

Prevalence of Low Energy Availability in Collegiate Female Runners and Implementation of Nutrition Education Intervention

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Abstract

Objective: This study examined the prevalence of low energy availability in a sample of female collegiate athletes (N=25) then delivered nutrition education related to the female athlete triad and assessed change in knowledge and dietary behaviors.

Methods: Average energy intake was assessed pre- and post-education using Automated Self-Administered 24-Hour Dietary Recalls. We assessed body composition with multiple-site skinfold measures. Energy expenditure was assessed with accelerometers and a physical activity diary over a 3-day period. A 73-item questionnaire was used to assess knowledge and behavior changes.

Results: At baseline, 92% had an index of energy availability <45 kcal/kg of fat free mass/day. 40% of participants were amenorrheic, and 32% had a history of stress fractures. There was an increase in summed nutrition knowledge, post-nutrition education (p=0.001), but no increase in caloric intake (p=0.979).

Conclusion: Low energy availability was common in this sample of female collegiate track athletes, but did not improve with a targeted intervention.

Keywords: Sports nutrition; Female athletes; College; Female athlete triad; Intervention

Introduction

Physically active females, especially those who participate in sports that may place an emphasis on being thin, may restrict their dietary intake to maintain a low body weight [1]. Many athletes are unaware of the amount of energy needed to support basic physiological functions as well as high levels of physical activity. These physically active females, in sports with pressure to be thin are at an increased risk of developing components of the female athlete triad (Triad) [2-5]. One component of the Triad is low energy availability (EA), which is the condition of consuming fewer calories than needed [6]. The other two components, menstrual dysfunction and low bone mineral density (BMD), are consequences of the condition of having low EA [6].

Low EA is a modifiable risk factor and contributes to decreased physical performance; independent of the consequences related to menstrual dysfunction and bone and can negate the effects of physical training [3-7]. Low EA can contribute to both menstrual dysfunction and low BMD [3]. EA is the amount of remaining dietary energy to support physiological functions in the body after energy has been expended through physical activity [6]. This EA is converted to an Index of EA which is then interpretable against cut points to assess risk for the Triad.

The condition of low EA can be operationalized using the index of EA developed by Ihle and Loucks [8]. The EA index is defined as caloric intake minus exercise energy expenditure (kcal) divided by kilograms (kg) of fat free mass (FFM) per day [6]. An EA index less than 45 kcal/kg of FFM/day [9] has been associated with physiological changes to reduce the amount of energy used for reproduction and other physiological functions as an attempt to restore energy balance [10]. When caloric intake is below an index of EA of 30 kcal/kg of FFM/day in controlled laboratory settings, significant negative changes in reproductive function [11], and metabolism and bone [8] occur to provide an energy balance as the body is placed in survival mode [9].

Women who are physically active should seek to be at or above 45 kcal/kg of FFM/day to ensure they have adequate EA for healthy physiological functions [10]. Low EA must be corrected by increasing dietary intake and adjusting physical activity expenditure [6]. Improving EA is central to preventing menstrual dysfunction and low BMD among female athletes at risk for the Triad. The existence of any one Triad component can be detrimental and should prompt an investigation for the other Triad components [6]. The 2014 Female Athlete Triad Coalition stresses the importance of an early intervention to prevent the progression of more serious endpoints that include: subclinical eating disorders and low EA, amenorrhea and osteoporosis [6]. Early intervention is necessary to prevent the progression of the Triad and the development of eating disorders [6].

Positive correlations have been observed between dieting behavior and general nutrition knowledge in female athletes [12,13] however, few studies have assessed the effect of nutrition education in female collegiate athletes. In a study using the Eating Attitudes Test-26 (EAT-26) which is used to determine risk for disordered eating, it was observed that the level of nutrition knowledge that an athlete possessed had a positive influence on their eating behaviors [14]. Another educational intervention study conducted by Zawila, et al. [15] concluded that female athletes either do not have adequate nutrition knowledge, or they simply choose not to comply with the knowledge they possess. Zawila, et al. [15] also stated that the female athlete may be receptive to nutrition education, and that the potential for behavior change toward better eating habits may exist.

The objectives of this study were to examine the prevalence of low EA and other risk factors of the Triad in a sample of collegiate female athletes and then deliver an education intervention to assess change in knowledge and dietary behaviors. The results of this study will be used to guide the development of future intervention programs to influence dietary behavior change in athletes at risk for the Triad.

Materials and Methods

This study was reviewed and approved by the USU Institutional review board. A total of 27 out of 35 (77%) female runners from a Division I track and field team consented to participate. Two athletes dropped out of the study, and the remaining 25 of the 27 (93%) athletes completed all of the study assessments. Female distance runners, sprinters, hurdlers and jumpers were recruited. Other track and field participants were excluded because runners have an increased risk for food restriction and other factors that put them at a higher risk for the Triad [5].

Participants underwent body composition measurements, completed two separate 3-day diet recalls before and after the nutrition education was provided, and they completed a pre/post knowledge questionnaire related to general nutrition and the Triad, before and after the nutrition education was provided. Nutrition education was provided for six weeks. Participants attended once a week on Tuesdays after practice for 30 minutes in a classroom setting, while a registered dietitian or dietetic undergraduate student presented.

Anthropometrics

Height was measured to the nearest centimeter with a portable stadiometer (Charder HM-200P, Taiwan). Participants were instructed to remove shoes and socks for height measurements. Weight was measured with a BODPOD scale to the nearest 0.01 kg, (Body Composition System; Life Measurement Instruments, Concord, CA) with minimal, tight-fitting clothing consisting of a sports bra and spandex bottoms.

Body composition

A 3-site skinfold (SKF) at the abdomen, thigh, and triceps [16] was measured to calculate the FFM of each participant. SKF measurements were taken on the right side of the body with a calibrated Lange Caliper (Cambridge Scientific Industries, Cambridge, Md.). According to the specifications of Evans and colleagues [16], SKF measurements were completed by a trained researcher. The 3-site SKF equation used was: Percent body fat (BF) = $8.997 + 0.24658^*(3SKF) - 6.343^*(gender) - 1.998^*(race)$, with gender coded as female = 0 and male = 1, and race coded as white=0 and black = 1 [16]. This 3-site equation was

developed with female collegiate athletes and was validated against a 4-component reference model, which is the criterion measure in elite collegiate athletes [16].

Questionnaire: A questionnaire was completed before and after nutrition education was provided to assess change in nutrition related knowledge. The questionnaire contains 73 questions assessing demographics, prior nutrition knowledge, familiarity with the Triad, and questions about body-image and sources of external pressures to be thin.

Triad knowledge was assessed using a modification of questions used by Pantano [17]. Three questions were also added specific to EA. Stress fracture and menstrual history questions were adapted from a screening tool developed by Beals and Hill [18] that has previously been used in the collegiate athlete population.

Body dissatisfaction and body distortion were assessed using a body mass index (BMI) –based silhouette matching test (SMT) which was created and validated by Peterson, et al. [19]. The BMI-SMT is a 27-item interval scale that references four gender-specific BMI based silhouettes [19]. Each box along the scale represents a BMI score from 14-40. Participants select one BMI-silhouette that they feel best reflects her current body image and her ideal body image [19]. The BMI-SMT Test is validated as a measure of body image perceptions, as well as in estimating body weight and BMI scores [20]. Body dissatisfaction scores represent the level of change an athlete would prefer in their body to achieve their Ideal BMI and is calculate as perceived ideal BMI – perceived current BMI [19].

Risk for disordered eating was assessed using the Eating Attitudes Test (EAT-26). EAT-26 has been used to assess eating disorder risks in many populations, including athletes [21,22]. As recommended by the developers of the EAT-26 tool, scores of 00320 or above on the Eat-26 assessment indicated eating disorder behaviors [23]. Scores falling below 20 were assessed as low risk for eating disorder behaviors [23]. Risk for disordered eating was determined by an EAT-26 score >20, along with a low BMI (<18.5) and any positive answers to certain behavioral questions [24] about the occurrence and frequency of bingeing, vomiting, use of laxatives or diuretics, excessive exercise for weight loss, and the loss of 20 pounds or more in the last six months [25].

Diet

Dietary recalls were completed over a 3-day period by each participant using a web-based automated self-administered 24-hour recall (ASA24) tool to record their intake. The 3-day diet recall included two weekdays and one day from the weekend to capture an average of participant's 'usual' intake. This method is based on the USDA's Multiple-Pass Method which has been validated and has been proven to be accurate in estimating mean total energy in adults [26]. The ASA24 website guides participants through a 24-hour dietary recall via an animated penguin to prompt the participant of any forgotten snacks, drinks or additives [27]. There was a five week period between the first and second 3-day dietary recalls.

Exercise

Energy expenditure was recorded for a 3-day period using an Actigraph GTX3 triaxial accelerometer (Pensacola, FL, USA). Participants recorded energy expenditure using the accelerometers for the 3-days that their coach believed to be the 'peak' training period

during the 6 weeks of our study. The 3-days that we recorded energy expenditure do not directly align with when participants recorded their dietary intake due to this scheduling by the coaches. Triaxial accelerometers worn for at least three days have shown an objective measure of physical activity among free-living people [28-30]. The validity and reliability of the GTX3 has been shown to be similar to other accelerometer devices in the laboratory in measurements of daily activities [31]. The accelerometer records integrated acceleration information in raw counts, which provide an estimation of intensity of the vertical, anteroposterior and mediolateral body movements [32,33].

An accelerometer is a small, light electronic device that was worn on a belt around the participant's waist. Participants were instructed to wear the accelerometer on the right side of her body, just above the hip [30]. Participants wore the accelerometer during waking hours for three consecutive days. Participants were instructed to only remove the accelerometer when they showered and slept. Energy expenditure was calculated using raw counts or arbitrary units of measurement converted to energy expenditure using the Williams Work-Energy equation [34].

Because accelerometers do not take into account any additional weight load, or movement up an incline, a physical activity diary was kept by participants and additional activities of this nature were analyzed for exercise energy expenditure according to the 2011 Compendium for Physical Activities [35]. This method of using the Compendium of Physical Activities is recommended by the 2014 Female Athlete Triad Coalition [6] to calculate exercise energy expenditure according to: $\text{kcal} = \text{metabolic equivalents of task} \times \text{weight of athlete in kilograms} \times \text{duration of activity in hours}$ [35].

Index of EA

EA was calculated by subtracting average daily energy expenditure from the average daily energy intake and was then converted to an index of EA by dividing EA by kg of FFM [6]. The index of EA can be compared to cutoff scores to assess risk for the Triad. The following cutoff scores were defined by Loucks and Thuma [11] consuming ≥ 45 kcal/kg of FFM/day as being in energy balance, consuming < 45 kcal/kg of FFM/day is below energy balance where negative physiological effects may begin to occur and ≤ 30 kcal/kg of FFM/day as restricted energy intake where hormone pulsatility has been observed to be abruptly disrupted.

Description of Nutrition Education

Participants were invited to attend six interactive sessions of nutrition education focusing on aspects of the Triad which were taught by either an undergraduate dietetic students or a Registered Dietitian from Utah State University. The nutrition education sessions were delivered in thirty minute increments in a classroom setting once a week after participant's completed track and field practice. The nutrition education intervention curriculum was a modification of curriculum for high school athletes [36]. Session 4 which discusses the importance of a healthy body image was a modification of previously developed curriculum by Becker, et al. [37]. Becker, et al. [37] focused their approach on an intervention towards a healthy body image rather than for athletes to seek for a thin body. Two additional sections were added to the original curriculum to explain the body composition tests the athletes would undergo, and an introduction to the study for participants. Education was presented via a powerpoint presentation

with the opportunity for discussion and questions following the presentation. Refer to Table 1 for an outline of the curriculum that was provided in our nutrition education sessions.

Session	Curriculum
1	Introduction to Triad/energy balance/ tracking diet/portion sizes
2	Triad: risk factors, side effects
3	Energy and bone health
4	A focus on health: positive body image, eating disorders, sports nutrition
5	Body composition
6	Introduction to the study and activity monitors

Table 1: Nutrition Education Intervention Outline

Data Analysis

SPSS software was used to complete the statistics for this study. Crosstabs using chi-squared were used to examine associations between categorical values. McNemar's statistic was used to compare differences between pre- and post- tests in categorical data, including comparing the proportion of athletes answer to individual questions as correct or not correct. Paired t-tests were used to assess differences between caloric intakes, naming the three components of the Triad, and to compare the summed change in nutrition knowledge as well as other continuous factors that were measured from the baseline and after nutrition education. Answers to individual knowledge questions were coded as "Correct" answer =1 and "Incorrect"/"I don't know" =0. Scores for individual questions were summed to obtain a nutrition knowledge score. We also ran sub-analyses by event and year in school against EA, and body dissatisfaction. Participants were classified into three categories based on index of EA cutoffs, ≤ 30 kcal/kg of FFM/day, < 45 kcal/kg of FFM/day, and ≥ 45 kcal/kg of FFM/day.

Results

96% (24 participants) of participants were white and 4% (1 participant) were African American. Participant's demographics are shown in Table 2. The mean age for the sample was 19 years.

Energy availability, menstrual dysfunction and history of stress fracture

The mean caloric intake was 2171 calories. The mean index of EA was 30.8 kcal/kg of FFM/day. A large percentage, 92% (23 participants) were below 45 kcal/kg of FFM/day, and 52% (13 participants) were below 30 kcal/kg of FFM/day. Average EA was 1275 ± 733 kcal. No differences were observed between athletes in event groups. The mean index of EA for distance runners was 26.8 ± 16.2 kcal/kg of FFM/day and the index of EA for sprinters was 30.1 ± 14.6 kcal/kg of FFM/day. ($P=0.578$) According to the questionnaire, 40% (10 participants) of the female athletes were amenorrheic, having gone longer than three months without menstruating. 36% (9 participants) were also very irregular in their menstruation, with their menstruation being off by more than 10 days from their anticipated start date. Two participants reported that they were currently using oral contraceptives, but that their menstruation was regular preceding the use of contraceptives earlier this year, and these individuals were not at

risk for other factors associated with the Triad. 32% (8 participants) reported having a history of one or more stress fractures.

BMI-SMT body dissatisfaction

Pre-intervention mean body dissatisfaction scores showed a positive increase from -1.74 ± 2.17 to -1.13 ± 1.10 after nutrition education ($p=0.614$). The category of female athletes with an Index of EA that was <30 kcal/kg of FFM/day had 11 participants (44) with a body dissatisfaction score ≥ 1 . In the second category, the female athletes with an Index of EA ranging from 30 kcal/kg of FFM/day to 45 kcal/kg of FFM/day had five participants (20%) with a body dissatisfaction score ≥ 1 . In the final category where index of EA was >45 kcal/kg of FFM/day there was one participant (4%) with a body dissatisfaction score ≥ 1 .

	Baseline n=25 Mean \pm SD
Age, yrs	19.5 \pm 1.8
Height, cm	168.8 \pm 4.7
Weight, kg	61.1 \pm 6.9
Body Fat percent	22.3 \pm 3.3
Desired body weight change in kg	3.1 \pm 5.2
BMI ¹	21.4 \pm 1.8
Daily exercise expenditure, kcals	711.5 \pm 524
Lean body mass, kg	47.4 \pm 4.8
EA ²	30.7
EA <30 kcal/kg of FFM/day	52%
EA <45 kcal/kg of FFM/day	92%
Grade	
Freshman	44.4%
Sophomore	29.6%
Junior	7.4%
Senior	18.5%
Ethnicity	
White	96%
Black	4%
Event	
Sprint	54.8%
Distance	45.2%
¹ Weight in kg/ height in meters ²	
² kcal/kg of FFM/day	

Table 2: Demographics

Pre- nutrition education intervention

Triad Knowledge/Questionnaire: 76% (19) of participants reported having some degree of previous formal nutrition education in their life. There were no guidelines as to what was viable as nutrition education; this was left to participant's discretion. 60% (15) of participants had never heard of the Triad prior to this study. Only 8% (2) could name all three components of the Triad prior to nutrition education (low EA, low BMD, and menstrual dysfunction). 24% (6) could name at least two of the components of the Triad. The most commonly missed question was, "Each athlete has a set body fat percentage they should aim for to maximize their athletic performance", to which the correct answer was false. Only 16% (4) of participants answered this question correctly.

Post-nutrition education intervention

Change in Knowledge/Questionnaire: Change in the percent of participants that answered individual nutrition knowledge questions correctly is shown in Table 3. There was an increase in summed nutrition knowledge scores from the pre-intervention questionnaire to the post-intervention questionnaire ($p=0.001$). The mean for the summed nutrition knowledge scores before the nutrition education intervention was 12.8 ± 2.5 . The mean for the summed nutrition knowledge scores post-nutrition education intervention was 14.8 ± 1.8 .

Several of the observed changes in the percent of participants answering nutrition knowledge were unexpected. 'Exercise/training too much could cause me to lose my period' dropped from 100% (25) to 96% (24). It was also concerning that 40% (10) indicated that there is a set body fat percentage necessary for optimal performance, and 64% (16) thought skipping a period was normal. 52% (13) of participants could list at least two components of the Triad after nutrition education, however, only 48.5% (5) of these listed low EA as one of these components. Not unexpectedly, the response to Triad question "Skipping my period is my body's way saying I'm training too hard" had a significant change after the nutrition education intervention as it increased from 40.7% of participants answering the question correctly initially, to 62.5% of participants answering it correctly after the intervention ($p=0.016$).

Diet

Average daily baseline caloric intake from the 3-day diet record for participant's was 2211 ± 582 kcals. After nutrition education was provided, average daily caloric intake from the 3-day diet recall was 2208 ± 598 kcals ($p=0.979$).

EAT-26

All participants scored <20 on the EAT-26 assessment which indicating none were screened at risk for eating disorders according to the EAT-26 recommendations. No participant answered affirmatively to the behavioral questions regarding disordered eating. The average score for the Eat-26 assessment was 5.9 ± 4.6 .

EAT-26 scores dropped significantly following the nutrition education intervention from 5.1 ± 3.1 to 2.6 ± 2.3 ($p=0.003$).

Body composition

Average Body Fat (BF) percentage analyzed using the 3-site skinfold method was 22.3% ± 3.3%. Average FFM in kg was 47.4 ± 4.8. We observed a difference between the average BF% between sprinters and distance runners. The average BF% for sprinters was 21.2%, and for distance runners BF% was 24% (p=0.029).

	Pre-interventi on don't know	Correct	Post-interventi on don't know	Correct	P-value
Triad Knowledge					
Age when females build the most bone (13-18)	0%	44.4%	0%	72%	0.125
Skipping my period can make my bones weak. (True)	14.8%	70.4%	0%	95.8%	0.125
Stress fractures occur most often in girls that skip their period. (True)	22.2%	63%	0%	95.8%	0.125
Not eating enough could cause me to lose my period. (True)	7.4%	88.9%	0%	100%	0.250
Teenagers with weaker bones will likely still have weaker bones as adults. (True)	11.1%	81.5%	0%	95.8%	0.250
I'm not old enough to have weak bones (False)	3.7%	92.6%	0%	95.8%	0.500
Skipping my period is my body's way of saying I'm training too hard. (True)	25.9%	40.7%	12.5%	62.5%	0.016
How much I eat does not affect my bone health. (False)	11.1%	85.2%	0%	91.7%	>0.99
I feel that skipping my period while playing sports is normal. (False)	7.4%	48.1%	0%	76%	0.063
Exercise/training too much could cause me to lose my period. (True)	0%	100%	0%	96%	>0.99
¹ Correct answer					

Table 3: Changes in Triad Knowledge and sports nutrition knowledge (n=25)

Discussion

A total of 92% of participants had EA ≤ 45 kcals/kg of FFM/day. This is consistent with a study by Barker, et al. [2] concluding that the majority of female endurance athletes (88%) were below this same threshold. 52% of participants had an index of EA<30 kcals/kg of FFM/day, a level at which menstrual dysfunction may occur [11] and which may also result in increased bone turnover, putting these athletes at an increased risk for the Triad. No athletes were at risk for disordered eating, which contrasts the 15% reported by Beal and Manore [4].

The mean daily index of EA was 30.8 kcals/kg of FFM/day which is far below the optimal level of 45 kcals/kg of FFM/day. There is a great need for an intervention and early prevention in this population.

Around two thirds of our population had some form of menstrual dysfunction. These results were higher than other similar studies had reported. A study by Beals and Manore [4] found that menstrual irregularity was reported by about one third of female athletes participating in their study, and that only 6% self-reported that they were amenorrheic [4], compared to 40% in this study. Another study by Beals and Hill [18] found that menstrual dysfunction was reported by 26% of athletes, again much lower than was seen in this study.

In the current study, 32% of participants reported having a history of one or more stress fractures. In the study by Beals and Hill [18], 18.75% of athletes reported having a history of stress fractures. These findings indicate that risk markers for the Triad are higher in our participants than was found in other studies.

Although we observed an increase in nutritional knowledge when knowledge scores we resumed over all questions, we did not observe a change in their eating behavior. Average daily baseline caloric intake from the 3-day diet recall for participant's was 2211 ± 582 kcals. After nutrition education was provided, average daily caloric intake from the 3-day diet recall was 2208 ± 598 kcals (p=0.979). Another nutrition education intervention study for collegiate female athletes conducted by Abood, et al. [38] had similar results, (n=15) observing an increase in nutrition knowledge from pre-test to post-test, while the mean caloric intake pre-test was 1969 kcals and post-test was 1974 kcals with little change after nutrition education. This indicates that female athletes increased nutritional knowledge, but failed to change their dietary behaviors. This is consistent with a study by Zawilla, et al. [15] where they concluded that female athletes may have the nutrition knowledge necessary for correct eating patterns, but choose not to comply with the knowledge they have for other unknown reasons. Abood, et al. [38] concluded that to bring about more positive changes in dietary behavior, the nutrition intervention needs to focus on opportunities to practice dietary skills and other barriers to making dietary behavior change may also need to be addressed.

Of the 52% of participant's who were able to name two components of the Triad, 51.5% of them did not include EA as one of the components of the Triad. It was the component that was most commonly left out, even though it was the most stressed component in the nutrition education intervention. From this we can conclude that more time needs to be spent focusing on EA and its effect on the Triad when a nutrition intervention is provided.

Collegiate athletes are limited in the time that they have available to spend on their dietary behaviors, which then requires that an intervention be efficient [38]. Barker, et al. [2] discussed that nutrition intervention programs should focus on both behavioral and

psychosocial changes alongside nutritional awareness. Barker, et al. [2] concluded that future research should also focus on measurements to identify problems regarding poor nutritional choices despite adequate nutrition knowledge. Researcher Julie Waldrop [39], states that changing the way an athlete thinks about her body, the way she trains and how she eats is a challenge. Providing education is likely not enough. Psychological therapy, more specifically cognitive behavior therapy has been shown to be the most effective therapy for eating disorders and challenges the negative thought patterns about one's self and the world in order to remove the negative, unwanted patterns of behavior [39].

This study has a small sample size, which may have limited results. It was difficult to persuade athletes to attend each nutrition education session, and not all participants attended every session. It would be helpful to educate coaches as well as athletes so that the coaching staff would support the study and their athletes. There is always a risk with self-report dietary recalls that participants will forget some of the items they consumed each day or that they will misrepresent what they actually ate by choosing incorrect serving sizes, etc. This ASA24 dietary recall is validated and has been proven to accurately estimate average daily intake when used correctly, but was time consuming and participants seemed to lose interest the second time they completed their dietary recall. This may be improved by using a simpler method that does not take as long, or if participants could enter foods in real time as they consume them. Other limitations of this study include only using three days for the dietary recall, and the use of accelerometers for exercise energy expenditure due to the risk that a participant may not use it as specified.

Strengths of this study include measured energy expenditure. Body composition measures were completed using a validated method specific to this population. This allowed us to look at index of EA on an individual level for each participant. We had good compliance from the participants, and were able to work with a population that has a high risk for the Triad while they were in season to get a more accurate view of their EA on a day to day basis while in training and competition.

In conclusion, this study showed that there is a high prevalence of risk factors in this population of collegiate female athletes, and that early prevention of the Triad, and an aggressive intervention for those already at risk is necessary. Nutrition education provided in a classroom setting increased nutrition knowledge scores among participants, but did not change dietary behavior. A change in behavior is necessary to decrease the risk of short and long term consequences associated with the Triad.

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