The Effect of Psychological Stress, Training Load, and Energy Availability on the Prevalence of Athletic Amenorrhea in NCAA Division I and Division III Distance Runners

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ABSTRACT

DEANNA BABCOCK: The Effect of Psychological Stress, Training Load, and Energy Availability on the Prevalence of Athletic Amenorrhea in NCAA Division I and Division III Distance Runners
(Under the direction of Anthony C. Hackney, PhD, DSc)

This study quantified the prevalence of athletic amenorrhea in division (D) I and DIII distance runners and examined relationships between training load, energy availability, psychological stress, and amenorrhea. Participants (n=98) completed surveys assessing menstrual history, energy availability, psychological stress, and training load. The prevalence of amenorrhea was 20% and did not differ between divisions. Of all training parameters, only running mileage differed between divisions; DI athletes reported greater mileage ($p<0.0005$). There was a positive association between mileage and amenorrhea ($p=0.045$). Division I athletes reported greater running ($p<0.0005$) and overall ($p=0.005$) energy expenditure than DIII athletes. Energy availability did not differ between divisions and was not predictive of amenorrhea. Psychological stress did not differ between divisions, though was predictive of amenorrhea; increased psychological stress reduced the risk of amenorrhea ($p=0.040$). In conclusion, the prevalence of amenorrhea did not differ between divisions; only running mileage and psychological stress were predictive of amenorrhea.

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LIST OF ABBREVIATIONS

atu	arbitrary training units
BMI	body mass index
cm	centimeters
d	days
DI	National Collegiate Athletic Association division I
DIII	National Collegiate Athletic Association division III
d/wk	days per week
EDI	eating disorder inventory
EE	energy expenditure
FFQ	food frequency questionnaire
FHA	functional hypothalamic amenorrhea
ft	feet
h/d	hours per day
h/wk	hours per week
in	inches
kcal/d	kilocalories per day
km	kilometers
kg	kilograms
km/d	kilometers per day
lbs	pounds
m	meters
MET	metabolic equivalent
mi	miles
mi/wk	miles per week
min	minutes
min/wk	minutes per week
mo	months
NCAA	National Collegiate Athletic Association
PSS	perceived stress scale
SCL	Hopkins symptom checklist
wk	week
yr	year

CHAPTER 1

BASIS OF STUDY

Introduction

Amenorrhea, the absence of menses for three or more consecutive months (1), occurs more frequently in some sub-populations of female athletes than in the general population of healthy females (2, 3). Although athletic amenorrhea has been viewed by some athletes as a convenient side effect of training that is indicative of overall fitness, this is incorrect. According to Pauli and Berga (4), athletic amenorrhea is a type of functional hypothalamic amenorrhea (FHA) in which the dominant stressor is exercise. In addition to exercise stress, low energy availability and psychological stress also appear to play a role in the development of athletic amenorrhea (5, 6).

A number of deleterious health effects are associated with athletic amenorrhea. Relative to eumenorrheic athletes, amenorrheic athletes develop reduced peak bone mineral density (1). Low bone mineral density is associated with a greater risk of bone fracture and osteoporosis both early and late in life (1, 7). Recent evidence also indicates that athletes with amenorrhea have reduced endothelial function similar to that observed in cardiovascular disease patients (1). Reduced endothelial function is a precursor to the formation of atherosclerotic plaque and serves as a predictor of future cardiovascular events (8).

Because of the health concerns associated with athletic amenorrhea, it is important to have current prevalence estimates so that health interventions can be appropriately guided.

Estimates of the prevalence of athletic amenorrhea vary throughout the literature for several reasons. One reason is that some researchers opt to include females currently taking oral contraceptives (9), while others exclude subjects who have recently taken oral contraceptives (10). Additional reasons for variable estimates of the prevalence of amenorrhea include differences in the definition of amenorrhea, competition level of athletes surveyed, and training type and volume associated with different sports (11).

The prevalence of amenorrhea is known to be greatest among athletes participating in sports emphasizing a lean physique, such as distance running (11). Estimates of the prevalence of amenorrhea among distance runners of varying competition levels range from 5.3-35% (2, 12, 9, 13, 10). Data on the prevalence of amenorrhea in collegiate distance runners are lacking. Few studies have been performed in which only collegiate athletes were sampled. More commonly, researchers have included athletes from multiple competition levels (i.e., both collegiate and non-collegiate runners) (13, 9, 2). To date, researchers who have sampled only collegiate athletes have failed to specify which National Collegiate Athletic Association (NCAA) division the sample was taken from (12, 10), even though the current NCAA divisional structure has been in place since 1973 (14). It appears that no research has specifically examined potential differences in the prevalence of amenorrhea between NCAA division I (DI) and NCAA division III (DIII) athletes.

Purpose

The purpose of this research was to quantify the prevalence of amenorrhea in NCAA athletes. Specifically, differences in prevalence of athletic amenorrhea between NCAA DI and DIII distance runners were examined. In addition to estimating the prevalence of amenorrhea, the predictive value of training load, low energy availability, and psychological stress in the development of athletic amenorrhea were examined using logistic regression.

Significance of study

Most studies on the prevalence of athletic amenorrhea to date (2, 9, 13) have used mixed sample populations that included combinations of high school athletes, collegiate athletes, elite athletes, or club athletes. Only one study (12) has examined the prevalence of athletic amenorrhea in collegiate distance runners in the previous ten years. It is important to have current, reliable estimates of the prevalence of athletic amenorrhea so that health interventions may be appropriately guided.

It is necessary to study both NCAA DI and DIII athletes because there are differences between the divisions that may affect the prevalence of amenorrhea. First, though it may seem reasonable to believe that DI runners train more because they are faster than DIII runners, there is currently no evidence in the literature to support this. Nonetheless, the number of recent studies explicitly stating the mean weekly training mileage in collegiate distance runners at different divisional levels appears to be few (15, 16, 17, 18), and the possibility of differences in weekly training volumes at different divisional levels should not be ruled out.

Another possible difference between DI and DIII athletes is the amount of psychological stress associated with competition. For example, Picard (19) surveyed athletes from multiple sports and found that DI athletes experienced more pressure to perform than DIII athletes. The increased emphasis on performance at the DI level may result in increased psychological stress in DI athletes, possibly increasing the prevalence of athletic amenorrhea (20).

A confounding factor, however, is that DI coaches report greater usage of formal, athlete monitoring protocols and also have more resources in place to address amenorrhea than DIII coaches (21). Thus, although DIII athletes may have similar training volumes and experience less competition stress (19) compared to DI athletes, they may actually have a higher prevalence of amenorrhea. Estimating the prevalence of athletic amenorrhea in both DI and DIII athletes is important because, although approximately 3.4 times more female athletes compete at the DI level than the DIII level (22), athletes at all competition levels should be entitled to resources that ensure they are able to train and compete safely.

Research questions

1. Does the prevalence of amenorrhea differ between NCAA DI and DIII distance runners?
2. Are increased levels of psychological stress associated with amenorrhea?
3. Is low energy availability associated with amenorrhea?
4. Is training load associated with amenorrhea?
5. How do psychological stress, low energy availability, and training load simultaneously explain the development of athletic amenorrhea?

Hypotheses

1. The prevalence of athletic amenorrhea will be greater in NCAA DI distance runners than DIII distance runners.
2. There will be a positive association between psychological stress and amenorrhea.
3. There will be a negative association between energy availability and amenorrhea.
4. There will be a positive association between training load and amenorrhea.
5. Psychological stress, low energy availability, and training load will be simultaneously associated with athletic amenorrhea.

Delimitations

1. Only healthy, collegiate distance runners training to compete in race distances of 1500 m or greater were surveyed.
2. National Collegiate Athletic Association division II athletes were excluded.
3. Only athletes attending colleges and universities in the United States were surveyed.
4. Only athletes participating in the 2012 track and field season were surveyed.
5. Athletes must have been training to compete in distance running at their current NCAA divisional level for at least one full academic semester.

Limitations

1. Data was gathered using a convenience sample of collegiate athletes. Though efforts were made to enhance homogeneity, sampling was not truly random.
2. Self-reported surveys were used to gather all data. Although the survey questions were worded to minimize subjective interpretation, both random and systematic measurement error may have occurred.
3. Recollection of past menstrual cycles may be inaccurate (11), leading to inaccuracies in the diagnosis of amenorrhea. However, the diagnosis of amenorrhea is relatively straightforward using the definition proposed below, and it is expected that the number of inaccurate diagnoses was low.
4. Menstruation, psychological stress, and eating patterns are sensitive topics among athletes (11). Although survey results were anonymous and confidential, athletes may have altered survey responses related to eating patterns or menstrual function due to fear of retribution from coaches or peers (11).

5. The food frequency questionnaire (FFQ) is a convenient tool that provides reasonably accurate quantitative and qualitative estimates of individual intake (23). Though similar tools have been validated for use in athletic populations (23), the FFQ used in this study was not validated for use in an athletic population.

Definitions of terms

1. Amenorrhea: the absence of menses for three or more consecutive months after menarche (1).
2. Athletic amenorrhea: non-organic amenorrhea that occurs in individuals who regularly perform strenuous exercise (6, 1).
3. Eumenorrhea: menstrual cycles of 25-38 d occurring monthly for three or more consecutive months (24).
4. Distance runners: athletes who train to compete in running race distances of 1500 m or greater.
5. Low energy availability: negative balance between calories consumed and energy expended through daily activity, including exercise (25).
6. Exercise stress: all stress associated with exercise except the energy cost (25).
7. Training load: the product of mean weekly training intensity and mean weekly training duration (26).

CHAPTER 2

REVIEW OF LITERATURE

Introduction

The health benefits of exercise are well known. Exercise decreases the risk of heart disease and some types of cancer and mitigates the health problems associated with obesity and diabetes (27). Despite these benefits, females participating in sports emphasizing a lean physique appear to be at a greater risk for some health problems, including eating disorders, osteoporosis, and menstrual dysfunction (3). Although much research focuses on the female athlete triad, a syndrome including disordered eating, osteoporosis, and amenorrhea, current research indicates that amenorrhea may have negative health effects even when occurring alone (1).

Athletic amenorrhea appears to be caused by the synergistic effects of stress due to caloric insufficiency, exercise training, and psychological factors (6). Estimates of the prevalence of athletic amenorrhea vary throughout the literature due to differences in the inclusion or exclusion of athletes using oral contraceptives (9, 10) and differences in the definition of amenorrhea, competition level of athletes surveyed, and training type and volume associated with different sports (11); however, athletes participating in sports that emphasize leanness appear to be at a higher risk of athletic amenorrhea than athletes in other sports (3, 11).

In studies examining amenorrhea in distance runners, prevalence estimates ranged from 5.3-35% (2, 12, 9, 13, 10). Few studies to date have surveyed only collegiate distance runners (12, 10). Of the studies that included only collegiate distance runners, both Thompson (12) and Feicht et al. (10) failed to specify which NCAA division the athletes competed in, making generalizations about the prevalence of athletic amenorrhea across all NCAA divisional levels invalid. Furthermore, it appears that no research has specifically examined potential differences in the prevalence of amenorrhea between NCAA DI and DIII athletes.

Definition of athletic amenorrhea

Secondary amenorrhea is conservatively defined as the absence of menses for three or more consecutive months in women who were previously cyclic (1, 24). Athletic amenorrhea has been defined as non-organic amenorrhea occurring in individuals who regularly perform strenuous exercise (1, 6). Organic causes of menstrual dysfunction include tumors, thyroid problems, or polycystic ovarian syndrome, and must be diagnosed by a physician (1). Following the elimination of pregnancy or other organic causes of altered menses, a clinical diagnosis of athletic amenorrhea is determined after measurement of reproductive hormones over time (1). For the purpose of this research, athletic amenorrhea was defined as the non-organic absence of menses for three or more consecutive months after menarche in individuals who perform regular exercise training with the intent of improving distance running performance.

Negative health effects of amenorrhea

Historically, athletes have viewed amenorrhea as a desirable side effect of training. Recently, however, awareness of the health problems associated with athletic amenorrhea has grown. As will be discussed below, athletic amenorrhea is known to be associated with low bone mineral density and vascular dysfunction.

Amenorrheic athletes have reduced bone mineral density relative to eumenorrheic athletes (1). Low bone mineral density has both short- and long-term health effects. In a sample of track and field athletes (mean age 20.4 yr, n=46 females), those who suffered a clinically-diagnosed stress fracture in a single training season reported significantly fewer menses in the previous year than athletes without stress fractures (28). Barrow and Saha (29) also reported significant associations between menstrual irregularity and stress fractures. In a self-report survey of 241 collegiate distance runners (800 m to 10 km), runners with 10-13 menses per year reported reduced incidence of stress fractures throughout their running career relative to runners with 6-9 or 0-5 menses per year (29%, 39%, and 49%, respectively). Additionally, runners who were classified as amenorrheic (0 menses per year) were more likely to have recurrent stress fractures than eumenorrheic runners (10-13 menses per year) (29). Reduced bone mineral density, in addition to increasing the likelihood of injury during training, also presents long-term health concerns. Failure to achieve adequate bone mineral density as a young adult may be predictive of osteoporosis and fracture risk later in life (7).

In addition to the effects of amenorrhea on bone mineral density and fracture risk, recent evidence shows that hypoestrogenism associated with athletic amenorrhea may place amenorrheic athletes at an increased risk for cardiovascular disease (1). The cardioprotective role of estrogen is largely mediated by its effects on blood lipids, vascular inflammatory processes, and nitric oxide synthase (30). Although the literature is still mixed, amenorrheic athletes appear to have a "less favorable lipid profile" than eumenorrheic athletes, a difference that could lead to increased risk of endothelial dysfunction (1, p. 444). In addition to the effects of estrogen on lipid metabolism and cholesterol, estrogen appears to increase the bioavailability of nitric oxide, an important vasodilator (1). Hoch et al. (31) measured the brachial artery vasodilatory response to reactive hyperemia in 32 women (mean age 20.9 yr) who ran at least 25 mi/wk. Women were classified as amenorrheic (absence of menstruation by age 16 yr or absence of six or more consecutive menstrual cycles after menarche), oligomenorrheic (cycles greater than 38 d for at least 2 yr), and eumenorrheic (menstrual cycles 28-30 d for at least 1 yr). Hoch et al. found that the brachial artery vasodilatory response was significantly lower in amenorrheic runners (1.08%) compared to controls (6.38%) and oligomenorrheic (6.44%) runners. The reduced endothelial function in amenorrheic athletes is alarming because vascular dysfunction has been linked to atherosclerosis, hypertension, and heart failure (31).

Prevalence estimates

The prevalence of amenorrhea is known to differ between sports and to be highest in sports emphasizing a lean physique or low bodyweight, such as distance running (2, 11). Prevalence estimates of amenorrhea vary among distance runners due to differences in the inclusion or exclusion of athletes taking oral contraceptives, the definition of amenorrhea, and the competition level of the sample population (11). Most studies to date have used mixed samples that included combinations of high school athletes, collegiate athletes, elite athletes, or club athletes (2, 9, 13). It appears that only one study has examined the prevalence of athletic amenorrhea exclusively in collegiate distance runners in the last ten years (12). Because of the lack of studies examining only collegiate distance runners, studies that included collegiate distance runners for at least part of the sample population are discussed below.

In one of the earliest studies to document the prevalence of athletic amenorrhea in collegiate athletes, Feicht et al. (10) surveyed 128 cross country and track and field athletes from 12 colleges (NCAA division unspecified). Amenorrhea was defined as three or fewer menstrual cycles per year in postmenarchal women, and athletes who had taken birth control within the past 6 mo were excluded. Among 54 middle-distance runners, the self-reported prevalence of amenorrhea was 35%. The term “middle-distance runner” was not well-defined by Feicht et al. but appeared to refer to athletes competing in running race distances of 800-1500 m (p. 1145).

Sanborn et al. (13) mailed questionnaires to swimmers, cyclists, and runners to examine the correlation between weekly training mileage and the prevalence of amenorrhea across multiple sports. Runners included those who had competed in the 1977 United States Collegiate championships (sport and NCAA division unspecified) as well as age-matched marathon runners. Subjects with primary amenorrhea or those who had used birth control within the previous 6 mo were excluded. Amenorrhea was defined as three or fewer cycles per year; athletes not classified as amenorrheic were automatically classified as eumenorrheic. Among the 237 runners who completed and returned the surveys, the prevalence of amenorrhea was 25.7%.

Carlberg et al. (2) surveyed 254 collegiate, high school, and club female athletes (mean age 20.7 yr) in 9 sports (distance running, track and field, basketball, volleyball, swimming and diving, tennis, gymnastics, softball, and skiing) using both questionnaires and oral interviews. Athletes who had used oral contraceptives within the previous 6 mo were excluded, and all subjects were at least one year post menarche. Of the 254 athletes surveyed, 83 athletes (mean age unspecified) were classified as distance runners, athletes competing in running race distances of 1500 m or greater. In classifying menstrual dysfunction, Carlberg et al. did not distinguish between oligomenorrhea, less than four periods in the previous year, and amenorrhea, the absence of menstruation for the previous 3 mo. The prevalence of oligo/amenorrhea in distance runners was 18%. Because amenorrhea and oligomenorrhea were lumped into a single category, the prevalence reported by Carlberg et al. may have overestimated the actual prevalence of amenorrhea.

Robinson et al. (9) used self-report surveys to examine the effects of menstrual dysfunction on bone mineral density in runners, gymnasts, and controls (n=60, mean age 20.4 yr). The 20 runners included in the study competed in race distances ranging from 800 m to 26.2 mi, had trained for at least the last year, ran a minimum of 4 d/wk, and ran at least 30 mi/wk. Fourteen of the 20 runners belonged to a NCAA DI team; six others were United States nationally ranked distance runners. Amenorrhea was defined as 0-2 cycles per year with zero in the past 6 mo; oligomenorrhea was defined as 3-6 cycles per year at intervals greater than 36 d. Of the 20 runners surveyed, 15% were classified as oligomenorrheic and 15% were classified as amenorrheic. Because the definition of amenorrhea used by Robinson et al. (absence of menses for six or more months) is more restrictive than that proposed by De Souza and Williams (1) (absence of menses for three or more months), the actual prevalence of amenorrhea in distance runners may be greater than estimated by Robinson et al. Additionally, Robinson et al. included subjects who used oral contraceptives. Because oral contraceptives are sometimes prescribed to female athletes in order to correct menstrual irregularity (3), failing to exclude athletes using oral contraceptives may also have deflated the estimated prevalence of amenorrhea in the sample population.

In the most recent study quantifying the prevalence of amenorrhea in distance runners, Thompson (12) surveyed 300 collegiate cross country runners (NCAA division I, II, and III; mean age 19.6 yr; 90% Caucasian) from 44 states and 1 foreign country using self-report surveys. Thompson did not state whether athletes using oral contraceptives were included or excluded, a major study limitation. Amenorrhea was defined as the absence of menses for six or more months; oligomenorrhea was defined as a 42 d cycle; and eumenorrhea was defined as 25-35 d cycles. Approximately 5% of runners reported amenorrhea and 17.7% of runners reported oligomenorrhea. Thompson's study presents the lowest prevalence estimate of amenorrhea in runners, perhaps due to the conservative definition of amenorrhea (6 mo vs. 3 mo) and the possible inclusion of subjects using oral contraceptives.

According to the studies outlined above, the prevalence of amenorrhea appears to range from about 5-35% in young distance runners. It is worth noting, however, that one study estimated the prevalence of amenorrhea to be as high as 65% in distance runners. Marcus et al. (32) recruited 17 distance runners (mean age 21 yr) from collegiate teams (division unspecified) and non-collegiate running clubs on the basis of race performance, weekly mileage, and menstrual history. All subjects had run a sub-three-hour marathon, currently ran at least 40 mi/wk, were Caucasian, had not taken exogenous estrogens, and could be clearly defined as either amenorrheic or eumenorrheic. Amenorrheic subjects had zero menses in the last 1-7 yr and eumenorrheic subjects had 11 or 12 menses per year without interruption since menarche. Although not clearly stated, it appeared that the researchers did not attempt to influence the ratio of amenorrheic to eumenorrheic subjects that participated in the study, as additional subjects volunteered for the study but did not meet the inclusionary criteria. Marcus et al. found that 11 of the 17 subjects included in the study, or 65%, were amenorrheic. Though the prevalence estimate of Marcus et al. cannot be included in literature-based estimates due to the unspecified sampling methodology, their study indicates that athletic amenorrhea could be more prevalent than previously thought.

Causes

According to Pauli and Berga (4), athletic amenorrhea may be viewed as a type of FHA, a condition in which acute or chronic stress disrupts the hypothalamic-pituitary-ovarian axis, resulting in menstrual dysfunction (6). The stressors related to the development of amenorrhea may be broken into three categories: low energy availability, exercise, and psychological (6). Regardless of the type or types of stressors, a total stress load that exceeds the body's ability to cope results in the alteration of homeostasis in an effort to adapt to the allostatic load (4). The total stress load required to trigger allostatic adaptation varies from individual to individual; some individuals are more resistant to FHA than others (4). The possible roles of exercise training load, low energy availability, and psychological stress in the development of athletic amenorrhea will be discussed further.

Training load

By definition, athletic amenorrhea is associated with exercise. However, multiple stressors originate from exercise. Exercise may cause low energy availability through increased energy expenditure or may cause a general stress response due to the homeostatic challenges initiated through exercise. Stress originating from exercise, but not related to the energy cost of exercise, is known as exercise stress (25). Only one study to date appears to have attempted to separate the effects of exercise stress from the effects of low energy availability (25). Instead, most studies have focused on training volume alone, failing to account for the possibility of increased exercise energy expenditure with increasing training volume.

An additional limitation of the current literature is failure to account for exercise intensity and duration. Because exercise stress is related to both training duration and intensity (33), training volume alone may not strongly predict overall exercise stress. A final limitation of the current literature is that most studies examining the relationship between training volume and amenorrhea have employed simple correlation. As sample size increases, small correlation coefficients are more likely to be found significant (34), and correlation alone is not indicative of causation. Despite these limitations, studies relating training volume to the incidence of amenorrhea are discussed further.

Feicht et al. (10) surveyed 128 collegiate track and field and cross country athletes. Amenorrhea was self-reported and defined as three or fewer periods in one year. Though a significant correlation between weekly training volume (mi/wk) and the incidence of amenorrhea was found, the magnitude of the correlation was unreported. Additionally, Feicht et al. did not control for variables that may have affected amenorrhea, such as body weight and caloric intake. Thus, although it may be concluded that the incidence of amenorrhea increases as weekly mileage increases, few other conclusions may be drawn based on Feicht et al.

Sanborn et al. (13) surveyed 237 collegiate and age-matched distance runners (mean age unreported) to examine the relationship between body weight, training volume, and amenorrhea. All subjects were postmenarchal and had not used oral contraceptives within the past 6 mo. Amenorrhea was defined as three or fewer menstrual periods per year, and eumenorrhea was defined as four or more menstrual cycles per year. Like previous work (10), a significant, positive correlation was found between training volume (mi/wk) and the prevalence of amenorrhea. When controlling for body weight by classifying athletes as low, medium, and high body weight, the positive correlation between amenorrhea and training volume remained. Like Feicht et al. (10), however, Sanborn et al. did not report the magnitude of the correlation and failed to adequately control for energy availability; few conclusions can be drawn.

Cobb et al. (35) recruited competitive female distance runners from collegiate cross-country teams, running clubs, and road races. All subjects ran at least 40 mi/wk, competed in running races, and had not used hormonal contraception within 6 mo of beginning the study. The 91 subjects (mean age 21.7 yr) completed a self-administered survey assessing training, menstrual history, and diet and eating behaviors. Mean weekly mileage was calculated from year-long training journals. Usual nutrient intakes during the previous 6 mo was assessed using a modified version of the National Cancer Institute FFQ. Eumenorrhea was defined as ten or more menstrual cycles in the past year, oligomenorrhea as 4-9 cycles in the past year, and amenorrhea as four or fewer cycles in the past year. Athletes with oligomenorrhea and amenorrhea were lumped for comparisons. Cobb et al. found that the mean weekly running mileage of oligo/amenorrheic athletes was significantly greater than that of eumenorrheic athletes (39.0 vs. 33.0 mi/wk, respectively). Interestingly, mean daily caloric intake between the two groups did not differ significantly. Thus, although Cobb et al. appeared to relate training volume to menstrual dysfunction, differences in energy availability were not controlled for.

Torstveit and Sundgot-Borgen (11) examined factors related to present menstrual dysfunction by surveying 669 elite Norwegian athletes (mean age 21.3 yr) from 66 sports or events. Present menstrual dysfunction was defined as primary amenorrhea (absence of menarche by age 16 yr), secondary amenorrhea (absence of three or more consecutive cycles), oligomenorrhea (cycles of 35 d or more), or short luteal phase (menstrual cycle less than 22 d). Training volume (h/wk) was defined as weekly mean training volume during the previous year's training and competition period. Using binary logistic regression, Torstveit and Sundgot-Borgen found that age, age at menarche, body mass index, body dissatisfaction, and nulliparity were significantly associated with present menstrual dysfunction in athletes from multiple sports, but training volume was not. The results of Torstveit and Sundgot-Borgen differ from those of other authors perhaps because Torstveit and Sundgot-Borgen included athletes from multiple sports in their analysis. Sanborn et al. (13) found that the prevalence of amenorrhea in swimmers and cyclists did not increase as weekly training mileage increased.

Energy availability

While early research noted an association between low body fat and amenorrhea, surmising a causal relationship, current research indicates that low body fat does not inherently cause athletic amenorrhea (36). Instead, chronically low energy availability, which leads to weight loss and low body fat, appears to be the more proximal cause of amenorrhea (3). The American College of Sports Medicine defines energy availability as "the amount of dietary energy remaining for other body functions after exercise training" (3, p. 1868-1869). Stated alternatively, energy availability describes the balance between food consumed (energy intake) and energy required to perform activities of daily living and exercise training (energy expenditure). Low energy availability occurs when an athlete's energy intake is less than energy expenditure. Chronic caloric deficiency triggers a central suppression of reproductive function (1), including menstruation, in an attempt to adjust to the allostatic load (3). The specific pathways by which chronic energy deficiency may suppress reproductive function and cause menstrual dysfunction are discussed further by Meczekalski et al. (6). Few direct studies have been performed on energy availability and athletic amenorrhea in humans due to ethical concerns; however, there is evidence for a causal role of low energy availability in the development of amenorrhea.

Kopp-Woodroffe et al. (37) examined the role of low energy availability in the development of amenorrhea in case studies of four amenorrheic athletes. The subjects were recreationally active or collegiate athletes, ranged in age from 18-25 yr, and exercised more than 7 h/wk. Amenorrhea was defined as fewer than 3-4 periods during the previous year or no period within the last 3 mo and was confirmed with basal measurements of reproductive hormones. Energy intake was calculated using 7-day weighed food logs, and energy expenditure was calculated using 7-day activity logs in which activity was recorded in 15-30 min intervals. Subjects were found to eat 300-1200 kcal less than their estimated daily energy needs. Following a 20-week intervention in which dietary intake was increased by 360 kcal/d and training volume was decreased, the magnitude of energy deficiency was decreased by 17-69% and menstrual function was restored in three of four subjects.

Williams et al. (38) used primates in an attempt to show that low energy availability associated with exercise, not exercise itself, causes amenorrhea. Amenorrhea was induced in eight primates by periodically increasing training volume while maintaining dietary intake. At peak training volumes, primates ran 8-16 km/d, 7 d/wk for 2 h/d. In an effort to reverse amenorrhea, training volume was held constant but daily caloric intake was increased such that daily caloric intake exceeded daily energy expenditure. Subsequent to the dietary intervention, amenorrhea was reversed in four primates by increasing dietary intake by an average of 58%. The speed of menstrual cycle restoration was proportional to the magnitude of increased dietary intake. Because increased caloric intake restored menstrual function while exercise volume was maintained, the authors concluded that amenorrhea was due to low energy availability rather than exercise stress.

Lastly, Hilton and Loucks (25) attempted to separate the effects of energy availability and exercise stress on the diurnal rhythm of leptin, a hormone that is indicative of energy status in the body and affects the release of luteinizing hormone (6). Energy availability was defined as the difference between dietary intake and energy expenditure; exercise stress was defined as "everything associated with exercise except its energy cost" (p. E43). Sixteen healthy, habitually sedentary, normally menstruating women (mean age 21 yr) were assigned to two groups: sedentary or exercising. Subjects in each group were studied under two conditions: low energy availability and balanced energy availability. In sedentary subjects, low energy availability was achieved through caloric restriction; in exercising subjects, low energy availability was achieved through both exercise and caloric restriction. After 4 d of intervention, leptin levels were measured for 24 h in all groups. Exercise stress alone did not have a suppressive effect on leptin, but low energy availability strongly suppressed the diurnal rhythm of leptin. While this research highlights the importance of low energy availability in the development of amenorrhea, it does not rule out the role of exercise stress in the development of amenorrhea. First, the exercise intervention took place in 30 min bouts at 70% of maximal aerobic capacity with 10 min rests between exercise bouts. In athletes training to enhance performance, exercise bouts typically vary in both duration and intensity. Secondly, based on mean lean body mass in the exercising group, daily exercise caloric expenditure during the intervention was 1377 kcal/d. This likely represents a more severe calorie deficit than would typically be induced in a single training day, even in collegiate distance runners. Lastly, the exercise intervention lasted only 4d, and habitually sedentary subjects were used. Exercise stress could affect trained individuals differently, and the chronic effect of exercise stress may be different than the acute exercise stress (33).

Psychological stress

Periods of severe psychological stress have been associated with amenorrhea in healthy women (20); thus, it seems plausible that psychological stress may play at least some role in the development of athletic amenorrhea. Cortisol, a stress hormone, is elevated in amenorrheic women relative to eumenorrheic women (20, 4), and non-athletic women with FHA report greater difficulty coping with daily life stress, feelings of insecurity, and lack of control than eumenorrheic women (39).

Despite the evidence for a causal role of psychological stress on amenorrhea in non-athletic women, research on the relationship between psychological stress and athletic amenorrhea is mixed. Galle et al. (40) surveyed 105 female runners recruited from a sports medicine clinic, running centers, and road races. Runners ranged in age from 15-50 yr, and total weekly mileage ranged from 50-90 mi/wk. Of the 105 runners surveyed, 15% were amenorrheic, defined as absence of menstrual cycles for 6 mo or longer. All runners completed the Hopkins Symptom Checklist (SCL), an inventory used to evaluate emotional stress. Galle et al. found that amenorrheic runners had significantly higher SCL scores than eumenorrheic runners for obsessive-compulsive behavior and feelings of isolation.

Differences in SCL scores did not appear to be a function of or related to weekly training mileage, as the prevalence of amenorrhea did not differ between groups when runners were stratified by weekly mileage.

Unlike Galle et al. (40), Schwartz et al. (41) found that the psychological profiles and stress associated with running did not differ significantly between amenorrheic and eumenorrheic long distance runners. As part of a larger study, Schwartz et al. surveyed 70 runners (mean age 29.7 yr) recruited from running races, local running clinics, posted signs, and other runners. Of the 70 runners surveyed, 34 were classified as eumenorrheic long distance runners (> 30 mi/wk) and 12 were classified as amenorrheic runners (no menses for at least 4 mo prior to study). The two groups did not differ significantly in total weekly running mileage. Runners completed four psychological tests to "assess factors most likely to influence menstrual dysfunction" (p. 663) and were asked to rank the stress associated with running on a scale from 1-10. Schwartz et al. found that the psychological profiles of both groups of runners fell within "normal" ranges. Additionally, eumenorrheic long distance runners did not report running to be more stressful than amenorrheic runners.

The relative importance of psychological stress in the development of athletic amenorrhea remains unclear. Although severe psychological stress may cause amenorrhea in otherwise healthy, non-exercising women (20), the types of major life events known to cause such extreme psychological stress are generally rare in college students (42, 43) and may not play a significant role in the development of athletic amenorrhea. Instead, the bulk of stressors reported by college students are relatively minor daily hassles (43). Though psychological stress may not play a significant role in the development of athletic amenorrhea, the effects of stress on general menstrual function are well-documented. Thus, the possible role of stress in the development of athletic amenorrhea warrants further examination.

Synergism between causes

Williams et al. (44) argue that minor psychological stressors may synergistically interact with minor stressors related to low energy availability to cause FHA. To test this, Williams et al. manipulated both metabolic (exercise plus low energy availability) and psychosocial stress and measured reproductive hormones in monkeys. Monkeys were placed into three treatment groups who were exposed to either metabolic stress (n=9), psychosocial stress (n=8), or metabolic and psychosocial stress concurrently (n=10). Metabolic stress was induced by 1 h/d of treadmill running at roughly 80% of maximal oxygen uptake coupled with 20% caloric restriction. Psychological stress was induced by a change in housing location, an event previously shown to be a minor psychological stressor. Baseline measures of menstrual cycle length and hormonal profiles were recorded for two menstrual cycles. Near the end of the baseline menstrual cycles, interventions were imposed, and intervention effects on the menstrual cycle were measured for two cycles then compared to baseline. When menstrual abnormalities were analyzed in each group across time, neither the psychosocial stressor nor the metabolic stressor alone caused the frequency of menstrual abnormalities to differ from baseline. In contrast, the frequency of menstrual abnormalities in the exercise plus metabolic stressor group was significantly greater than during baseline. The proportion of monkeys experiencing menstrual abnormalities in the exercise and metabolic stress group (70%) was significantly greater than either the metabolic stress group (11%) or the psychosocial stress group (13%). The authors concluded that the two types of stressors (metabolic and psychosocial) interacted synergistically to compromise reproductive function.

Further evidence for synergism among several stressors causing amenorrhea is provided by Berga et al. (45). Sixteen women (mean age 24 yr) with FHA, confirmed by hormonal measurements, were recruited. Subjects were excluded if they had organic anovulation, an Axis I psychiatric disorder (any psychiatric disorder other than a personality disorder), were underweight, ran more than 10 mi/wk, or exercised more than 10 h/wk. Subjects were randomly divided into either a control or cognitive behavior therapy group. The cognitive behavior therapy group received 16 individual counseling sessions over a period of more than 20 wk. Topics covered included healthy eating and exercise patterns, body image, weight regulation, problem solving techniques, and life coping skills. Hormonal measurements were taken over 20 wk in both groups in order to observe changes. Women were classified as fully recovered from FHA if they had resumed ovulation and unrecovered if estradiol and progesterone levels remained low. Berga et al. found that more women receiving cognitive behavior therapy resumed ovulation (75%) than in the control group (13%). The authors concluded that cognitive behavior therapy may be beneficial in treating FHA by addressing the psychological traits that lead to unhealthy eating, metabolic imbalance, and elevated psychological stress.

In summary, exercise stress, low energy availability, and psychological stress may all play an independent role in the development of athletic amenorrhea. However, there is also evidence that the three, discrete categories of stressors interact synergistically, further compromising reproductive function. Relatively low levels of exercise stress, low energy availability, and psychological stress may interact to cause amenorrhea.

Prevalence of athletic amenorrhea in DI and DIII athletes

Athletic amenorrhea may be caused by the interaction of exercise stress, low energy availability, and psychological stress. Variation in the stress load contributed by each of these factors in different environments may lead to disparities in prevalence of amenorrhea in athletes competing in different athletic environments. There are several differences in the athletic environment between DI and DIII schools that may affect the prevalence of athletic amenorrhea.

First, though it may seem reasonable to believe that DI athletes train more because they are faster than DIII athletes, there is not strong evidence in the literature to support this notion. Nonetheless, the number of recent studies explicitly stating the mean weekly training mileage in collegiate distance runners at different divisional levels appears to be few (15, 16, 17, 18), and the possibility of differences in weekly training volumes at different divisional levels should not be ruled out.

In addition to possible differences in training load, energy availability may also differ between DI and DIII distance runners. Picard (19) surveyed DI athletes (n=38), DIII athletes (n=40), and non-athlete controls (n=31) and found that athletes at higher levels of competition showed more signs of pathological eating as indicated by Eating Attitudes Test and Eating Disorder Inventory (EDI) scores. Cobb et al. (35) found that female distance runners with elevated EDI scores consumed, on average, 19% fewer kilocalories per day and had increased prevalence of amenorrhea compared to similar distance runners with lower EDI scores. Based on the results of Picard and Cobb et al., it is reasonable to believe that DI athletes may have lower energy availability than DIII athletes, even when controlling for training volume, due to restrictive food intake. However, a confounding factor is that DI coaches report more monitoring, management behaviors, and resources available to treat athletes with eating disorders than coaches in other divisions (21). Whether or not DI and DIII athletes experience differences in energy availability leading to differences in the prevalence of amenorrhea has not been directly studied.

Lastly, athletes competing at the DI and DIII levels may be exposed to different levels of psychological stress during their collegiate athletics career. Although research shows that students attending colleges and universities of all sizes experience similar stressors (46), the athletic environment differs greatly between DI and DIII. Picard (19) surveyed athletes from multiple sports and found that DI athletes experienced more pressure to perform than DIII athletes. The higher level of pressure felt by DI athletes may be related to the greater emphasis on athletics at DI schools than DIII schools. For example, DI athletes are typically awarded scholarships based on athletic performance, but DIII athletes do not receive athletic scholarships (47).

It seems plausible that the pressure to perform in order to continue receiving athletic scholarships could affect the stress associated with being a student-athlete, leading to differences in prevalence of amenorrhea between DI and DIII athletes. However, according to the mental health model of sports performance, psychological profiles between more talented and less talented athletes may differ, further confounding the relationship between athletic stress, perceived stress, and menstrual dysfunction. Raglin (48) indicated that certain personality traits, such as extroversion and emotional stability, were moderately associated with sport participation. However, the link between athletic performance and emotional stability continues to be somewhat tenuous (48), indicating that DI and DIII athletes may not differ strongly in emotional traits related to perceived stress.

Summary and conclusions

Athletic amenorrhea, the non-organic absence of menses for three or more consecutive months after menarche in individuals who perform regular exercise training, is associated with health problems including low bone mineral density and vascular dysfunction (1). Estimates of the prevalence of athletic amenorrhea vary throughout the literature due to differences in the definition of amenorrhea, competition level of athletes surveyed, and training type and volume associated with different sports (11). The prevalence of amenorrhea differs between sports and is highest in sports emphasizing a lean physique or low bodyweight, such as distance running (2, 11).

Estimates of the prevalence of amenorrhea among distance runners of varying competition levels range from 5.3-35% (2, 12, 9, 13, 10). Possible explanations for the high variability of estimates observed in the literature include differences in inclusionary criteria, definitions of amenorrhea, and competition levels of athletes surveyed (11). Only one study has examined the prevalence of athletic amenorrhea exclusively in collegiate distance runners in the last 10 yr (12). Additionally, despite differences in the athletic environment between NCAA divisions, it appears that no study has attempted to examine potential differences in the prevalence of athletic amenorrhea between divisions.

According to Pauli and Berga (4), athletic amenorrhea may be viewed as a condition in which acute or chronic stress disrupts the hypothalamic-pituitary-ovarian axis, resulting in menstrual dysfunction (6). However, the specific stressors related to the development of athletic amenorrhea remain unknown. Research indicates that exercise stress, low energy availability, and psychological stress may all play a role in the development of amenorrhea (6).

Several studies have attempted to examine the relationship between training volume and amenorrhea. In general, research has found a positive association between training mileage and menstrual dysfunction (10, 13, 35). However, in a well-controlled experimental study, Hilton and Loucks (25) found that, when controlling for energy availability, increased exercise volume alone did not alter the diurnal rhythm of leptin, a hormone affecting the release of luteinizing hormone. Thus, the effects of training load on menstrual dysfunction remain unclear.

Low energy availability, or caloric expenditure in excess of caloric intake, has also been associated with amenorrhea. Though few experimental studies have been performed in humans due to ethical concerns, there is evidence for a causal role of low energy availability in the development of amenorrhea. For example, in heavily-exercising primates, amenorrhea has been reversed following the introduction of a eucaloric diet (38). Additionally, Hilton and Loucks (25) found that exercise training alone did not affect leptin (permissive for luteinizing hormone), though low energy availability was associated with leptin suppression.

Lastly, psychological stress may play a role in the development of athletic amenorrhea. Periods of severe psychological stress have been associated with amenorrhea in healthy women (20); in athletes, however, the data are mixed. Galle et al. (40) found that amenorrheic runners had significantly higher SCL scores than eumenorrheic runners, indicating increased obsessive-compulsive behavior and feelings of isolation. However, Schwartz et al. (41) found that the psychological profiles and stress associated with running did not differ between amenorrheic and eumenorrheic long distance runners. Thus, the importance of psychological stress in the development of athletic amenorrhea remains unclear.

Exercise stress, low energy availability, and psychological stress may all play a role in the development of athletic amenorrhea. Because of the potential for these stressors to vary between DI and DIII athletes, the prevalence of amenorrhea may also differ between athletes in different NCAA divisions. Although approximately 3.4 times more female athletes compete in NCAA DI than NCAA DIII (22), athletes at all competition levels are entitled to resources that ensure they are able to train and compete safely. Thus, the purpose of this research was to quantify the prevalence of amenorrhea in NCAA athletes across the United States. Specifically, potential differences in prevalence of athletic amenorrhea between DI and DIII distance runners were examined. In addition to estimating the prevalence of amenorrhea, the association between training load, low energy availability, psychological stress, and the prevalence of athletic amenorrhea were also examined.

CHAPTER 3

METHODOLOGY

Subjects

Subjects were collegiate distance runners currently training to compete at the DI or DIII level. Distance runners were defined as athletes who train to compete in running race distances of 1500 m or greater. Individuals who were pregnant or breastfeeding or individuals who had taken birth control within the last 6 mo were excluded. Individuals who had been diagnosed with an eating disorder, tumor, thyroid problems, or polycystic ovarian syndrome were also excluded. Subjects were recruited from colleges and universities across the United States through solicitation via email, with permission from coaches. The NCAA directory was used to verify that only coaches at DI and DIII schools were contacted. Participants self-classified their current NCAA divisional level and must have been competing at their most recent divisional level for at least one full academic semester in order to be included. All participants were age 18 yr or older and were required to understand and sign a consent form in English. A university-approved informed consent was obtained prior to study participation.

Survey measurements

All data was gathered using anonymous, online surveys emailed to athletes after receiving permission from coaches. Surveys included a brief health history to determine study eligibility. Individuals who did not meet the inclusionary criteria were automatically directed to the end of the survey; incomplete surveys were not analyzed. In addition to a brief health history, subject height, weight, age, current NCAA divisional classification, menstrual status, training load, psychological stress, and energy availability were assessed. All data were self-reported. The survey may be viewed in Appendix A.

Subject characteristics

Subjects were asked to record current age (yr, mo), height (ft, in), weight (lbs), duration of weight maintenance (49), NCAA division, and length of time they had been competing in their current division. Survey data was reported in United States customary units in order to improve subject understanding. Prior to analysis, data reported in United States customary units were converted to international system units. Body mass index (BMI) was calculated from the height and weight reported for each subject using the following formula: mass in kg / (height in m)^2.

Athletic amenorrhea

Athletic amenorrhea was defined as the non-organic absence of menses for three or more consecutive months after menarche in individuals who perform regular exercise training with the intent of improving distance running performance (1, 6). Subjects who reported the absence of menstruation for three or more consecutive months were classified as amenorrheic. Subjects who reported menstrual cycles of 25-38 d occurring monthly for three or more consecutive months were classified as eumenorrheic. Subjects who reported neither amenorrhea nor eumenorrhea as defined above were excluded from the analysis.

Training load

Training parameters were calculated based on the subjects' estimates of the previous 3 mo of training (50). Mean weekly training volume and duration were reported as estimated mean weekly mileage (mi/wk) and estimated mean time spent running or cross-training (min/wk), respectively. In order to estimate mean training intensity, survey respondents were asked to estimate the percentage of their weekly training time falling into one of ten categories of the Borg CR-10 scale (51).

Survey responses measuring parameters related to training load (weekly running mileage, weekly time spent running or cross training) were reviewed for accuracy. Apparent errors in time spent cross training were corrected based on subject-provided, journal descriptions of the mode, duration, and intensity of cross training. Then, using a method similar to Foster et al. (26), mean weekly training load was calculated by summing the product of the number of minutes spent training in each Borg category and the magnitude of that Borg category (Appendix B). Training load was reported in arbitrary training units (atu).

Energy availability

Habitual energy intake was estimated using the semi-quantitative, self-administered, 1-week FFQ included in Nutritionist Pro Diet Analysis Module (version 4.3, Axxya Systems, Stafford, TX). Diet monitoring periods of 3-7 d have been found to "provide reasonably accurate and precise estimations of habitual energy and macronutrient consumption" in athletes (23, p. 540), while minimizing the declines in recall ability that occur with time (52). Though FFQs are commonly used to assess habitual dietary intake over long periods of time (53), they may also be used to assess dietary intake over shorter periods (23). Eck et al. (54) compared two, week-long FFQs to 3-day food records, 6-day food records, and single, 24-hour recalls. Total energy intake from both FFQs had similar reproducibility to 3- and 6-day diet records and better reproducibility than a single, 24-hour recall (54). Additionally, when the two FFQ-based estimates of individual caloric intake were compared to 6-day food records, 65-80% of FFQ-based caloric estimates were within 500 kcal or less of individual caloric intakes estimated using the 6-day food record (54).

The FFQ was adapted for online completion. The online FFQ interface appeared slightly different from, but was functionally similar to, the original FFQ. The food list presented online was identical to the food list in the original FFQ, with the exception of two additional food items. Both sports drinks and soy milk were added in an effort to make the food list more applicable to the survey population (35). Nutrition information for sports drink and soy milk was obtained from manufacturer websites. Unlike the original FFQ, the online FFQ allowed for partial, as well as whole, servings of foods to be recorded. For example, if an online respondent consumed half a cup of skim milk, they could record ½ serving of skim milk. Using the original FFQ, the respondent would have had to omit the partial milk serving or round up to a whole serving of milk. Including portion-size flexibility may improve the accuracy of estimated caloric intake from foods that generally come in natural units such as slices of bread and pieces of fruit (55) but is unlikely to change the validity of caloric estimates on the whole (56).

Subjects were presented with a list of 115 similar food groups (Appendix A) and directed to select the number of servings typically consumed. Total number of servings was reported either as servings per day or servings per week depending on frequency of consumption. Portion sizes for each food group were indicated using typical household measures (ounces, cups, tablespoons, etc.). Daily caloric intake for each respondent was estimated using the algorithms used by the Nutritionist Pro software. Calculations of weekly caloric intake were performed using Microsoft Excel (2007, Microsoft, Redmond, WA).

Mean daily caloric intake for each athlete was calculated by summing caloric intake across 1 wk and dividing by seven.

Daily energy expenditure was estimated using the Harris and Benedict equation for resting metabolic rate and corrected for activities of daily living (57). Energy expended through daily physical activity, not including running or cross-training, was calculated as the product of resting metabolic rate and a coefficient of physical activity (1.3) for adults who are sedentary and engage in typical daily living activities (58).

Mean daily energy expenditure due to running was estimated using American College of Sports Medicine equations (59) based on reported training data. Mean daily caloric expenditure from cross-training was estimated using metabolic equivalent (MET) values provided by the Diet Analysis Plus software program (version 7.0.1, Thompson Corporation) and American College of Sports Medicine equations (59). Energy availability was calculated as the difference between estimated mean daily caloric intake and estimated mean daily energy expenditure. These equations may be found in Appendix C.

Psychological stress

Psychological stress was measured using the perceived stress scale (PSS). The PSS survey, developed by Cohen et al. (42), measures “the degree to which situations in one's life are appraised as stressful” (p. 385). Perceived stress is a measure of stress experienced by an individual, and is a function of objectively stressful events, coping, and personality. The original 14-item PSS was found to be a better predictor of health outcomes than traditional life event scales (42). The modified 10-item PSS is similar in reliability and validity to the 14-item PSS (60) and was used in this study. Possible PSS scores range from 0-40, with higher scores indicative of greater perceived stress (60). Scoring of the PSS was performed as described by Cohen et al. (42).

Data analysis

Data analysis was performed using SPSS statistical software (SPSS version 19, LEAD Technologies, Inc., Chicago, IL, USA). Mean and standard deviations for height, weight, age, and BMI were calculated. The χ^2 test of independence was used to test the null hypothesis that the prevalence of amenorrhea does not differ between NCAA DI and NCAA DIII athletes. A series of independent-samples t-tests were conducted to determine if subject characteristics (age, body mass, height, BMI), variables related to training load (time spent running, time spent cross training, weekly running mileage, weekly training load), PSS score, and variables related to energy balance (energy expenditure due to running, energy expenditure due to cross training, total daily energy expenditure, energy availability, and daily caloric intake) differed between divisions. Family-wise error rates were controlled using the Bonferroni adjustment ($\alpha = 0.05$ divided between a maximum of six, family-wise comparisons), and the null hypothesis was rejected if $p \leq 0.01$.

A series of binary logistic regression analyses were used to determine if a significant relationship existed between variables associated with training load (weekly time spent cross training, weekly time spent running, total weekly running mileage, and training load), energy availability (total daily energy expenditure, energy expenditure due to running, energy expenditure due to cross training, daily caloric intake, and energy availability), psychological stress (PSS score), and the incidence of amenorrhea. A total of ten, univariate binary logistic regression analyses using markers of training load, energy availability, and psychological stress to predict the incidence of amenorrhea were performed. Additionally, a single, multivariate binary logistic regression analysis (main effects and interaction effects) was performed to determine if training load, energy availability, and psychological stress simultaneously explained variance in the incidence of amenorrhea. Data from DI and DIII athletes was pooled for all regression analyses. For all logistic regression analyses, p-values reported by SPSS were rounded to the nearest hundredth and the null hypothesis was rejected if $p \leq 0.05$.

CHAPTER 4

RESULTS

Response rate

Head track and field coaches at 556 colleges and universities across the United States were contacted for permission to include their athletes in the research study. Of the 556 coaches contacted, 75 coaches (28 DI, 47 DIII) in 27 states agreed to allow their athletes to participate. Because most coaches chose to forward the survey directly to their athletes via email rather than to share email addresses, the exact number of athletes contacted to participate is unknown.

Of the athletes contacted to participate, 471 athletes accessed the survey online and 439 athletes completed questions designed to assess eligibility. Approximately 50% (n=221) of athletes screened were eligible to participate. In general, the number of athletes who continued to answer survey questions declined across each portion of the 20 minute survey. Thus, out of 221 eligible subjects, only 130 subjects completed the survey from start to finish. In addition to incomplete surveys (n=123), two completed surveys were discarded because of non-sensical, unverifiable responses to questions designed to assess type and volume of cross training. In total, out of 471 survey attempts, 128 complete and accurate surveys were obtained.

Additionally, because one of the purposes of this research was to model the prevalence of athletic amenorrhea, subjects who could not be clearly classified as either amenorrheic or eumenorrheic based on their survey responses were excluded from further analysis. After discarding the surveys of women who were neither amenorrheic nor eumenorrheic (n=30, 23% of survey responses), 98 complete and accurate surveys remained, 20.8% of total surveys attempted.

Subject characteristics

Of the 98 distance runners classified as either amenorrheic or eumenorrheic, 33% (n=32) were DI athletes and 67% (n=66) were DIII athletes. All subjects had been competing at their current divisional level for at least one whole academic semester. Self-reports indicated subjects had not taken birth control within the last 6 mo, and no subjects had a history of eating disorder, tumor, thyroid problems, or polycystic ovarian syndrome. No subjects were pregnant or breastfeeding. Age, height, body mass, and BMI did not differ between NCAA divisions ($p \geq 0.541$ for all comparisons). Subject characteristics are summarized in Table 1.

Table 1. Participant physical characteristics (n=98)

	DI Athletes (n=32)		DIII Athletes (n=66)	
Measure	Mean ± SD	Range	Mean ± SD	Range
Age (yr)	20 ± 1	18-23	20 ± 1	19-23
Height (cm)	166.5 ± 5.6	157.5-177.8	166.9 ± 6.7	152.4-180.3
Body Mass (kg)	57.5 ± 6.0	46.3-72.6	57.0 ± 5.9	45.4-72.6
BMI (kg/m^2)	20.7 ± 1.5	18.3-24.0	20.5 ± 1.8	17.5-26.5

Prevalence of athletic amenorrhea in DI and DIII athletes

Eumenorrhea, defined as having a menstrual cycle once every 25-38 d for the past 3 consecutive months, was reported by 80% (n=78) of the 98 survey respondents who could be classified as either amenorrheic or eumenorrheic. Amenorrhea, defined as lack of menstruation for three or more consecutive months, was reported by 20% (n=20) of respondents. The percentage of athletes classified as amenorrheic did not differ between divisions, though approached significance (p=0.064). The prevalence of amenorrhea among DI athletes was 31% (n=10), while the prevalence of amenorrhea among DIII athletes was 15% (n=10).

Training load

Time spent cross training (p=0.877), time spent running (p=0.146), and training load (p=0.131) did not differ between DI and DIII athletes (Table 2). However, DI athletes had significantly greater weekly running mileage than DIII athletes (p<0.0005, Table 2).

Table 2. Mean training load, time spent cross training, and time spent running in athletes from both NCAA divisions. Within a row, lower case letters indicate significant differences between divisions (α = 0.01).

	DI Athletes		DIII Athletes	
Measure	Mean ± SD	Range	Mean ± SD	Range
Cross Training (min/wk)	143 ± 108	0-450	148 ± 140	0-645
Running (min/wk)	485 ± 124	210-780	426 ± 211	60-1680
Training Load (atu)[1]	1139 ± 909	270-5280	881 ± 721	300-4140
Running Mileage (mi/wk)	46 ± 14 a	10-80	36 ± 11 a	5-55

1. atu = Arbitrary training units

Weekly time spent cross training (p=0.580), weekly time spent running (p=0.215), and training load (p=0.126) were not related to the presence or absence of amenorrhea. Total weekly running mileage, however, did significantly predict amenorrhea (Nagelkerke R^2 = 0.067, correct overall classification percentage = 79.6%). Main effects, as well as their slope estimates and significance, are shown in Table 3.

Table 3. Logistic regression model predicting risk of amenorrhea using weekly running mileage.

Parameter	β	Exp[β][1]	P-Value
Total Weekly Running Mileage	0.042	1.043	0.045
Constant	-3.092	0.045	0.001

1. Exp[β] is an odds ratio that may be interpreted two ways. First, if weekly running mileage increases one unit, the odds of successfully predicting a case of amenorrhea increase by a factor equal to Exp[β] (when other variables are controlled). Secondly, a one unit increase in running mileage increases the odds of developing amenorrhea by Exp[β] (when other variables are controlled).

Energy availability

Mean daily energy expenditure due to cross training did not differ between DI and DIII athletes ($p=0.918$). However, DI athletes had significantly greater daily energy expenditure due to running ($p<0.0005$) and significantly greater total daily energy expenditure than DIII athletes ($p=0.005$). Despite differences in energy expenditure between divisions, neither mean daily caloric intake ($p=0.863$) nor energy availability ($p=0.722$) differed between DI and DIII athletes (Table 4).

Table 4. Mean daily energy expenditure, caloric intake, and energy availability in DI and DIII athletes. Within a row, lower case letters indicate significant differences between divisions ($\alpha = 0.01$).

	DI Athletes		DIII Athletes	
Measure	Mean ± SD	Range	Mean ± SD	Range
Cross training EE[1] (kcal/d)	124 ± 99	0-413	127 ± 118	0-599
Running EE (kcal/d)	676 ± 207 a	253-1177	535 ± 146 a	68-840
Daily EE (kcal/d)	2642 ± 271 b	2115-3326	2500 ± 205 b	2071-3211
Daily Caloric Intake (kcal/d)	2821 ± 1232	1172-7404	2776 ± 1204	951-6786
Energy Availability (kcal/d)	179 ± 1290	-2154-4829	276 ± 1240	-1773-4541

1. EE = Energy expenditure

Total daily energy expenditure (p=0.213), energy expenditure due to running (p=0.088), and energy expenditure due to cross training (p=0.750) did not predict the presence or absence of amenorrhea. Daily caloric intake (p=0.943) and energy availability (p=0.759) were also unrelated to the presence or absence of amenorrhea.

Psychological stress

Psychological stress, as measured by the PSS (42), did not differ significantly between divisions (p=0.100, Table 5). Mean PSS score was predictive of the presence or absence of amenorrhea (Nagelkerke $R^2 = 0.073$, correct overall classification percentage = 79.6%, Table 6).

Table 5. Mean PSS scores by division

Division	Mean ± SD	Range
DI (n=32)	15.4 ± 6.3	3-33
DIII (n=66)	17.4 ± 5.2	8-27
Overall (n=98)	16.7 ± 5.6	3-33

Table 6. Logistic regression model predicting risk of amenorrhea using mean PSS score.

Parameter	β	Exp[β][1]	P-Value
Mean PSS score	-0.104	0.901	0.040
Constant	0.281	1.324	0.725

1. Exp[β] is an odds ratio that may be interpreted two ways. First, if PSS score increases by one unit, the odds of successfully predicting a case of amenorrhea increase by a factor equal to Exp[β] (when other variables are controlled). Secondly, a one unit increase in PSS score increases the odds of developing amenorrhea by Exp[β] (when other variables are controlled).

Synergism between causes

The overall multivariate logistic regression model predicting the probability of amenorrhea as a function of PSS score, training load, energy availability, and interaction factors was significant (p=0.043), with a Nagelkerke $R^2 = 0.196$, and a correct overall classification percentage of 80.6% (Table 7). In the full model, only training load was significantly related to the risk of amenorrhea ($p=0.046$). There were no significant interactions between training load, energy availability, and PSS score.

Table 7. Full model predicting risk of amenorrhea using PSS score, training load, energy availability, and their interactions.

Parameter	β	Exp[β][1]	P-Value
PSS Score	0.002	1.002	0.981
Training Load	0.003	1.003	0.046
Energy Availability	0.001	1.001	0.176
Training Load * Energy Availability	0.000	1.000	0.568
PSS Score * Energy Availability	0.000	1.000	0.135
Training Load * PSS Score	0.000	1.000	0.115
Constant	-2.186	0.112	0.112

1. Exp[β] is an odds ratio that may be interpreted two ways. First, if the independent variable increases by one unit, the odds of successfully predicting a case of amenorrhea increase by a factor equal to Exp[β] (when other variables are controlled). Secondly, a one unit increase in an independent variable increases the odds of developing amenorrhea by Exp[β] (when other variables are controlled).

CHAPTER 5

DISCUSSION

The purpose of this research was to examine differences in prevalence of athletic amenorrhea between NCAA DI and DIII distance runners and to determine the predictive value of training load, energy availability, and psychological stress in the development of athletic amenorrhea. It was hypothesized that the prevalence of athletic amenorrhea would be greater in NCAA DI distance runners than DIII distance runners and that the risk of amenorrhea would increase as psychological stress and training load increased; the risk of amenorrhea was expected to decrease as energy availability increased. These hypotheses were evaluated using a self-completed survey of 98 distance runners. The survey evaluated study eligibility, menstrual function, psychological stress, training load, and energy availability.

Training load

Previous research has linked running mileage to menstrual irregularity. Cobb et al. (35) found that amenorrheic and oligomenorrheic athletes did not differ from eumenorrheic athletes in body fat percentage or training age, but did differ in weekly training mileage. Eumenorrheic women were found to run an average of 33 mi/wk, while amenorrheic and oligomenorrheic women ran an average of 39 mi/wk (35). Barrow and Saha (29) also reported a similar trend. Runners classified as very irregular (n=69), defined as having 0-5 menses per year, reported significantly greater weekly training mileage than regular (n=120) runners (10-13 menses per year). Barrow and Saha found that mean weekly training mileage in the regular runners was 41.2 mi/wk, while mean weekly training mileage in very irregular runners was 47.9 mi/wk.

A similar, positive association between run training mileage and the risk of amenorrhea was found in the current study. The estimated slope constant (β) for the logistic regression analysis predicting the incidence of amenorrhea using run training mileage was 0.042. In binary logistic regression, a slope estimate of zero indicates that the independent variable (run training mileage) has no predictive value for the dependent variable (incidence of amenorrhea). A significant, positive slope estimate indicates that the risk of developing amenorrhea increases as running mileage increases. The exponentiated slope constant ($Exp[\beta] = 1.043$) indicates that each 1 mi/wk increase in running mileage is expected to increase the odds of developing amenorrhea by approximately 1.043.

Paradoxically, although weekly running mileage was associated with the risk of developing amenorrhea, weekly time spent running and cross training were not. Because training load was calculated, in part, using weekly time spent running and cross training, it is unsurprising that training load was also not associated with menstrual dysfunction. The lack of association between training time and menstrual dysfunction in the present study is in agreement with Torstveit and Sundgot-Borgen (11), who reported that, among members of the Norwegian national team (66 different sports), training time (hr/wk) was not related to menstrual dysfunction.

As other researchers have noted, the association between exercise training and menstrual dysfunction may result from either a direct effect of exercise training on menstrual function or from the negative effects of exercise training on energy availability and menstrual function (25). However, current research in both humans and primates supports the notion that low energy availability, secondary to exercise training, rather than exercise training alone, is the more probable cause of exercise-associated menstrual dysfunction (25, 38).

The lack of association between variables related to training time (total time spent running or cross training, total training load) and menstrual dysfunction may lend further support to the premise that menstrual dysfunction is a function of low energy availability, secondary to exercise training, rather than exercise training itself. Due to differences in exercise intensity between individuals, running mileage is likely more proximally related to exercise energy expenditure than time-based parameters such as time spent running, time spent cross training, and training load.

If some property inherent to exercise training caused menstrual dysfunction, it seems likely that all variables related to exercise training (run mileage, time spent running and cross training, training load) would be significantly associated with menstrual dysfunction. Instead, only run mileage was predictive of menstrual dysfunction, perhaps because of the close association between run mileage and energy expenditure. However, this last point is only a speculation and is in need of research clarification.

Energy availability

Calculations of energy availability were based on energy expenditure due to running (mean miles run and total time spent running), cross training (mode, time, and intensity), and mean daily energy expenditure (excluding exercise). Some subjects neglected to provide a sufficient description of the mode and intensity of cross training performed weekly, making calculations of calories utilized due to cross training impossible. In cases where the description of cross training was incomplete (n=26), rather than excluding the survey responses, calorie expenditure due to cross training was estimated. For this procedure, average calories expended per minute spent cross training was calculated based on complete responses (n=97) of all subjects who met the basic inclusion criteria (n=128), rather than subjects who met the basic inclusion criteria and could also be classified as either amenorrheic or eumenorrheic (n=98), in order to improve the estimation quality by increasing sample size. An estimated total caloric expenditure was calculated as the product of total minutes of cross training and mean caloric expenditure per minute of cross training.

Mean daily caloric intake across both divisions was approximately 2500-2600 kcal/d, well above the minimum of 1800-2000 kcal/d (30 kcal/kg fat-free mass/day) that Rodriguez et al. (58) suggest is necessary to maintain energy balance and preserve neuroendocrine function in female athletes. Mean energy availability, which was approximately 180-280 kcal/d in athletes from both divisions, indicated that the athletes, in general, appeared to consume adequate calories to meet their daily energy needs. Based on the Harris and Benedict equation and physical activity coefficients of 1.6-1.89 (58), the mean daily energy requirement of the athletes sampled was estimated to be 2253-2660 kcal/d, further supporting the notion that, on the whole, energy balance was adequate.

Though previous research has noted an association between low energy availability and menstrual dysfunction in humans (37, 25), such an association was absent in the current study. Measures of energy expenditure (energy expenditure due to cross training or running, total daily energy expenditure), energy intake (daily caloric intake), and energy availability (the difference between daily caloric intake and total daily energy expenditure) were not predictive of menstrual status ($p \geq 0.088$ for all comparisons).

A possible explanation for the lack of association between measures of energy balance and menstrual status is that energy expenditure was approximately well-balanced with energy intake in the athletes sampled. The slightly positive mean energy availability in both DI and DIII athletes supports this position. However, it is also possible that the measures used to calculate energy expenditure and daily caloric intake were not sensitive enough to capture the variations in energy balance across the sampled athletes, obscuring the true relationship between energy balance and menstrual function. Indeed, examination of the standard deviation of energy availability shows large variability across both divisions. The coefficient of variation was in excess of 400% in DIII athletes and more than 700% in DI athletes.

The large variation in energy balance found in the present study may have been due to inaccurate survey responses. Magkos and Yannakoulia reported that athletes may omit foods considered undesirable, falsely report foods considered desirable, and inaccurately report serving sizes (23). While such errors are, to a certain extent, inherent in self-reported dietary intakes (23), FFQs are, nonetheless, useful for the estimation of usual dietary intakes of large groups (53). Despite the ease of use of FFQs for self-reported assessment of usual dietary intake (23), reducing measurement error, perhaps by using a more sensitive measure of energy balance would likely improve estimation of mean energy availability and improve statistical power (61).

Psychological stress

While some researchers have speculated that collegiate athletes face greater psychological stress compared to non-athlete students due to the additive effects of academic stress and sporting stress, others have posited that the opposite is true due to the protective effect of sport participation on mental health (62). Data from the current study appears to indicate that the athletes sampled do not experience greater psychological stress than the general undergraduate population. Roberti et al. (60) sampled 225 female undergraduates at three universities in the southeast United States and found that the mean PSS score was 18.4 ± 6.5, while Massimini and Peterson (63) surveyed 300 male and female undergraduates at a Mid-Atlantic university and found that the mean PSS score was 17.98 ± 5.59. The mean PSS score of the athletes sampled in the current study was 16.7 ± 5.6. Conversion of the mean PSS score to a z-score based on the findings of Roberti et al. and Massimini and Peterson suggest no difference between the mean PSS scores of athletes and non-athletes ($z = -0.26$ and -0.23, respectively).

Research has shown that high levels of psychological stress can cause menstrual dysfunction in otherwise healthy females (20). An association between mean PSS score and menstrual dysfunction was also found in the current study; however, the direction of the relationship between stress and menstrual dysfunction was opposite from what was expected. The slope constant ($\beta = -0.104$) and exponentiated slope constant ($Exp[\beta] = 0.901$) for the relationship between PSS score and menstrual dysfunction indicate an inverse relationship. Specifically, as PSS score increased by one unit, the odds of developing amenorrhea decreased by 0.901. Stated alternatively, a one unit increase in PSS score increases the odds of an athlete being eumenorrheic by 1.109.

The divergent relationship between mean PSS score and menstrual dysfunction in the current study may indicate that psychological stress does not play a large role in the development of athletic amenorrhea. This is, of course, only speculation. Division I athletes, who reported a greater incidence of menstrual dysfunction, had lower mean PSS scores, and

DIII athletes, who reported a lower incidence of menstrual dysfunction, had higher mean PSS scores.

As indicated by Schwartz et al. (41), it appears that other factors, such as weekly running mileage, may be more important than psychological stress in the development of athletic amenorrhea. When controlling for weekly running mileage, Schwartz et al. found that 34 eumenorrheic runners and 12 amenorrheic runners both had normal psychological profiles and did not differ in their perception of stress associated with running.

Synergism between causes

Synergism is an increase in the likelihood of a measured outcome (such as amenorrhea) greater than that expected based on individual factor inputs (training load, energy availability, and psychological stress). Although athletic amenorrhea may be caused by either low energy availability (38) or psychological stress (20) independently, there is also evidence that marginally low energy availability and psychological stress may synergistically increase the risk of menstrual dysfunction (44).

The results of the multivariate logistic regression predicting the risk of amenorrhea as a function of PSS score, training load, and energy availability in the present study do not support the notion of synergism between main effects. Significant interaction effects in multivariate models are synonymous with synergism (64). Because there were no significant interactions between main effects in the multivariate model, the current results do not support a synergistic interaction between psychological stress and low energy availability as reported by Williams et al. (44).

Prevalence of athletic amenorrhea in DI and DIII athletes

Overall

The prevalence of athletic amenorrhea in 98 female distance runners who could be classified as either amenorrheic or eumenorrheic was 20%. This is in relatively close agreement with other studies that excluded subjects due to birth control usage. For example, Robinson et al. (9) found that 15% of the 20 distance runners sampled were amenorrheic (absence of menses for 6 mo or longer). Carlberg et al. (2) found that 18% of the 83 distance runners sampled were oligo/amenorrheic (less than four periods in the previous year or the absence of menstruation for the previous 3 mo). Lastly, Sanborn et al. (13) found that 25.7% of 237 collegiate and age-matched, non-collegiate distance runners were amenorrheic (3 or fewer periods per year).

Differences between divisions

The incidence of amenorrhea, though approaching statistical significance, did not differ between divisions ($p=0.064$). The prevalence of amenorrhea among DI athletes was 31%, while the prevalence of amenorrhea among DIII athletes was 15%. Weekly running mileage, energy expenditure due to running, and total daily energy expenditure, however, were found to differ between divisions in the present study. Though anecdotal evidence suggests that DI athletes train more than DIII athletes, there is not strong evidence in the literature to suggest this (15, 16, 17, 18). The results of the present study indicate that DIII athletes run about 10 mi/wk, or 22%, less than DI athletes. Because DI and DIII athletes did not differ in energy expenditure due to cross training or daily caloric intake, energy expenditure due to running and total daily energy expenditure were both greater in DI athletes than DIII athletes.

Mean PSS scores did not differ significantly between divisions, though approached significance (p=0.100). Division III athletes tended to have slightly higher perceived stress levels than DI athletes. These results are somewhat surprising, as Picard (19) reported that DI athletes experience more pressure to perform than DIII athletes, and the athletic performance of DI athletes, but not DIII athletes, is associated with the potential gain or loss of athletic scholarships (47). The PSS measures only general life stress and is not designed to distinguish between sporting and non-sporting stressors. It is possible that DI athletes experience more stress directly related to athletics and DIII athletes tend to experience more non-sporting stressors; however, this is speculation.

Of the variables of interest found to approach a difference between divisions, only PSS score and weekly running mileage were also significantly related to the risk of amenorrhea. As discussed previously, however, the direction of the relationship between mean PSS score and the risk of amenorrhea was opposite than expected, rendering the predictive value of PSS in the development of athletic amenorrhea dubious. Thus, in the present set of data, differences in weekly running mileage between DI and DIII athletes appear to best explain the trend of somewhat higher risk of amenorrhea in DI athletes compared to DIII athletes.

Conclusion

In conclusion, the prevalence of amenorrhea did not differ between DI and DIII distance runners. The prevalence of amenorrhea observed in the current study was similar to that previously reported in the literature. Though DI athletes reported greater weekly running mileage than DIII athletes, other training parameters did not differ between the groups. Of weekly time spent cross training and running, training load, and total weekly running mileage, only total weekly running mileage was predictive of the risk of athletic amenorrhea. That is, as training mileage increased, the risk of amenorrhea also increased. In general, measures of energy expenditure, caloric intake, and energy availability did not differ between DI and DIII athletes; the exceptions, however, were daily energy expenditure due to running and total daily energy expenditure, which were significantly greater in DI athletes than DIII athletes. No measures of energy expenditure, caloric intake, or energy availability were predictive of the risk of amenorrhea. Contrary to the expected results, psychological stress was found to be inversely related to the risk of amenorrhea. Though PSS scores did not differ between DI and DIII athletes, DIII athletes tended to have elevated PSS scores relative to DI athletes but a lower risk of amenorrhea, potentially explaining the unexpected, inverse relationship between psychological stress and risk of amenorrhea. Lastly, though some research indicates that energy availability and psychological stress may synergistically increase the risk of amenorrhea, that was unsupported in the present study.

It is noteworthy that only 50% of athletes screened initially were eligible to participate in the survey. Though not exclusively, most athletes were excluded due to birth control usage in the past 6 mo. Obviously, an individual may choose to take birth control for any number of reasons, but oral contraceptives may also be prescribed in order to correct menstrual dysfunction (3). However, use of oral contraceptives may fail to restore menstrual cyclicity and bone mineral density in previously amenorrheic athletes (3). Thus, the ill effects of athletic amenorrhea likely reach beyond those subjects included in this study.

Limitations

There are several limitations of this study worth noting. First, though nearly 471 athletes attempted the survey, 128 complete and accurate surveys were obtained. Of these, only 98 belonged to athletes that could clearly be classified as either amenorrheic or eumenorrheic, 21% of the original 471 athletes who attempted the survey. Because nearly four out of five athletes were either excluded from the study or failed to complete it, the applicability of survey results to the whole population of DI and DIII distance runners is compromised. A second limitation is that power calculations for the χ^2 test of independence testing differences in the prevalence of amenorrhea between DI and DIII athletes indicate that the study was underpowered (β=0.236). Original sample size calculations were based on the assumption of a greater difference in the prevalence of amenorrhea between DI and DIII athletes than that observed. A third limitation is that energy expenditure due to cross training was estimated in 26 of the 98 subjects. Calculations based on energy expenditure due to cross training are dependent on the quality of estimates used in place of missing data. Lastly, the FFQ used in this study has not been validated in an athletic population. Though the FFQ data appear reasonable, the external validity of nutritional data obtained within the sample of athletes studied here is limited.

Future directions

Based on the results of this study, approximately 20% of DI and DIII distance runners are amenorrheic. Because all female athletes have a right to train and compete while minimizing the risk of deleterious health outcomes, further research examining possible causes of amenorrhea is warranted. As supported by the current study, the association between running mileage and athletic amenorrhea is significant. However, other research has found that it is not exercise, but low energy availability associated with exercise, that causes amenorrhea. Though a relationship between energy balance and menstrual dysfunction was not observed here, additional research examining the relationship between energy availability and menstrual dysfunction in athletes is still warranted. Because the ethics of manipulating energy availability in human subjects are questionable, observational studies using high-sensitivity tools to measure both energy expenditure and energy intake in athletes are warranted. Additionally, though a relationship between psychological stress and menstrual dysfunction was observed in the current study, the direction of the relationship was opposite from that which was expected. Studies further examining the relationship between psychological stress and menstrual dysfunction in athletic populations may be valuable in the future.

APPENDICIES

A. Survey

B. Calculation of training load

C. Calculation of energy availability

Appendix A: Survey

Informed Consent Form

Introduction
The purpose of this research is two-fold. First, I hope to quantify and understand potential differences in the prevalence of athletic amenorrhea between National Collegiate Athletic Association Division I and Division III distance runners. Secondly, I hope to examine the relationship between training load, nutritional status, psychological stress, and the prevalence of athletic amenorrhea in distance runners. Approximately 100 athletes will be included in this study.

Procedures
If you choose to participate in this study, you will be asked to complete an anonymous, electronic survey. The survey consists of 38 questions and should take 15-20 minutes to complete. Questions are broadly divided into four categories. The first category includes questions about height, weight, age, and NCAA division, as well as a brief health history to determine study eligibility. The second category includes questions designed to assess the amount of psychological stress you encounter in day-to-day living. Category three questions ask about your average weekly training volume over the course of the previous three months. Lastly, category four questions ask you to select the types and amounts of foods you normally eat. Again, all survey responses are anonymous.

Risks/Discomforts
Risks are minimal for involvement in this study. However, you may feel emotionally uneasy when asked to answer questions about your health, including menstrual status. You may also feel emotionally uneasy when asked to answer questions about your daily stress levels, training volume, and eating patterns.

Benefits
You are not guaranteed to benefit directly by participating in this study. Upon study completion, the results will be shared with coaches who may choose to share the results with their athletes. Through a better understanding of the factors contributing to amenorrhea in distance runners, the health of athletes participating in this study may be improved.

Female athletes as a whole will benefit from the knowledge obtained about the causes of amenorrhea in distance runners. By better understanding the factors that cause amenorrhea in distance runners, treatment of athletic amenorrhea may be improved, potentially decreasing the prevalence of amenorrhea in female athletes.

Confidentiality
All data obtained from participants are anonymous and will be kept confidential. Data will only be reported in an aggregate format (by reporting only combined results and never reporting individual ones). Survey results will be secured, and no one other than then the primary investigator and persons listed below will have access to survey results. The data

collected will be stored in the HIPPA-compliant, Qualtrics-secure database until it has been deleted by the primary investigator.

Compensation
You will not receive compensation by participating in this study.

Participation
Participation in this research study is completely voluntary. You have the right to withdraw at anytime or refuse to participate entirely without penalty or jeopardy to your athletic or academic status. If you wish to withdraw, simply close your internet browser without completing the survey. Because survey responses are anonymous, you will not be able to have your responses withdrawn upon completion and submission of the survey.

Questions about the Research
If you have questions regarding this study, you may contact Deanna Babcock at dbabcock@live.unc.edu or 989-387-1251. If you have questions you do not feel comfortable asking the primary investigator directly, you may contact Dr. Hackney at ach@email.unc.edu or 919-962-0334.

Questions about your Rights as Research Participants
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject, or if you would like to obtain information or offer input, you may contact the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

By checking "yes", I certify that I am at least 18 years old and have read and understood the above consent form and desire of my own free will to participate in this study.

☐ Yes

☐ No

Please record the following information so that it is correct to the best of your knowledge.

Today's date (mm/dd/yyyy):

Current age rounded to nearest whole month:
Years
Months

Please enter your height in feet and inches:
Feet
Inches

Please enter your weight in pounds.

Are you currently gaining or losing weight? Weight gain or loss is defined as a change in weight greater than ±3% of body weight. For a person weighing 125 lbs, 3% corresponds to ±4 lbs.

- Yes
- No

National Collegiate Athletic Association (NCAA) division of college or university you attend:

- I
- III

Have you been competing in the same NCAA division for your entire collegiate running career?

- Yes
- No

If you answered "no" to number 7, how long have you been competing in your current NCAA division? *Example: I transferred to D I from D III in 2010.*

Medical history. Answer each question to the best of your knowledge.

Please select "yes" or "no" to the following health history questions.

	Yes	No
Has a physician ever diagnosed you with an eating disorder?	☐	☐
Has a physician ever diagnosed you with a tumor?	☐	☐
Has a physician ever diagnosed you with thyroid problems?	☐	☐
Has a physician ever diagnosed you with polycystic ovarian syndrome?	☐	☐
Are you currently pregnant or breastfeeding?	☐	☐
Have you taken birth control within the last 6 months?	☐	☐

I have had a period once every 25-38 days (or about once a month) for the past 3 consecutive months or longer.

- ☐ Yes
- ☐ No

About how long ago was your last menstrual cycle?

- ☐ 1 month ago
- ☐ 2 months ago
- ☐ 3 months ago
- ☐ 4 months ago
- ☐ 5 months ago
- ☐ 6 or more months ago

Stress levels. Please choose a single response for each of the following questions.

In the last month, how often have you been upset because of something that happened unexpectedly?

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Fairly often
- ☐ Very often

In the last month, how often have you felt that you were unable to control the important things in your life?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you felt nervous and "stressed"?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you felt confident about your ability to handle your personal problems?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you felt that things were going your way?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you found that you could not cope with all the things that you had to do?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you been able to control irritations in your life?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you felt that you were on top of things?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you been angered because of things that were outside of your control?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

- Never
- Almost never
- Sometimes
- Fairly often
- Very often

Training volume. Please estimate the following based on an average of your last three months of training.

In the last three months, have you sustained any injuries that have prevented you from completing team workouts as directed?

- Yes
- No

In the last three months, on average, how many days per week do you have at least one training session?

In the last three months, what was your average total weekly running mileage?
(Example: 40 mi/wk)

In the last three months, what was your average total time spent running per week?
(Example: 9 hours and 45 minutes)
Hours:
Minutes:

In the last three months, what was your average total time spent cross-training (exercise other than running) per week?
(Example: 2 hours and 0 minutes)
Hours:
Minutes:

Please list the type, time, and perceived difficulty of cross-training usually performed. Example: 50 minutes of stationary cycling at level 4; 20 minutes of swimming at level 3. Use the 10-point scale below to rate difficulty. If you do not typically cross-train, answer "n/a."

RPE	Description
0	complete rest
1	very, very easy
2	easy
3	moderate
4	somewhat hard
5	hard
6	
7	very hard
8	
9	
10	extremely hard (almost maximal)
——	exhaustion

Source: Adapted from Borg, G., Hassmén, P. & Lagerstrom, M. 1987. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *European Journal of Applied Physiology*, 56 (6), 679–85.

(text box for survey response)

Estimate the usual percentage of total weekly training time falling within the levels of difficulty below. Include both running and cross-training in your estimate. Your answers should add up to 100%.

1 very easy exercise

0

2 easy exercise

0

3 moderate exercise

0

4 somewhat difficult exercise

0

5 difficult exercise

0

6

0

7 very difficult exercise

0

8

0

9

0

10 extremely difficult (maximal) exercise

0

Total

Nutrition information.

Based on the serving size listed for each food type, please estimate the number of servings you consume either daily or weekly during a **typical week**.

Read through the list of food items below. In the "Usual # of servings" column, enter the number of servings usually consumed for the foods listed. You may enter partial servings using decimals. Next, in the "Daily or weekly" column, select either "daily" or "weekly" to indicate frequency of consumption. If there are foods that you do not consume in a normal week, enter "0" for usual number of servings and select either "daily" or "weekly" in the second column.

Example 1: If you consume a cup of coffee per day, enter "1" in the number of servings column, then select "daily" in column 2.

Example 2: If you consume ice cream on Saturday and Sunday, enter "2" in the number of servings column, then select "weekly" in column 2.

Breads, cereals, and grain products

	Usual # of servings .	Daily or weekly	
		Daily	Weekly
Whole grain breads (whole wheat, rye, pumpernickel) (1 slice)			
White breads (French – 2 slices, burger/hot dog bun - 1 item) (1 serving)			
English muffin, bagel, pita bread (1 item)			
Whole grain crackers: Triscuits, Wheat Thins, etc. (4-6 each) (1 serving)			
Other crackers: Saltines, Ritz, etc. (4-6 each) (1 serving)			
Tortilla, corn, 6 inch diameter (medium) (1 item)			
Muffins (1 item)			
Pancakes (2), waffles (1 - 7 inch diameter) (1 serving)			
Whole grain hot cereal: rolled oats, rolled wheat, Roman Meal (0.5 cup)			
Instant or quick hot cereal: cream of wheat, cream of rice (0.5 cup)			
Cold cereals: shredded wheat, raisin bran, or bran flakes (0.75 cup)			
Cold cereals: Frosted Flakes, Sugar Smacks, etc. (0.75 cup)			
Rice, cooked (0.5 cup)			
Pasta, cooked (0.5 cup)			

Protein foods

	Usual # of servings .	Daily or weekly Daily	Weekly
Legumes: lentils, pinto beans, navy beans, cooked (1 cup)			
Nuts and seeds: peanuts, almonds, sunflower seeds, etc. (0.25 cup)			
Peanut butter, nut butters (1 tablespoon)			
Tofu or other meat substitutes (3 ounces)			
Beef: rib roast, steak, pot roast, veal, etc. (3 ounces)			
Beef, ground, cooked (3 ounces)			
Pork: chops, roast, ham (3 ounces)			
Lamb: chops, roast (3 ounces)			
Poultry: chicken, turkey, duck (3 ounces)			
Fish, canned with oil: tuna, sardines (3 ounces)			
Tuna, water pack (3 ounces)			
Fish, fresh or frozen, no breading: trout, halibut, sole, etc. (3 ounces)			
Shellfish: shrimp, scallops, lobster, clams (3 ounces)			
Eggs, whole, large (1 item)			
Egg substitutes or egg whites (0.25 cup)			
Lunch meats: bologna, salami, etc. (1 ounce)			
Frankfurters or sausage link (4 inches x 1 1/8 inches) (1 item)			

Fruits and juices

	Usual # of servings .	Daily or weekly Daily	Weekly
Apple or pear, fresh, medium (1 item)			
Banana, medium (1 item)			
Orange (1 item) or grapefruit (1/2 item) (1 serving)			
Peach (1), nectarine (1/2), or apricots (2) (1 serving)			
Berries (0.75 cup)			
Cantaloupe, medium (0.25 item)			
Other melon (watermelon, honeydew, casaba) (1 cup)			
Pineapple, fresh (0.5 cup)			
Dried fruits: raisins (2 tablespoons), dates (2), prunes (2), dried apricots (4) (1 serving)			
Canned fruit or frozen fruit (0.5 cup)			
Orange or grapefruit juice (0.5 cup)			
Tomato juice or vegetable juice (0.5 cup)			
Other juices: apple, grape, pineapple, or cranberry (0.5 cup)			
Fruit drinks: lemonade, punch, Koolaid (0.5 cup)			

Milk, yogurt, and cheeses

	Usual # of servings .	Daily or weekly Daily	Weekly
Skim milk or low-fat milk (1 cup)			
Whole milk (1 cup)			
Chocolate milk (1 cup)			
Soy milk, sweetened (1 cup)			
Yogurt (1 cup)			
Cheese: cheddar, Colby, American, Monterey Jack, etc. (1 ounce)			
Other cheeses: Swiss, mozzarella, ricotta, string, etc. (1 ounce)			
Cottage cheese (0.5 cup)			

Vegetables

	Usual # of servings .	Daily or weekly Daily	Weekly
Salads: lettuce, celery, green peppers, onions (1 cup)		☐	☐
Dark green leafy vegetables, raw or cooked (0.5 cup)		☐	☐
Carrots, raw or cooked (0.5 cup)		☐	☐
Tomatoes, fresh, medium (1 item)		☐	☐
Starchy vegetables, cooked: corn, peas, mixed vegetables (0.5 cup)		☐	☐
Other vegetables, cooked: green beans, beets, zucchini (0.5 cup)		☐	☐
Cauliflower, broccoli, brussel sprouts, cabbage (0.5 cup)		☐	☐
Winter squash, cooked: acorn, butternut, hubbard (0.5 cup)		☐	☐
White potato, baked, boiled, or mashed (1 item)		☐	☐
Sweet potatoes or yams, cooked (0.5 cup)		☐	☐

Fats and oils

	Usual # of servings .	Daily or weekly Daily	Weekly
Vegetable oils: corn, safflower, soy, etc. (1 tablespoon)		☐	☐
Olive oil (1 tablespoon)		☐	☐
Shortening (1 tablespoon)		☐	☐
Lard (1 tablespoon)		☐	☐
Margarine (1 teaspoon)		☐	☐
Butter (1 teaspoon)		☐	☐
Mayonnaise (1 tablespoon)		☐	☐
Regular salad dressings (1 tablespoon)		☐	☐
Low-calorie dressings (1 tablespoon)		☐	☐
Sour cream (1 tablespoon)		☐	☐
Cream cheese (1 tablespoon)		☐	☐
Half & half, table cream (1 tablespoon)		☐	☐

Miscellaneous

	Usual # of servings .	Daily or weekly Daily	Weekly
Pizza (1 slice)			
Hamburger or cheeseburger (1 item)			
Burrito or taco (1 item)			
Bacon (2 slices)			
Popcorn, popped (2 cups)			
Potato chips, corn chips, tortilla chips (1 ounce)			
Catsup or chili sauce (1 tablespoon)			
Tomato-based sauce (spaghetti sauce) (0.5 cup)			
Pickles or pickle relish (1 tablespoon)			
Olives (5 items)			
Avocado (1/8 item)			
Sauces: soy sauce, steak sauce, barbecue sauce (1 tablespoon)			
Brown gravy, giblet gravy, or white sauce (0.25 cup)			
Soups, vegetable or noodle type (1 cup)			
Soups, cream (1 cup)			
Chewing gum (1 item)			
Sugar, honey, jam, jelly, syrups (1 tablespoon)			

Desserts and sweets

	Usual # of servings .	Daily or weekly Daily	Weekly
Cookies: chocolate chip, oatmeal, peanut butter, etc. (2 items)			
Brownies, 2 inches (1 item)			
Doughnut or sweet roll (1 item)			
Cake, 1/12 of 9 inch diameter (1 slice)			
Granola bars (1 item) or granola (1/2 cup) (1 item)			
Pie, 1/8 of whole pie (1 slice)			
Gelatin, flavored (0.5 cup)			
Pudding or custard (0.5 cup)			
Ice cream (0.5 cup)			
Ice milk (0.5 cup)			
Sherbet (0.5 cup)			
Candy bar, chocolate bar (1 bar), M&M's (1 package)			
Hard candy, gum drops, Lifesavers (1 item)			

Beverages

	Usual # of servings .	Daily or weekly Daily	Weekly
Cola drinks (1 can = 12 fluid ounces)			
Diet cola drinks (1 can = 12 fluid ounces)			
Non-cola drinks: 7-Up, Sprite, Slice, etc. (1 can = 12 fluid ounces)			
Diet non-cola drinks (1 can = 12 fluid ounces)			
Sports drink (1 cup = 8 fluid ounces)			
Coffee or tea (1 cup = 8 fluid ounces)			
Decaffeinated coffee or teas: Sanka, herbal tea, etc. (1 cup = 8 fluid ounces)			
Hot chocolate or cocoa (1 cup = 8 fluid ounces)			
Beer (1 can = 12 fluid ounces)			
Wine, dry or table (red, white, or blush) (4 fluid ounces)			
Liquor: vodka, whiskey, gin, rum, etc. (1.5 fluid ounces)			

Appendix B: Calculation of Training Load

1. Please estimate the following parameters based on an average of your last three months of training:
   a. Number of training days per week ___*6*___ days
   b. Total weekly training mileage _*40*_____ miles
   c. Total time spent running per week __*7*____ hours and ___*0*___ minutes
   d. Total time spent cross-training per week ___*2*___ hours and __*0*__ minutes
   e. Type, time, and perceived difficulty* of cross-training performed:

      __*60 minutes of stationary cycling, level 4;* ______________________________

      *60 minutes of swimming, level 4*______________________________________

      ____

      ____

      ____

      (*example: 50 minutes of stationary cycling at level 4, 20 minutes of swimming at level 3)*
      **Please see scale under letter f for index of perceived difficulty.*

   f. Please estimate the percentage of total weekly training time falling within the levels of difficulty below. Include both running and cross-training in your estimate.

      _*5*__ 1 very easy exercise
      __*15*_ 2 easy exercise
      _*20*__ 3 moderate exercise
      _*45*__ 4 somewhat difficult exercise
      __*5*_ 5 difficult exercise
      _*5*__ 6
      __*3*_ 7 very difficult exercise
      __*2*_ 8
      _*0*__ 9
      _*0*__ 10 extremely difficult (maximal) exercise

Total training time = 7 hr + 2 hr = 9 hr = 540 min

Borg Category	Percentage of Training Time	Total Minutes	Training Load
1	5	27	27
2	15	81	162
3	20	108	324
4	45	243	972
5	5	27	135
6	5	27	162
7	3	16.2	113.4
8	2	10.8	86.4
9	0	0	0
10	0	0	0

1. Percentage of training time transcribed from subject response.
2. Total minutes of training corresponding to each category is the product of percentage of training time and total weekly training time (540 min). For example, 45% of training time corresponds to a Borg category of 4; 0.45 *540 minutes = 243 minutes.
3. Training load is the product of total minutes and the corresponding Borg category. For example, 243 minutes * 4 = 972 training load (arbitrary units).
4. Total weekly training load is obtained by summing the training load corresponding to each Borg category. Total weekly training load is 1982 arbitrary training units.

Appendix C: Calculation of Energy Availability

Energy availability was calculated as the balance between calories consumed and energy expended through daily activity, including exercise (25).

Resting metabolic rate (RMR) (57):

$$\mathrm{RMR} = 655.1 + 9.56(\mathrm{Wt}) + 1.85(\mathrm{Ht}) - 4.68(\mathrm{age})$$

where Wt is weight in kg, Ht is height in cm, age is age in years, and RMR is in units of kcal/day.

Energy expended through daily physical activity (DPA) (58):

$$\mathrm{DPA} = 1.3 * \mathrm{RMR}$$

where DPA is in units of kcal/day

Mean running speed

$$s = t/mileage$$

where s is mean running speed (min/mi), t is total weekly time spent running (min), and mileage is total weekly mileage (mi)

Oxygen uptake during running (59):

$$\mathrm{VO_2} = 0.2\mathrm{S} + 3.5$$

where VO_2 is oxygen uptake in ml/kg/min, and S is mean running speed in m/min. The running grade is assumed to be 0%. Mean running speed in min/mi will be converted to mean running speed (S) in m/min.

Caloric expenditure during running (RE):

$$\mathrm{RE} = \frac{\mathrm{VO_2} * \mathrm{t} * \mathrm{Wt} * 5}{1000}$$

where VO_2 is oxygen uptake during running, t is total weekly time spent running (min), Wt is subject weight (kg), and RE is total energy expended during running (kcal).

Caloric expenditure during cross-training (CE):

1. Information from survey responses:
   a. Weight: 57.6 kg
   b. Average total time spent cross training per week: 180 min/wk
   c. Type, time, and perceived difficulty of cross-training usually performed: 15 minutes of stationary cycling at level 2 / 40 minutes of swimming at level 6

2. Calculations
   a. Calculate kcal/min expended from each activity listed using the following equation: $kcal/min = (METs * 3.5 * body\ weight\ in\ kg)/200$
      i. stationary cycling
         kcal/min = (6*3.5*57.6)/200 = 6.05 kcal/min
      ii. swimming
         kcal/min = (10*3.5*57.6)/200 = 10.08 kcal/min
   b. Calculate total calories expended from each activity listed using the following equation: *total kcal = kcal/min * activity time in minutes*
      i. stationary cycling
         total kcal = 6.05*15 = 90.72 kcal
      ii. swimming
         total kcal = 10.08*40 = 403.2 kcal
   c. Calculate total calories burned as the sum of calories burned from each activity
      i. total calories burned = 90.72+403.2 = 493.92 kcal
   d. Correct for apparent underreporting
      i. Total calories burned was calculated based on 15 minutes + 40 minutes = 55 minutes per week of cross training. However, the individual reported 180 min/wk of cross training usually performed.
      ii. A correction factor of 180/55 = 3.27 is applied to the total calories burned in order to calculate total cross training energy expenditure per week. Calculation is as follows:
         493.92*3.27 = 1616 kcal /wk

Estimated daily energy expenditure (EE):

$$\mathrm{EE} = \frac{\mathrm{RE}}{7} + \frac{\mathrm{CE}}{7} + \mathrm{DPA}$$

where EE is in units of kcal/d

Energy availability (EA):

$$\mathrm{EA} = \mathrm{DCI} - \mathrm{EE}$$

where DCI is daily caloric intake (kcal/d) and EA is in units of kcal/d.

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