The Prevalence of the Female Athlete Triad In Recreational Endurance Runners

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Prevalence of the Female Athlete Triad in Recreational Endurance Runners

Introduction

The female athlete triad (FAT) is of concern for women who are very physically active or engaged in intense athletic training and competition. While the original triad was defined by disordered eating (anorexia), irregular menstrual function (amenorrhea), and low bone mineral density (12), the current paradigm uses low energy availability with the same menstrual and bone perspectives. These components can further lead to serious health risks including development of eating disorders (1-17), osteopenia or osteoporosis (1, 2, 4-7, 11, 12, 16, 18-27) and functional hypothalamic amenorrhea (1, 2, 4-6, 11, 12, 16, 25, 28-36). The purposes of this thesis are to

1) explore the recent literature on the female athlete triad,
2) explain in detail the prospective study *The Prevalence of the Female Athlete Triad in Recreational Endurance Runners*,
3) discuss how this study will vastly improve what is already known about the female athlete triad and
4) outline a follow-up study that will evaluate treatment methods for the female athlete triad.

Although the presence of the female athlete triad has been established (4, 18, 28, 37) there is still controversy about its existence (38-40). Some wonder why the female athlete triad is being publicized in a time when obesity is plaguing the country (39), do not see the prevalence of all three components at once except in a few rare cases (38), or do not see the difference in the prevalence of the triad as any different from a control group (40). These doubts have been rebutted by prominent researchers (41, 42) and the evidence for the triad in past research will be demonstrated in my thesis as well.

<u>FAT Components and History</u>

Low Energy Availability

FAT was formally delineated in 1993, and energy imbalance was included as a spectrum of disordered eating (118). In 2007, the American College of Sports Medicine published new guidelines for the female athlete triad that re-defined low energy availability as the likely initiator for development of the female athlete triad (12). Before the new guidelines, researchers rationalized that menstrual disorders and low bone mineral density were the direct result of intense training (43, 44), caloric restriction (45), or moderate amounts of both (7, 46). Dueck *et al* hypothesized that a chronic energy drain was to blame for the effects of the FAT due to the additional stresses placed on the body (31). The current model proposes that the energy deficit caused by low caloric intake paired with high energy expenditure causes changes in the metabolism at the hypothalamic-pituitary level, increasing the release of cortisol, reducing the amount of thyroid hormone and lowering the ovarian hormones of the female athlete. The changes observed in the hypothalamic-pituitary axes are physiological adaptations in order to survive the caloric restriction. Essentially, the female athlete suffering from the triad has a hormonal profile of a post-menopausal woman, thus experiences the same bone health risks (31).

The concept of low energy availability encompasses elements of these past research models such as low caloric intake, high energy expenditure, and energy drain as well as more recent research on the triad. Loucks describes low energy availability as energy expended through physical activity subtracted from the energy taken in through nutrition and then divided by the lean body mass of the athlete (32, 41, 43, 45-54).

> Energy Availability = (Dietary Energy Intake - Exercise Energy Expenditure) / Fat Free Mass

Energy availability less than 30 kcal/kg of lean body mass is suggested to be too low to support the hypothalamic-pituitary axes. (54). When an athlete reaches below this energy threshold, reproductive function and bone formation are impaired from the hypothalamic level (55). Other consequences of low energy availability include a decreased immune response, increased risk injury, increased time for recovery, and decreased performance (56). The American Dietetic Association, Dietitians of Canada, and ACSM recently released a position statement regarding proper nutrition related to athletes, and the suggestions include concern for avoiding the triad (57). The position highlights the optimization of physical activity, athletic performance, and exercise recovery by proper nutrition. An emphasis of energy and macronutrient to maintain body weight, replenish glycogen stores, build and repair tissue, produce essential fatty acids, and maintain weight and energy needs is discussed by the authors as a means to avoid unnecessary weight loss and preservation of lean mass in athletes (57).

Low energy availability (LEA) affects menstrual and bone status through a cascade of events. LEA is sensed by the hypothalamus which influences the adrenal, ovarian, and thyroid axes of the pituitary gland (27, 51). The primary cause of menstrual dysfunction in athletes is disrupted pulsatility of gonadotropin-releasing hormone (GnRH) from the hypothalamus, which causes disruption in the pulsatility of luteinizing hormone (LH) from the pituitary. LH is then responsible for ovarian production of estrogen. When LH pulsatility is disrupted, estrogen production wanes, and both menstrual status and bone mass are compromised. A study by Loucks *et al* demonstrates that LH pulse frequency was reduced by 10% ($p<0.01$) during waking hours in exercising women as compared to sedentary controls (50). Relative to menstrual status, amenorrheic athletes had fewer LH pulses ($p<0.05$) in a 24-hour period than eumenorrheic athletes (51). Loucks has also demonstrated the influence of LEA on the thyroid axis in a prospective study of 27 untrained women. Women receiving 19.0-24.0 kcal/kg of lean body mass had a 16% lower T3 level as compared to women receiving 30 kcal/kg of lean body mass ($p<0.00001$) (50).

Of course, it stands to reason that athletes with formal eating disorders, such as anorexia or bulimia, are at an increased risk for LEA (12,42, 58), and the cascade of sequelae. Female athletes involved in sports emphasizing a thin physique may be at a greater risk for engaging in disordered eating than their non-athletic counterparts (1, 2, 4, 8, 12, 23-25, 33, 36). The prevalence of eating disorders in leanness sport has been showed by Torstveit *et al.* in Scandinavian national level athletes using clinical interviews (17). The athletes (n= 186) ranged in age from 13-39 years and were compared with a control group of similar age. It was concluded that 46.7% of the athletes participating in sports emphasizing leanness had clinical eating disorders, while only 19.8% of the participants in non-leanness sports were diagnosed with clinical eating disorders. An increased incidence of disordered eating has also been found in 1145 college athletes from various sports, (9), 181 adult elite middle and long distance runners (60), and 300 Norwegian female football players. Other factors have also shown to create a greater risk for disordered eating in female athletes such as excessive physical activity (13) and young age of athletes (59). Data on the high prevalence of DE in leanness sports is of special concern in our research because runners are often encouraged or motivated to keep a lean, linear physique to aid with speed and agility (17).

Menstrual Disorders

Menstrual disorders have long been recognized in female athletes (32). It was once thought that the "stress" of exercise was responsible for these disorders, but the paradigm shift identifies low energy availability as the root cause of disrupted reproductive function in athletes (53). Factors that increase the prevalence of menstrual disorders include aesthetic, endurance, and weight class-sports, athletes of a younger age, increase of years training, and lower body weights (34). Effects of menstrual disorders range from infertility, low bone mineral density, endothelial-dependent vasodilation (61), and decreased skeletal muscle metabolism (61, 62).

The two easily identifiable classes of menstrual dysfunction often considered in triad research are amenorrhea (AM) and oligomenorrhea (OM). AM is the absence of menstrual cycle for at least three months (60, 63) or three or fewer cycles per year (3); OM is defined as menstrual cycles that are at intervals ranging from 35 to 90 days (29, 64, 65) or as four to nine cycles per year (60, 63). Eumenorrhea (EU) is 10-13 menstrual cycles per year or where cycles are less than 35 days long (63, 65). The new ACSM position stand also includes luteal suppression and anovulation as subsets of menstrual dysfunction which are often not as apparent to the athlete, but have a negative influence on BMD (12). Luteal phase defects and anovulation have been shown in endocrine measurements in nearly 80% of regularly menstruating female recreational runners ($n=35$, $p<0.01$) (66). The percentage of women in the general population with menstrual dysfunction ranges from 2-5% (65, 67), while 6-79% of female athletes have irregular cycles (20, 65, 67). It has been shown that amenorrheic athletes restrict energy availability by an average of 67%, which can lead to impaired reproductive capabilities and compromised bone formation (68).

The lack of EU menstrual status is likely the most visible sign to an athlete that she may be at risk for the FAT. Often times, coaches, athletes, and parents are not educated about the female athlete triad and believe that the absence of menses is a natural side effect of intense training (2, 7, 67, 69-71). Noticing a menstrual disorder and seeking medical help is an important step in preventing a permanent decrease in bone mass (72).

Low Bone Mineral Density

Low bone mineral density (BMD) is the third component of the FAT and, as discussed, is caused by the chain of events resulting from low energy availability and resultant drop of estrogen in the female athlete. When energy availability is low, the body prioritizes expenditure and restricts the energy it spends on growth and reproduction, ultimately lowering the amount of estrogen produced (73). Estrogen suppresses bone resorption by inhibiting the work of osteoclasts, therefore athletes who demonstrate oligo- or amenorrhea (due to low estrogen) often have advanced bone resorption rates (31, 65, 67). Estrogen also augments bone density as it is needed to promote calcium absorption and deposition into bone (19). Due to the insufficiency of bone structure, the prevalence of stress fractures is much higher in women suffering from the female athlete triad (74). The occurrence of stress fractures in female collegiate athletes is twice that of their male counterparts (4). Bone fragility and decline is ironic and of special concern in runners since female athletes are assumed to normally have higher BMD's than the general population due to the amount of weight-bearing training (66, 75, 76).

There are several factors proposed to impact the bone mineral density of athletes, including the weight bearing nature of the sport, (19, 77, 78), athlete age (73, 79), body composition (80), and hormones (23). In a study of 109 elite endurance runners, increased running distance predicted low BMD ($p<0.01$) and higher body mass index predicted a higher BMD in females ($p<0.001$) (80). When athletes across different sports are compared, the BMD is shown to be lower in runners despite the weight bearing nature of the sport. In a study comparing the BMD of Division I gymnasts and cross country runners (n=26), the gymnasts had a higher BMD at all sites both preseason and during the competitive season ($p<0.05$) (77). Similarly, a study which compared females competing in collegiate gymnastics, softball, cross country, track, field, hockey, soccer, crew, and swim/dive (n=99) showed that the cross country runners had the lowest total body and site specific BMD ($p<0.01$) compared to all of the other sports (78).

The type of running may also play a role in BMD status According to a 12-month longitudinal study, power runners (sprinters, jumpers, hurdlers) had significantly higher BMD at the lumbar spine than endurance athletes (long and middle distance runners) (19). Age also predicts BMD where both ends of the spectrum are at increased risk for low bone mass. The adolescent athlete is at an increased risk due to 50% of all adult bone being gained between puberty and 18 years of age (73). Like all people, as athletes age, they have an increased risk for osteoporosis, not only due to the effects of menopause but also due to the fact that the BMD of the lumbar spine and femur declines with age (79). The loss of bone mass from the lumbar spine and femur was attributed to the relationship between age and BMD of these specific sites in a study of 903 moderately active females ages 20 and older (79).

Review of the Literature

There are several limitations of the current base of research concerning the female athlete triad. Research is focused more upon elite athletes or competitive athletes instead of the prevalence of the female athlete triad in *recreational* runners. The only study to focus on recreational runners was by DeSouza *et al*, and it focused only on aspects of GnRH and LH pulsatility (66). To date, no published research has effectively measured the prevalence of all three components of the FAT in a large-scale cross sectional study in recreational adults. Recent research in the field has instead focused on the relation of one component of the triad to the prevalence of another or the effectiveness of intervention for treatment of the FAT. The following list and review demonstrates the dyads investigated to date:

1. Relationship of menstrual irregularity (MI) to low bone mineral density (BMD)
2. Relationship of low energy availability (EA) to MI
3. Relationship of low EA to low BMD
4. The successes and limitations experienced in interventions

Our study will contribute to this literature by *simultaneously* looking at *all three* FAT components in adult female *recreational* endurance runners in a large scale cohort.

Relationship of MI to BMD

Multiple studies show that menstrual irregularity (MI) reported by female athletes is positively correlated to low BMD. An early study by Drinkwater *et al* set the stage for further research in the growing literature of the FAT (6). Twenty-eight women athletes were recruited, 14 AM and 14 EU. Both groups were matched for sport, training regimens, age, weight, and height. In each group, 11 of the athletes were runners and 3 were crew members. Dual-photon and single-photon absorptiometry were taken in all participants at the lumbar spine. Blood samples were used to measure plasma estradiol and progesterone levels. The AM group showed both lower estradiol and progesterone levels than the EU group (AM: 38.58 pg/ml and 1.25 ng/ml; EU: 106.99 pg/ml and 12.75 ng/ml). AM athletes also showed a significant reduction in BMD of the lumbar spine as compared to the EU group ($p<0.01$) (6). A host of more recent studies, both longitudinal and cross-sectional, have also shown positive associations between impaired menstrual function and compromised bone health.

In a cross sectional study designed by Christo *et al*, 21 athletes with amenorrhea (AM) , 18 athletes with eumenorrhea (EU), and 18 non-athletic females with normal menstrual cycles were assessed by DXA for bone mineral density. All participants were between the ages of 12-18 years of age, and DXA sites of interest were the whole body, hip and spine. Results showed lower z-scores at the spine and whole body for females with AM as compared to EU and control groups. The AM group also showed decreased hip BMD as compared to the EU group (20).

Specifically, different training distances of runners and the presence of menstrual dysfunction has predicted low bone mineral density. In a self-reported study by Mickelsfield of the Two Oceans Marathon involving both full and half-marathon runners (n=613), the full marathon runners had a higher incidence of self reported injury than the half marathon runners (21%, 14%, $p<0.005$) (25). The same study showed that irregular menstrual cycles were also highly correlated with increased bone injury ($r=.85, p<0.05$) (25).

EU athletes have been shown to have higher BMD than AM counterparts. Gibson *et al* focused on the BMD relationship to menstrual irregularity in elite female runners. The BMD of athletes was assessed by DXA at the proximal femur and total body, and results were compared with BMD of the general population for the same age. The BMD of the runners with AM was the lowest on average, and that of EU runners was highest. In fact, the BMD of runners with EU was greater than that of the control population, thus exemplifying the potential effects of weight-bearing training when partnered with apparently normal menstrual function (22). A similar study in Italy by Bertelloni also showed that EU female athletes who participated in load bearing sports had higher BMD than control counterparts (63). The effect of load bearing training could also explain the significantly lower leg BMD ($p<0.01$) of swimmers in data presented in a cross sectional study by Edwards (81), which analyzed site-specific BMD of athletes involved in cross country, track, swimming, field hockey, soccer, and crew. It is curious to note that runners in this study had the lowest BMD of whole body, spine, and hip ($p<0.01$). The degree of energy deficit due to the endurance nature of the sport and emphasis on leanness in runners may play a critical role in incidence of FAT (81).

Adolescent runners have also been proposed to have a higher incidence of the FAT due to impaired bone formation during a pivotal time in bone formation and consolidation. Barrack *et al* analyzed 93 competitive high-school female runners ages 13-18 in a cross-sectional study. The Eating Disorder Questionnaire (EDE-Q) was used to assess eating attitudes and behaviors, and menstrual status and history were self reported. DXA scan sites included total body, total hip, and spine. Z-scores were used to analyze bone mass relative to female age-matched controls (normative data). Results showed that nearly 12% of runners had a Z-score of -2, and, independently, 28% had a Z-score of -1, indicating a significant deficit in bone density. Overall, 25.8% of females reported menstrual irregularity. When BMD was assessed with menstrual irregularity, DXA results for BMD at the total hip and lumbar spine were lower in athletes reporting menstrual irregularity than those who did not. Similarly, z-scores for lumbar spine were lower in runners who reported menstrual irregularity ($p<0.05$) (18). These studies continue to emphasize the importance of a normal menstrual cycle as an indicator of bone health.

Okano *et al* focused on teenage runners to analyze the effects of exercise and amenorrhea on serum osteocalcin and calcitonin as markers of bone formation in eight runners. Four of the subjects were amenorrheic runners and were age matched controls with a higher weight. The results showed that osteocalcin and calcitonin measures in the amenorrheic group were significantly lower than the control group ($p<0.01$) (83). Though this study is biased due to weight differences, it could also be that the underlying energy restriction is responsible for all the differences, weight, menstrual status and markers of bone formation.

Elite adolescent runners were studied by Bonis *et al* to examine the correlation between menstrual disorder and bone mineral density. Twenty-eight adolescent elite cross country runners ages 15-16 years old (17 eumenorrheic, 11 amenorrheic) had BMD measured by DXA both preseason and postseason. Both groups had similar bone profiles at the preseason scan, with the eumenorrheic group having slightly higher (non-significant) BMD than the amenorrheic group. The eumenorrheic group had significantly higher BMD postseason than the amenorrheic group ($p<0.05$), showing that amenorrhea is highly associated with low BMD (60). Although there may be bias present due to weight differences between the athletes, the study shows that the EU group gained more bone during the course of the season than the AM group (60).

The effectiveness of oral contraceptives in preventing low BMD associated with irregular menstruation has also been reviewed. In a study by Cobb *et al* (2007), 150 female runners between the ages of 18 and 26 were assigned at random to be either on an oral contraceptive or a control for a period of two years. BMD of the participants was measured yearly by DXA. Stress fractures were self reported and confirmed by a physician. Oligo/amenorrheic runners who used OC consistently throughout the trial showed an improvement of about 1% in both spine and overall BMD, and the same gain was seen in runners who spontaneously gained their period during the trial. Independent of OC use, calcium intake and weight gain both showed gains in BMD. The conclusion of this trial was that oligo- and amenorrheic athletes should be advised to increase calcium intake and take steps to either increase caloric intake or decrease training in order to regain proper energy availability (75). The use of OC is often not implemented in the athletic setting because of the fear of weight gain. However, Elizabeth Proctor-Gray *et al.* showed that athletes prescribed to OC for six months did not gain weight and instead showed an increase in lean mass (84). Both the OC group and controls had similar baseline weight, lean mass, fat mass, and caloric intake.

Relationship of Low EA to MI

Studies also suggest a strong link between eating disorders and menstrual irregularity (35). An analysis of fifty female British endurance runners showed that MI accurately predicted for a higher risk of eating disorder ($p<0.01$). In the study, menstrual irregularity was self reported. The nutritional intake of the endurance runners was assessed using the Eating Attitudes Test (EAT26) and Bulimia Investigatory Test Edinburg (BITE) questionnaires. Of these 50 participants, 24 had AM and 9 had OM. A higher score on the EAT 26 and BITE was highly associated to the prevalence of menstrual irregularity. (35). In another study of 300 collegiate cross country runners, 19.4% had current or previous eating disorders, 23.0% had irregular menses, and 14.8% had both eating disorders and irregular menses (85).

Athletes are suggested to be more prone than non-athletes to develop disordered eating or distorted body image perceptions and irregular menstrual cycles. In a study comparing 151 female college athletes and 70 non-athlete controls, athletes were shown to have more irregular menstrual cycles (29%) as compared to non athletes (15.7%) ($p<0.01$) (86). However, there was not a statistical significance between the two groups when comparing the results of the Eating Disorder Index. This may indicate that the athletes have lower energy availability due to higher energy expenditure with a similar EDI than the non-athletic controls, which produces disruptions in the menstrual cycle (86). Similar results were shown by Hulley *et al* when examining different nationalities and ethnicities using self-reported menstrual status and the EDE-Q. Results showed that nationality and ethnicity do have influence on eating disorder psychopathology, however, regardless of nationality or ethnicity, athletic participation was associated with less regular menstrual periods (87).

The induction of menstrual disorders by low energy availability has been demonstrated in two prospective studies. Bullen *et al* induced menstrual disorders by increasing exercise in untrained women. Twenty-eight untrained women were divided into either weight loss or weight maintenance groups. The weight maintenance group was given additional calories in an effort to match the increased expenditure of exercise. Both groups incrementally increased daily exercise, starting at running 4 miles per day and progressing to 10 miles per day by the fifth week, as well as daily engagement in moderate intensity sports for 3 1/2 hours. Only four subjects of the 28 (three in the weight maintenance group and one in weight loss group) had normal menstrual cycles during the training period. The number of women who lost luteal surge increased significantly throughout the duration of the study ($p<0.01$). After six months of termination, all women participating in the study had returned to normal menstrual cycles (30). The second study which induced menstrual disorders was performed in an animal model with 8 adult female monkeys. The monkeys were put on a rigorous training program for 24 months with constant food intake throughout the study. All of the monkeys developed exercise-induced amenorrhea. Four of the eight monkeys were then given supplemental calories that comprised 138-181% of calorie intake during amenorrhea, Hormone levels and ovulatory cycles were restored within 12-57 days from initial re-feeding (36).

Relationship of Low EA to Low BMD

Low BMD has also been related to low energy availability in a host of studies. Animal models have been used in two cases to clearly show this relationship. In a longitudinal study, DiMarco *et al* presented a model with rats that were age, weight, and body-size controlled for the FAT (88). Results showed that rats with restricted dietary intake had a lower bone mineral content (BMC) as compared to controls over a 12-week period (88). Lane and Handy demonstrated similar findings using a rhesus monkey model to manipulate the level of energy restriction. Positive effects were demonstrated up to 30%

energy restriction. When energy restriction was lowered beyond this point, reduced BMD resulted (89).

Stress fractures or insufficiency fractures are the potential consequence of low BMD or osteopenia. Bennell *et al* (91) conducted a longitudinal study over the course of twelve months using track athletes. 53 female and 58 male competitive track and field athletes (ages 17-26) were followed for stress fractures during the study. A total of 26 athletes (combination of both genders) had 26 stress fractures, showing an incidence rate of 21.1%. No statistical difference was seen between the prevalence of male or female stress fractures. Middle and long distance runners showed an increase in the amount of long bone and pelvic fractures ($p<0.05$). This study relates the high prevalence of stress fractures to the running community. In a longitudinal study to identify the factors related to stress fractures in competitive young (ages 18-26) female cross country runners, Kelsey *et al.* (24) tracked participants for almost two years. BMD was initially determined by DXA at the left proximal femur, spine, and whole body. Participants were given a modified version of the National Cancer Institute Health Habits and History food frequency questionnaire to assess typical nutrient intake from the past six months. Three subscales (drive for thinness, bulimic tendencies, and body dissatisfaction) of the EDI were used to indicate eating disorders. Over the course of the study, 18 of the runners had at least one stress fracture. Results showed that the factors relating to increased fracture risk included dietary calcium intake, previous stress fractures, low BMD, and younger chronological age. Training-related factors such as the surface of running (training on concrete or pavement, amount of miles per week) did not present a statistically significant risk for stress fractures.

Interventions

A persistent lack of knowledge shown by medical professionals shows the immense need for improved education and prevention programs regarding the triad (67, 69, 70, 99). In a recent study by Carlson, almost 80% of clinicians polled at college health conferences and adolescent health conferences (n=27 and n=99, respectively) reported insufficient guidelines and recommendations for evaluation and treatment of amenorrhea (67). Physicians and medical personnel are also lacking in the knowledge of the FAT, with only 48% of physicians, 43% of physical therapists, 38% of athletic trainers, 32% of medical students, and 8% of coaches being able to correctly list all three components of the triad (99).

Coaches and athletic programs are also poorly informed of the female athlete triad. A study by De La Torre and Snell was performed to evaluate the effectiveness of athletic programs in screening for the triad and distributing educational materials to athletes and coaches. Results showed that a majority of the high school athletic programs were not screening for components of the triad and athletes and coaches were not being educated about the triad (69). Research by Lassiter and Watt exemplified the lack of education for coaches as well. Only 4% of 61 graduate students majoring in physical education and sport in West New York were able to list all three components of the triad. Only 5% could name 12 or more correct signs or symptoms, and only 18% could specify 3 resources that coaches could use for help when talking to athletes about the triad(70).

The lack of knowledge underscores a dire need for prevention through educational programming (2,7,16,67,69-71,80,85,92-99). Prevention should be based on education and requires an interdisciplinary approach that involves medicine, nutrition, mental health, athletic training, and athletics administration (2). The Norwegian Olympic Training Committee speaks of their success and bases their program on trust between medical doctors, sports nutritionists, exercise scientists, and psychiatrists (17). Treatment is necessarily an individualized care plan (98).

Interventions for the FAT have recently integrated a participatory and ecological approach. Buchholz *et al.* (3) carried out a longitudinal study which implemented a positive body image intervention on Canadian gymnastic clubs. Seven participating clubs were randomly selected to be an intervention group (IG) or control group (CG). IG groups were given a lecture on self efficacy and body image and then discussed the material. Data for both groups was collected at the pre-intervention stage and then three months later. Measures used in data collection included the Climate in Sport Setting Scale (CISSS), Body Esteem Scale for Adolescents and Adults, Eating Attitudes Test, Socio-cultural Attitudes Toward Appearance Questionnaire (SATAQ), and Self Efficacy and Dieting Pressures in Sports Club Questionnaire. Results from the pre-intervention showed that the majority (over 50%) of coaches, parents, and athletes thought having a lower body weight would help athletic performance. Approximately one-third thought that breasts and hips were a disadvantage for gymnasts. Such results indicate that many athletes and support teams are ill-informed of the nutritional concerns of the athlete and the detriments of the FAT. After the second evaluation, results showed a significant decrease of scores on the "Pressure to be Thin" subset of CISSS in the intervention group ($p<0.036$). Overall, results demonstrated that the integration of both a participatory and ecological approach may increase the effectiveness of preventative programs (3).

Interventions should also focus on shifts in training methods. According to *The ACSM Position Stand Regarding the Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness and Flexibility in Healthy Adults* resistance training can improve bone mass (95). A study of 109 endurance runners showed that the lumbar spine BMD was higher in runners who participated in resistance training twice a week ($p<0.001$) (80). More research is needed with controlled variables to specifically interpret if resistance training slows bone loss or increases gains.

Innovations in screening for the triad have been developing in Canada (96, 97). Rumball and Lebrum have utilized the pre-participation physical examination (PPE) and added female specific questions to the standardized form in an effort to screen for the triad. In order to see if the changes made to the PPE were helping, the researchers assessed the use of the PPE in both 2000 and 2002. Surveys were faxed or emailed to affiliated universities. In 2000, 35 universities participated and results showed that 80% implemented the PPE changes and only 70% of the universities conducted a follow-up if it was necessary. Improvements were made in 2002, with 87% implementing the PPE and an increase in the number of forms that target female athletes. An increase in the number of universities raising awareness through education about the triad was 14.3% in 2000 and 33.3% in 2002 (97).

Limitations of the Research

The review of the literature exemplifies the interrelatedness of the components of the FAT, however, it does not present many studies which simultaneously measure all three components (low energy availability, menstrual disorders, low bone mineral density) in adult women across the age spectrum. Only two studies in the past ten years have shown the interrelatedness of MI, low BMD, and DE exclusively in female runners (4, 18). One study by Nichols shows the prevalence of the triad in high school athletes of various sports (37), and another study shows the prevalence of the triad among US collegiate athletes (28). A review of these studies will demonstrate the areas for improvement.

The first of the complete triad studies to focus on runners was by Cobb *et al* in 2003 (4). The study showed a correlation between MI and the Eating Disorder Index (EDI) in predicting low BMD in a cross sectional study of 91 female endurance runners, ages 18-26. Participants were grouped either as menstrual irregularity (MI) (< 9 cycles per year), or eumenorrhetic (EU) (10-13 cycles per year). The Eating Disorder Index (EDI) was used to assess the level of disordered eating. Results showed that MI runners had lower BMD at the spine (-5%), hip (-6%), and whole body (-3%) (4). The results also showed that EU runners with a high score on the EDI had lower BMD at the spine (-11%), and although not statistically significant, lower BMD at the hip and whole body than EU runners with a lower EDI score. Because self reported measures were used to measure menstrual irregularity rather than laboratory measures, it is possible that subclinical menstrual abnormalities were missed. This study suggests that inadequate diet is an underlying cause for bone density issues. However, the participant pool was limited to female endurance runners ages 18-26 (premenopausal), thus eliminating the possibility for a unique relationship between components of the FAT and postmenopausal women. Loucks has proposed that as women age, reproductive function is not as dependent on energy availability (4).

The second study to show the interrelatedness of all three components in runners was by Barrack *et al* in 2008 with a subject cohort of 93 adolescent runners (18). The study showed a strong association between high level of dietary restraint and low total body and lumbar spine BMD (18). Factors that were highly associated with decreased BMD also included menstrual irregularity, participation in five or more running seasons, low body mass index, and an increased proportion of lean tissue mass. According to the DXA scan, alarming rates of the adolescents were classified as osteoporotic or osteopenic (11.8% and 28%, respectively). These numbers represent 1 in 4 adolescent runners who have less than expected BMD (18).

Nichols showed the prevalence of the triad among high school athletes in an observational cross sectional study of 170 female high school athletes representing eight sports. Disordered eating and menstrual disorders were evaluated using interviewerassisted questionnaires. BMD was assessed using DXA scans of the hip, lumbar spine (L2-L4) and total body. Results showed that 18.2% of the athletes had some sort of disordered eating, 23.5% had a form of menstrual disorder, and 21.8% had low bone mass. 5.9% of athletes were shown to have two components of the triad, and 1.2% presented all three components of the triad (37).

Beals and Manore (28) also examined the relationship between all components of the FAT, but subjects were not limited to only runners. In a cross-sectional analysis, collegiate athletes (n=425) from 7 teams across the United States were assessed for disordered eating, menstrual irregularities, and musculoskeletal injuries. Teams were divided into two groups, sports that were aesthetic or endurance in nature. The EAT26 and Eating Disorder Body Dissatisfaction (EDI-BD) scale were used to define disordered eating, and average results for both the groups showed that 15.2% of participants were "at risk" for an eating disorder as defined by the EAT26, while 32.4% were "at risk" according to the EDI-BD. The aesthetic teams scored higher on the EAT26 ($p<0.02$) than endurance athletes. Menstrual irregularity was reported in 31% of the athletes (both groups), excluding those who were on oral contraceptives. There was not a significant difference in the menstrual irregularity reported by aesthetic versus endurance groups. Muscle and bone injuries were assessed by a health/medical questionnaire and results showed a prevalence of 65.9% and 34.3%, respectively. Aesthetic athletes were more likely to report muscle ($p=0.05$) and bone ($p<0.001$) injuries. Also, those athletes who were noted as "at risk" for eating disorders were more likely to report menstrual irregularity ($p=0.004$) and more bone injuries ($p<0.001$). This study clearly shows the link between menstrual irregularity, low bone mineral density and disordered eating (28). However, it does not focus solely on the female recreational endurance runner outside the college age years.

Proposed Study: *Female Athlete Triad in Recreational Endurance Runners*

Because our research will encompass both older and younger adult women, we will have the ability to analyze with the influence of age and menopausal status BMD alongside energy availability. Overall, our proposed research will provide conclusive data on the prevalence of MI (both AM and OM), low BMD, and low EA in female recreational runners. Such valuable normative data will serve as a baseline for future studies to measure the effectiveness of interventions for the FAT.

Materials and Methods

Subjects

Subjects for the study will consist of 150 healthy adult recreational endurance runners in the central Ohio community. The number of subjects for the study was derived based on previous studies. The present study seeks to analyze a large cohort in order to showcase a range of data that has not been investigated by previous studies in the field. Valuable comparisons will be made related to age, experience as a runner, average mileage, menstrual status, dietary intake, and bone mineral density as well as some serological analyses.

Recruitment for subjects will take place in both campus and non-campus affiliated running groups in and around Central Ohio. Advertised seminars and sporting goods stores will also be utilized as recruitment methods. IRB-approved oral scripts and advertisements will be used for recruitment in many venues.

Not all female recreational runners in the Central Ohio area can qualify for the study. Participants must be 18 years of age or older and have consistent endurance running of an average 15 miles per week (33 kilometers) for the past 6 weeks. Exclusion criteria will be screened through the online pre-participation questionnaire and includes thyroid or adrenal abnormalities, any known condition affecting bone metabolism, or regular corticosteroid usage. As a safeguard, all participants will be screened for pregnancy using a urine test prior to participation in the study.

Participation in the study poses multiple benefits as well as possible risks. Participants will be informed of the low radiation emitted by the iDXA as part of the human subjects consent process. Knowledge of the results of the tests (bone mineral density, body composition, hormonal levels, nutrition analysis and perceived body image) can be individually perceived as either a benefit or a risk. We expect that many of the participants will use the results as motivation to improve dietary intake and overall health. However, upon learning results, some participants may endure emotional distress. Emotional distress may also be caused merely by the act of answering questionnaires based on eating habits, attitudes, and eating disorders. Physical distress may be caused by the venous blood draw. As with any blood draw, slight pain, discomfort, bruising and/or risk of infection are possible at the puncture sight.

The study will take several precautions to address and limit the above risks. Subjects are not forced to learn results; the primary investigator will ask each subject if she would like to learn her individual results. Referrals to a physician, dietitian, and eating disorder specialist will be provided only upon subject request. Blood draws will be performed by a trained phlebotomist, and study materials such as the vacutainer system will be implemented to limit the needle stick to one time for multiple tubes. All instruments will be sterile, and all subjects will receive appropriate cleaning and dressing of wounds.

Time commitment by the participants will be approximately two hours. Completion of a three-day food and activity record and the online assessment tool will take approximately 30 minutes each. A one- time laboratory visit will take an hour to complete. At this laboratory visit, the participant will receive four iDXA scans: total body, hip precise mode, lumbar spine, and forearm. These scans will take approximately 20 minutes including positioning and analysis. Blood draws taken at the lab will take an estimated ten minutes. Long term follow-up is not required for the study.

Privacy and confidentiality are of the upmost concern in all human studies. Although the educational and advertisement aspect of the study are public, participation in the study will be strictly voluntary and with an individualized approach. Data will be stored on the

College of Education and Human Ecology and Labs in Life server, which will be set up by the Education and Human Ecology Informational Technology group. Data will be password protected, and laboratory data will be account protected by the primary investigator. Consent forms and data sheets will be locked in filing cabinets in a locked office in a locked lab. Only Jackie Buell and Carmen Swain, the primary investigators of the lab, will have the keys to the filing cabinet. Labs in Life uses a consent policy where all data is identified only numerically after the consent process so this minimizes risk of breach of confidential information.

Experimental Protocol

Various devices and methods will be used assess bone mineral density and body composition, dietary intake, menstrual status, hormonal levels, and perceptions of body image and eating disorders. All devices are IRB approved and subjects will be informed of the devices prior to participation. The following sections explain in detail how each component of the triad will be assessed. The concluding paragraph will chronicle the expected protocol that a subject can expect when participating in the study.

Assessment of Bone Mineral Density and Body Composition

The GE Lunar iDXA will be used to assess bone densitometry and body composition. This fan beam densitometer uses two low energy x-rays in order to estimate both bone density as well as lean and fat mass. The GE Lunar iDXA will be used for the present study due to its good precision and resolution, as well its very low dose of radiation compared to other densitometers on the market. Participants will be warned that ionizing radiation does have the potential to mutate proteins in the body (i.e, DNA). It should be noted that adverse effects from bone densitometers are not common and the amount of radiation emitted by the DXA is inconsequential to the subject's daily dose of radiation. The subject will receive 4 iDXA scans at the laboratory visit: total body, lumbar spine (L1-L4), hip, and radial (forearm) scans. For all four scans, only 1.4 millirems of radiation are emitted to the subject. This amount of radiation is approximately equal to the radiation one would receive from living for 2 days in our background radiation, or flying once from New York to Los Angeles. As another point of reference, a typical chest x-ray from front to back is about 30-35 mrem.

Assessment of Diet

Quality and quantity of the diet will be analyzed using a combination of a three day food record and a series of questionnaires to identify the presence and depth of restrictive eating, body image issues, and weight attitudes. The nature and details of this questionnaire will be explained in the section dealing with assessment of menstrual function and body image, although some of the questions will be focused toward nutrition. As with all of the information, identifiers will be removed from subject data and an ID number will be used instead.

The three day food record will ask for two typical days Monday through Friday, as well as food intake from Saturday or Sunday. A Bouchard log of activity in these same days will also be kept in order to estimate energy expenditure. Food Processor SQL will be used to assess the calories and macronutrient composition of the diet as well as the micronutrients calcium and iron. The food processor will also estimate energy expenditure to gauge the appropriate amount of daily calories needed per day. Such calculations are critical to determining the athlete's appropriate energy consumption for optimal energy availability. Energy availability will be assessed according to Loucks (54). Finding energy availability is a two-step process. First, the energy expended from physical activity is subtracted from the energy gained through food consumption in a typical day. Second, this difference in calories is then divided by the lean mass of the subject, yielding calories per kilogram lean mass per day.

Not only will completion of the food record give critical information about the energy availability of the subject, but it will also give dietary clues to the bone mineral density. Nutritional factors such as vitamin D, calcium, phosphorus, protein, sodium, and fiber play an important role in the formation and resorption of bone.

Assessment of Body Image, Disordered Eating, and Related Factors using Questionnaires

Questionnaires will be utilized to assess an array of disorders or tendencies that will give myriad data into the intricacies of the triad. The questionnaires that will be used are the Eating Disorder Examination, Beck Depression Inventory-II, Multidimensional Body Self Relations Questionnaire, Tendency to Diet Scale, and Quick Calcium Screen. These questionnaires can be completed on-line either at home or on a secure server using the Select Survey tool through the College of Education and Human Ecology during the laboratory visit. The following table shows the name, number of questions, and estimated amount of time to complete for each tool that will be used.

Name of Tool	**Number of Questions**	**Time to Complete**
Eating Disorder Examination	28	8
Beck Depression Inventory -II	21	7
Multidimensional Body Self Relations Questionnaire	19	5
Tendency to Diet Scale	15	5
Quick Calcium Screen	36	5
Total	121	30 minutes

The present study will use the Eating Disorder Examination Questionnaire 6.0 (EDE-Q6) in order to help identify signs of cautious eating or early symptoms related to eating disorders (100, 101). Outcomes derived from the EDE-Q6 will help to better understand the etiology of the female athlete triad and serve as a base for comparison against other data such as bone mineral density, menstrual status, and energy availability (102). This questionnaire is self-reported and gathers information related eating disorder symptoms as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) as well as eating psychopathology (100, 101). Four different subscales and a level of severity are utilized and have been shown to have satisfactory reliability (Restraint, r= .75; Eating Concern, r= .78; Weight concern, r=.68, and Shape Concern, r= .82) (101).

The Beck Depression Inventory-II is used in the present study in order to show possible underlying mood disturbance, as population studies have suggested that 50% of women who suffer from anorexia nervosa also have depressive symptoms (10). Results from the Beck Depression Inventory will then be used to compare against the prevalence of anorexia nervosa found in the subjects in order to make our own correlation about the presence of depressive symptoms and eating disorders. This tool is also based off of the criteria for major depressive disorder found in the text revision of the DSM-IV and shows adequate reliability and validity in multiple studies. For each question asked in the BDI-II, there are four possible responses (103). These responses correlate to a severity rating of zero to three. The higher the severity rating throughout the study, the more likely that the subject is experiencing depressive disorder (103).

Results of both the EDE-Q6 and the BDI-II are strictly confidential and without identifiers. If the subject wishes to see her results, then the PI will individually review results with the subject. Runners will be encouraged to share the results of the tests with an appropriate physician, and referrals will be made if a significant psychopathology presents and the subject wishes to receive treatment at her own cost.

In order to assess body image, we will use two subscales presented in the Multidimensional Body Self Relations Questionnaire (MBSRQ). Body image is defined in the present study as one's mental perception of the body and includes perceptual, attitudinal, and behavioral components (104). Behaviors such as restrictive eating or prolonged intense physical activity are often directly associated with a desire to control weight and/or shape (105). The two subscales used are related to the body image components and are known as Appearance Evaluation and Appearance Orientation. Appearance Evaluation will measure how critical the subject is of her appearance characteristics, while Appearance Orientation will measure how much time and effort the subject puts into developing a proper appearance and what her appearance means to her self-worth or perception (104). These subscales have been shown to have great validity (r= .80-.90) and have been used in studies dealing with eating, exercise, and substance abuse with much success (106-110).

The Tendency to Diet Scale assesses the likelihood of the subject to practice diet cycling. Questions are focused around the how the subject would feel if she gained or lost 5, 10, or 15 pounds (111). The Tendency to Diet Scale is important to include in the questionnaires given to the subjects because most subjects will not view the questions as a means to determine an eating disorder. The scale will also give us data on how much fear there is among recreational runners of gaining weight, as well as the amount of an acceptable or unacceptable amount of weight gain (111). The RENO Diet and Heart

Study originally created the Tendency to Diet Scale.

The Quick Calcium Screen (QCS) is a questionnaire that lists 36 food items and asks the subject to list how often she consumes the food on either a daily, weekly, or monthly basis (112). The tool is semi-quantitative and asks also for any supplement consumption that may increase calcium levels. In the present study, the results of the QCS will help to add more information to the three day food record that the subject will complete. The QCS is commonly used in a healthcare setting to quickly and inexpensively screen for calcium intake in order to gauge whether or not nutrition intervention is needed (113).

The onset and frequency of menses, as well as oral contraceptive use, years running history, current weekly mileage, history of pregnancies, history of stress fractures, and weight history will also be evaluated through the on-line questionnaire. These values may be important in evaluation of the presence of the triad.

Assessment of Menstrual Function

As previously mentioned, the series of questionnaires completed by the subject ask about the frequency and history of menstrual cycles. However, including a study of serological values will add to the depth of menstrual history and relation to the other two components of the triad. The general and hormonal markers planned for this study and their justification are presented in the table below.

Serum Markers	**Justification**
Parathyroid Hormone (PTH)	Increases bone resorption and blood calcium levels
25-hydroxycholecalciferol	Indicator of vitamin D status and actively influences bone metabolism
Osmometry	Marker of hydration, ensures other serum markers are not concentrated or diluted
Pre-albumin	Marker of general nutrition; tells if nutrition is adequate to support synthesis of proteins
Hematocrit and Hemoglobin	Common markers of general nutrition status
TSH	Hormonal driver of thyroid axis
Free T4	Blood indicator of thyroid activity/axis
Cortisol	Blood indicator of adrenal activity/axis

A total of 13 mls of serum per subject is needed for laboratory evaluation. Assuming a 50% serum yield, 26 mls of blood for serum processing and 6 mls in the lavender top tube will be collected from each subject by a trained phlebotomist. This amount of blood is equal to 5 SST tubes and 1 EDTA tube using the vacutainer system. Stress of the veni-punctures on the subject will be reduced by following strict protocol to appropriately clean the site prior to blood draw and minimizing the number of needle sticks (and thus infection) by using vacutainer needle systems. In terms of teaspoons, subjects will be asked to provide 6-7 teaspoons of blood. After the blood draw, the sites will be checked, cleaned and dressed in order to minimize infection.

Blood samples will be placed in the appropriate tubes and immediately processed and refrigerated, with the exception of parathyroid hormone, which will be frozen. Samples will then be transported on a daily basis to the OSU Hospital Laboratories in order to carry out the proper assays. Upon completion of biohazards training, key personnel will be responsible for the transportation of the blood samples. These key personnel will have the proper training and instruction pertaining to preventing laboratory spills and how to handle blood samples. Many steps will be taken to ensure that the samples are transported safely and efficiently. First, the samples will be bagged and then labeled according to the protocol of the OSU Hospital Laboratories. The samples will then be placed inside of a foam cooler which will be placed inside of a plastic igloo cooler in order to ensure that no spills will occur during transportation. Biohazard placards will be used to mark all containers.

Subject Protocol

Efforts will be made to ensure that the subjects' time is used most efficiently. Subjects who wish to be included in the study will either complete the online pre-participation questionnaire at home or at the start of the laboratory visit. If a subject chooses to complete the questionnaire at home before visiting the laboratory, she will be sent an email including a copy of the informed consent form as well as her individual subject ID number. The subject will be directed to a link for the questionnaire as well as information about implied consent. The implied consent statement will state "Your completion of this questionnaire prior to the laboratory visit for protocol 2009HXXXX implies that you have read the informed consent attached to the e-mail and that you will freely consent at your laboratory visit." The subject also has the option of completing the questionnaire at the laboratory at the start of their visit on private laptops with a secure connection to the College of Education and Human Ecology server. In order to immediately de-identify the data and keep the upmost confidentiality, subjects will begin the questionnaire by entering their subject ID. Instructions for completion of the three day food and activity record will be given at the end of the questionnaire in case the subject would like to complete the record prior to the laboratory visit.

Through e-mail or telephone contact, a laboratory visit to COSI Labs in Life will be scheduled, and directions to the lab and parking instructions shared. The laboratory visit will start with the subject being formally consented. After the consent process, the PI will be responsible for de-identifying the data. Signed consent forms with the subject's ID number will be locked in the office of the PI. Any further communication will be with subject number and the PI will be responsible for cross checking to ensure accuracy. Students and workers in the lab will not have access to any identifiers associated with the subjects.

After the consent process, the runners will be asked to provide a small urine sample for pregnancy screening. We have also decided to run a small nested study to compare urine refractometry with the serum osmometry measures to evaluate the adequacy of using urine refractometry as the primary method of ensuring proper hydration prior to the DXA and blood measures. Once the urine screens negative for pregnancy (hCG), the iDXA scans for the total body, non-dominant hip, lumbar spine, and non-dominant forearm will be completed. The subject will then be seated at a phlebotomy station where a certified phlebotomist will proceed with the blood draw. As previously described, the wound of the subject will be cleaned and dressed, and samples will be immediately processed and refrigerated or frozen according to the proper assay.

The three day food and activity record is the final component of the present research study. Participants can either hand the record in during the laboratory visit or they can make arrangements to drop it off at a later time. The laboratory website has the files available for subjects to download or the lab will provide a hard copy of the forms at the laboratory visit.

Data Analysis

Data compiled during the present study will have identifiers removed and referred to by identification number. Laboratory students will help with data entry. The prevalence of the female athlete triad will be described for each of the components: low energy availability, irregular menstrual cycles, and low bone mass. A detailed description of analysis of each component will follow.

The following table depicts the cutoff points that will be used in the present study to identify the presence of the female athlete triad.

Component of the Triad	**Data Analysis**
Low Bone Mass	T score of less than 2
Low Energy Availability	Less than 30 calories per kilogram of lean body mass calculated as previously described
Menstrual irregularity	
Amenorrhea	0-3 periods in the last year or no period for last 3 months
Oligomenorrhea	4-9 periods per year or cycles lasting longer than 35 days

The mathematical algorithm for figuring energy availability based on Loucks work will be calculated for each athlete. A cutoff point of below thirty kilocalories per kilogram of lean body mass will be used to define low energy availability; below this threshold the physiological mechanisms of the athlete begin to decline (32, 41, 43, 45-54).
Age matched T-scores will be used to identify the presence of the female athlete triad. The T-score used will be the lowest of the iDXA hip or lumbar spine scan. T-scores will be used because they have proven validity (114) and the purpose of the study is to screen for osteoporosis, not clinically diagnose osteoporosis. If clinical diagnosis were needed, Z-scores and secondary risk factors would be used instead (115). In the present study, a score of less than -2 standard deviations from the age-matched score will signify the prevalence of low bone mass. A score of -1 to -2 will be borderline low bone mass, and runners with this score will be advised to see a physician for treatment advice.

Menstrual irregularity will be self reported and will rely primarily on the honesty and memory of the subject. The two subsets of menstrual irregularity, amenorrhea and oligomenorrhea, will both be used in the identification of the female athlete triad but will be distinguished in the final results. Amenorrhea will be defined as 0-3 menstrual cycles per year or a lack of menstrual function in the past 3 months. Oligomenorrhea will be defined as 4-9 periods per year or cycle length lasting longer than 35 days. Eumenorrhea will be defined as 10 or more cycles per year or cycle length shorter than 35 days.

Statistical Analysis

SPSS on the laboratory computers will be used perform statistical analyses of the data. Since the data will not have identifiers, volunteer students as well as key personnel will be primarily responsible for data entry. The data collected through the three day food and activity record will be analyzed through regression analysis with low bone mass. The relationship between menstrual dysfunction and low energy availability will also be analyzed, as will the relationship between low energy availability and the relative presence of serological hormone markers.

Discussion and Recommendations

The present study will add important information to the depth and knowledge of the female athlete triad. However, more longitudinal studies are needed to find the most effective methods of both prevention and treatment for the female athlete triad. Past research studies agree that education is critical in developing an awareness of the triad and is pivotal in preventing future cases of the triad. Treatment of the Triad has been disputed in the research. Some studies make recommendations for increasing energy intake (116), decreasing energy expenditure (117), increasing calcium and vitamin D intake (71), implementing a form of behavioral therapy (62), or a combination of these methods (40). I recommend a longitudinal study as a follow up to the present study. The methods for this study are discussed in the following paragraphs.

Follow-Up Study: *Treatment Methods for Recreational Runners Presenting the*

Female Athlete Triad: A Longitudinal Study

The primary aim for this study is to assess the effectiveness of treatment options both in the short term and long term recreational runners presenting with the female athlete triad. Three treatment options will be analyzed in the study: an increase in caloric consumption only, a decrease in mileage per week only, and education only.

Subjects for the study will come from the present research study. It will be a goal to include all subjects who met the diagnostics for the FAT in all three areas (energy availability less than 30 kcal/kg of lean body mass/day, bone density less than 2 standard deviations from the normative data, and self reported menstrual irregularity as either oligomenorrhea or amenorrhea). If there is an insufficient number of subjects who are diagnosed with the true female athlete triad, those with two components of the triad may also participate. Subjects will be divided into four groups: one will increase dietary intake, one will reduce training mileage and/or intensity, one will receive education on a biweekly basis, and one will be a control group.

Such a study has numerous benefits. The literature on treatment for the female athlete triad is lacking. Many studies that deal with female triad interventions deal with the pre-participation examination (96, 97), are only short term studies (7, 71), or only assess one case study (92). As to my knowledge, this will be the only study that will analyze different treatment options including both direct and indirect measures of treatment over a long period of time in more than one subject at a time. Data collected in the study will help future researchers to investigate the most effective ways of implementing the treatment in order to prevent the devastating consequences of chronic low energy availability in the female athlete. Also, the study will be carried out in the Labs in Life at COSI and will serve as a learning tool for student workers as well as a point of education for those visiting COSI.

The limitations of the study should also be discussed. At this point, it is hard to estimate what the true prevalence of the female athlete triad in recreational endurance runners will be. Although the hypothesis is that there will be a significant number of runners with the triad, there is always the possibility that only a few, if any, will present with the true triad. The response rate to continue this study might also be low, even if recruiting those who presented with two components of the triad. Adherence rates may be low, especially if the subjects are in college and graduate or move out of the Columbus area. Finally, there are multiple variables to control for when matching the groups. Ideally, each group would have subjects who were similar in age, training volumes, and years of training, however, the probability of finding perfect matches is low. Different ages, training volumes and years training could potentially skew the results and compromise the data.

Methods

Subjects

The subjects will be broken into four groups based on treatment. It will be the goal of the study to have five subjects per group for a total of twenty subjects. Subjects in each group will be matched for age, average mileage run per week, and years training.

The first group will increase energy intake to yield 45 kcal/kg of lean body mass/day. A dietitian will work with the group to ensure adequate results, and a 24-hour recall using the multiple pass method will be given at the end of each month by a trained interviewer. This group will not alter training routines. The second group will decrease training by 50% of baseline mileage. This group will not alter dietary intake. The third group will receive a weekly educational session, which will focus on reasons for change and strategies to help in the change process. Focuses for the session will be on how to make lasting dietary changes, ways to cross train and add resistance training to the program, and the major consequences of the female athlete triad. The session will be carried out by a trained student worker or by a faculty member who is familiar with the information. Finally, Group 4 will be a control group. This group will not modify any part of diet or training, nor will the subjects in this group be required to come to the educational sessions.

Experimental Protocol

Treatment will continue over a twelve month period. Subjects will be required to check in with the PI monthly either in person or through telephone communication, depending on the assigned group.

Subjects in Group 1 (increase in diet) will make an appointment at the beginning of each month to meet with the dietitian for the study, or they can schedule a time to talk via telephone. At the end of the month, these subjects will be called by a trained interviewer who will use the Multiple Pass Approach for collection of a 24-hour recall. These recalls will be processed by trained student workers, and the results will be analyzed and tracked in a database.

Group 2 (decrease in training volume) will track one week worth of training in a physical activity log and submit this to the lab at the end of each month. Multiple modes of communication for this log will be given, such as email, telephone, federal mail, or dropping the log off in person. The deadline for the logs will be the last day of each month.

Due to the nature of Group 3, all subjects will be required to come to the lab on a biweekly basis. The day and time of the meeting will be determined at the beginning of the study according to the needs of the subjects. If necessary, subjects will be able to make up a session, but it is required that all subjects attend all sessions in order to obtain accurate results. The sessions will be educational in nature and will last approximately one hour.

Assessment of Methods

All subjects from all groups will be required to have a laboratory appointment every three months. Appointments will be scheduled the last two weeks of the appropriate month. There will be two main tests done at this appointment in order to check for improvements made in regard to the triad. The first test will be for main markers tested in the present study and will largely depend on the funds of the research. Ideally, all of the markers tested in *Female Athlete Triad in Recreational Endurance Runners.* The second test will be a bone density scan using the same iDXA, and will measure the same four sites as the present study: lumbar spine, total body, hip, and forearm. The results of the follow up tests will be compared to the baseline results. Similar tests will be run at the six month mark, as well as the nine month and twelve month marks. Modifications in the frequency and intensity of the tests will be made due to appropriate funds and support.

Long Term Follow-Up

After the year-long study, subjects will be given the option of continuing the study in a long term capacity. The extension of the study will require the subjects to come into the laboratory at 6 months, 1 year, and 2 years after termination of the study. The purpose for the long term assessment is to analyze adherence rates to the programs. Prior to the visit, all subjects will be required to complete a 3-day food record and weekly activity log, as well as the online questionnaires that were initially assessed at baseline. The questionnaires will give an interesting dimension to the study because they will assess the prevalence of any underlying disordered eating or body image issues.

Conclusion

Despite the lack of education of most coaches and athletes, as well as the lack of large-scale longitudinal studies, we believe that the female athlete triad is a real concern for highly active women who may not be refueling appropriately. The female athlete triad, namely the interrelated components of low energy availability, low bone mineral density, and menstrual irregularities, has been potentially under-diagnosed for too long in too many athletes.

The review of the literature shows that many studies have effectively proven one or two components of the triad. However, more research is needed to ascertain connections among all three components of the triad as well as etiology, prevention, and treatment methods. The data in these past studies has served as a building block for forming the present study, *Prevalence of the Female Athlete Triad in Recreational Runners.* This will add immensely to the present literature of the triad for multiple reasons. First of all, it will be a large scale study, with 150 female runners as the subject base. Secondly, the present study will serve to find true prevalence of the female athlete triad as defined by **all three components**. Another important distinguishing characteristic is the inclusion of recreational runners instead of only elite athletes. While many studies have assessed bone mass of adult elite runners, there have been no previous studies that have properly assessed all three components of the triad in a large scale study and through a wide span of ages in adult recreational runners.

A prospective additional follow-up study, *Treatment Methods for Recreational Runners Presenting the Female Athlete Triad: A Longitudinal Study,* which analyzes the treatment options including increasing caloric consumption, reducing training load, and incorporating education, will be a great addition to the research as well. The study will be much broader than just focusing on the pre-participation examination. It will be a long term study, which will gather data not only on short term effects of treatment but also individual adherence after termination of formal treatment. Data collected through the study will be play a pivotal role in helping future researchers investigate effective ways to implement treatment. By having the study carried out at the Labs in Life at COSI, the general public can gain awareness of the triad and prevention techniques.

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