The relationship between the female athlete triad and injury rates in collegiate female athletes (#53616)

First submission

Guidance from your Editor

Please submit by **6 Nov 2020** for the benefit of the authors (and your $200 publishing discount) .

Structure and Criteria
Please read the 'Structure and Criteria' page for general guidance.

Custom checks
Make sure you include the custom checks shown below, in your review.

Raw data check
Review the raw data.

Image check
Check that figures and images have not been inappropriately manipulated.

Privacy reminder: If uploading an annotated PDF, remove identifiable information to remain anonymous.

Files

Download and review all files from the materials page.
5 Table file(s) 1 Other file(s)

Custom checks **Human participant/human tissue checks** Have you checked the authors ethical approval statement?

Does the study meet our article requirements?

Has identifiable info been removed from all files?

Were the experiments necessary and ethical?
For assistance email peer.review@peerj.com

Structure and Criteria

Structure your review

The review form is divided into 5 sections. Please consider these when composing your review: **1. BASIC REPORTING**

2. EXPERIMENTAL DESIGN

3. VALIDITY OF THE FINDINGS

4. General comments

5. Confidential notes to the editor

You can also annotate this PDF and upload it as part of your review

When ready submit online.

Editorial Criteria

Use these criteria points to structure your review. The full detailed editorial criteria is on your guidance page.

BASIC REPORTING

Clear, unambiguous, professional English language used throughout.

Intro & background to show context.
Literature well referenced & relevant.

Structure conforms to PeerJ standards, discipline norm, or improved for clarity.

Figures are relevant, high quality, well labelled & described.

Raw data supplied (see PeerJ policy). **VALIDITY OF THE FINDINGS**

Impact and novelty not assessed.
Negative/inconclusive results accepted. Meaningful replication encouraged where rationale & benefit to literature is clearly stated.

All underlying data have been provided; they are robust, statistically sound, & controlled.

EXPERIMENTAL DESIGN

Original primary research within Scope of the journal.

Research question well defined, relevant & meaningful. It is stated how the research fills an identified knowledge gap.

Rigorous investigation performed to a high technical & ethical standard.

Methods described with sufficient detail & information to replicate.

Speculation is welcome, but should be identified as such.

Conclusions are well stated, linked to original research question & limited to supporting results.

1. Basic Reporting

Clear and unambiguous, professional English used throughout.

Reviewer Response: The manuscript should be reviewed for consistency, tense and grammar.

Literature references, sufficient field background/context provided.

Reviewer Response: The references are complete and appropriate. The introduction does not build a case for the purpose and hypothesis. Both the Triad and REDs were introduced but there was no discussion of their differences or similarities. The main purpose was to use the Female Athlete Triad Cumulative Risk Assessment but previous uses of the tool were not included and the reason to use this tool was not clear. What are the instances of injury in female athletes? Why would this tool help?

In lines 60-62; It seems that RED-S is a well established theoretical concept, when in fact it's the opposite. Based on the DeSouza 2014b reference that they provided, which doesn't (currently) support the use of RED-S as a well established model, should include some a disclaimer or limitations as to how the IOC actually misinterprets or is lacking evidence behind their claims.

Professional article structure, figures, tables. Raw data shared.

The structure of the article should conform to an acceptable format of 'standard sections' (see our Instructions for Authors for our suggested format). Significant departures in structure should be made only if they significantly improve clarity or conform to a discipline-specific custom.

Figures should be relevant to the content of the article, of sufficient resolution, and appropriately described and labeled.

All appropriate raw data have been made available in accordance with our Data Sharing policy.

Reviewer Response: Raw data was shared in accordance with the Data Sharing policy.

The titles of the tables are incorrect for Tables Consistent terminology should be used for the tool Female Athlete Triad Cumulative Risk Assessment. The tables refer to the measure as female athlete triad coalition scoring category and triad risk categories, consistent terms are needed.

Self-contained with relevant results to hypotheses.

The submission should be 'self-contained,' should represent an appropriate 'unit of publication', and should include all results relevant to the hypothesis.

Coherent bodies of work should not be inappropriately subdivided merely to increase publication count.

2. Experimental design

Original primary research within Aims and Scope of the journal.
Research question well defined, relevant & meaningful. It is stated how research fills an identified knowledge gap.

The submission should clearly define the research question, which must be relevant and meaningful. The knowledge gap being investigated should be identified, and statements should be made as to how the study contributes to filling that gap.

Reviewer Response: The main hypothesis of this work is interesting but is not supported by the current introduction. The background of why this is important is unclear and how the current data will contribute to the knowledge gap. The Introduction needs to be re-worked so the readers understand "why" this is an important topic and how these data will add to the knowledge gap in this area.

Rigorous investigation performed to a high technical & ethical standard.

The investigation must have been conducted rigorously and to a high technical standard. The research must have been conducted in conformity with the prevailing ethical standards in the field.

Methods described with sufficient detail & information to replicate.

Methods should be described with sufficient information to be reproducible by another investigator.

Reviewer Response: Medical Examinations: Who completed the examinations and attaching the questionnaire would be helpful. Was injury self report?

Anthropometry: Insufficient detail on all measures was given.

The ultrasound methods and estimation of energy deficiency should each have their own sections to explain how the data was collected. It is unclear what measures were collected from the ultrasound device and how BMD was determined from the standard measures of Speed of Sound (SOS) and broadband ultrasound attenuation (BUA) that are collected from these methods (REFS).

Ln 136 more information is needed on how the Z Scores from ultrasound measures were determined. Does the Female Athlete Triad Cumulative Risk Assessment allow for measures of BMD other than from DXA measurements?

Ln 137 was the history of stress fracture self report or verified through medical records? How was a stress fracture vs a trabecular stress fracture determined?

Ln 115-117 The triad is not defined by the energy availability but one factor of the triad is low energy availability. More detail on the classifications in De Souza et al should be included as well as references to other studies that have utilized this method to determine energy availability. Furthermore, the limitations of this approach should be addressed.

Ln 118-119: low EA is not entirely defined as BMI <17.5 kg/m^2. Athletes may have low EA but a 'normal' BMI. Looking at other methods such as detailed food intake and energy expenditure can be used to determine this (DeSouza 2014a).

Injury Rate:

Were the injury data collected based on medical reports or by team/athlete physical therapists during the season? How many physical therapists were reporting the data and how was consistency between therapists determined and verified?

Statistical analysis:

More detail on the statistical analysis is needed. Which comparisons are testing the hypothesis from the introduction, " the moderate and high-risk 93 groups have higher *injury rates than the low-risk group on the triad risk assessment score". Also which statistical program was used.*

3. Validity of the Findings

Impact and novelty not assessed. Negative/inconclusive results accepted. Meaningful replication encouraged where rationale & benefit to literature is clearly stated.

> Decisions are not made based on any subjective determination of impact, degree of advance, novelty, being of interest to only a niche audience, etc. Replication experiments are encouraged (provided the rationale for the replication, and how it adds value to the literature, is clearly described); however, we do not allow the 'pointless' repetition of well known, widely accepted results.

Reviewer Response: Results:

Ln 157 Patients Characteristics, should not be referred to as patients but as participants or athletes. Could information on their age or duration of sports participation be added to these results.

Ln 167 Title of this section does not clarify the results that are being addressed. Can the exact p values be included in the text or table not just the reference to $p < 0.05$.

Ln 162: These data should be from parts of Table 2 but it is unclear where these numbers are from.

Ln 171-172: indicate that a high history of bone stress fracture was from the combined moderate and high risk. Also reporting on the other factors of the triad may be interesting from table 2.

Ln 175 add "one" to the "since there was only one participant…"

Ln 178-179 please report exact p values for these 2 comparisons.

Ln 181-184 Is Table 4 needed and more detail on what Table 5 is illustrating.

All underlying data have been provided; they are robust, statistically sound, & controlled.

> The data on which the conclusions are based must be provided or made available in an acceptable discipline-specific repository. The data should be robust, statistically sound, and controlled.

Conclusions are well stated, linked to original research question & limited to supporting results.

> The conclusions should be appropriately stated, should be connected to the original question investigated, and should be limited to those supported by the results. In particular, claims of a causative relationship should be supported by a well-controlled experimental intervention. Correlation is not causation.

Reviewer Response: Discussion:

The first paragraph of the discussion should highlight the main results on the data. Was the hypothesis supported? What was the main take away from these data. The second paragraph of the discussion should be in the results section. Paragraph 5 addresses the primary hypothesis and should be addressed earlier in the discussion. The limitations say that injury rate could not be determined but the first paragraph states "there have been no studies of the relationship between the triad risk assessment 190 score and sports injury rate." Terminology and the use of injury risk and injury rate need to be defined and clarified throughout the manuscript.

The conclusion states: "This study clarified the relationship between the triad risk assessment score and the one year sports injury rate for female college students of multiple sports." It is not clear how the relationship has been clarified with the data presented. The discussion needs to convince the reader of this claim and in its current format the conclusion does not seem to be supported. In addition, the conclusion states " This was not a prospective survey, but its 255 results suggest that athletes with RED-S may be at increased risk of injury. " The authors used the Triad Cumulative Risk assessment so why is the conclusion focused on REDs? Both should be introduced and discussed in the manuscript, but should not be used interchangeably throughout the manuscript.

Speculation is welcome, but should be identified as such.

Standout reviewing tips

3

The best reviewers use these techniques

Tip Example

Support criticisms with evidence from the text or from other sources

Give specific suggestions on how to improve the manuscript

Comment on language and grammar issues

Organize by importance of the issues, and number your points

Please provide constructive criticism, and avoid personal opinions

Comment on strengths (as well as weaknesses) of the manuscript

Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.

Your introduction needs more detail. I suggest that you improve the description at lines 57- 86 to provide more justification for your study (specifically, you should expand upon the knowledge gap being filled).

The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult.

1. Your most important issue
2. The next most important item
3. …
4. The least important points

I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC

I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.

The relationship between the female athlete triad and injury rates in collegiate female athletes

Mutsuaki Edama Corresp., [1, 2] , **Hiromi Inaba** [1, 3] , **Fumi Hoshino** [3] , **Saya Natsui** [3] , **Sae Maruyama** [2] , **Go Omori** [1, 4]

[1] Athlete Support Research Center, Niigata University of Health and Welfare, Niigata, Japan, Niigata, Niigata, Japan

[2] Institute for Human Movement and Medical Sciences, Niigata University of Health and Welfare, Niigata, Japan, Niigata, Niigata, Japan

[3] Department of Health and Nutrition, Niigata University of Health and Welfare, Niigata, Japan, Niigata, Japan

[4] Department of Health and Sports, Niigata University of Health and Welfare, Niigata, Japan, Niigata, Niigata, Japan

Corresponding Author: Mutsuaki Edama
Email address: edama@nuhw.ac.jp

Background This study aimed to clarify the relationship between the Triad risk assessment score and the sports injury rate in 116 female college athletes in 7 sports at the national level of competition. **Methods** Bone mineral density (BMD) was measured on the heel of the right leg using an ultrasonic bone densitometer. Those with menstrual deficiency for >3 months or <6 menses in 12 months were classed as amenorrheic

athletes. Low energy availability was defined as BMI ≤17.5 kg/m^2. Low BMD was defined as a BMD Z-score <−1.0. The total score for each athlete was calculated, and the cumulative risk of stress fractures was defined as follows: a total score of 0-1 was low risk, a score of 2-5 was moderate risk, and a score of 6 was high risk. The injury survey recorded injuries referring to the injury survey items used by the International Olympic Committee. **Results** In swimming, significantly more athletes were in the low-risk category than in the moderate and high-risk categories. In athletics long-distance, significantly more athletes were in the moderate-risk category than in the low and high-risk categories. In the moderate and high-risk categories, significantly more athletes were in the injury group, whereas significantly more athletes in the low-risk category were in the non-injury group. Significantly more athletes at moderate and high risk had bone stress fractures and bursitis than athletes at low risk. **Discussion** Though this was not a prospective study, it suggested that athletes with relative energy deficiency in sport may be at increased injury risk.

The relationship between the female athlete triad and injury rates in collegiate female athletes

Mutsuaki Edama[1,2], Hiromi Inaba[1,3], Fumi Hoshino[3], Saya Natsui[3], Sae Maruyama[2], Go Omori[1,4]

[1] Athlete Support Research Center, Niigata University of Health and Welfare, Niigata, Japan

[2] Institute for Human Movement and Medical Sciences, Niigata University of Health and Welfare, Niigata, Japan

[3] Department of Health and Nutrition, Niigata University of Health and Welfare, Niigata, Japan

[4] Department of Health and Sports, Niigata University of Health

and Welfare, Niigata, Japan

Corresponding author: Mutsuaki Edama

Institute for Human Movement and Medical Sciences Niigata University of Health and Welfare 1398 Shimami-cho, Kita-ku, Niigata City, Niigata 950-3198, Japan

Tel/Fax: +81 25 257 4723, E-mail: edama@nuhw.ac.jp

ORCID: 0000-0002-2784-6466

Abstract

Background

This study aimed to clarify the relationship between the Triad risk assessment score and the sports injury rate in 116 female college athletes in 7 sports at the national level of competition.

Methods

Bone mineral density (BMD) was measured on the heel of the right leg using an ultrasonic bone densitometer. Those with menstrual deficiency for >3 months or <6

menses in 12 months were classed as amenorrheic athletes. Low energy availability was defined as BMI ≤17.5 kg/m^2. Low BMD was defined as a BMD Z-score <−1.0. The total score for each athlete was calculated, and the cumulative risk of stress fractures was defined as follows: a total score of 0-1 was low risk, a score of 2-5 was moderate risk, and a score of 6 was high risk. The injury survey recorded injuries referring to the injury survey items used by the International Olympic Committee.

Results

In swimming, significantly more athletes were in the low-risk category than in the moderate and high-risk categories. In athletics long-distance, significantly more athletes were in the moderate risk category than in the low and high-risk categories. In the moderate and high-risk categories, significantly more athletes were in the injury group, whereas significantly more athletes in the low-risk category were in the non-injury group. Significantly more athletes at moderate and high risk had bone stress fractures and bursitis than athletes at low risk.

Discussion

Though this was not a prospective study, it suggested that athletes with relative energy deficiency in sport may be at increased injury risk.

Key words: RED-S; low energy availability; The Female Athlete Triad Cumulative Risk Assessment [a]

Manuscript to be reviewed

Introduction

The American College of Sports Medicine (ACSM) defined the female athlete triad (hereafter referred to as triad) in 1997 and updated it in 2007 and 2014.(De Souza et al. 2014a; Nattiv et al. 2007) The Triad has three components: (a) low energy availability (LEA) with or without disordered eating (DE)/eating disordered (ED); (b) menstrual dysfunction; and (c) low bone mineral density (BMD).(De Souza et al. 2014a) The International Olympic Committee (IOC) suggested that relative energy deficiency in sport (RED-S) affects growth, mental conditioning, cardiovascular function, immunity, and BMD, resulting in decreased overall performance. Both RED-S and the Triad emphasize the importance of appropriate energy intake to support exercise.(De Souza et al. 2014b; Mountjoy et al. 2014; Mountjoy et al. 2015; Mountjoy et al. 2018) [b]

The advances in our understanding of risk factors and management of the triad are reflected in evidence-based guidelines developed by the Female Athlete Triad Coalition in 2014 to help guide medical decision-making for female athletes.(De Souza et al. 2014a) The resulting Female Athlete Triad Cumulative Risk Assessment includes the following 6 items scored on a scale from 0 to 2: low LEA with or without DE/ED; low body mass index (BMI); delayed menarche; oligomenorrhea (6-9 periods in 12 months) or amenorrhea (<6 periods in 12 months); low BMD; and prior stress reaction/fracture.(De Souza et al. 2014a) The resulting risk assessment score is used to classify an athlete into 1 of 3 categories: low risk (0-1 points), moderate risk (2-5 points), or high risk (6 points).(De Souza et al. 2014a) Using risk assessment scores to help manage treatment for athletes is important[c], especially considering the evidence for adverse health consequences resulting from the triad. For example, a higher number of triad risk factors is associated with an increased risk for bone stress injuries and low BMD.(Barrack et al. 2014; Gibbs et al. 2014; Tenforde et al. 2013) Furthermore, for female athletes who have one component of the triad, the risk of developing stress fractures is 2.5 times higher than that of ath[d]letes with no components of the triad; the risk

is 4.7 times higher for those with two or more components.(Mallinson & De Souza 2014) In addition, collegiate athletes with triad risk factors including oligomenorrhea/amenorrhea or increased risk assessment scores had higher grade bone stress injuries on magnetic resonance imaging and longer return to play. (Nattiv et al. 2013)

RED-S is based on a relative e[e]nergy deficit and is reported to affect various factors.(Mountjoy et al. 2018) However, there are many studies of bone stress fractures and amenorrhea, and their relationships with the occurrence of sports injury have not been examined. It was previously reported that the frequency of sports injuries was higher in women than in men, suggesting a relationship between the menstrual cycle and sports injury.(Hewett et al. 2007; Park et al. 2009) It has been suggested that there is a strong relationship between the risk of both RED-S and sports injuries.

Therefore, this study aimed to clarify the relationship between the triad risk assessment score and the sports injury rate. The hypothesis of this study was that the moderate and high-risk groups have higher injury rates than the low-risk group on the triad risk assessment score.

Materials and methods

Recruitment

A total of 116 female college athletes [f]were investigated; they were involved in 7 sports (swimming, athletics sprint, athletics long-distance, athletics throwing/jumping, soccer, basketball and volleyball). All sports were at the national level of competition. The Niigata University of Health and Welfare of ethical approval to carry out the study within its facilities (18032). The study content was fully explained to the subjects. Written, informed consent was obtained from all subjects. [g]

Medical examinations

Medical examinations and anthropometry were conducted from August 2018 to January 2019. The participants were asked about age at menarche, date of last menstrual period,

number of menstrual cycles per 12 months, history of bone stress fracture (site and times), dietary restriction, and present or past history of ED/DE using the questionnaire form. Those with menstrual deficiency for >3 months (definition of the Japan Society of Obstetrics and Gynecology) or <6 menses in 12 months were classed as amenorrheic athletes.(De Souza et al. 2014a)

Anthropometry

Height (cm) and body weight (kg) were measured using a body composition monitor (DC150, TANITA, Tokyo, Japan). BMD was measured on the heel of the right leg using an ultrasonic bone densitometer (AOS-100SA, Hitachi Aloka Medical, Tokyo, Japan).[h] The triad is defined as energy intake minus energy expenditure of exercise relative to fat-free mass (FFM) <30 kcal/kg of FFM/d(De Souza et al. 2014a), but it is too complicated to calculate energy balance this way during examinations. Alternatively, the ACSM defines LEA in adult athletes as a BMI ≤[i]17.5 kg/m^2.(De Souza et al. 2014a) Therefore, this criterion was used in the present study.(De Souza et al. 2014a) BMI was calculated as body weight (kg)/height (m^2).

The Female Athlete Triad Cumulative Risk Assessment

The Female Athlete Triad Cumulative Risk Assessment, which was updated by the Triad coalition in 2014, was used.(De Souza et al. 2014a) The following six factors were scored: (a) LEA with or without DE/ED; (b) low BMI; (c) delayed menarche; (d) oligomenorrhea and/or amenorrhea; (e) low BMD; and (f) stress reaction/fractures. With respect to LEA, athletes who received treatment by a psychiatrist received a score of 2, those with some dietary restriction as evidenced by self-report or low/inadequate energy intake on diet logs received a score of 1, and those with no history received a score of 0. Athletes with a BMI ≤17.5 kg/m^2 received a score of 2, and athletes with a BMI between 17.6 and 18.4 kg/m^2 received a score of 1. A score of 0 was given to athletes with a BMI ≥18.5 kg/m^2. For delayed menarche, athletes who had their

menarche at age >16 years received a score of 2, athletes who had their menarche at age 15-16 years received a score of 1, and those with menarche at under 15 years received a score of 0. For athletes with amenorrhea (>3 months or <6 menses in 12 months) were scored 2, 6-9 menses in 12 months were scored 1, and eumenorrheic athletes (>9 menses in 12 months) were scored 0. For low BMD, athletes with a Z-score ≤−2 were scored 2, and those between −1 and −2 were scored 1; a score of 0 was given to those over −1. For a history of stress fractures, those with a history of 2 or more stress fractures or trabecular bone stress fractures were scored 2, those with only one past stress fracture were scored 1, and those with no stress fractures were scored 0. Next, the total score for each athlete was calculated, and the cumulative risk of stress fractures was defined as follows: a total score of 0-1 was low risk, a score of 2-5 was moderate risk and a score of 6 was high risk.(De Souza et al. 2014a)

The injury rate [j]

An injury survey during sports activities was conducted for one season from April 2018 to March 2019. The injury survey collected injuries that resulted in failure to participate in practice and competition for more than 24 hours after injury, referring to the injury survey items used by the IOC.(Junge et al. 2008) Data were collected by physical therapists.

Statistical analysis

The chi-squared test wa[k]s used to compare differences in the risk categories for each sport, to compare differences in the number of injuries by risk categories, and to compare differences in injured body part-location and the type of injury diagnosis by risk category. The level of significance was set at 5%.

RESULTS

Patients' characteristics [l]

The sports undertaken by the participants were swimming (n=11), athletics sprint (n=19), athletics long-distance (n=8), athletics throwing/jumping (n=8), soccer (n=27), basketball (n=26), and volleyball (n=17).

The three triad components

There were 2/116 (1.7%) athletes with LEA with or without DE/ED (BMI ≤17.5 kg/m^2), 6/116 (5.2%) athletes with amenorrhea (>3 months or <6 menses in 12 months), and 0/116 (0.0%) athletes had low BMD (Z-score <-1.0). No players had all three triad components.

Prevalence of the 7 events for 116 athletes assigned to triad risk categories[m]

In swimming, there were significantly more in the low-risk category than in the moderate and high-risk categories ($p<0.05$). In athletics long-distance, there were significantly more in the moderate-risk category than in the low and high-risk categories ($p<0.05$) (Table 1). In each scoring category, there was a high proportion (41/116, 35.3%) with a history of bone stress fracture, particularly in athletics long-distance (7/8, 87.5%) (Table 2).

Number of injuries and injury rates by triad risk categories (Table 3)

Since there was only [one] [n]participant in the high-risk category, the high and moderate-risk categories were combined for the analysis. The number of injuries was 65 (n=41) in one year.[o] In the moderate and high-risk categories, there were significantly more in the injury group than in the non-injury group ($p<0.05$). In the low-risk category, there were significantly more in the non injury group than in the injury group ($p<0.05$).

Injured body part location and type of injury diagnosis by risk category

There was no significant difference in the injured body part location (Table 4).[p] For stress fracture and bursitis, there were significantly more in the moderate and high-risk categories than

in the low-risk category ($p<0.05$) (Table 5).

Discussion

This study clarified the relationship between the triad risk assessment score and the one-year sports injury rate for female college students of multiple sports. To the best of our knowledge, there have been no studies of the relationship between the triad risk assessment score and sports injury rate.

In this study, there were 2/116 (1.7%) athletes with LEA with or without DE/ED, 6/116 (5.2%) with amenorrhea, and 0/116 (0.0%) with low BMD. No athletes had all three triad components. In previous studies of elite Japanese athletes, the number of athletes with LEA was 42/300 (14.0%), with amenorrhea was 117/300 (39.0%), and with low BMD was 68/300 (22.7%). Seventeen athletes (5.7%) had both amenorrhea and LEA, whereas 39 (13%) had both amenorrhea and low BMD, and two (0.7%) had low BMD and LEA. Sixteen (5.3%) had all three components of the triad. In previous studies of American collegiate athletes, the number of athletes with LEA was 2/323 (0.6%), the number with oligomenorrhea or amenorrhea was 64/239 (26.8%), and the number with low BMD was 19/323 (5.9%).(Tenforde et al. 2017) Although the level of competition was different, the present female athletes were considered to be well managed.

In swimming, the number in the low-risk category was significantly higher than in the moderate and high-risk categories. In athletics long-distance, the number in the moderate-risk category was significantly higher than in the low-risk category. In a previous study, athletics (64/86; 74.4%),(Nose-Ogura et al. 2019) track (0/4; 0.0%),(Tenforde et al. 2017) cycling (3/4; 75.0%),(Nose-Ogura et al. 2019) swimming (7/11; 63.6%),(Nose-Ogura et al. 2019) gymnastics (7/7; 100.0%)(Nose-Ogura et al. 2019) (9/16; 56.2%), (Tenforde et al. 2017) rhythmic gymnastics (31/35; 88.6%),(Nose-Ogura et al. 2019) and cross-country (23/47; 48.9%)(Tenforde et al. 2017) were in the moderate or high-risk categories. Although there is no clear consensus, it was considered that there were many endurance and aesthetic sports athletes in the middle- and high-risk categories.

In addition, for each scoring category, there was a large proportion (41/116, 35.3%) with a history of bone stress fractures, particularly in athletics long-distance (7/8; 87.8%). In previous studies, female athletes were at a higher risk of bone stress fractures than male athletes.(De Souza et al. 2014a; Nose-Ogura et al. 2019) It has also been reported that the frequency of bone stress fractures among 1616 female Japanese athletes and 537 controls (non-athletes) was 22.6% for athletes competing at the international level, 23.3% for athletes competing at the national level, 20.8% for athletes competing at the local level, 18.8% for athletes competing at other levels, and 4.3% for controls.(Takamatsu & Kitawaki 2016) Therefore, the athletes in the present study had a high rate of bone stress fractures. Furthermore, it was thought that one needs to carefully consider the reason why significantly more athletes were in the moderate-risk category than in the low-risk category in athletics long-distance.

Regarding the number of injured athletes by triad risk category, in the moderate and high-risk categories, there were significantly more athletes in the injury group than in the non injury group. In previous studies, attention was paid to the relationship between the Female Athlete Triad Cumulative Risk Assessment and bone stress fractures.(Barrack et al. 2014; Gibbs et al. 2014; Mallinson & De Souza 2014; Tenforde et al. 2013) The IOC suggested that RED-S affects growth, mental conditioning, cardiovascular function, immunity, and BMD, resulting in decreased overall performance. In addition, the performance parameters identified in the RED-S conceptual model have been shown to be involved in increased injury risk.(Mountjoy et al. 2018) Though this was not a prospective survey, it suggests that athletes with RED-S may be at increased risk of injury.

Regarding the type of injury diagnosis by risk category, bone stress fracture and bursitis were significantly higher in the moderate and high-risk category than in the low-risk category. In previous studies, a higher number of triad risk factors was associated with an increased risk for bone stress injuries and low BMD.(Barrack et al. 2014; Gibbs et al. 2014; Tenforde et al. 2013) Furthermore, for female athletes with one component of the triad, the risk of developing stress fractures was 2.5 times higher than that of athletes with no components of the triad; the risk was 4.7 times higher for those with two or more components.(Mallinson & De Souza 2014) Therefore, this study was considered to have supported the results of the previous studies. However, it is necessary to examine bursitis in greater detail in the future.

Several limitations must be considered in this study. First, injury rates could not be calculated by 1000 athlete exposures. Second, the survey of injuries during sports activities was conducted for one season from April 2018 to March 2019, but medical examinations and anthropometry were conducted from August 2018 to January 2019. Therefore, this was not a prospective study.

Conclusions

This study clarified the relationship [q]between the triad risk assessment score and the one year sports injury rate for female college students of multiple sports. Regarding the number of injured athletes and injury rates by risk category, in the moderate and high-risk categories, there were significantly more athletes in the injury group than in the non-injury group. In addition, there were significantly more athletes in the moderate and high-risk categories than in the low-risk category with bone stress fractures and bursitis.[r] This was not a prospective survey, but its results suggest that athletes with RED-S m[s]ay be at increased risk of injury. In the future, prospective research was considered necessary.

Acknowledgements

This study was supported by a Grant-in-Aid for Scientific Research (19K11358) from the Japanese Society for the Promotion of Science (JSPS) and Commissioned by the Japan Sports Agency (Female Athletes Development and Support Projects 2020).

References

Barrack MT, Gibbs JC, De Souza MJ, Williams NI, Nichols JF, Rauh MJ, and Nattiv A. 2014. Higher incidence of bone stress injuries with increasing female athlete triad-related risk factors: a prospective multisite study of exercising girls and women. *Am J Sports Med* 42:949-958. 10.1177/0363546513520295

De Souza MJ, Nattiv A, Joy E, Misra M, Williams NI, Mallinson RJ, Gibbs JC, Olmsted M, Goolsby M, and Matheson G. 2014a. 2014 Female Athlete Triad Coalition Consensus Statement on Treatment and Return to Play of the Female Athlete Triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. *Br J Sports Med* 48:289. 10.1136/bjsports-2013-093218

De Souza MJ, Williams NI, Nattiv A, Joy E, Misra M, Loucks AB, Matheson G, Olmsted MP, Barrack M, Mallinson RJ, Gibbs JC, Goolsby M, Nichols JF, Drinkwater B, Sanborn C, Agostini R, Otis CL, Johnson MD, Hoch AZ, Alleyne JM, Wadsworth LT, Koehler K, VanHeest J, Harvey P, Kelly AK, Fredericson M, Brooks GA, O'Donnell E, Callahan LR, Putukian M, Costello L, Hecht S, Rauh MJ, and McComb J. 2014b. Misunderstanding the female athlete triad: refuting the IOC consensus statement on Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med* 48:1461-1465. 10.1136/bjsports-2014-093958

Gibbs JC, Nattiv A, Barrack MT, Williams NI, Rauh MJ, Nichols JF, and De Souza MJ. 2014. Low bone density risk is higher in exercising women with multiple triad risk factors. *Med Sci Sports Exerc* 46:167-176. 10.1249/MSS.0b013e3182a03b8b

Hewett TE, Zazulak BT, and Myer GD. 2007. Effects of the menstrual cycle on anterior cruciate ligament injury risk: a systematic review. *Am J Sports Med* 35:659-668. 10.1177/0363546506295699

Junge A, Engebretsen L, Alonso JM, Renström P, Mountjoy M, Aubry M, and Dvorak J. 2008. Injury surveillance in multi-sport events: the International Olympic Committee approach. *Br J Sports Med* 42:413-421. 10.1136/bjsm.2008.046631

Mallinson RJ, and De Souza MJ. 2014. Current perspectives on the etiology and manifestation of the "silent" component of the Female Athlete Triad. *Int J Womens Health* 6:451-467. 10.2147/ijwh.S38603

Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, Meyer N, Sherman R, Steffen K, Budgett R, and Ljungqvist A. 2014. The IOC consensus statement: beyond the Female Athlete Triad--Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med* 48:491-497. 10.1136/bjsports-2014-093502

Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N, Lebrun C, Meyer N, Sherman R, Steffen K, Budgett R, and Ljungqvist A. 2015. Authors' 2015 additions to the IOC consensus statement: Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med* 49:417-420. 10.1136/bjsports-2014-094371

Mountjoy M, Sundgot-Borgen JK, Burke LM, Ackerman KE, Blauwet C, Constantini N, Lebrun C, Lundy B, Melin AK, Meyer NL, Sherman RT, Tenforde AS, Klungland Torstveit M, and Budgett R. 2018. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br J Sports Med* 52:687-697. 10.1136/bjsports-2018-099193

Nattiv A, Kennedy G, Barrack MT, Abdelkerim A, Goolsby MA, Arends JC, and Seeger LL. 2013. Correlation of MRI grading of bone stress injuries with clinical risk factors and return to play: a 5-year prospective study in collegiate track and field athletes. *Am J Sports Med* 41:1930-1941. 10.1177/0363546513490645

Nattiv A, Loucks AB, Manore MM, Sanborn CF, Sundgot-Borgen J, and Warren MP. 2007. American College of Sports Medicine position stand. The female athlete triad. *Med Sci Sports Exerc* 39:1867-1882. 10.1249/mss.0b013e318149f111

Nose-Ogura S, Yoshino O, Dohi M, Kigawa M, Harada M, Hiraike O, Onda T, Osuga Y, Fujii T, and Saito S. 2019. Risk factors of stress fractures due to the female athlete triad: Differences in teens

and twenties. *Scand J Med Sci Sports* 29:1501-1510. 10.1111/sms.13464

Park SK, Stefanyshyn DJ, Ramage B, Hart DA, and Ronsky JL. 2009. Alterations in knee joint laxity during the menstrual cycle in healthy women leads to increases in joint loads during selected athletic movements. *Am J Sports Med* 37:1169-1177. 10.1177/0363546508330146

Takamatsu K, and Kitawaki J. 2016. Annual report of the Women's Health Care Committee, Japan Society of Obstetrics and Gynecology, 2016. *J Obstet Gynaecol Res* 42:1419-1438. 10.1111/jog.13130

Tenforde AS, Carlson JL, Chang A, Sainani KL, Shultz R, Kim JH, Cutti P, Golden NH, and Fredericson M. 2017. Association of the Female Athlete Triad Risk Assessment Stratification to the Development of Bone Stress Injuries in Collegiate Athletes. *Am J Sports Med* 45:302-310. 10.1177/0363546516676262

Tenforde AS, Sayres LC, McCurdy ML, Sainani KL, and Fredericson M. 2013. Identifying sex-specific risk factors for stress fractures in adolescent runners. *Med Sci Sports Exerc* 45:1843-1851. 10.1249/MSS.0b013e3182963d75

Legend

Table 1. Numbers of athletes assigned to triad risk categories by event Data presented as n (%).

[a]$p<0.05$ vs. moderate and high risk category

[b]$p<0.05$ vs. low and high risk category

Table 2. Number of low-, moderate- and high-risk athletes in each event by female athlete triad coalition scoring category

Data presented as n (%).

Table 3. Injury rates by triad risk category

Date presented as n (%).

[a]: $p<0.05$, Non-injury group in moderate risk (%)

[b]: $p<0.05$, Injury group in low risk (%)

Table 4. Injured body part location by risk category

Date presented as n (%).

Only items that occurred are listed.

Table 5. Injury diagnosis by triad risk category

Date presented as n (%).

Only items that occurred are listed.

[a]$p<0.05$ vs. low risk category in stress fracture

[b]$p<0.05$ vs. low risk category in bursitis

Table 1 (on next page)

Table 2. Nu[t]mber of low-, moderate- and high-risk athletes in each event by female athlete triad coalition scoring category

Data presented as n (%).

Table 1. Numbers of athletes assigned to triad risk categories by event

Sport	No. of athletes	Low risk	Moderate risk	High risk
Swimming	11	11 (100.0) [a]	0 (0.0)	0 (0.0)
Athletics sprint	19	13 (68.4)	6 (31.6)	0 (0.0)
Athletics long-distance	8	2 (25.0)	5 (62.5) [b]	1 (12.5)
Athletics throwing/jumping	8	7 (87.5)	1 (12.5)	0 (0.0)

Soccer 27 20 (74.1) 7 (25.9) 0 (0.0) **Basketball** 26 21 (80.8) 5 (19.2) 0 (0.0) **Volleyball** 17 14 (82.4) 3 (17.6) 0 (0.0) **Total** 116 88 (75.9) 27 (23.3) 1 (0.8) Data presented as n (%).

[a] $p<0.05$ vs. moderate and high risk category

[b] $p<0.05$ vs. low and high risk category

[u]

Table 2(on next page)

Table 2. Number of low-, moderate- and high-risk athletes in each event by female athlete triad coalition scoring category

Data presented as n (%).

1 **Table 2. Number of low-, moderate- and high-risk athletes in each event by female athlete triad coalition scoring category**

Category and risk	Swimming (n=11)
Low energy availability	

Athletic sprint (n=19)
Athletic long distance (n=8)
Athletic throwing/ Jumping (n=8)
Soccer (n=27)
Basketball (n=26)
Volleyball (n=17)
Total (n=116)

Low 9 (7.8) 16 (13.8 6 (5.2) 8 (6.9) 25 (21.6) 25 (21.6) 16 (13.8) 105 (90.5) **Moderate** 2 (1.7) 3 (2.6) 2 (1.7) 0 (0.0) 2 (1.7) 1 (0.9) 1 (0.9) 11 (9.5) **High** 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) **Body mass index**

Low 11 (9.5) 16 (13.8) 7 (6.0) 7 (6.0) 26 (22.4) 26 (22.4) 17 (14.7) 110 (94.8) **Moderate** 0 (0.0) 2 (1.7) 0 (0.0) 1 (0.9) 1 (0.9) 0 (0.0) 0 (0.0) 4 (3.4) **High** 0 (0.0) 1 (0.9) 1 (0.9) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 2 (1.7) **Age at menarche**

Low 11 (9.5) 17 (14.7) 3 (2.6) 7 (6.0) 23 (19.8) 21 (18.1) 15 (12.9) 97 (83.6) **Moderate** 0 (0.0) 2 (1.7) 4 (3.4) 1 (0.9) 4 (3.4) 4 (3.4) 2 (1.7) 17 (14.7) **High** 0 (0.0) 0 (0.0) 1 (0.9) 0 (0.0) 0 (0.0) 1 (0.9) 0 (0.0) 2 (1.7) **Oligomenorrhea/ amenorrhea**

Low 11 (9.5) 13 (11.2) 6 (5.2) 7 (6.0) 24 (20.7) 21 (18.1) 16 (13.8) 98 (84.5) **Moderate** 0 (0.0) 5 (4.3) 1 (0.9) 1 (0.9) 1 (0.9) 2 (1.7) 0 (0.0) 10 (8.6) **High** 0 (0.0) 1 (0.9) 1 (0.9) 0 (0.0) 2 (1.7) 3 (2.6) 1 (0.9) 8 (6.9) **Low bone mineral density**

Low 11 (9.5) 19 (16.4) 8 (6.9) 8 (6.9) 27 (23.3) 26 (22.4) 17 (14.7) 116 (100.0)

Moderate 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0)

High 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) 0 (0.0) **Stress reaction/fracture**

Low 11 (9.5) 10 (8.6) 1 (0.9) 6 (5.2) 18 (15.5) 20 (17.2) 9 (7.8) 75 (64.7) **Moderate** 0 (0.0) 8 (6.9) 4 (3.4) 2 (1.7) 9 (7.8) 6 (5.2) 7 (6.0) 36 (31.0) **High** 0 (0.0) 1 (0.9) 3 (2.6) 0 (0.0) 0 (0.0) 0 (0.0) 1 (0.9) 5 (4.3) 2 Data presented as n (%).

Table 3(on next page)

Table 3. Injury rates by triad risk category

Date presented as n (%). [a]: $p<0.05$, Non-injury group in moderate risk (%) [b]: $p<0.05$, Injury group in low risk (%)

1 **Table 3. Injury rates by triad risk category**

Kind of sport	Injury group (n=41)	Non-injury group (n=75)

Low risk (%) Moderate and high risk (%) Low risk (%) Moderate and high risk (%)
Swimming 3 (7.3) 0 (0.0) 8 (10.7) 0 (0.0) **Athletics sprint** 0 (0.0) 1 (2.4) 13 (17.3) 5 (6.7) **Athletics long-distance** 0 (0.0) 3 (7.3) 2 (2.7) 3 (4.0) **Athletics throwing/jumping** 2 (4.9) 1 (2.4) 5 (6.7) 0 (0.0) **Soccer** 12 (29.3) 6 (14.6) 8 (10.7) 1 (1.3) **Basketball** 5 (12.2) 2 (4.9) 16 (21.3) 3 (4.0) **Volleyball** 4 (9.8) 2 (4.9) 10 (13.3) 1(1.3) **Total** 26 (63.4) 15 (36.6) [a] 62 (82.7) **[b]** 13 (17.3)
2 Date presented as n (%).
3[a]: p<0.05, Non-injury group in moderate risk (%)
4[b]: p<0.05, Injury group in low risk (%)

Table 4(on next page)

Table 1. N[v]umbers of athletes assigned to triad risk categories by event

Data presented as n (%). [a]p<0.05 vs. moderate and high risk category [b]p<0.05 vs. low and high risk category

Table 4. Injured body part location by risk [w]category

Injured body part	**Low risk**	**Moderate and high risk**
Face (incl. eye, ear, nose)	1 (1.5)	0 (0.0)
Head	3 (4.6)	1 (1.5)
Neck / cervical spine	1 (1.5)	0 (0.0)
Lumbar spine / lower back	3 (4.6)	1 (1.5)
Shoulder / clavicle	2 (3.1)	0 (0.0)
Elbow	1 (1.5)	0 (0.0)
Wrist	1 (1.5)	0 (0.0)
Finger	1 (1.5)	0 (0.0)
Thumb	1 (1.5)	0 (0.0)
Hip	0 (0.0)	2 (3.1)
Thigh	4 (6.2)	2 (3.1)
Knee	11 (16.9)	2 (3.1)
Lower leg	4 (6.2)	1 (1.5)
Ankle	8 (12.3)	9 (13.8)
Foot/toe	3 (4.6)	0 (0.0)
Others (heatstroke)	2 (3.1)	1 (1.5)
Total	46 (70.8)	19 (29.2)

Date presented as n (%).

Only items that occurred are listed.

Table 5([x]on next page)

Table 5. Injury diagnosis by triad risk category

Date presented as n (%). Only items that occurred are listed. [a]$p<0.05$ vs. low risk category in stress fracture [b]$p<0.05$ vs. low risk category in bursitis [y]

Table 5. Injury diagnosis by triad risk category

Injury diagnosis	Low risk	Moderate and high risk
Concussion	4 (6.2)	1 (1.5)
Fracture	2 (3.1)	0 (0.0)
Stress fracture	0 (0.0)	4 (6.2)[a]
Other bone injuries	1 (1.5)	0 (0.0)
Dislocation, subluxation	5 (7.7)	1 (1.5)
Ligamentous rupture	2 (3.1)	0 (0.0)
Sprain	8 (12.3)	6 (9.2)
Lesion of meniscus or cartilage	3 (4.6)	0 (0.0)
Strain / muscle rupture / tear	4 (6.2)	0 (0.0)
Contusion / hematoma/ bruise	6 (9.2)	0 (0.0)
Tendinosis / tendinopathy	5 (7.7)	1 (1.5)
Bursitis	1 (1.5)	4 (6.2)[b]
Muscle cramps or spasm	1 (1.5)	1 (1.5)
Nerve injury / spinal cord injury	1 (1.5)	0 (0.0)
Others (nail trouble, heatstroke)	3 (4.6)	1 (1.5)
Total	46 (70.8)	19 (29.2)

Date presented as n (%).

Only items that occurred are listed.

[a]p<0.05 vs. low risk category in stress fracture

[b]p<0.05 vs. low risk category in bursitis

[a]add injury?

[b]The main purpose of this paragraph is to highlight the importance of energy intake and injury? Both the triad and REDs have a component of energy deficiency in their definitions. But the main point of this paragraph is not set up well. Is the focus on injury? If so put the triad and the REDs in that context and are they similar or different and is that important.

[c]Risk factors for the triad are noted in this paragraph. Why is it important to determine the risk factors for the triad? The importance is not set up. well. in the first paragraph.

[d]The incidence of injury in female athletes should be introduced earlier and the factors that are associated with those injuries, low energy availability and menstrual irregularities. Then introduce both the triad and REDs

[e]Seems like this paragraph should be earlier. What are the "various factors" that REDs. affects?

[f]How were they recruited? Volunteer basis? what were the criteria?

[g]This section is a bit unclear. What is the. universities ethics committee named? Also the last 2 sentences could be combined.

[h]Much more detail is needed on the specifics of data collection. And to explain the use of BMD as the outcome variable for ultrasound measures and not BUA and SOS.

[i]more justification should be reported for not using standard practices of calculating LEA. Have other investigators used this approach?

[j]Was this the number of injuries over the span of time or for a certain number of exposure hours. The term rate can be misleading.

[k]which Chi-Squared test? Were there any sub analyses that were done. I am not an expert in this analysis but seems that more information is needed. Which program used. identification of variables etc.

[l]Patients Characteristics, should not be referred to as patients but as participants or athletes. Could information on their age or duration of sports participation be added to these results.

[m]Title of this section does not clarify the results that are being addressed. Can the exact p values be included in the text or table not just the reference to p < 0.05.

[n]add "one"

[o]The. analysis from the 116 athletes to the 65 injuries in one year should be explained better in the statistical section in the methods.

[p]Meaning that injury sites didn't overlap significantly amongst any of the participants?

[q]very vague. What part of the relationship was clarified with these data?

[r]Only these two injuries were significant?

[s]or the triad? or athletes with a higher risk on the assessment?

[t]Update Label

[u]Give exact p-values (reference paper on p-values)

[v]Update label

[w]Is this table needed for the assessment of your hypothesis?

[x]May need an extra column for 'No-Risk' group

[y]Where these the only significant injuries found? The differences in concussion, dislocation, sprain and tendinopathy look significant