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Bone mineral density and body composition according to menstrual status in female gymnasts: An observational study.

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Abstract

Objective: To evaluate Bone Mineral Density (BMD) and body composition in adolescent female gymnasts with different menstrual status in comparison with normal controls.
Design: Observational, cross-sectional study.
Methods: Twenty oligomenorrheic gymnasts, twenty eumenorrheic gymnasts and twenty age-matched eumenorrheic controls participated in this study. Their ages ranged from 12 to 17 y old. Bone mineral density and body composition were evaluated by dual X-ray absorptiometry. Menstrual status and training profile were assessed through a self-administered questionnaire.
Results: Both oligomenorrheic and eumenorrheic gymnasts had significant lower total BMD, total fat percentage, and total and regional fat mass (P<0.05) when compared with eumenorrheic controls. Also, oligomenorrheic gymnasts had significant lower BMD at arms and legs (P<0.05) when compared with eumenorrheic controls. Trunk lean mass was a strong indicator for trunk BMD in all groups (P<0.05). In oligomenorrheic gymnasts, there were significant positive correlations between BMD and lean and fat mass (at total body, trunk and legs) (P<0.05).
Conclusion: Gymnastics training during puberty is associated with low body mass, total and regional fat mass, and total BMD, regardless of menstrual status.

Keywords: Bone mineral density, Body composition, Oligomenorrhea, Menstrual status, Gymnasts.

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Introduction

There is a tremendous increase in the number of females participating in sports. Consequently, more females become able to get the educational, social and physiological benefits of sport training. However, there are some problems related to sport participation, including menstrual dysfunction and low bone mass [1]. The reported prevalence of primary amenorrhea, secondary amenorrhea and oligomenorrhea among female athlete's ranges from 0% to 56.0%, 1% to 60.0% and 3.5% to 52.5%, respectively. However, the range of prevalence of osteopenia and osteoporosis among female athletes was 0% to 39.8% and 0% to 15.4% respectively. Moreover, the estimated prevalence of menstrual dysfunction and low bone mass concurrently ranges from 0% to 7.5% [2].

Gymnasts are liable to a significant energy deficit that starts early in the prepubertal age. They limit their energy intake to meet their sports requirements for a thin body. The poor intake, low body weight and intensive physical training may disturb the hypothalamic-pituitary-ovarian axis leading to delayed puberty and menstrual dysfunction [3]. Other important factors linked to exercise-related menstrual disturbance include body composition, psychological stress and sport type [4]. The hypoestrogenic status, of female athletes with menstrual dysfunction, results in bone loss and failure to attain peak bone mass. Thus, athletes with menstrual dysfunction have increased risk of stress fractures and bone fractures, especially in overuse [5].

Body composition is a key factor that affects both menstrual status and bone health. Menarche occurs when body fat reaches 17% of body weight and menstrual status is disturbed when body fat falls below 22% of body weight [6]. Also, there are strong positive associations between body composition (lean and fat mass) and both whole body bone mineral content and BMD in adolescent female athletes. However, these associations varied according to sport type [7].

Although previous research had examined BMD and body composition in female gymnasts during childhood [8-10], few studies have addressed this question in adolescent female gymnasts with or without normal menstruation in comparison with normal controls. Therefore, the aim of this study was to compare BMD and body composition in oligomenorrheic gymnasts, eumenorrheic gymnasts and eumenorrheic controls during adolescence. Additional objective was to investigate the correlations between BMD and body composition at total body, trunk, abdomen, arms and legs.

Materials and Methods

Design

The study was an observational cross sectional design.

Recruitment

A convenient sample of sixty adolescent females (20 oligomenorrheic gymnasts, 20 eumenorrheic gymnasts and 20 eumenorrheic controls) were enrolled into this study. Gymnasts were selected from local clubs in Cairo, Egypt, through advertisements. The sedentary eumenorrheic controls were recruited from preparatory and secondary schools in Cairo, Egypt. Informed consent was obtained from each participant after explaining the nature, purpose, and benefits of the study, informing them of their right to refuse or withdraw at any time, and about the confidentiality of any obtained information. This study was approved by the Research Ethical Committee of the Faculty of Physical Therapy, Cairo University.

The inclusion and exclusion criteria:

To be included in the study, the participants' ages ranged from 12 to 17 y old, had the same social status. The participants were healthy, non-smokers and didn't use any medications or hormonal treatment that can affect bone metabolism. Gymnasts group started training at age of 6-8 y and performed intensive exercise for 15-20 h/w. In addition, none of them were using oral contraceptive pills. According to their menstrual status in the past year, subjects were categorized as eumenorrheic or oligomenorrheic. Eumenorrhea was defined as 10 or more menstrual cycles per year while, oligomenorrhea was defined as 4-9 menstrual cycles per year [11]. Then, subjects were divided into three groups: group of twenty oligomenorrheic gymnasts, group of twenty eumenorrheic gymnasts and group of twenty eumenorrheic controls.

Outcome measures

Anthropometric measures: weight-height scale was used to measure the weight and height of each female in the three groups. Then, the Body Mass Index (BMI) was calculated by dividing weight by height squared (Kg/m^2).

Questionnaire

A self-administered questionnaire was given to each female to assess her menstrual history and training profile [11]. It included questions about age at menarche (y), number of menstrual cycles in the past year and menstrual cycle length (d). Also, each gymnast was asked about her age of participation to gymnastics (y) and the number of hours training per week (h/w). Then, training experience (y) was calculated by subtracting the gymnast’s age of participation to training from her chronological age.

Total and regional BMD and body composition measurements

Dual energy X-ray Absorptiometry (Norland Xr 46, version 3.9.6/2.3.1, America) was used to measure BMD and body composition for each female in the three groups. BMD measurements (g/cm^2) were taken at total body, trunk, abdomen, arms and legs. Body composition including total fat percentage, total fat mass (g), total lean mass (g) and regional fat and lean mass (g) at trunk, abdomen, arms and legs were also measured. All females were asked to avoid physical activity in the previous day before screening in order to avoid the hydration status effect on different measures of body composition.

Sample size estimation and statistical analysis

Based on pilot study, 10 subjects/group, sample size was calculated according to the difference in the mean value of total BMD between the three studied groups (oligomenorrheic gymnasts=0.79; eumenorrheic gymnasts=0.82 and eumenorrheic controls=0.93) with average standard deviation equal to 0.065. Assuming α=0.05, an effect size=0.41 and power of 80%, so a sample size of 20 subjects per group would be required (GPower 301 http:www.psycho.uni-duesseldorf.de).

Results were expressed as mean ± standard deviation. Test of normality, Shapiro Wilk test, was used to study the distribution of data. Accordingly, comparison between normally distributed variables in the three groups was performed using one-way ANOVA followed by Tukey HSD test if significant results were recorded. In not normally distributed data, comparison was performed using Kruskal Wallis ANOVA test followed by Mann-Whitney test if significant results were recorded. Correlation between different variables was performed using either Pearson or Spearman's rho correlation coefficients. Statistical analysis was performed using SPSS computer program (version 19 windows). P value ≤ 0.05 was considered significant.

Results

Baseline characteristics

The participants' anthropometric, menstrual and training data are summarized in Table 1. Age showed non-significant difference between the three groups (P>0.05). Also, BMI showed non-significant difference between oligomenorrheic and eumenorrheic gymnasts (P>0.05), while it was significantly lower (P<0.05) in both oligomenorrheic and eumenorrheic gymnasts than eumenorrheic controls. Age at menarche showed non-significant differences between eumenorrheic gymnasts and both oligomenorrheic gymnasts and eumenorrheic controls (P>0.05), while oligomenorrheic gymnasts had significantly later age at menarche than eumenorrheic controls (P<0.05). Also, oligomenorrheic gymnasts had significantly higher menstrual cycle length and lower number of menstrual cycles in the past year than both eumenorrheic gymnasts and eumenorrheic controls (P<0.05). Regarding training profile of gymnasts, results showed non-significant differences between oligomenorrheic and eumenorrheic gymnasts in age of participation to gymnastics (P=0.143), training experience (P=0.779) and the number of hours training per week (P=0.112).

BMD

Oligomenorrheic gymnasts had significantly lower BMD at total body, arms and legs (P<0.05) and non-significantly lower BMD at trunk and abdomen (P>0.05) than eumenorrheic controls. Eumenorrheic gymnasts had significantly lower total BMD (P<0.05) and non-significantly lower BMD at trunk, abdomen, arms and legs (P>0.05) than eumenorrheic controls. Also, oligomenorrheic gymnasts had significantly lower arms BMD (P<0.05) and non-significantly lower BMD at total body, trunk, abdomen and legs (P>0.05) than eumenorrheic gymnasts (Table 2).

Body composition

Oligomenorrheic gymnasts had significantly lower total fat percentage, total fat mass, trunk fat mass, abdomen fat mass, arms fat mass and legs fat mass (P<0.05) and non-significantly higher total lean mass, trunk fat mass, abdomen lean mass, arms lean mass and legs lean mass (P>0.05) than eumenorrheic controls. Eumenorrheic gymnasts had significantly lower total fat percentage, total fat mass, trunk fat mass, abdomen fat mass, arms fat mass and legs fat mass (P<0.05) and non-significantly higher total lean mass, trunk lean mass, abdomen lean mass, arms lean mass and legs lean mass (P>0.05) than eumenorrheic controls. Also, there were non-significant differences between oligomenorrheic and eumenorrheic gymnasts regarding total fat percentage, total fat mass, total lean mass, trunk fat mass, abdomen fat mass, arms fat mass, legs fat mass, trunk lean mass, abdomen lean mass, arms lean mass and legs lean mass (P>0.05), (Table 3).

Correlations between BMD and body composition

In oligomenorrheic gymnasts, total BMD showed strong positive correlations with both total fat and lean mass (P<0.05). Also, there were strong positive correlations between regional BMD and regional fat and lean mass at trunk and legs (P<0.05). For the abdomen, abdomen BMD showed a significant positive correlation with abdomen fat mass only (P<0.05), (Table 4).

In eumenorrheic gymnasts, there were significant positive correlations between regional BMD and regional lean mass at trunk and abdomen (P<0.05). Also, a strong positive correlation was found between arm BMD and arm fat mass only (P<0.05), (Table 4). In eumenorrheic controls, there were strong positive correlations between regional BMD and regional lean mass at trunk and arm (P<0.05), (Table 4).

Table 1. *Baseline characteristics of oligomenorrheic gymnasts, eumenorrheic gymnasts and eumenorrheic controls.*

Variables	Oligomenorrheic gymnasts (n=20)	Eumenorrheic gymnasts (n=20)	Eumenorrheic controls (n=20)	P value
Age (y)	15.10 ± 1.21	15.00 ± 1.03	15.25 ± 1.62	0.832
BMI (kg/m^2)	19.39 ± 2.05	20.04 ± 1.71	22.35 ± 1.55 ab	0.001
Menstrual status				
Age at menarche# (y)	13.40 ± 1.14	13.00 ± 1.12	12.40 ± 0.82 a	0.007
Menstrual cycle length# (d)	51.40 ± 9.04	29.80 ± 0.62 a	29.40 ± 1.39 a	0.001
No. of menstrual cycles in past year#	7.20 ± 1.28	12.10 ± 0.31 a	12.20 ± 0.62 a	0.001
Training profile				
Age of participation# (y)	7.60 ± 0.50	7.30 ± 0.66	---	0.143
Training experience# (y)	7.40 ± 1.39	7.50 ± 1.15	---	0.779
Amount of training# (h/w)	18.00 ± 2.51	16.75 ± 2.31	---	0.112

Data are expressed as mean ± SD; P>0.05=not significant; P<0.05=significant; [a]P<0.05 relative to oligomenorrheic gymnasts group; [b]P<0.05 relative to euomenorrheic gymnasts group. #non-parametric statistics.

Table 2. *BMD of oligomenorrheic gymnasts, eumenorrheic gymnasts and eumenorrheic controls.*

Variables	Oligomenorrheic gymnasts (n=20)	Eumenorrheic gymnasts (n=20)	Eumenorrheic controls (n=20)	P value

Total BMD (g/cm^2)	0.83 ± 0.06	0.85 ± 0.06	0.90 ± 0.07^{ab}	0.002
Trunk BMD (g/cm^2)	0.79 ± 0.06	0.80 ± 0.06	0.83 ± 0.06	0.058
Abdomen BMD (g/cm^2)	0.95 ± 0.10	0.98 ± 0.09	1.00 ± 0.08	0.201
Arms BMD (g/cm^2)	0.49 ± 0.07	0.56 ± 0.07^a	0.58 ± 0.08^a	0.001
Legs BMD (g/cm^2)	0.86 ± 0.07	0.88 ± 0.08	0.94 ± 0.07^a	0.005

Data are expressed as mean ± SD. P>0.05=not significant; P<0.05= significant. ^{a}P<0.05 relative to oligomenorrheic gymnasts group. ^{b}P<0.05 relative to euomenorrheic gymnasts group. $^\#$non-parametric statistics.

Table 3. *Body composition of oligomenorrheic gymnasts, eumenorrheic gymnasts and eumenorrheic controls.*

Variables	Oligomenorrheic gymnasts (n=20)	Eumenorrheic gymnasts (n=20)	Eumenorrheic controls (n=20)	P value
Total fat percentage$^\#$	24.2 ± 6.55	24.8 ± 4.58	33.1 ± 5.42 ^{ab}	0.001
Total fat mass (g)	12600 ± 4958.29	12800 ± 2770.65	18500 ± 4033.29^{ab}	0.001
Total lean mass (g)	36300 ± 2815.80	36800 ± 3759.35	34700 ± 2641.37	0.098
Trunk fat mass (g)	6114.2 ± 2588.79	6559.5 ± 1661.56	9057.3 ± 2234.16^{ab}	0.001
Trunk lean mass (g)	16700 ± 1909.54	16700 ± 2292.65	15700 ± 1192.14	0.162
Abdomen fat mass$^\#$ (g)	2536 ± 988.01	2812.8 ± 740.65	3881.2 ± 797.41^{ab}	0.001
Abdomen lean mass (g)	7685.8 ± 925.38	7825.4 ± 937.31	7248.8 ± 664.71	0.092
Arm fat mass$^\#$ (g)	1302.2 ± 417.40	1508.2 ± 268.91	1772. ± 327.21^{ab}	0.001
Arm lean mass (g)	3080.4 ± 374.85	3008.6 ± 311.01	2989.4 ± 297.68	0.657
Leg fat mass$^\#$ (g)	5351.9 ± 1469.77	5419.9 ± 1179.58	7555.7 ± 1626.31^{ab}	0.001
Leg lean mass (g)	13000 ± 1310.28	13000 ± 1719.37	12600 ± 1586.98	0.582

Data are expressed as mean ± SD; P>0.05=not significant; P<0.05=significant; ^{a}P<0.05 relative to oligomenorrheic gymnasts group; ^{b}P<0.05 relative to euomenorrheic gymnasts group; $^\#$non-parametric statistics.

Table 4. *Correlations between BMD and body composition in oligomenorrheic gymnasts, eumenorrheic gymnasts and eumenorrheic controls.*

	Oligomenorrheic gymnasts		Eumenorrheic gymnasts		Eumenorrheic controls	
	r or ρ	p value	r or ρ	p value	r or ρ	p value
	Total BMD					
Total fat mass	0.566	0.009*	0.119	0.616	-0.306	0.19
Total lean mass	0.555	0.011*	0.163	0.493	0.324	0.164
	Trunk BMD					
Trunk fat mass	0.728	0.001*	0.239	0.311	-0.288	0.218
Trunk lean mass	0.508	0.022*	0.751	0.001*	0.662	0.001*
	Abdomen BMD					
Abdomen fat mass$^\#$	0.527	0.017*	0.261	0.267	-0.195	0.411
Abdomen lean mass	0.256	0.276	0.798	0.001*	0.158	0.505
	Legs BMD					
Leg fat mass$^\#$	0.527	0.017*	0.03	0.899	-0.127	0.593
Leg lean mass	0.709	0.001*	-0.146	0.54	0.388	0.091
	Arms BMD					
Arm fat mass$^\#$	0.018	0.939	0.527	0.017*	-0.006	0.98
Arm lean mass	0.322	0.166	258	0.271	0.487	0.029*

r=Pearson or $^\#$Spearman's rho correlation coefficient (ρ); P>0.05=not significant; *P<0.05=significant.

Discussion

Over-training and dieting strategies in female gymnasts make them at high risk for energy insufficiencies and affected BMD [12]. However, little is known about the effect of gymnastics training on total and regional BMD and body composition (at trunk, abdomen, arms and legs) in adolescent gymnasts with regard to their menstrual status. Therefore, this cross-sectional study aimed to evaluate total and regional BMD and body composition in adolescent female gymnasts with or without normal menstruation in comparison with eumenorrheic controls.

Regarding anthropometric measures, the results of this study revealed that there was statistically significant decrease in BMI of both oligomenorrheic and eumenorrheic gymnasts compared with eumenorrheic controls. Nevertheless, gymnasts still had BMI within the normal range. The results of this study showed that there were non-significant differences in the age at menarche between eumenorrheic gymnasts and both oligomenorrheic gymnasts and eumenorrheic controls, while oligomenorrheic gymnasts had significantly older age at menarche than eumenorrheic controls. These findings suggest that both menstrual status and sport training interact synergistically with each other to affect age at menarche while they can't act individually. These findings were consistent with Ackerman et al. [13] who found the same results in adolescent endurance athletes.

Regarding training profile, the results of this study revealed that there were statistically non-significant differences in age of participation to gymnastics, training experience and the number of hours training per week between oligomenorrheic gymnasts and eumenorrheic gymnasts. These results agreed with Vardar et al. [14] who reported the same findings in Turkish female athletes participating in different sports. Regarding total BMD, it showed significant decrease in both oligomenorrheic and eumenorrheic gymnasts compared with eumenorrheic controls. However, it showed non-significant difference between oligomenorrheic gymnasts and eumenorrheic gymnasts. These results were consistent with Sabbour and El-Deeb [11] who found the same outcomes in Egyptian female ballet dancers. Also, a previous study on elite athletes found that they had lowered total BMD compared with their controls. The authors reported that the decrease in BMD may be due to low BMI and low energy intake in athletes [15]. In addition, Nichol et al. [16] and Mudd et al. [17] found non-significant differences in the total BMD between eumenorrheic athletes and oligo/amenorrheic athletes. This may be due to the early age of studied athletes, their relatively brief history of menstrual dysfunction and the dependence of amount of BMD reduction on the length and severity of menstrual dysfunction.

On the other hand, Kirchner et al. [18] and Robinson et al. [19] found that total BMD was significantly higher in female gymnasts compared with non-athletic controls. They reported that gymnastics training may induce greater bone mineralization because gymnasts experience ground reaction forces 12 times their body weight [20]. Also, the result of this study was in contrast with Cobb et al. [21] who found that the total body BMD was significantly higher in eumenorrheic female runners compared with oligo/amenorrheic female runners. They reported that menstrual dysfunction results in hypoestrogenism and subsequent reduction of BMD.

Regarding regional BMD, the results of this study showed that oligomenorrheic gymnasts had significantly lower BMD at arms and legs compared with eumenorrheic controls. This result was in agreement with Sabbour and El-Deeb [11] who found that oligomenorrheic ballet dancers had significantly lower BMD at arms and legs compared with control females. The authors explained that result by the significant positive correlations that they had found between BMI and measured sites BMD. Moreover, Munoz et al. [22] found that rhythmic gymnasts had lower BMD at total radius compared with controls. They reported that the reduction in bone mass of rhythmic gymnasts could be related to an increase in bone resorption markers. In contrast, Helge and Kanstrup [23] showed that gymnasts had higher BMD in both axial and appendicular skeleton than controls in spite of having menstrual dysfunction. Furthermore, Ducher et al. [24] found that BMD of gymnasts with a history of menstrual dysfunction was similar to that of non-athletic controls.

Results of this study revealed that there were statistically non-significant differences between eumenorrheic gymnasts and eumenorrheic controls regarding all measures of regional BMD. Higher BMD in female gymnasts was not predictable because of their lower BMI. These results agreed with Taaffe et al. [25] who reported non-significant differences regarding arms and legs BMD between eumenorrheic gymnasts and controls.

Oligomenorrheic gymnasts had significantly lower arms BMD and non-significantly lower BMD at trunk, abdomen and legs compared with eumenorrheic gymnasts. These results can be explained by the negative effects of estrogen deficiency on bone health in female athletes with menstrual dysfunction. However, the amount of bone mineral loss is related to the duration and degree of menstrual dysfunction and the quantity of trabecular and cortical bones [26].

Regarding body composition, both oligomenorrheic and eumenorrheic gymnasts had significantly lower total fat percentage and total and regional fat mass compared with eumenorrheic controls. However, they had non-significantly higher total and regional lean mass than controls. These findings were consistent with studies on female gymnasts [19,27-29]. On the contrary, Taaffe et al. [25] found that female gymnasts had significantly higher lean mass than controls. Also, Marwaha et al. [30] found that Indian sportswomen had higher total and regional lean mass compared with controls while, there were non-significant differences between them concerning total and regional fat mass. However, the sportswomen in that study didn't represent a single sport and they were slightly older than the gymnasts in the current study.

Results of this study showed that there were non-significant differences between oligomenorrheic gymnasts and eumenorrheic gymnasts as regards to total fat percentage and total and regional fat and lean mass. Similar results were reported in female ballet dancers [11], endurance athletes [13] and runners [31]. Also, Klentrou and Plyley [29] found non-significant difference between oligomenorrheic gymnasts and eumenorrheic gymnasts regarding total fat percentage. These findings suggested that lowered body fat is not the main etiological factor leading to menstrual dysfunction in female athletes.

It is interesting that, in all groups, trunk lean mass was a strong predictor for trunk BMD. This result can be supported with Kang et al. [32] who explored significant positive correlations between spinal BMD and all components of trunk lean mass in Korean female farmers.

In the present study, BMD was significantly correlated to lean and fat mass at total body, trunk and legs in the group of oligomenorrheic gymnasts. In line with the present findings, a recent study reported strong associations between BMD and lean and fat mass indices in adolescent females while these associations varied in weightlifters, swimmers and non-athletic females [7].

Conclusions and Clinical Implication

Adolescent gymnasts with or without menstrual dysfunction have low BMI, low body fat and compromised total BMD. Furthermore, gymnasts' oligomenorrhea can compromise their upper and lower extremities BMD. Thus, gymnasts, parents, coaches and health professionals should be educated about the detrimental effects of intense exercise training, altered body composition and exercise-associated oligomenorrhea on BMD. Exercise-associated menstrual dysfunction induces additional deleterious effects on regional BMD. Consequently, educational programs should be designed to enhance exercise moderation, correct nutritional deprivation and altered body composition, restore menstruation and promote bone health.

Conflicts of Interests

There are no conflicts of interest.

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