The Female Athlete Triad in High-Level Female Collegiate Athletes

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1.0 Abstract

Exercise is very beneficial for people of all ages and can promote bone growth and development and overall health, but when individuals overexert themselves, exercise can become detrimental. Women in particular are at higher risk due to a syndrome called The Female Athlete Triad. The Triad is the interrelationships between three components: low energy availability (EA), menstrual dysfunction (MD), and low bone mineral density (BMD). The goal of this research is to compare the risk of symptoms of the Triad in elite (NCAA) athletes and recreational (club) athletes. A survey was given to the participants and their responses will be analyzed and compared across the two different populations to determine whether or not NCAA athletes have a higher prevalence of the Female Athlete Triad compared to their recreational counterparts. In the data analysis, it was discovered that the NCAA athletes do not exhibit more symptoms of the Triad and the analysis pointed towards recreational athletes having a higher prevalence of Triad symptoms. This indicates that in addition to NCAA athletes, recreational athletes should be screened and educated on the Triad to benefit their overall health. In the future, research could be expanded to all athletes or active individuals as it has been seen that one group does not have a tendency to exhibit more symptoms. Doctors would then be more aware of this condition and this could be part of prevention of the Female Athlete Triad.

2.0 Introduction and Review of Literature

Athletics are an effective way to maintain health for individuals of all ages. However, injuries have become very common in different populations and some are at more risk than others due to both intrinsic and extrinsic risk factors.

Exercise is encouraged for health benefits and to prevent long-term injuries, but excess exercise can be harmful (Amorin et al. 2017). Common injuries in athletes of all ages can be caused by sudden or gradual damage. Stress fracture is one type of such injury and is common in many sports. Running and sports of similar nature are repetitive and high impact, which damage weak bone structures and apply strong forces on bones, leading to a higher prevalence of a stress-related injury (Meardon et al. 2015; Willems et al. 2006).

Though over-exercise can be harmful for all, there are a number of risk factors that increase the risk for certain populations. The most prevalent risk factor is a history of stress fracture. Stress fractures develop when bone breakdown due to exercise exceeds bone repair and

remodeling (Meardon et al. 2015). Low levels of vitamin D is another risk factor. Vitamin D regulates calcium and phosphorus levels in the body and when an individual has a deficiency, muscles become weaker (Gorter et al. 2017). The low muscle mass from the lack of vitamin D therefore leads to increased risk of injury (Kahanov et al. 2015).

Another leading risk factor is sex. Females have a raised risk of injury due to anatomical factors (Wentz et al. 2011), which may cause women to develop injuries at a younger age compared to men (Korpelainen et al. 2001). Young female dancers studied prior to professional dance training had lower bone density compared to other girls their age. This may prevent them from reaching peak bone mass as an adult, which could also cause injury (Amorin et al. 2017).

Hormones and specific cells are activated during bone healing and remodeling processes. In females, estrogen is one of the hormones that assists in bone repair. When estrogen is lower than normal, it can disturb the remodeling process, requiring a longer recovery period (Williamsom et al. 2018).

The Female Athlete Triad is a reason that females have a greater risk and prevalence of stress fracture. This syndrome is the set of three inter-related components that affect the overall health of a female athlete. The components are low energy availability (EA), menstrual dysfunction (MD), and low bone mineral density (BMD) (Márquez et al. 2013). The Triad was discovered in the 1980s/1990s after Title IX was passed. When the syndrome was first discovered is was characterized as a female athlete having an eating disorder, amenorrhea, and osteoporosis simultaneously. These criteria were later changed because they were deemed to be too restrictive (Thein-Nissenbaum et al. 2017).

The prevalence of the Female Athlete Triad with the original restrictions was 1-4% of the female athlete population (Brown et al. 2017). With the updated criteria, prevalence has increased. Those that have been diagnosed with one component have a prevalence of 16-60%, 2.7-27% have been diagnosed with two, and 0-15.9% have been diagnosed with all three (Mehta et al. 2018). The population with the highest prevalence of the Triad is aesthetic and leanness sports. Sports such as dance, gymnastics, running, etc. require a lean physique which causes these athletes to restrict their diets to maintain the desired physique (Brown et al. 2017).

Diagnosis of the Triad is a difficult process. At this time, the most effective way to diagnosis this syndrome is through a questionnaire. The questionnaire should include questions related to nutritional and pubertal health. Although a questionnaire is the best means of

diagnosis, pre-screening for the Triad should be required at female athletes' annual physical. Many doctors do not incorporate this into their exams, and the addition would diagnose the syndrome earlier and allow for a faster and more effective recovery (Nazem et al. 2012).

Low energy availability (EA) is the driving component of the Triad. The other two factors usually stem from this one (Márquez et al. 2013; Mehta et al. 2018). Low EA occurs when an individual's energy expenditure is greater than the caloric intake and can be caused by eating disorders. When an individual has low EA, other bodily functions are compromised. For example, normal EA is 45 kcal•kg^{-1} fat free mass (FFM) per day. Menstrual dysfunction begins around 30 kcal•kg^{-1} FFM per day, although this threshold may vary between women (Temme et al. 2013).

Treatment of low EA is associated with nutrition and improving the calories obtained. The first goal of treatment is to increase energy availability. This can be accomplished by increasing caloric intake and decreasing energy expenditure. Vitamin D and calcium should be supplemented if the individual is not getting these minerals from their diet. If the athlete is diagnosed with an eating disorder, they should be treated as that is one of the driving forces of low EA (Temme et al. 2013).

Menstrual dysfunction (MD) is the next factor. This factor runs on a spectrum from amenorrhea (primary or secondary) to oligomenorrhea. Primary amenorrhea is when a girl does not start menstruating by the age of thirteen. Secondary amenorrhea is when menses stop for three months after having a normal onset of menses. Oligomenorrhea is when there are more than thirty-five days in between each cycle (Temme et al. 2013). The low estrogen levels caused from MD will suppress reproductive health, which may lead to negative effects later in life (Mehta et al. 2018).

The third and final component is low bone mineral density (BMD). Usually it occurs when an individual has low estrogen levels, which then leads to the overactivity of osteoclasts. Osteoclasts are bone cells that absorb bone tissue during the bone growth and remodeling processes. The osteoclasts will begin to absorb more bone than what is being repaired and cause a lower BMD. If this process continues bone will continue to be absorbed and lead to osteoporosis. The prevalence of osteoporosis is 0-13% in individuals suffering from the Triad while the normal prevalence is 2.3% of the population (Mehta et al. 2018).

The risk factors for the Female Athlete Triad include intense training, sport specialization before puberty, leanness or aesthetic sports and perfectionism. Athletes participating in intercollegiate competition (NCAA athletes) are more likely to be exposed to these and many other risk factors than those participating in recreational or club sports.

2.1 Research Question and Hypotheses

Is the prevalence of the Female Athlete Triad higher in NCAA athletes compared to recreational or club athletes?

H_0: There is no relationship between level of physical activity and prevalence of the Female Athlete Triad (low energy availability/disordered eating/eating disorders, menstrual dysfunction, and bone stress injuries) in female collegiate athletes.

H_1: Female athletes that perform at a higher level are more likely to exhibit low energy availability/disordered eating/eating disorders, menstrual dysfunction, and bone stress injuries (e.g. The Female Athlete Triad) than club or recreational athletes.

3.0 Methods

The data from the questionnaire were statistically analyzed using a t-test in order to determine the prevalence of the Female Athlete Triad in female collegiate athletes. There were two separate groups: NCAA athletes and recreational/club athletes. The participants answered questions in the survey regarding their health and habits for their sports. Their answers were analyzed in order to determine which group would exhibit more symptoms of the Female Athlete Triad.

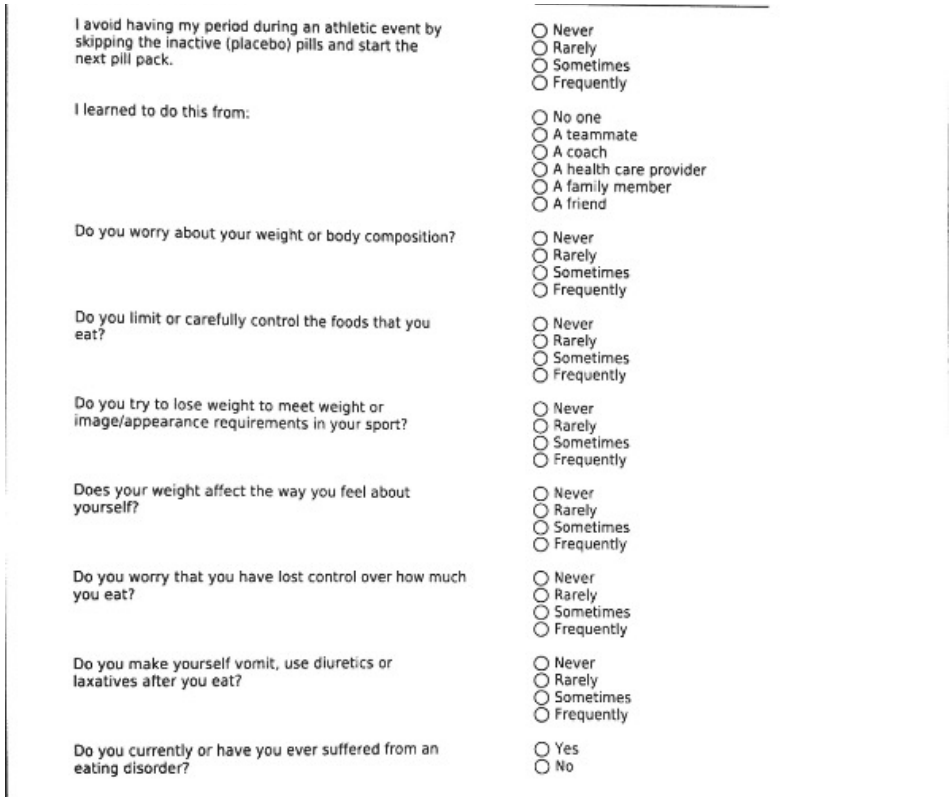
3.1 Participants

The participants in the study were all female collegiate students that participated in sports at either the elite level (NCAA) or the recreational/club level. The survey was anonymous and each individual that completed it, was assigned an ID number to prevent any breach of confidentiality.

3.2 Survey

Each participant was given a survey that asked them questions about their physical health. The survey included questions of age, race, intensity and type of sport. Other questions asked the participants about their menstrual health and the impacts that their menstrual cycle has on their sports performance. The last section included questions regarding eating disorders,

athletic performance while menstruating, and bone health. Each of those questions could be answered using the options: “never,” “rarely,” “sometimes,” or “frequently.” These questions all referred to possible symptoms of the Female Athlete Triad.



I avoid having my period during an athletic event by skipping the inactive (placebo) pills and start the next pill pack.
○ Never ○ Rarely ○ Sometimes ○ Frequently

I learned to do this from:
○ No one ○ A teammate ○ A coach ○ A health care provider ○ A family member ○ A friend

Do you worry about your weight or body composition?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Do you limit or carefully control the foods that you eat?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Do you try to lose weight to meet weight or image/appearance requirements in your sport?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Does your weight affect the way you feel about yourself?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Do you worry that you have lost control over how much you eat?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Do you make yourself vomit, use diuretics or laxatives after you eat?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Do you currently or have you ever suffered from an eating disorder?
○ Yes ○ No

Do you ever eat in secret?
○ Never ○ Rarely ○ Sometimes ○ Frequently

Have you ever had a stress fracture?
○ Yes ○ No

What type(s) of stress fracture(s)? (Select all that apply)
☐ Back ☐ Pelvis/hip ☐ Shin ☐ Foot ☐ Other

Please specify "Other".

Have you ever been told you have low bone density (osteopenia or osteoporosis)?
○ Never ○ Rarely ○ Sometimes ○ Frequently

3.3 Statistical Analysis

A statistical analysis of these data was performed in order to evaluate whether or not female athletes that perform sports at a higher-level exhibit more symptoms of the Female Athlete Triad. Certain characteristics of the Triad will be analyzed between the two populations

(NCAA and recreational/club) to evaluate whether or not NCAA athletes have a higher prevalence of the Female Athlete Triad.

A two-sample t-test was done on these data in order to test their statistical significance. Each of the responses to the questions regarding the Triad symptoms were quantified (i.e. Never = 1, Rarely = 2, Sometimes = 3, Frequently = 4). All of the responses were then summed to get the total amount of 1's, 2's, 3's, and 4's for both groups. The data were input into the calculator and determine the t-test statistic and corresponding p-value, as well as the means and standard deviations for each group. The goal of the research was to determine whether or not NCAA athletes had a higher prevalence of exhibiting Triad symptoms than recreational athletes, so the t-test was designed to indicate whether or not there was enough evidence to conclude that $\mu_{NCAA} > \mu_{rec}$, meaning that the NCAA athletes had a higher mean survey score than their recreational counterparts.

4.0 Results

The survey was sent out to 1366 female collegiate athletes. 1109 of them completed and sent back the survey. 1020 of them being NCAA athletes and only 89 recreational/club athletes. The mean survey score of the NCAA and recreational athletes were calculated to be 1.93 and 2.15 respectively, where a higher score indicates increased prevalence of Female Athlete Triad symptoms.

The calculated t-test statistic was -4.99 and the p-value was 0.99. This indicates that there was practically no evidence to support rejecting the null hypothesis in favor of the alternative hypothesis, which stated that the NCAA mean survey score was greater than the Rec group's mean survey score. In fact, the data seems to indicate that the opposite may be the case.

5.0 Discussion

Since the t-test statistic and p-value were so large, it indicates that these data had no significance relative to the hypothesis. This points to the exact opposite being true that the recreational athletes were more symptomatic than the elite NCAA athletes. The calculation gives no reason to refute the null hypothesis, but also does not prove the alternative hypothesis.

The findings from these data can indicate that recreational athletes also have a higher prevalence for the Triad and should be focused on in addition to NCAA athletes. As of now,

NCAA athletes are the most prevalent population for this syndrome. This indicates that recreational athletes should be screened for the Triad in addition to the already known population.

A major limitation to this analysis was the unevenly distributed sample size. There were 1020 NCAA responses and only 89 recreational athlete responses. Ideally, there should be more evenly matched sample sizes.

Future research could include studying the type of sport that the athlete participates in or get more specific and include the number of hours the athlete spends on the sport per week. This could be done in both groups and if the prevalence of symptoms in the two different groups remains the same, physicians should also focus on recreational athletes when screening for the Triad.

6.0 Conclusion

Athletes that perform at a higher level do not necessarily exhibit more symptoms of the Female Athlete Triad compared to recreational athletes. In fact, the results of this analysis indicate that recreational athletes may be at a similarly high risk for the Female Athlete Triad as their elite NCAA counterparts.

Further research on this condition could increase awareness of it and allow doctors and other healthcare professionals to screen for it in all active individuals. The increase in awareness could help with treatment in those that already suffer from the Triad, but also prevent the syndrome in many others.

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8.0 Certifications

STUDENT

Certification

The Student, Teacher and Scientist Certifications are the last pages of the research paper.

Student Name: Julia Lucarelli School Name: Briarcliff High School

Please be as specific as possible in answering the following questions.

1. What steps led you to your hypothesis (where did you get the idea for your research)?
   My mentor provided me with the data set that I used for this research and asked me to develop my own hypothesis from the data. I read through the data to see what questions it could potentially answer and eventually developed it into my research.

2. Where did you conduct the major part of your work (home, school, other institutional setting, university lab, medical center, etc.)?
   The major part of my work was completed at home.

3. If you worked in an institutional setting, did you work on your project as part of a team/group? If YES, who was on the team (students, adult researchers, etc.) and what was your role?
   I did not work in an institutional setting.

4. Describe the parts of the research you did on your own and where you received help (literature search, hypothesis, experimental design, use of special equipment, gathering data, evaluation of data, statistical analysis, conclusions and preparation of written report (abstract and/or paper).
   I compiled many articles to create the introduction/review of literature and did a statistical analysis of the data provided to me by my mentor. I also developed the research question and hypothesis from this data with the aid of my mentor. I wrote the paper/abstract myself.

5. If this is a continuation of an investigation that was previously submitted to a Sub-Regional JSHS describe how you have expanded your investigation?
   This is not a continuation project.

Student Signature (hand written) Julia Lucarelli Date 11/22/20

SCIENTIST MENTOR

Certification

The Student, Teacher and Scientist Certifications are the last pages of the research paper.

Student Name: Julia Lucarelli

School Name: Briarcliff High School

Your sharing of information reflects strongly on the student's performance.

1. State the origin of the project idea: Was it an assignment, chosen from a list of possibilities, the student's suggestion, or did it arise from discussion, continuation of previous work?
The project was born out of Julia's interest in the Female Athlete Triad. She worked with an existing data set to develop her particular research question, protocol and analysis.

2. Did the student work on the project as a team member? If yes, please state the make-up of the team; i.e., whether they were students, professional researchers, etc. Please describe the student's role on the team.
She primarily worked with myself and her science teacher. She had some limited interaction with research staff in my department.

3. Estimate the student's level of dependence (0%) versus independence (100%) on each part of the project listed below. Example: For a student on a three member team who worked as a fully participating member, the answer would be 30-35%.

Experimental design	80	%	Gathering data	100	%
Choice of techniques	50	%	Evaluation of data	80	%
Use of special equipment	n/a	%	Results/discussion	90	%
Construction of equipment	n/a	%			

4. How many weeks was the student's research project at your institution? Intermittent

5. Indicate whether or not the student received a salary or other compensation for this research

☐ yes ☑ no If yes - dollar amount

6. Other comments
Julia has done an excellent job on this project. She has demonstrated dedication, follow through and autonomy.

Supervising Scientist: Ellen Casey, MD Email: caseye@hss.edu

Affiliation: Hospital for Special Surgery Phone: 212.606.1149

Signature (hand-written): Ellen Casey Date: 11/23/20

TEACHER

Certification

The Student, Teacher and Scientist Certifications are the last pages of the research paper.

Student Name: Julia Lucarelli

School Name: Briarcliff High School

Specific comments will help judges understand the student's motivation, independence, overall performance and your input in the selection process of this student's research.

1. **Originality, Motivation, Creativity, Ingenuity**: Discuss the student's role in identification and selection of the project; where he/she received help; i.e., literature search, hypothesis, experimental design, use of special equipment, gathering data, evaluation of data, statistical analysis, conclusions and preparation of written report – abstract and/or paper.

Julia conducted a review of literature and received pre-collected data from her mentor. She developed the hypotheses and research question with her mentor's aid. Julia learned about the statistical tests on her own so that she could analyze the data and write the discussion and conclusion for her paper, with minor edits by her mentor.

2. **Initiative:** The student's role if this was a team project, the nature of that team, i.e., other participants and the student's role on that team.

This was not a team project.

3. **Other comments**: Regarding the student's investigation, independence, overall performance and motivation. This is your opportunity to give judges a ranking of your student versus other students.

Julia is very diligent and independent. When faced with the statistical analysis, Julia opted not to ask for help, but researched statistical methods on her own and taught herself about significance tests. She is a highly motivated student with a very bright future in the STEM world.

Teacher Name: Annmarie O'Brien

Signature (hand written) Annmarie O'Brien Date 11/17/20

9.0 Acknowledgments

I would like to thank my mentor, Dr. Ellen Casey for all of her assistance and guidance through this research project. I would also like to thank my parents and teachers that have supported me through my time as a Science Research student.