje, gimnastiku i lakros, imaju najveći udeo sportistkinja u kategorijama umerenog i visokog rizika ka Trijadi. Preporuka za buduća istraživanja je da treba da budu fokusirana na pojačan nadzor fizički aktivnih žena, kako bi se u slučaju pojave nekih od rizika, delovalo na prevenciji Trijade, preloma i osteoporoze.

Ključne reči: *trijada sportista, stres fraktura, nivo energije, menstrualni poremećaji, amenoreja, koštano mineralna gustina*