Nursing and Health Sciences (2005), **7**, 259–265

Research Article

Menstrual status and bone mineral density among female athletes

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Abstract The present study investigated the relationship between menstrual status and bone mineral density (BMD). Sixty-three elite female athletes competing at the regional level participated. Self-reported menstrual status, stress during the past 6 months, dietary intake of calcium, blood samples for hormonal study, mid-thigh skinfold thickness, triceps, iliac crest, spine and femoral neck BMD were determined. It was found that more than half of the athletes were eumenorrheic while almost half were menstrually dysfunctional. The bone mineral density at the lumbar spine and the femoral neck were within normal ranges. Menstrual dysfunction in female athletes was related to a low BMD at the lumbar spine but not at the femoral neck. Delayed menarche and menstrual dysfunction during the first 2 years after menarche were related to current menstrual dysfunction, but low percent body fat was not related to menstrual dysfunction. This study suggests that exercise in elite female athletes might be an underlying cause of menstrual dysfunction and that there is a relationship between lumbar spine BMD and menstrual dysfunction. The assessment of menstrual history and percent body fat could be used as a screening tool for menstrual dysfunction.

Key words bone mineral density, eumenorrhea, female athletes, menstrual dysfunction.

INTRODUCTION

Menstrual dysfunction has been observed in a significant proportion of female athletes (Baker *et al*., 1981; Wakat *et al*., 1982; Highet, 1989; Loucks *et al*., 1992; Patterson, 1995; Gidwani, 1999). Numerous studies have investigated the relationship between physical activity and menstrual dysfunction, a syndrome that also is called "exercise-induced menstrual dysfunction" (Loucks, 1990; Loucks *et al*., 1992; Matthews, 1997). The reported incidence of exercise-induced menstrual dysfunction varies among adolescent athletes: from 1–66% depending on the type and intensity of athletic activities and the definition of menstrual dysfunction (Shanglod & Levine, 1982; Loucks & Horvath, 1985; Patterson, 1995; Smith, 1996).

There are many influences on athletes' menstrual cycle including age, weight, psychological stress, nutritional inadequacies, genetic predisposition, percent body fat, amount of exercise, and others (Greydanus & Patel, 2002). The endocrinal equilibrium that regulates reproductive function in women can be affected by physical and psychological factors. Intensive physical exercise in female athletes can lead to competition-induced stress and reduction of body fat and total body weight, which are predisposing factors to menstrual dysfunction (Anderson, 1999; Volk, 1999).

Weight-bearing exercise is beneficial to the skeleton. Slemenda and Johnston (1993) reported a marked effect of impact-loading on the pelvis and leg bone mineral density (BMD) of young figure skaters compared with non-athletes. Although weight-bearing physical activity in women, such as basketball, volleyball, weightlifting, and running is beneficial to the

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Received 11 August 2004; accepted 25 March 2005.

skeleton, excessive exercise to the point of incurring menstrual dysfunction might also be a risk factor for decreased bone mass (De Souza *et al.*, 1997; New, 2001). The beneficial effect of physical activity in women on BMD can be lost if the amount of exercise is so intensive that it brings about menstrual disturbances (Seibel *et al.*, 1999).

Thai women now engage in strenuous competitive and various physical activities. Studies about the health conditions and health problems of Thai female athletes related to sports have been limited. The prevalence of exercise-induced menstrual dysfunction or low BMD in Thai female athletes is not known. Thus, the purpose of this study was to describe the menstrual status and BMD among Thai female athletes.

METHODS

A mixed-methods approach of descriptive design was used for this study. The study was approved by the research ethical committee of the Faculty of Nursing, Chiang Mai University.

Sample

Sixty-three female athletes were invited and agreed to participate in the study. The participants exercised on average 19 h/week (10–30 h). The participants completed questionnaires to assess demographic data, including personal data, sports training, weight control, BMD information, menstrual status (MSQ) (oligomenorrhea = 4–9 cycles/year; amenorrhea = 0 ≤ 3 cycles/year; short cycle ≥ 13 cycles/year; eumenorrhea = 10–13 cycles/year). The MSQ collected information on the history of menstruation from menarche up to the current cycle. The calcium (Ca) intake was assessed by the Food Frequency Questionnaire. Stress in the past 6 months was also measured by a Female Athletes Stress Inventory (FASI). Blood samples for hormonal study were drawn after the questionnaires were completed. Immunoassay for the *in vitro* quantitative determination of follicle stimulating hormone (FSH), luteinizing hormone (LH), prolactin, estradiol, and progesterone in human serum and plasma were conducted and read by an expert in endocrinology at the Faculty of Medicine, Chiang Mai University.

To be included in the study, the participants had to be postmenarcheal, non-pregnant, and they competed at regional levels more than once per year. Participants were recruited from regional basketball and volleyball teams in Chiang Mai and Lamphun provinces. They completed questionnaires before the start of the study in order to draw blood for hormone studies and dual energy X-ray absorptiometry (DEXA). They were excluded from the study if they could not complete the questionnaires or refused to give a blood sample for the hormonal study.

Procedures

Before initiation of the data collection, the purposes and procedures were explained verbally and in writing to each participant. Informed, written consent was obtained from all participants prior to testing.

Participants were weighed and their height measured using a balance beam scale (Seca, Danbury, CT, USA). The BMD was measured at the lumbar spine (L1–L4) and femoral neck using DEXA (DGR 4500W, Hologic, Waltham, MA, USA). The standard Hologic protocol for positioning the lumbar spine and femor was used. Bone mineral results were expressed as BMD (g/cm^2). All scans were conducted and analyzed at Maharaj Nakorn Chiang Mai Hospital. The *in vivo* and *in vitro* precision of DEXA for BMD in the laboratory was <1% for both the lumbar spine and femoral neck.

Statistical analysis was carried out using the SPSS PC, version 9 (SPSS, Chicago, IL, USA). The frequencies, percentages, means, medians, and standard deviations (SDs) were used to describe the characteristics of the participants. The chi-squared test was employed to examine the association between menstrual status investigated by the MSQ and the hormonal study. As data were not distributed normally, non-parametric statistical analysis (Spearman's rho and Kendall's tau) was used to investigate the relationship between the dependent and independent variables. Alpha was set at 0.01 for all statistical procedures.

RESULTS

The study sample included 63 Thai female student athletes aged between 14 and 22 years who played weight-bearing sports in secondary schools (68%) or university (32%). Approximately 52% were volleyball players and 48% were basketball players. The characteristics of the participants are shown in Table 1. The mean percent body fat of participants was < 22%. Over 60% of the participants had moderate stress and 23.8% had mild stress. The Ca intake of the participants ranged from 216.4–1364.6 mg/day.

Menstrual status of the participants

The mean age at menarche among the participants was 12.6 years. Female athletes who started training before menarche had a mean age of menarche at 12.7 years, whereas those who started training after menarche had a mean age of menarche at 11.9 years. The mean ages at menarche of these two groups showed a significant difference ($t = 6.177$, $P < 0.000$).

Of the 63 participants, eumenorrhea was found in 55.6% and menstrual dysfunction was found in 44.4% (amenorrhea 57%, oligomenorrhea 25%, short cycle 18%). Sixty-one percent of the participants reported that their menstrual dysfunction occurred after they became an athlete. Self-reported menstrual situation information obtained using the MSQ was significantly correlated with the results from the hormonal profile ($\chi^2 = 17.53$, $P < 0.001$).

Comparison of the median values of hormone profiles between eumenorrheic and menstrually dysfunctional female athletes are displayed in Table 2. In this study, the menstrual status was not used as a criterion in the timing of drawing blood for the hormonal study.

Table 1. Characteristics of participants ($n = 63$)

Variable	Mean (SD)
Age (years)	17.8 (1.8)
Weight (kg)	55.0 (2.3)
Height (cm^2)	161.5 (6.1)
Body mass index	21.0 (2.2)
Body fat (%)	19.0 (3.7)
Age at onset of training (years)	11.0 (2.3)
Training per week (h)	12.6 (1.3)
Years of training	6.5 (3.1)
Menarcheal age	12.6 (1.3)
Gynecologic age (years)	5.0 (2.3)
FASI score	82.5 (27.6)
Calcium (mg/day)	636.0 (26.0)
Lumbar spine BMD (g/cm^2)	1.02 (0.1)
Femoral neck BMD (g/cm^2)	1.00 (0.1)

Gynecologic age is the number of years since menarche. BMD, bone mineral density; FASI, Female Athletes Stress Inventory.

In eumenorrheic athletes, blood samples were taken during the follicular phase in 20 participants and during the luteal phase in another 15 participants. In 28 participants, the time of blood-testing in relation to the menstrual cycle could not be identified because of amenorrhea or total cycle irregularity. The median value of FSH and LH levels in athletes with menstrual dysfunction were similar to the eumenorrheic athletes who had blood drawn during the follicular phase. Likewise, the median values of LH/FSH ratios among the three groups were also similar.

In contrast, the median values of estradiol and progesterone in menstrually dysfunctional athletes were lower than in eumenorrheic athletes who had blood drawn during the luteal phase. Prolactin levels in both groups were not higher than 70–80 ng/mL; therefore, menstrual dysfunction in these groups was not considered to be a result of hyperprolactinemia (Marshall *et al*., 2001).

Bone mineral density of the participants

The mean lumbar spine BMD and T-score (1.02 ± 0.1 and 0.12 ± 0.9, respectively) and femoral neck BMD and T-score (1.00 ± 0.1 and 1.3 ± 0.8, respectively) were within normal ranges. The T-score for the lumbar spine was <–1 SD in eight of the 63 female athletes (12.7%), which showed a low lumbar spine BMD.

Relationship between menstrual status and bone mineral density, and factors associated with menstrual status and bone mineral density

Non-parametric correlation analysis was employed to test the association between menstrual status and BMD, and the studied variables and menstrual status and BMD. It was found that the menstrual status of the female athletes was significantly inversely correlated with the lumbar spine BMD but not with the femoral neck BMD (Table 3). The menstrual status of the par-

Table 2. Hormonal profiles in eumenorrheic and menstrually dysfunctionl athletes

	Eumenorrhea		
Hormonal profile	Follicular phase ($n = 20$) (M)	Luteal phase ($n = 15$) (M)	Menstrual dysfunction ($n = 28$) (M)
FSH (IU/L)	6.12	2.81	5.88
LH (IU/L)	5.08	4.87	7.07
LH/FSH ratio	1.41	1.99	1.63
Estradiol (pg/mL)	29.68	144.90	43.00
Progesterone (pg/mL)	0.48	5.31	0.48
Prolactin (ng/mL)	13.41	14.16	13.88

FSH, follicle stimulating hormone; LH, luteinizing hormone; M, median.

Table 3. Correlation of menstrual status and the studied variables

Variable	Menstrual status†
Weight	0.208
Height	0.131
Body mass index	0.171
Weight control	–0.007
Body fat (%)	–0.327*
FASI score	0.135
Training h/week	–0.048
Age at training onset	0.162
Number of years of being an athlete	–0.456
Age at menarche	0.280*
Menstrual status 1st–2nd year after menarche	0.482*
Number of years menstruating	–0.083
Lumbar density	–0.258*
Femoral neck density	–0.057

*$P < 0.01$. †Kendall's tau. FASI, Female Athletes Stress Inventory.

Table 4. Correlation of bone mineral density and studied variables

Variable	Bone mineral density: Lumbar density†	Bone mineral density: Femoral neck density†
Age	0.286*	0.180*
Weight	0.274*	0.367*
Height	0.054	0.062
Body mass index	0.171	0.236
Age at menarche	–0.143	0.151
Duration of menstrual dysfunction	–0.197	–0.028
Training h/week	0.100	0.186
Number of years of being an athlete	0.189	0.165
Calcium intake	–0.101	–0.107

*$P < 0.01$. †Spearman's rho.

ticipants was found to be statistically significantly correlated with age at menarche, menstrual status during the first two years of menarche, and percent body fat. There was no statistically significant correlation found with weight, height, body mass index (BMI), weight control, number of years of menstruation, FASI score, training h/week, age at training onset, or duration of being an athlete.

Age, however, was found to be correlated with BMD at the lumbar spine and femoral neck, as was weight (Table 4). There were no significant correlations found between the BMD variables and height, BMI, age at menarche, duration of menstrual dysfunction, training h/week, duration of being an athlete, Ca intake, or percent body fat.

DISCUSSION

This study demonstrated a similar rate of menstrual dysfunction in female athletes as in other studies. The rate of menstrual dysfunction in other studies varied from 1–66% depending on the type of athletic event and the definition of menstrual dysfunction (Baker, 1981; Wakat *et al.*, 1982; Highet, 1989; Marshall, 1994; Patterson, 1995; Gidwani, 1999).

To confirm the menstrual status of female athletes in this study, levels of FSH, LH, estradiol, progesterone, and prolactin were measured. Although some of the female athletes (15.9%) had a prolactin level > 24 ng/mL, none of their levels were > 70–80 ng/mL. Such levels were considered by the investigator to be borderline and could have resulted from fear or stress during venipuncture. Unfortunately, a second blood level of prolactin could not be obtained to confirm or refute a diagnosis of hyperprolactinemia. The mean value of estradiol in eumenorrheic athletes during the luteal phase was higher than in athletes with menstrual dysfunction. A possible explanation was that strenuous exercise could potentially suppress the hypothalamic–pituitary–ovarian axis. Indeed, strenuous exercise is known to suppress hypothalamic gonadotrophin-releasing hormone secretion, causing a state of hypothalamic amenorrhea (Neinstein, 1990; Chrousos *et al.*, 1998).

When menstrual status in the first to second year of menarche was compared with the current menstrual status, some interesting features emerged. The number of eumenorrheic athletes in current cycles (55.6%) was lower than during the first 2 years of menarche (61.9%). Most female athletes (95.3%) in this study had been menstruating for > 2 years, and one would assume that they already had achieved maturity of the hypothalamic–pituitary–ovarian axis. As such, one would expect a higher number of eumenorrheic athletes in current cycles than during the first 2 years of menarche. In this study, the number of menstrually dysfunctional athletes in the current menstrual status (44.4%) increased from the first to second year after menarche (38.1%) rather than decreased. This possibly could be explained by the fact that the menstrual status of the female athletes in this study was associated with their athletic life, as 60.7% of the menstrually dysfunctional athletes reported that their menstrual dysfunction occurred following sports training.

All participants had normal BMD at the femoral neck and only 12.7% had low BMD at the lumbar spine (L1–L4). The data suggested that the femoral neck, rather than the lumbar spine, was the site that benefited most from weight-bearing exercise. No significant differences in lumbar spine and femoral neck BMD were present among athletes with normal or dysfunctional cycles. This result was consistent with a report by Moen *et al*. (1998), who found no significant difference in lumbar spine BMD among amenorrheic runners, eumenorrheic runners and non-athletes. The effects of long-term sporting activities on bone mass differs at different parts of the skeleton. The lumbar spine, which is trabecular bone, is less responsive to mechanical loading than cortical bone (Nichol *et al*., 2000).

The need for a threshold level of weight-bearing exercise to stimulate bone growth has been well-documented, as has the fact that women who participate regularly in high-impact physical activity during premenopausal years have higher BMD at most skeletal sites than non-athletic women (Dook *et al.*, 1997). A possible explanation for the low BMD at the lumbar spine site in 12.7% of the subjects is that these athletes in this study were relatively young and might not have achieved peak bone mass.

Both the age and the weight of the participants were associated with lumbar spine and femoral neck BMD. Peak bone mass appears to be complete by 16 years in the femoral neck (Theintz *et al*., 1992), whereas in the lumbar spine, bone mass increases throughout the third decade of life (Recker *et al*., 1992). As participants in this study were adolescents aged 14–22 years, many of them were still in the period of gaining bone mineral content and had not yet reached peak bone mass. The most rapid gain in bone mass occurs during adolescence and accompanies the pubertal growth spurt. Previous studies (Bailey *et al.*, 1996) have shown that physical activity increases skeletal mass during growth. Our findings also support the conclusions of Weaver *et al*. (2001) that exercise results in a positive effect on total bone mineral content, with a greater effect in younger women than in older women. That is, physical activity might have had a beneficial effect on BMD in the studied participants.

This finding implied that female athletes with dysfunctional cycles were likely to be associated with lower BMD at the lumbar spine. No correlation between menstrual status and the femoral neck BMD was found. These findings were consistent with a report by Drinkwater *et al*. (1984), who found that lumbar spine mineral density was significantly lower in the amenorrheic than the eumenorrheic group. That study also found no significant differences in BMD at other sites. Previous studies of BMD in female athletes with menstrual dysfunction also found an association between menstrual dysfunction and decreased BMD, especially at the lumbar spine (Drinkwater *et al*., 1984; Barrow & Saha, 1988; Keay *et al.*, 1997).

In this study, delayed menarche and menstrual dysfunction in the first two years after menarche were found to be significantly related with current menstrual dysfunction. Athletes who started training before menarche showed a significantly later age at menarche and also exhibited a higher rate of menstrual dysfunction, a finding which is supported by many previous studies (Malina *et al*., 1978; Frisch *et al*., 1981; Frisch, 1987). It is possible that intensive exercise could delay menstrual function by creating an energy deficiency and, thus, prevent the achievement of critical body weight or fat content, which are a prerequisite for normal menstruation (Malina *et al*., 1978; Frisch *et al*., 1981; Frisch, 1987).

We found that 39.3% of the participants had had menstrual dysfunction since menarche. This finding is consistent with previous studies by Bonen (1992) and Rogol *et al*. (1992), which also found that the initiation and maintenance of intense training regimens appear to have less effect on menstrual function in reproductively mature individuals than in premenarcheal adolescents. Two scenarios have been proposed to explain this situation. One suggests either that reproductively immature individuals are more sensitive to the effect of intense exercise or that younger women with exercise-induced menstrual dysfunction are somehow predisposed to the menstrual dysfunction before the onset of training (Rosetta, 1993). Exercise might also alter the menstrual cycle more when it is started in the early postmenarcheal period than at later ages (Frisch *et al*., 1981; Marcus *et al*., 1985). Alternatively, as a consequence of maturation of the hypothalamic–pituitary–ovarian axis, which occurs with age, older athletes are less likely to develop amenorrhea following exercise than younger athletes (White & Hergenroeder, 1990).

The low percent body fat of participants in this study was not related to menstrual dysfunction. A possible explanation is the role that fatty tissue plays in the interconversions of steroid hormones which are a source of estrogen, where too little body fat will result in underproduction of estrogen (Sinning & Little, 1987). An alteration in body composition, especially body fat, from strenuous exercise has been hypothesized, altering the circulating levels of estrogen and, thus, altering feedback regulation of the hypothalamus or the pituitary gland (Chen & Brzyski, 1999). Body fat in girls and women is also important for menstruation. Frisch and McArthur (1974) reported that women require at least 22% body fat to maintain the menstrual cycle after 16 years. Strenuous exercise in female athletes increases their strength and fat-free mass, and decreases body fat (Cullinen & Caldwell, 1998); however, female athletes who lose body weight and body fat are more likely to have menstrual dysfunction (Bullen *et al*., 1985; Sinning & Little, 1987; Yeager *et al.*, 1993).

LIMITATIONS OF THE STUDY

As no control group of sedentary girls and women was available for comparison, no conclusions can be drawn as to the menstrual status and BMD of athletic training compared with normal physical activity in this age group. As this study focused only on weight-bearing exercises, the findings may not be generalized to women who participate in other types of sports or sedentary women.

SUGGESTIONS FOR FURTHER RESEARCH

This study was a first step in obtaining information about the relationship between menstruation and BMD in Thai female athletes. Further studies are needed to gain more complete knowledge about menstrual dysfunction and risk factors, premature bone loss, and the risk of stress fracture in other types of sports in which female athletes participate; for example, a similarly designed study that involves different types of weight-bearing and non-weight-bearing exercise. The prevalence of menstrual dysfunction and BMD problems in sedentary women also should be conducted to allow the findings to be generalized to a larger population.

CONCLUSION

The findings in this study suggest that menstrual dysfunction in female athletes is associated with lumbar spine BMD. We also observed a relationship between menstrual history (i.e. delayed age at menarche and menstrual dysfunction during the first 2 years of menarche) and current menstrual dysfunction of the athletes, but not a relationship between menstrual dysfunction and percent body fat. Age and weight were factors associated with BMD at both the lumbar spine and the femoral neck. Our results suggest that the assessment of menstrual history and percent body fat could be used as a screening tool for menstrual abnormality. Programs for education about exercise-induced menstrual dysfunction and subsequent premature bone loss should be established and provided to female athletes, coaches, parents, and sports administrators to help ensure safe training and to promote women's health.

ACKNOWLEDGMENTS

We would like to thank Professor Dr Margaret M. Heitkemper, School of Nursing, University of Washington, USA, and Associate Professor Dr Kay C. Avant, School of Nursing, University of Texas at Austin, USA, for their excellent assistance. The present study was partially supported by the Graduate Study, Chiang Mai University, Thailand.

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