The Female Athlete Triad Exists in Both Elite Athletes and Controls

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ABSTRACT

TORSTVEIT, M. K., and J. SUNDGOT-BORGEN. The Female Athlete Triad Exists in Both Elite Athletes and Controls. *Med. Sci. Sports Exerc.*, Vol. 37, No. 9, pp. 1449–1459, 2005. **Purpose:** To examine the prevalence of the female athlete triad (the Triad) in Norwegian elite athletes and controls. **Methods:** This study was conducted in three phases: (part I) screening by means of a detailed questionnaire, (part II) measurement of bone mineral density (BMD), and (part III) clinical interview. In part I, all female elite athletes representing the national teams at junior or senior level, aged 13–39 yr (N = 938) and an age group–matched randomly selected population-based control group (N = 900) were invited to participate. The questionnaire was completed by 88% of the athletes and 70% of the controls. Based on data from part I, a stratified random sample of athletes (N = 300) and controls (N = 300) was selected and invited to participate in parts II and III of the study. 186 athletes (62%) and 145 controls (48%) participated in all parts of the study. **Results:** Eight athletes (4.3%) and five controls (3.4%) met all the criteria for the Triad (disordered eating/eating disorder, menstrual dysfunction, and low BMD). Six of the athletes who met all the Triad criteria competed in leanness sports, and two in nonleanness sports. When evaluating the presence of two of the components of the Triad, prevalence ranged from 5.4 to 26.9% in the athletes and from 12.4 to 15.2% in the controls. **Conclusion:** Our results support the assumption that a significant proportion of female athletes suffer from the components of the Triad. In addition, we found that the Triad is also present in normal active females. Therefore, prevention of one or more of the Triad components should be geared towards all physically active girls and young women. **Key Words:** EATING DISORDERS, MENSTRUAL DYSFUNCTION, AMENORRHEA, OSTEOPENIA, BONE MINERAL DENSITY

For most women, participation in physical activity contributes to significant health benefits, overall well-being and improved physical fitness. Furthermore, sports performance may lead to high self-esteem, healthy body image, and positive health status (24). However, according to the 1997 ACSM position stand on the female athlete triad (21), physically active girls and women participating in a wide range of physical activities may be at risk for developing the female athlete triad (the Triad), a syndrome consisting of three components: disordered eating, amenorrhea, and osteoporosis. These three medical problems are interrelated with respect to etiology, pathogenesis, and consequences and can alone, or in combination, negatively affect health and, for athletes, impair athletic performance (21).

Several factors may contribute to the development of the Triad. Pressure to excel in sports, be thin and/or achieve a low body weight, or insufficient energy availability in general, may lead to disordered eating, and/or menstrual dysfunction, and subsequently loss of BMD potentially resulting in osteopenia or osteoporosis (21).

The existence of the Triad is implied in studies that establish a relationship between disordered eating and/or energy deficit and menstrual dysfunction (2,9,35) and between menstrual dysfunction and low BMD (9,25,34,35). It is also possible that disordered eating /eating disorders and/or energy deficit may be directly linked to low BMD (35).

Recently, it has been suggested that each component of the Triad develops on a continuum (8,27), suggesting that there might be Triad "stages." If early stages are not treated properly, they can progress toward the extremes of the Triad (8,27). The continuum model of disordered eating ranges from abnormal eating behaviors to clinical eating disorders such as anorexia nervosa and bulimia nervosa (27). Athletes with disordered eating attempt to lose weight or body fat by inducing a negative energy balance and/or employing a

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wide range of disordered eating practices including fasting, diet pills, laxatives, diuretics and vomiting (2,28,29). Data from existing prevalence studies estimate that 1-78% of female athletes suffer from disordered eating or eating disorders (3). The range of menstrual dysfunction varies from luteal phase dysfunction, anovulation, and oligomenorrhea to primary or secondary amenorrhea (8). It has been reported that delayed menarche, primary and secondary amenorrhea and oligomenorrhea occur in 6–79% of women engaged in athletic activity (5). The wide range of both disordered eating and menstrual dysfunction observed in athletes may be explained by a number of methodological factors such as different definitions, different groups of athletes studied (i.e., age, performance level), or various sport disciplines (i.e., differences in culture and attitudes towards factors related to the Triad, or rules). In terms of BMD, the continuum ranges from normal BMD to osteopenia and osteoporosis (15). Only a few studies have presented data on the number of female athletes with osteopenic or osteoporotic values (4,17,22,26,34). The prevalence of osteopenia ranges from 22 to 50% and the prevalence of osteoporosis ranges from 10 to 13% in studies on ballet dancers (34) and runners (4,22,26).

Since the introduction of the term "the female athlete triad" in 1993 (33), several review articles, comments and letters concerning the Triad have appeared in various journals. To date, though, no controlled prevalence study on the Triad in elite athletes has been published. The lack of prevalence studies could be due to difficulties obtaining valid samples, because of the sensitive nature of the data collected, or difficulties in accurately assessing all three Triad components. In addition, conducting a prevalence study with enough subjects may be both time consuming and costly. Most prevalence data today concerning the Triad are collected from studies investigating only one or two of the components of the Triad, include few subjects and/or only one or a few sports, have no control groups, and/or use inaccurate measurement methods. To our knowledge, after the Triad was introduced as a term (33), only one study has investigated the three Triad components simultaneously (18), and the study population was military women, not athletes. However, one study has investigated high scores on the subtests of the Eating Disorder Inventory, menstrual dysfunction and BMD in 91 nonelite runners. No control group was included in this study (4).

Thus, prevalence data of the Triad is lacking and thus, the aims of this study were, (i) to investigate the prevalence of the Triad components in female elite athletes, and (ii) to investigate whether or not the Triad is present in population based women.

METHODS

This study was conducted in three phases: (part I) screening by means of a detailed questionnaire, (part II) measurement of BMD, and (part III) clinical interview.

Participants

The total population of female elite athletes in Norway, aged 13–39 yr ($N = 938$) and controls in the same age group ($N = 900$) were invited to participate in the study. Permission to undertake the study was provided by the Norwegian Olympic Committee and the Norwegian Confederation of Sports, the Data Inspectorate and the Regional Committee for Medical Research Ethics. The secretary general of each sport federation and the head of the healthcare team for each of the national teams received detailed written information about the procedures and aims of the study. In addition, all secretary generals were asked to return a list containing names, ages, and addresses of all eligible athletes in their federation competing for national teams. All athlete and control participants received an information letter and had to complete a written consent form in order to participate. Parents of responders younger than 18 yr of age had the opportunity to refuse participation on behalf of their child, and written parental consent was required for responders younger than 16.

We defined an elite athlete as one who qualified for a national team at the junior or senior level, or who was a member of a recruiting squad for that team. The athletes represented 66 different sports/events. An overview of these sports has been published elsewhere (31). The athletes had to be 13–39 yr old. Exclusion criteria for part I of the study are given in Figure 1.

A bureau of statistics that keeps records of all citizens of Norway randomly selected a sample of controls ($N = 900$) from the total population of female citizens in Norway aged 13–39 yr. Every county in Norway was represented and the sample's age distribution and geographical distribution approximated that of the total Norwegian women's population 13–39 yr of age. Exclusion criteria are given in Figure 1.

Assessment Procedures

Part I: Screening. A questionnaire including a battery of assessment questions regarding training and/or physical activity patterns, menstrual, dietary, and weight history, oral contraceptive use, and disordered eating behavior was sent to each of the 938 eligible athletes and 900 eligible controls. The response rate of the athletes and controls was 88.3 and 70.2%, respectively (Fig. 1).

Selection for parts II and III. Based on data from part I, a random sample of athletes ($N = 300$) and controls ($N = 300$) was selected and invited to participate in parts II and III of the study. This sample was stratified based on age-group (13–19, 20–29, and 30–39 yr) and "risk-profile" for the Triad (two groups: at risk and not at risk for the Triad). The risk criteria used in this selection process were low BMI (<18.5 kg·m^{-2}), use of pathogenic weight control methods, high score on subtests of the Eating Disorder Inventory, and self-reported eating disorder, menstrual dysfunction or stress fracture. The selection process is explained more in detail elsewhere (31). No pregnant women were included in parts II or III of the study. All together, 186 athletes (62%)

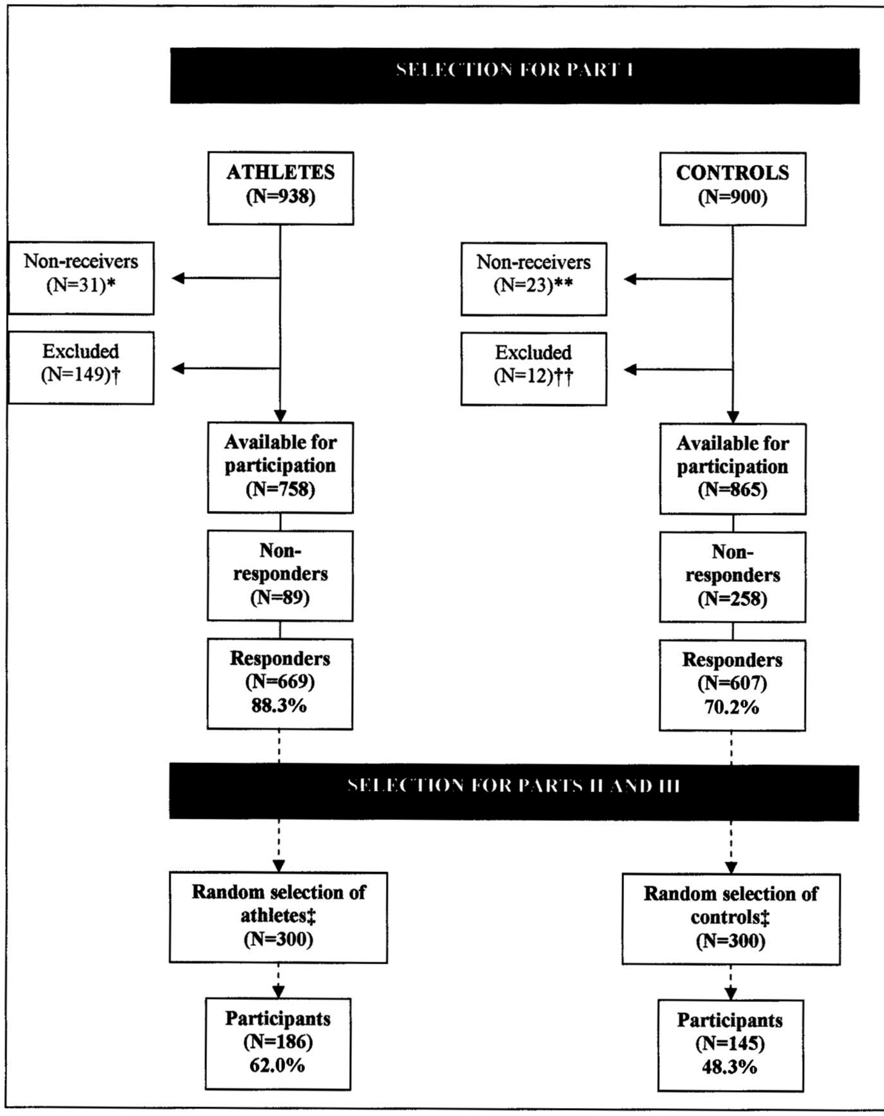

FIGURE 1—Flowchart showing selection of athletes and controls samples based on (part I) questionnaire mailing, exclusion process and questionnaire response, and selection for parts II and III. * Due to the fact that they were representing teams in other countries or were traveling. ** Due to problems finding their addresses. † Seventy-six athletes had ended their career, 35 did not compete at the national level, 15 were injured, eight were pregnant and did not plan to continue their athletic career after delivery, five were older than 39 yr of age, nine did not complete the questionnaire satisfactorily and one athlete competed in two different sport groups. †† Nine did not understand the Norwegian language and three were severely ill and were unable to fill in the questionnaire. ‡ Stratified by age-group and the "risk-profile" for the female athlete triad. Nonresponders were subjects who, for unknown reasons, never returned the questionnaire.

and 145 controls (48%) participated in all parts of the study (Fig. 1).

Part II: Assessment of BMD. BMD was measured with dual-energy x-ray absorptiometry (DXA) (Prodigy, Lunar). The measurement areas were total body, lumbar spine (L_2–L_4), femur neck, femur trochanter, femur shaft, and total femur. The BMD measurements were assessed by the same technician and at the same machine. Furthermore, all measurement results were double-checked for possible mistakes in the analysis. During the study period, no machine drift was observed. Furthermore, a test of reliability was performed. Ten subjects conducted two DXA measurements each on the same day. Between the two measurements for each subject, another subject conducted one of their measurements. Therefore, measurement one and two for each subject did not occur consecutively. The coefficient of variance (CV) was 0.97% for total body BMD, 0.71% for lumbar spine BMD, 1.08% for femur neck BMD, 0.87% for trochanter BMD, and 0.57% for total femur BMD.

Part III: Clinical interview. The same sample that participated in part II also participated in part III of the study. A professor (PhD) specially trained in eating disorders conducted all the interviews, and each interview lasted from 45 to 60 min. The same person did all the interviews, but a random selection of subjects (N = 15) was also interviewed by another expert (psychiatrist). All the diagnoses based on the primary expert were confirmed by the secondary expert. The Eating Disorder Examination (6) was included to determine whether subjects met the criteria for clinical eating disorders. In this study, participants meeting the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria (1) for anorexia nervosa, bulimia nervosa, or eating disorders not otherwise specified, were categorized as subjects with clinical eating disorders.

Definitions

Physical activity. Total training was defined as the total hours of training per week for the athletes (presented as a mean of the training and competition period during the previous year). Amount of physical activity for the controls was defined as the total hours of physical activity per week including physical education lessons, recreational sports and active daily living like walking. This value was calculated based on questions about type of physical activity, frequency and duration during the previous year (31). Furthermore, to assess health related physical activity we used a short version of the International Physical Activity Questionnaire (IPAQ). This valid and reliable questionnaire provides information on the time spent walking, in vigorous- and moderate-intensity activity and in sedentary activity (7).

Menstrual dysfunction and disordered eating. Present primary amenorrhea, secondary amenorrhea, oligoamenorrhea and short luteal phase, or a lifetime prevalence of primary or secondary amenorrhea, were all defined as menstrual dysfunction. Primary amenorrhea was defined as the absence of menarche by the age of 16 and secondary amenorrhea was defined as the absence of three or more consecutive menstrual cycles after menarche and outside pregnancy. Furthermore, we defined oligomenorrhea as menstrual cycles of 35 d or more and short luteal phase as a menstrual cycle of less than 22 d. Disordered eating included self-reported use of one or more pathogenic weight control methods (diet pills, hunger-repressive pills, laxatives, diuretics, or vomiting), high score on the Drive for Thinness or Body Dissatisfaction subscale of the Eating Disorder Inventory (11) ($\geq$15 or $\geq$14, respectively), or self-reported past or present eating disorder.

Low BMD. To date, insufficient data regarding the relationship between BMD and fracture risk has resulted in difficulties defining osteopenia and osteoporosis in premenopausal women (16). Furthermore, recent guidelines recommend the use of the term "low BMD" instead of osteopenia/osteoporosis and the use of Z-scores instead of *t*-scores in young women and children (14,19). In the present study we could calculate Z-scores and define low BMD by using the reference material provided by Lunar, manufacturer of the DXA. However, the normal values for BMD provided by manufacturers may not be fully representative of specific local populations. When data was collected, no normative data existed for the Norwegian population using Lunar densitometers, and it was uncertain whether the Lunar reference was representative of Norwegian women. Therefore we included a randomly selected sample of premenopausal women in Norway in the same age range as the athletes (control group). In this study, Z-scores were therefore calculated based on BMD mean values and SD of the national representative control group (aged 13–39 yr). The controls were divided into two age-groups, 13–19 yr and 20–39 yr, and Z-scores were calculated using the following equations:

$$\text{Athletes} < 20\text{ years: (Own BMD} - \text{mean BMD for athletes 13–19 years)} \; / \text{SD BMD for controls 13–19 years} \quad [1]$$

$$\text{Athletes} \geq 20\text{ years: (Own BMD} - \text{mean BMD for athletes 20–39 years)} \; / \text{SD BMD for controls 20–39 years} \quad [2]$$

$$\text{Controls} < 20\text{ years: (Own BMD} - \text{mean BMD for controls 13–19 years)} \; / \text{SD BMD for controls 13–19 years} \quad [3]$$

$$\text{Controls} \geq 20\text{ years: (Own BMD} - \text{mean BMD for controls 20–39 years)} \; / \text{SD BMD for controls 20–39 years} \quad [4]$$

In the present study we report both a low BMD indicated by a Z-score between -1.0 and -2.0, and a Z-score below -2.0. In reporting data on the prevalence of low BMD, a positive diagnosis in at least one of five measurement areas (total body, lumbar spine (L_2–L_4), femur neck, femur trochanter, or total femur) is included.

The Triad. We defined the Triad as the combination of disordered eating and/or eating disorders, menstrual dysfunction and low BMD (Z-score < -1.0). However, due to the three-phase study design in the present study, we were able to investigate the prevalence of the Triad components ranging in severity. In parts of the analysis, because the Triad occurs on a continuum, we grouped the athletes and controls into one of two groups with each group representing different stages on the continuum. Individuals were classified in the "moderate-severe" group (Triad Stage I) if they had been diagnosed with disordered eating, menstrual dysfunction and low BMD (Z-score < -1.0, but ≥ -2.0). Subjects were classified in the "severe" group (Triad Stage II) if they had been diagnosed with clinical eating disorders, menstrual dysfunction, and low BMD (Z-score < -2.0).

Statistical Analysis and Presentation of the Data

After the randomized selection of athletes was conducted for parts II and III of the study, 46 different sports/events were represented. For one part of the analysis, and in accordance with previous studies (29,31), the athletes were divided into two groups: athletes competing in leanness sports and nonleanness sports. Athletes competing in sports in which leanness and/or a specific weight were considered important (endurance, esthetic, weight-class and antigravitation sports) were included in the leanness group, whereas athletes competing in sports in which these factors were considered less important (technical, ball game, and power sports) were included in the nonleanness group.

All analyses were performed using SPSS software, version 11.0 (SPSS, Evanston, IL). Results are expressed as mean value and standard deviation (SD). Comparisons between athletes and controls, and between athletes competing in leanness and nonleanness sports, were carried out using two sample student's *t*-test for continuous data and chi-square test (Fisher's exact test) for categorical data. Differences were considered statistically significant for *P* values $\leq$ 5%. Logistic regression analysis was conducted to adjust

TABLE 1. Anthropometric data based on part II of the study for athletes competing in leanness sports (N = 90), nonleanness sports (N = 96), athletes total (N = 186), and controls (N = 145). Data are given as mean ± standard deviation (SD).

	Leanness (N = 90)	Nonleanness (N = 96)	Athletes Total (N = 186)	Controls (N = 145)
Age (yr)	20.8 (6.3)^{a,b}	23.5 (5.0)^{c}	22.2 (5.8)^{b}	29.6 (7.9)
Weight (kg)	57.3 (7.4)^{a,b}	65.6 (7.8)	61.5 (8.7)^{b}	66.4 (12.3)
Height (cm)	166.2 (6.5)^{a}	170.0 (6.7)^{c}	168.1 (6.9)^{d}	166.2 (6.3)
BMI (kg·m^{-2})	20.7 (2.1)^{a,b}	22.7 (2.2)^{d}	21.7 (2.4)^{b}	24.0 (4.2)
Menarcheal age (yr)	13.6 (1.4)	13.5 (1.3)	13.5 (1.4)^{c}	13.2 (1.3)
Total body BMD (g·cm^{-2})	1.18 (0.08)^{a,b}	1.25 (0.09)	1.21 (0.09)^{b}	1.18 (0.08)

^{a} $P < 0.001$ compared with nonleanness; ^{b} $P < 0.001$ compared with controls; ^{c} $P < 0.05$ compared with controls; ^{d} $P < 0.01$ compared with controls.

the significance level of age differences between the athletes and the controls, and between the leanness sport and nonleanness sport athletes. For parts of the analysis the physical activity level of the controls was divided into quartiles. The cut-off scores were 121.5 min·wk^{-1}, 210.0 min·wk^{-1}, and 357.5 min·wk^{-1} for the 25, 50, and 75 percentile, respectively.

RESULTS

Subject Characteristics

The athletes were younger and had lower BMI values compared with the controls ($P < 0.001$). BMI was lower in athletes than controls even after adjusting for age ($P < 0.001$) (Table 1). A total of 83 athletes and 25 controls were younger than 20 yr of age. The athletes trained an average of 13.9 ± 5.6 h·wk^{-1}. The controls were physically active 5.3 ± 5.3 h·wk^{-1}. Furthermore, we found that 63% of the controls aged 20–39 met the guidelines for physical activity for adults (at least 30 min of walking or other activities of at least moderate character), whereas 52% of the girls aged 13–19 met the guidelines for children and youth (at least one hour daily activity of at least moderate character).

Athletes competing in leanness sports were younger, had a lower BMI (Table 1), and reported a higher training volume (15.4 ± 5.1 h·wk^{-1}) compared with athletes competing in nonleanness sports (12.5 ± 5.1 h·wk^{-1}) ($P < 0.001$). A total of 14.8% of the athletes had been ranked among the three best, 14.2% had been ranked from place 4 to 10, and 12.4% from place 11 or lower in Olympic Games, World Championships, or World Cups. The remaining athletes had represented the national team in other international and/or national competitions at the junior or senior level or as recruits. Eighty-two percent of all the athletes had represented their national team in international competitions for at least one season.

Prevalence of the Triad Components

Athletes. Eight athletes met the criteria for all components of the Triad. Four of these athletes met the criteria for the Triad stage I, and four met the criteria for the Triad stage II. We also examined the percentage of athletes having two components of the Triad, and found a prevalence ranging from 5.4 to 26.9% depending on which two components were combined (Fig. 2). When investigating the combination of the severe components of the Triad (Triad stage II), six athletes (3.2%) had both clinical eating disorders and low BMD (Z-score < −2.0), four (2.2%) had both menstrual dysfunction and low BMD (Z-score < −2.0), whereas 45 (24.2%) had both clinical eating disorders and menstrual dysfunction. A total of 8% of the athletes and none of the controls were diagnosed with stress fractures. One of the athletes with stress fractures had low BMD (Z-score < −2.0). In the youngest age group (<20 yr of age), 33 athletes and five controls were diagnosed with clinical eating disorders.

A further analysis of the eight athletes with the Triad is shown in Table 2. In addition, their mean training volume was 13.4 (± 2.7) h·wk^{-1} (range 10.5–18 h·wk^{-1}) and mean age of sport specialization was 13.6 (± 2.6) yr (range 10–17 yr). Six of the athletes with the Triad competed in leanness sports (biathlon, swimming, bicycling, climbing, and middle/long distance running), and two in nonleanness sports (team handball and volleyball). More athletes competing in leanness sports than in nonleanness sports met the criteria for the combination of eating disorders and menstrual dysfunction ($P < 0.01$) (Table 3).

Controls. Five controls met the criteria for all components of the Triad, and they all met the criteria for the Triad stage I. We also examined the percentage of controls having two components of the Triad, and found a prevalence ranging from 12.4 to 15.2% depending on which two components were combined (Fig. 3). When investigating the combination of the severe components of the Triad (Triad stage II), one control had both clinical eating disorders and low

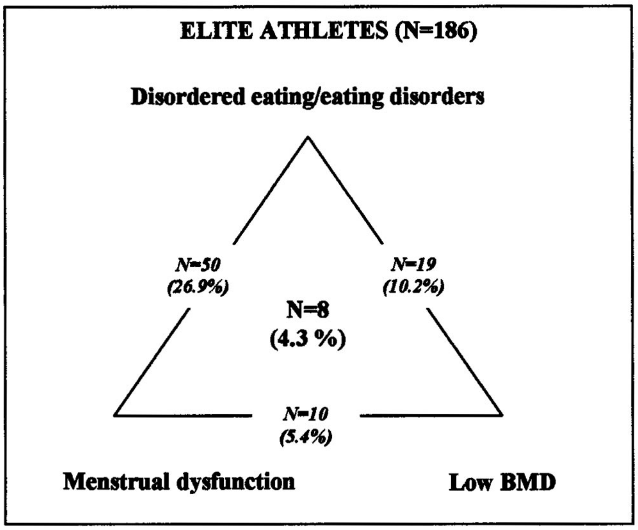

FIGURE 2—Prevalence of the combination of two or three of the components of the Triad in female elite athletes (N = 186). Data are given in numbers and percentage.

TABLE 2. Characteristics of the eight athletes classified with the Triad. Data are given for each athlete as well as mean values with standard deviation (SD).

Athlete	Age (yr)	Body Weight (kg)	BMI (kg·m^{-2})	Total Body Fat (%)	Age of Menarche (yr)	Drive for Thinness*	Body Dissatisfaction*
Volleyball	19.5	73.2	23.0	29.3	16.0	7	16
Handball	21.0	44.3	17.3	20.6	NR	NR	NR
Running**	22.6	51.2	19.0	5.9	13.0	2	6
Running**	28.2	55.6	19.0	10.5	11.8	6	4
Swimming	17.6	57.0	20.0	19.6	14.8	15	22
Biathlon	20.3	51.1	20.7	20.0	17.4	NR	NR
Bicycling	21.4	52.2	20.8	26.4	13.4	6	7
Climbing	18.2	56.8	21.8	28.8	16.5	0	1
Mean (SD)	21.1 (3.3)	55.2 (8.4)	20.2 (8.4)	20.1 (8.4)	14.7 (2.1)	6.0 (5.2)	9.3 (8.0)

NR, not reported (missing data not reported/answered by the subject).
* Subscales of the Eating Disorder Inventory. Mean values are reported. Definition of high scores are ≥15 for drive for thinness and ≥14 for body dissatisfaction.
** Long/middle distance running.

BMD (Z-score < -2.0), four (2.8%) had both menstrual dysfunction and low BMD (Z-score < -2.0), whereas 17 (11.7%) had both clinical eating disorders and menstrual dysfunction.

When dividing the controls' physical activity level into quartiles, we found that none of the subjects with the Triad were classified in the highest quartile (>6.0 h·wk^{-1}). A further analysis of the five controls with the Triad is showed in Table 4.

Athletes versus controls. A higher percentage of athletes (26.9%) than controls (13.8%) met the criteria for both disordered eating/eating disorders and menstrual dysfunction ($P < 0.01$). A difference between the groups was still present after adjusting for age ($P < 0.01$). A higher percentage of controls (12.4%) than athletes (5.4%) also had the combination of menstrual dysfunction and low BMD (Z-score < -1.0, but ≥ -2.0) ($P < 0.05$) when adjusted for age. No differences between athletes and controls were found in any other Triad component combinations.

Dropout Analysis

Of the 300 athletes and 300 controls that were invited to participate in parts II and III of the study, 114 athletes and 155 controls chose not to participate (dropouts) in the DXA measurement or the clinical interview. In the control group, no differences were found between participants and dropouts for age, body weight, BMI, weight-bearing activity, previous pregnancy, percentage of smokers, use of medications that may affect bone health, menstrual dysfunction, prevalence of stress fractures, oral contraceptive use, or self-reported eating disorders. The dropouts were, however, taller (168.2 ± 6.0 cm) than the participants (166.1 ± 6.3 cm) ($P < 0.05$). In addition, most of the participants grew up in the southeastern part of Norway, whereas the dropouts had a majority of people who grew up in the northern part of the country.

Among the athletes, no differences were found between the participants and the dropouts in age, age of sport specialization, training volume, height, percentage of smokers, use of medications that may affect bone health, prevalence of stress fractures, national or international performance ranking, or oral contraceptive use. The participants did have a lower body weight (60.3 ± 8.8 kg) and BMI (21.1 ± 2.4 kg·m^{-2}) than the dropouts (63.7 ± 9.3 kg and 22.1 ± 2.2 kg·m^{-2}, respectively) ($P < 0.01$). Furthermore, a higher percentage of participants than dropouts reported menstrual dysfunction (43.2 vs 24.6%, respectively) and self-reported eating disorders (26.9 vs 13.2%, respectively). In addition, a lower percentage of participants than dropouts reported previous pregnancy (7.1 vs 15.0%, respectively) ($P < 0.05$).

DISCUSSION

To our knowledge, this study is the first to publish data regarding prevalence of the Triad in elite athletes and controls from the general population. Our results support previous studies concluding that athletes commonly suffer from one or more components of the Triad (2–4,28,30) and the assumption that young female athletes suffer from the Triad syndrome (21). In addition, we found that the Triad is also present in normal active females.

Methodological Considerations and Use of Definitions

The Triad was originally defined as the combination of disordered eating, amenorrhea, and osteoporosis (33). However, researchers and clinicians argue for a possible continuum model for the three components of the Triad (8,27). Furthermore, early identification of symptoms related to the Triad is important to prevent development of the most

TABLE 3. Prevalence of the combination of two or three of the components of the Triad in athletes competing in leanness sports ($N = 90$) and nonleanness sports ($N = 96$). Data are given in numbers and the significant levels are age-adjusted.

	Leanness Sports ($N = 90$)	Nonleanness Sports ($N = 96$)
The Triad stage I	3	1
Disordered eating and menstrual dysfunction	20	15
Disordered eating and low BMD (Z-score < -1.0, but > -2.0)	4	6
Menstrual dysfunction and low BMD (Z-score < -1.0, but > -2.0)	5	1
The Triad stage II	3	1
Eating disorders and menstrual dysfunction	32[a]	13
Eating disorders and low BMD (Z-score < -2.0)	5	1
Menstrual dysfunction and low BMD (Z-score < -2.0)	3	1
The Triad (either stage I or stage II)	6	2

[a] $P < 0.01$.

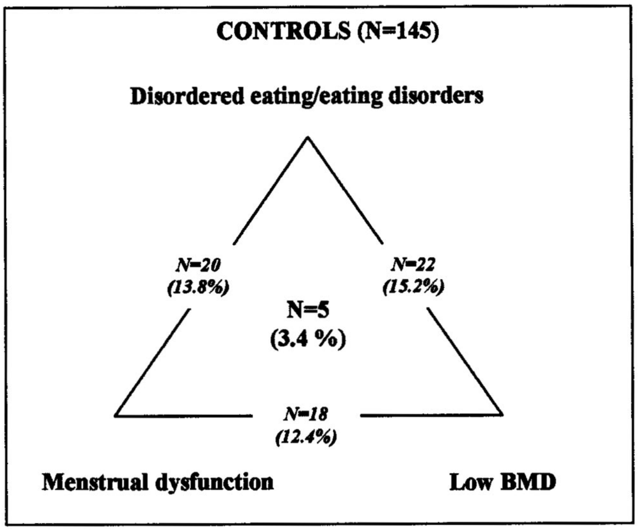

FIGURE 3—Prevalence of the combination of two or three of the components of the Triad in the controls (*N* = 145). Data are given in numbers and percentage.

severe disorders of the Triad. Therefore, we found it important to investigate not only the endpoints of the Triad continuum, clinical eating disorders, amenorrhea, and low BMD (Z-score < -2.0), but also to evaluate their less severe manifestations, disordered eating, menstrual dysfunction, and low BMD (Z-score < -1.0, but ≥ -2.0).

Disordered eating and eating disorders. Pressure placed on females to achieve or maintain unrealistically low body weight has been considered an important triggering factor for the Triad components. It has therefore been claimed that women who have significant weight, eating, and body image concerns may be at risk for the Triad (21). High scores on the Eating Disorder Inventory Drive for Thinness and Body Dissatisfaction subscales, as well as use of pathogenic weight control methods and self-reported eating disorders, are symptoms of disordered eating and/or eating disorders, and predict eating disorders (11,29). Therefore, participants in this study were classified with disordered eating if their scores on the Drive for Thinness or Body Dissatisfaction subscales were at or above the mean score for known anorectics (11), if they reported use of one or more pathogenic weight control methods, or self-reported past or present eating disorders. Based on research concluding that a clinical interview is needed to determine the presence of clinical eating disorders (3,29,30), we conducted a standardized clinical interview (6) to determine the number of females meeting the DSM-IV criteria (1) for anorexia nervosa, bulimia nervosa, or eating disorders not otherwise specified in the present study. Furthermore, the importance of using a person specifically trained in eating disorders should be noted.

Menstrual dysfunction. The prevalence of menstrual dysfunction depends strongly on how the term is defined. Ideally the menstrual dysfunction continuum would be determined by measurement of sex hormone levels during several menstrual cycles, and gynecological examination to exclude causes of menstrual dysfunction not related to exercise, thereby distinguishing between females with anovulation or luteal phase dysfunction, females with oligomenorrhea and females with primary or secondary amenorrhea. As it was not possible to conduct such an investigation in this study, we used questionnaire data to, as far as possible, determine subjects with past or present menstrual dysfunction. Despite a lack of consensus, some results have shown that, in addition to amenorrhea, anovulation and luteal phase dysfunction may also lead to loss of BMD (23). Therefore, we defined menstrual dysfunction as the presence of any of these conditions. We decided to include past as well as present menstrual dysfunction in both Triad models, because although a woman's current menstrual status seems to reflect her recent energy availability (20), her BMD reflects the entire history of energy availability and menstrual status. By investigating the condition of present menstrual dysfunction only, we would have run the risk of not detecting females at risk for bone loss.

Low BMD. To date, no threshold for BMD discriminates absolutely between those who will experience a fracture and those who will not (15). Based on the new ISCD guidelines (14,19) it is recommended that low BMD should be defined as a Z-score below -2.0 for premenopausal women and children. However, considering that female athletes are a special population and that they (at least athletes in weight-bearing sports) are expected to have 5–15% higher BMD values compared with nonathletes (10,13), we think it is important not only to apply a Z-score below –2.0, but also to register a Z-score below -1.0. In our opinion, if female athletes have a Z-score of less than -1.0, this is most unfortunate, and in combination with one or two of the other Triad disorders, should be noted and followed up. In terms of identifying at-risk athletes at an early stage, it might be useful to employ a threshold of a Z-score $<$ -1.0, in addition to a Z-score < -2.0, in that this may

TABLE 4. Characteristics of the five controls (A–E) classified with the Triad. Data are given for each subject as well as mean values with standard deviation (SD).

Control	Age (yr)	Body Weight (kg)	BMI ($kg \cdot m^{-2}$)	Total Body Fat (%)	Age of Menarche (yr)	Drive for Thinness*	Body Dissatisfaction*	Physical Activity ($min \cdot wk^{-1}$)
A	39.8	53.9	20.0	28.0	15.0	NR	NR	190
B	32.6	81.5	29.1	49.4	12.0	15	22	123
C	34.6	56.6	20.7	30.6	13.0	1	1	120
D	31.0	104.0	36.4	45.0	12.3	20	21	56
E	26.3	81.0	28.4	43.2	14.0	1	5	135
Mean (SD)	32.9 (4.9)	75.4 (20.6)	26.9 (6.8)	39.2 (9.4)	13.3 (1.3)	7.4 (9.4)	12.3 (10.8)	124.9 (47.7)

NR, not reported (missing data not reported/answered by the subject).
* Subscales of the Eating Disorder Inventory. Mean values are reported. Definition of high scores are ≥15 for drive for thinness and ≥14 for body dissatisfaction.

prevent development of a more serious outcome in terms of the Triad disorders. In order to have the opportunity to divide between the degree of seriousness, we therefore presented prevalence data for both a Z-score < -1.0 and < -2.0. It should be noted, however, that peak bone mass is probably not achieved among the youngest subjects in our study; thus, caution should be used in "labeling" children and adolescents with low bone mass.

Prevalence of the Triad

Elite athletes. In contrast to the 4% diagnosed with all components of the Triad in our study, none of the females in the study by Lauder et al. (18) met the criteria for all components of the Triad. It should be noted that despite the large sample size in part I of their study, only 18 women at risk for or diagnosed with menstrual dysfunction or eating disorders and 32 controls underwent DXA scans to assess BMD. Furthermore, their study was conducted on military women, and despite the authors' assumption that all military personnel are athletes, present or past physical activity level was not reported (18), and it is therefore difficult to compare these results directly with ours.

When examining the occurrence of two of the components of the Triad in the athletes, prevalence ranged from 5.4 to 26.9%. A total of 19% met the criteria for both disordered eating and menstrual dysfunction, whereas 24% met the criteria for the more advanced stage, eating disorders and menstrual dysfunction. Thus, as many as 15 athletes not having the combination of disordered eating and menstrual dysfunction met the criteria for eating disorders and menstrual dysfunction, which may indicate underreporting of disordered eating by these subjects. Results from the clinical interview verified that they met the criteria for anorexia nervosa, bulimia nervosa, or eating disorders not otherwise specified without being categorized as disordered-eating athletes in part I of the study. Such a discrepancy underscores the importance of conducting a clinical interview, on top of obtaining self-reported disordered eating behavior via questionnaire (29), particularly when investigating the prevalence of the Triad.

Cobb et al. (4) used three subscales of the Eating Disorder Inventory to screen for subclinical eating disorders, in addition to questions about menstrual status and measurement of BMD in 91 competitive runners. Their results agree with previous studies (28) finding that elevated Eating Disorder Inventory subscale scores were associated with oligo/amenorrhea. It was therefore expected that some of the athletes in our study with eating disorders would also have menstrual dysfunction, but that more than a fourth of the athletes had both disordered eating/eating disorders and menstrual dysfunction is surprising. Moreover, these numbers are much higher than what was reported in the study on military women, where 3.3% were found to be at risk for eating disorders and menstrual dysfunction, and 1.0% met the criteria for both eating disorders and menstrual dysfunction (18). With the present knowledge of the clinical consequences of this combination of risk factors on bone health (21), mitigating the risk factors in these athletes is of utmost importance. This can be further underlined by our results showing that 5% of the athletes had both menstrual dysfunction and low BMD, and 10% had both disordered eating/eating disorders and low BMD. These results agree with previous research showing an association between menstrual dysfunction and/or eating disorders and low bone mass (4,9,12,25,34,35).

Existence of the Triad components has been expected to be more common in leanness sports compared with other sport groups (2,3,28,29). Results from our study support previous findings in that six of the eight athletes diagnosed with the Triad competed in leanness sports. In addition, as expected, more athletes competing in leanness sports than in nonleanness sports met the criteria for the combination of eating disorders and menstrual dysfunction. It is possible that the increased focus on thinness and/or a low body weight in leanness sports leads to reduced calorie intake and/or increased energy expenditure and subsequently energy deficiency in these athletes (2).

When we investigated more in detail characteristics of the athletes with the Triad, we found that despite the resemblance in terms of sport-specific demands, other variables varied to a great extent, and it was difficult to sum up other similarities between the eight athletes. They ranged in age from 17.6 to 28.2 yr, and in age of menarche from 11.8 to 17.4 yr. All eight athletes had a BMI value in the lower end of the normal range ($\leq$23 kg·m^{-2}), whereas body fat percentage varied from 5.9% to as high as 29.3%. The athlete with the highest percent body fat was 15 yr old the first time she tried to lose weight, had a 4-yr history of dieting, and was at present very dissatisfied with her body. These factors may have led to loss of fat-free mass, leading to a high percentage of body fat despite a normal BMI value. It should further be noted that three of the athletes competed in nonweight-bearing sports (swimming, bicycling, and climbing), and only two of the athletes competed in sports characterized by high mechanical loading (ball game sports). According to recent literature, energy deficiency may be one important reason for the Triad disorders (20,35). It would therefore have been interesting to look at the energy balance in these athletes, but detailed measurement of energy intake and expenditure was not a part of this prevalence study.

Controls. The prevalence of eating disorders and menstrual dysfunction in nonathletic controls has been a focus of some previous studies (3,28–30). However, to our knowledge, nonathletes have never been the subject or a focus of a prevalence study of the Triad components, although they have been mentioned in the position stand from 1997 (21). It is therefore difficult to compare our results with samples other than our elite athlete group.

In the present study, an unexpectedly high number of controls met the criteria for two (12–15%) or three (4%) of the components of the Triad. However, when investigating the prevalence of the most advanced stage of the Triad disorders, it was found that only one woman was diagnosed with clinical eating disorders and low BMD (Z-score $<$

−2.0). Additionally, three women met the criteria for the combination of menstrual dysfunction and low BMD (Z-score < −2.0). This finding implies that a young woman can have serious low BMD while lacking clinical eating disorders. Recent literature indicates that it is not necessarily the disordered eating behavior itself, but the resulting negative energy balance that is important in the development of menstrual dysfunction, possibly leading to bone loss (20).

The fact that almost the same number of controls met the criteria for the Triad as compared with the athletes was quite surprising. Therefore, we found it interesting to investigate these five controls more in detail, and especially to analyze their physical activity level. We found, however, that none of them were included in the highest physical activity quartile. None were underweight, and their mean body fat percent was above the normal mean. We do not know their energy intake or exact energy expenditure, and due to the cross sectional design of this study, we are not able to explain why these controls suffer from the Triad. However, when looking at the dietary history of these females, they had all tried to lose weight several times because they felt either too fat or too heavy, and they had all used pathogenic weight control methods to reduce their weight. The mean number of years since they started to diet was 13.3 yr, ranging from 5.3 to 24.8 yr. We therefore speculate that the psychological stress related to their disordered eating may have affected the reproductive system, leading to menstrual disturbances and possible loss of BMD. Furthermore, periods of undernutrition combined with low weight-bearing physical activity may have had a negative influence on the bone health in these females.

Athletes versus controls. The present study is the first to confirm the claim made in the position stand from 1997 that the Triad has been found in nonathletes (21). Minor differences between athletes and controls in terms of prevalence of the Triad and the Triad components were observed in our study. However, as with earlier studies (3,28–30), we found that the simultaneous presence of menstrual dysfunction and disordered eating/eating disorders was more common in athletes than controls. Due to the low numbers with the Triad disorders we did not conduct further statistical analysis. Because we were able to look into a possible continuum of the Triad, we did observe an important difference between the athletes and the controls. Even if as many as five controls were diagnosed with the Triad, none of them had the Triad stage II. Among the Triad athletes, 50% met the criteria for the more extreme Triad disorders. Why the athletes seem to have developed a more serious condition as compared to the controls is not known, but may be due to a higher degree or a longer period of estrogen and/or energy deficiency.

Previous literature has shown that athletes participating in weight-bearing sports have higher BMD than nonathletic controls (10,13). This was also found in our samples (32), which may explain the higher percentage of controls than athletes meeting the criteria for the combination of menstrual dysfunction and low BMD. It should however be noted that the high prevalence of low BMD among the controls may be due to the cut-off score of < −1.0, which may lead to false positives. On the contrary, these females also suffered from menstrual dysfunction, an important risk factor for low BMD, and may therefore be true positives and at risk for osteoporosis. The high prevalence of controls with low BMD may be due to the type and level of activity, which may not be sufficient to offset the negative effects of menstrual dysfunction on BMD. In contrast, participation in medium impact and/or high impact sports at the elite level might to a certain degree reduce the loss of bone mass caused by menstrual dysfunction (25,34).

To summarize, we suggest that focus should be geared towards the components of the Triad stage I to prevent the more severe Triad stage II. Due to the assumed existence of the continuum of the Triad components, one can expect that those suffering from at least one of the less severe components of the Triad stage I may develop the more severe components of the Triad stage II if they do not receive proper guidance/treatment. In this study, four of the athletes with the Triad were diagnosed with the Triad stage I and had not yet developed the more severe form (Triad stage II). These athletes should be targeted for preventive strategies, including nutrition guidance. Ideally, *no* females should suffer from all components of the Triad; unfortunately, 4% of both the athletes and the controls in our study met these criteria. In addition, when we look at the simultaneous prevalence of two of the severe components of the Triad, these results should lead to intensive prevention and treatment efforts. The development of low bone mass may take time, but when 27% of the athletes and 14% of the controls had both disordered eating/eating disorders and menstrual dysfunction, the risk of progressive skeletal demineralization leading to a lower BMD, and the possible condition of osteoporosis, is high.

Limitations and Future Implications

Cross-sectional studies may be limited by the presence of factors that are not controlled. In cross-sectional Triad studies, such factors may include the athlete's bone density and BMI before starting sport-specific training (self-selection), as well as the athlete's level of physical activity during childhood and adolescence. Lifestyle habits that are not controlled (i.e., certain nutritional behaviors) may also affect results in Triad studies. Another limitation of cross-sectional studies is the potential for a masked volunteer effect, especially when sample selection methods are inadequate or not reported. In this study, we attempted to minimize the potential volunteer effect by drawing the study participants from as wide and random a population as possible: all elite athletes in Norway, and a randomly selected sample of females in the general population. Subjects invited to the clinical parts of the study were also randomly selected. However, despite taking such precautions, an age difference was observed between the athletes and controls. This age difference was taken into account when analyzing results.

Regardless of what factors cause weight loss and energy deficit, the consequences may be loss of menstruation and possible loss of bone mass. In fact, maintaining energy balance is critically important because it may prevent disrupted luteinizing hormone pulsatility, loss of menstruation, and consequent loss of bone mass (20). Despite the critical nature of energy balance, the objective of our study was to investigate the prevalence of the Triad, so we did not measure energy balance in the subjects. We do, however, recommend that future studies include an examination of the subjects' eating behaviors and history. Such data may explain some of the still unanswered questions regarding the causes of the Triad components. In terms of prevention and treatment, programs should focus not only on athletes with disordered eating and eating disorders, but should strive to help athletes achieve and maintain a healthy energy balance.

Generalization of the Results

The possibility for systematic selection bias is always present in studies such as ours, as those who meet for measurement (participants) distinguish themselves from those who do not meet (dropouts). Our dropout analysis showed that the only factors that distinguished the control participants from the dropouts were height and geographical location.

In the athletic group some factors distinguished the participants from the dropouts. Participants exhibited lower BMI and a higher prevalence of menstrual dysfunction and eating disorders than the dropouts. It is possible that the athletes with a family history of osteoporosis, or those who otherwise knew they were at risk for low BMD, were more willing to participate in the clinical parts of the study. Based on this, it is unlikely that the dropouts have lower BMD than the participants.

All the females diagnosed with the Triad were considered at risk for the Triad based on the results from part I of this study (31). Nevertheless, a higher frequency of athletes at risk for the Triad participated in parts II and III of this study compared with the dropouts. These results show that the Triad is prevalent in young females representing the "normal population," as well as female elite athletes. Altogether, we think that the results from this study can be generalized not only to female elite populations, but also to premenopausal women in general. The random selection of the controls, and the fact that few differences were detected between those controls participating in part I and those participating in parts II and III of the study, strengthen the assumption that a representative sample participated in all parts of the study. There are no reasons to suspect that the randomly selected and national representative sample of controls participating in this study is not comparable to females in general in other Western cultures and countries. However, it should be noted that the relatively high level of physical activity in the controls may not apply to all other populations, and also that genetic differences may be present.

The aim of this study was to investigate the prevalence of the Triad, and not to follow these females prospectively to look at possible changes. It would, however, be interesting to more closely compare the characteristics of the females suffering from the Triad stage I with those suffering from the Triad stage II. It would also be valuable to study these women over time to compare those who get well with those who do not. In terms of prevention of the Triad, it is important to note that examining all components of the Triad could be misleading and mask the potential problem among elite athletes.

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