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Stress fracture and premenstrual syndrome in Japanese adolescent athletes: a cross-sectional study

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Word count; 2368 words

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ABSTRACT

Objectives: To investigate the relationship between the occurrence of stress fracture and premenstrual syndrome (PMS)/premenstrual dysphoric disorder (PMDD) in Japanese adolescent athletes.

Design: Cross-sectional study.

Setting: Osaka, Japan

Participants: A school-based survey on menstruation and school life was conducted using a sample of 1818 Japanese female students who belonged to two public high schools in Japan. Among them, we recruited 394 athletes who had regular menstrual cycles (25–38 days) and completed a questionnaire about their premenstrual symptoms and their competitive career.

Main outcome measure: Premenstrual symptoms and the occurrence of stress fracture.

Results: The prevalences of moderate-to-severe PMS and PMDD were 8.9% and 1.3% respectively, which were the same as in collegiate athletes in a previous study. Premenstrual symptoms disturbed 'Work efficiency or productivity, home responsibilities', 'Relationships with coworkers or family', and 'Athletic performance in training or competition' more severely than menstrual pain ($P = 0.031$, $P = 0.004$, and $P<0.001$). Sixty-six athletes (16.8%) reported having experienced a stress fracture.

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The severity of 'Overeating or food cravings', 'Physical symptoms', and 'Performance

in training or competition' in athletes with previous stress fracture were much higher

than those of without a history of stress fracture (*P*=0.015, *P*=0.008, and *P*=0.006). In

terms of premenstrual symptoms, 'Physical symptoms' was associated with an

increased risk of stress fractures in athletes (odds ratio 1.66, 95% confidence interval:

1.06–2.62).

Conclusions: The results from this study indicated that premenstrual symptoms

affected not only athletic performance but also the risk of stress fractures in adolescent

athletes.

Running title: PMS and stress fracture in athletes

Key words: PMS, PMDD, Athlete, Stress fracture, High school student

Strength and limitations of this study

● This is the first study on the relationship between the symptoms of

PMS/PMDD and stress fractures in athletes.

- A key strength of this study is that we collected data from the female athletes with regular menstruation to evaluate PMS/PMDD status precisely.

- It may not be possible to generalize the findings to all female athletes in Japan, but we analyzed the data from female athletes who participated in authorized high school sports clubs and not elite athletes.

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INTRODUCTION

Premenstrual syndrome (PMS) is a complex constellation of mood, behavioral, and physical changes that are limited to the premenstrual phase. These symptoms recover within a few days after the start of menstruation [1]. Epidemiologic surveys have shown that the frequency of premenstrual symptoms is high (80–90%) [2]. Approximately 5% of women experience symptoms so severe that they interfere with personal or social relationships [3]. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association 2013) has defined such a severe form of PMS as premenstrual dysphoric disorder (PMDD) [4].

In the last 40 years, female athletic participation has increased dramatically, particularly at high school and collegiate levels [5]. Along with the increasing competition, intensive training has caused unique health problems for female athletes, known as the female athlete triad [5]. The triad includes a spectrum of health problems related to energy availability, menstrual function, and bone mineral density. They show the symptoms of eating disorders, amenorrhea, and nontraumatic stress fractures. There has been extensive research on this triad at high school and collegiate levels. Among the triad components, stress fractures are the most serious health problem for athletes, because of the interruption caused to training and their potential to end sporting careers

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in an extreme case [6]. The pathogenic mechanisms of nontraumatic stress fractures are thought to stem from microdamage to the bone caused by repetitive mechanical load that goes beyond the biological capacity of the bone [7]. Risk factors for stress fractutres identified in female athletes include late menarche, menstrual dysfunction, low bone density, and eating disorders, which are related to the female athlete triad.[8-10] On the other hand, many female athletes experience stress fractures without these risk factors.

Many reports have documented that the premenstrual phase is associated with decreased performance [11], but there are few reports about PMS/PMDD in athletes. Previously, we reported that PMS and PMDD are common menstrual problems in female collegiate athletes, and almost half of athletes felt a negative effect of premenstrual symptoms on athletic performance [12 13]. One previous report has demonstrated that women with PMS had a significantly greater postural sway than those without PMS. This may contribute to the higher rates of injury during the luteal phase [14].

The aim of this study was to investigate the relationship between the risk of stress fractures and PMS/PMDD in Japanese adolescent athletes.

METHODS

Ethics

The study was carried out in accordance with the principles outlined in the Declaration

of Helsinki. Our institutional review board at Kindai University approved the study

(approval number 26-193).

Study population

A school-based cross-sectional survey was conducted in December 2013 using a sample

of 1818 Japanese female students who belonged to two public high schools in Sendai,

the largest city in northeastern Japan. A total of 1578 students completed the

questionnaire with written informed consent. We selected 506 female students who

belonged to authorized high school sports clubs and were active athletes. Among them,

we further selected 394 students who had regular menstrual cycles (25–38 days) without

hormonal therapy.

Questionnaire

We used the Premenstrual Symptoms Questionnaire (PSQ), which was developed in our

previous study [15], to screen for premenstrual symptoms. The PSQ translates DSM-4

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criteria into a rating scale with degrees of severity described in Japanese and is essentially identical to the Premenstrual Symptoms Screening Tool [16]. The PSQ asked, "Within the last three months have you experienced the following premenstrual symptoms starting during the week before menses and remitting a few days after the onset of menses?" The premenstrual symptoms listed on the PSQ are 'Depressed mood', 'Anxiety or tension', 'Tearful', 'Anger or irritability', 'Decreased interest in work, home, or social activities', 'Difficulty concentrating', 'Fatigue or lack of energy', 'Overeating or food cravings', 'Insomnia or hypersomnia', 'Feeling overwhelmed', and 'Physical symptoms such as tender breasts, feeling of bloating, headache, joint or muscle pain, or weight gain'. The PSQ also asked whether such premenstrual symptoms interfered with 'Work efficiency or productivity, or home responsibilities', 'Social life activities', or 'Relationships with coworkers or family'. The PSQ asked the students to rate the severity of premenstrual symptoms as 'Not at all', 'Mild', 'Moderate', or 'Severe'. We divided students with premenstrual symptoms into three groups: 'PMDD', 'moderate-to-severe PMS', and 'no/mild PMS' according to the criteria reported previously [15,16]. In addition to the PSQ, we asked whether such premenstrual symptoms interfered with 'Performance in training or competition'. This additional question also asked the students to rate the severity as 'Not at all', 'Mild', 'Moderate',

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or 'Severe'. We asked the students about their severity of pain during menses with the categories of 'Not at all', 'Mild', 'Moderate', and 'Severe'. We also asked whether such menstrual pain interfered with 'Work efficiency or productivity, or home responsibilities', 'Social life activities', 'Relationships with coworkers or family', or 'Performance in training or competition'.

We further collected additional information about their age, body weight, height, age at menarche, age at commencing training, history of stress fracture diagnosed by a medical doctor, participation of national or international competition, weekly training duration, and restriction of body weight. Body-mass index (BMI) (kg/m^2) was calculated by dividing weight by height squared. Underweight was defined as BMI <18.5 kg/m^2. Athletes were grouped into six groups: ball games, gymnastics, track, swimming, fighting sports, and other sports.

Statistical analyses

Statistical analysis was performed using JMP 11.2.1 (SAS, Cary, NC, USA). Data are expressed as the means ± S.D. Statistical significance was set at $P < 0.05$. Wilcoxon signed-ranks test was applied to test the difference in interference with work, usual activities, or relationships between premenstrual symptoms, and menstrual pain.

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Mann–Whitney's U test was applied to test the difference in prevalence of dysmenorrhea, premenstrual symptoms, and severity of PMS/PMDD. Multivariate analysis was applied to analyze the factors that were significantly associated with stress fracture.

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RESULTS

The characteristics of the study population are presented in Table 1. Considering that a quarter of the athletes participated in national or international competitions, some of these clubs have a high ranking in Japanese high school sport. Sixty-six athletes (16.8%) with regular menstrual cycles reported having experienced a stress fracture.

The prevalence of menstrual pain and each premenstrual symptom is shown in Table 2. More than half reported 'menstrual pain' (83.2%), 'Anxiety or tension' (67.3%), 'Anger or irritability' (63.7%), 'Difficulty concentrating' (59.4%), 'Fatigue or lack of energy' (67.5%), 'Overeating or food cravings' (64.0%), and 'Physical symptoms' (53.0%). We further compared the difference in the degree of disturbance to social and life activities by menstrual pain or premenstrual symptoms. Premenstrual symptoms disturbed 'Work efficiency or productivity, home responsibilities', 'Relationships with coworkers or family', and 'Athletic performance in training or competition' more severely than menstrual pain ($P = 0.031$, $P = 0.004$, and $P < 0.001$ by Wilcoxon signed-ranks test).

The 'PMDD' group consisted of 5 athletes (1.3%), the 'moderate to severe PMS' group of 35 girls (8.9%); and the 'no/mild PMS' group of 354 girls (89.8%). In our previous report about Japanese collegiate athletes, the 'PMDD' group consisted of 5

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girls (2.9%), the 'moderate to severe PMS' group of 15 girls (8.6%) and the 'No/Mild

PMS' group of 154 girls (88.5%).[12] The rates of PMDD and moderate-to-severe PMS

in the current study population were the same as those in the collegiate athletes

population (*P* =0.596 by Mann-Whitney's U test).

Next we analyzed the prevalence difference of menstrual pain and premenstrual

symptoms with or without a history of stress fracture (Table 3). The severity of

'Overeating or food cravings' and 'Physical symptoms' in athletes with previous stress

fracture were much higher than those of without such a history (*P*=0.015 and *P*=0.008

by Mann–Whitney's U test). The severity of the effect on 'Performance in training or

competition' in athletes with previous stress fracture was much higher than that of

athletes without a history of stress fracture (*P*=0.006 by Mann–Whitney's U test).

The results of multivariate analysis of the factors that were significantly associated

with stress fractures are shown in Table 4. 'Restriction of body weight' and 'Weekly

training duration' showed an increased risk of stress fractures in athletes. Regarding

premenstrual symptoms, 'Physical symptoms' was associated with an increased risk of

stress fractures.

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DISCUSSION

Our data showed that premenstrual symptoms impaired athletic performance in 41.1% of adolescent athletes. This rate is almost the same as that reported previously about performance impairment in collegiate athletes [12 13]. It may be possible that premenstrual symptoms in collegiate athletes have been disturbing their athletic performance since high school. Dysmenorrhea is the commonest disease among adolescent girls, and clinicians tend to focus only on dysmenorrhea and underestimate PMS/PMDD. Our data showed the high prevalence rate of menstrual pain in athletes, but premenstrual symptoms disturbed their athletic performance more severely than menstrual pain. It is important to give a proper attention to PMS/PMDD in younger women.

Our data showed that the incidence of stress fracture in female athletes with regular menstrual cycles was 16.8%. It is well established that the female athlete triad is a significant risk factor for stress fractures in female athletes. For this reason, there have been no previous study about the stress fractures of female athletes with regular menstruation. It is difficult to compare our data with other data in similar populations.

Our data showed a relationship between stress fracture and premenstrual physical symptoms in athletes. Water retention symptoms, especially edema, may disturb the

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motion of athletes. These symptoms will also be exacerbated by athletic behavior and athletes feel much more load. One previous report demonstrated that women with PMS had a significantly greater postural sway than women without PMS [14]. The pathogenic mechanism of stress fractures is thought to involve micro damage to the bone caused by repetitive mechanical loads that go beyond the biological capacity of the bone. It may be possible that disturbed motion by premenstrual physical symptoms cause gawky movement and place an unnecessary burden on athletes' bone. Accordingly, physical symptoms of PMS may contribute to the higher risk of stress fracture.

Multivariate analysis revealed that 'Restriction of body weight' and 'Weekly training duration' showed an increased risk of stress fractures in athletes with regular menstruation. 'Restriction of body weight' will lead to energy insufficiency and trigger menstrual dysfunction. It should be noted that 'Restriction of body weight' could be an independent risk factor for stress fractures without ovarian insufficiency. The female athlete triad and its negative effects on bone health has been well recognized through research, but most female high school athletes still remain unfamiliar with this relationship [17]. Our data further emphasize the paramount importance of nutrition in bone health. It stands to reason that longer training times increase the risk of developing stress fractures. A prospective study reported that the hours per week of participation in

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sports could be a risk factor for stress fracture in adolescent females [18]. Our data on 'Weekly training duration' were in accord with this.

Our study had several limitations. The main limitation was that all our data were based on self-reporting; therefore, the study was susceptible to recall bias. The second limitation was that this study was conducted only in Japan. It is possible that our data may not be applicable to other countries. The proportion of the students in the third year was low in our study. This could be explained by the fact that school entrance examinations are extremely difficult in Japan, so most students give up their club activity in their third year. The further limitation was that we have checked the history of stress fracture by self-reported of data. We could not exclude the possibility that the self-reported stress fractures were caused by traumatic accidents. To collect more accurate information as far as possible, we took a past history of stress fractures diagnosed by medical doctor.

Despite these limitations, the findings from our study have several strengths. We analyzed the data from female athletes who participated in authorized high school sports clubs and not elite athletes. This will increase the generalizability of the study in this population. In addition, we collected data from the female athletes with regular menstruation. This will enable the evaluation of PMS/PMDD status precisely.

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Research into female athletes has focused on menstrual dysfunction, so ovulation-induced PMS/PMDD symptoms have been generally overlooked. After overcoming the female athlete triad, PMS/PMDD could be a major health concern in female athletes. Our previous data showed that almost half of athletes felt a negative effect of PMS/PMDD symptoms on their performance [12 13]. Moreover, our data suggested that premenstrual symptoms may increase the risk of stress fractures in female athletes. Further research using intervention for PMS/PMDD is warranted to confirm their importance for the health of female athletes.

To the best of our knowledge, this is the first study on the relationship between the symptoms of PMS/PMDD and stress fractures in athletes. Premenstrual symptoms disturbed social life activity and athletic performance more severely than menstrual pain. The incidence of stress fracture in female athletes with regular menstrual cycles was 16.8%. 'Restriction of body weight', 'Weekly training duration', and 'Physical symptoms of PMS' were associated with an increased risk of stress fractures. We should monitor premenstrual symptoms not only for athletic performance but also stress fractures.

Conflict of interest

The authors have no conflict of interest.

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Acknowledgments

Contributors

Data Sharing

No additional data available.

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Table 1. Characteristics of study participants (N=394)

Characteristic	
Age (years), mean ± SD	16.4 ± 0.78
School year, no. (%)	
First year	197 (50.0)
Second year	153 (38.8)
Third year	44 (11.2)
BMI (kg/m^2), mean ± SD	20.5 ± 1.76
BMI <18.5 kg/m^2, no. (%)	47 (11.9)
Age at menarche (years), mean ± SD	12.5 ± 1.34
Age at commencing training (years), mean ± SD	11.1 ± 3.80
Type of sport, no. (%)	
Ball games	212 (53.8)
Gymnastics	19 (4.8)
Track	23 (5.8)
Swimming	17 (4.3)
Fighting sports	26 (6.6)
Others	97 (24.6)
Participation in national or international competition, no. (%)	102 (25.9)
Weekly training duration (hrs/week), mean ± SD	15.4 ± 8.4
Restriction of body weight, no. (%)	88 (22.3)
Stress fracture, no. (%)	66 (16.8)

BMI: body mass index, SD: standard deviation.

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Table 2. Prevalence rates of menstrual pain, premenstrual symptoms, and interference with work, usual activities, or relationships with degrees of severity. N=394

Symptoms	Not at all	Mild	Moderate	Severe
Menstrual pain, no. (%)	66 (16.8)	137 (34.8)	156 (39.6)	35 (8.9)
Premenstrual symptoms				
Depressed mood, no. (%)	235 (59.6)	100 (25.4)	43 (10.9)	16 (4.1)
Anxiety or tension, no. (%)	129 (32.7)	155 (39.3)	89 (22.6)	21 (5.3)
Tearful, no. (%)	228 (57.9)	111 (28.2)	39 (9.9)	16 (4.1)
Anger or irritability, no. (%)	143 (36.3)	158 (40.1)	76 (19.3)	17 (4.3)
Decreased interest in work, home, or social activities, no. (%)	262 (66.5)	85 (21.6)	38 (9.6)	9 (2.3)
Difficulty concentrating, no. (%)	160 (40.6)	178 (45.2)	47 (11.9)	9 (2.3)
Fatigue or lack of energy, no. (%)	128 (32.5)	166 (42.1)	75 (19.0)	25 (6.3)
Overeating or food cravings, no. (%)	142 (36.0)	125 (31.7)	95 (24.1)	32 (8.1)
Insomnia or hypersomnia, no. (%)	221 (56.1)	94 (23.9)	58 (14.7)	21 (5.3)
Feeling overwhelmed, no. (%)	277 (70.3)	89 (22.6)	23 (5.8)	5 (1.3)
Physical symptoms, no. (%)	185 (47.0)	121 (30.7)	62 (15.7)	26 (6.6)
Interference with work, usual activities, or relationships	Upper line, by menstrual pain			
	Lower line, by premenstrual symptoms			
Work efficiency or productivity, home responsibilities, no. (%)	230 (58.4)	131 (33.2)	27 (6.9)	6 (1.5)
	211 (53.6)	139 (35.3)	41 (10.4)	3 (0.8)
	†p=0.031			
Social activities, no. (%)	331 (84.0)	52 (13.2)	8 (2.0)	3 (0.8)
	339 (86.0)	36 (9.1)	13 (3.3)	6 (1.5)
	†p=0.891			
Relationships with coworkers or family, no. (%)	341 (86.5)	42 (10.7)	9 (2.3)	2 (0.5)
	330 (83.8)	43 (10.9)	17 (4.3)	4 (1.0)
	†p=0.004			
Athletic performance in training or competition, no. (%)	261 (66.2)	104 (26.4)	25 (6.3)	4 (1.0)
	232 (58.9)	111 (28.2)	42 (10.7)	9 (2.3)
	†p<0.001			

Severity of PMS/PMDD	No/mild PMS	Moderate-to-severe PMS	PMDD
	354 (89.8)	35 (8.9)	5 (1.3)

† By Wilcoxon signed-ranks test.

PMDD: premenstrual dysphoric disorder, PMS, premenstrual syndrome.

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Table 3. Prevalence rates of menstrual pain, premenstrual symptoms and induced interference with work, usual activities, or relationships with or without stress fracture

	Not at all	Mild	Moderate	Severe	P (Mann–Whitney U test)
Menstrual pain, no. (%)	52 (16.2)	115 (35.8)	124 (38.6)	30 (9.3)	0.781
	14 (21.2)	18 (27.3)	30 (45.5)	4 (6.1)	
Premenstrual symptoms					
Depressed mood, no. (%)	189 (58.9)	85 (26.5)	33 (10.3)	14 (4.4)	0.586
	42 (63.6)	13 (19.7)	10 (15.2)	1 (1.5)	
Anxiety or tension, no. (%)	107 (33.3)	129 (40.2)	69 (21.5)	16 (5.0)	0.361
	20 (30.3)	24 (36.4)	18 (27.3)	4 (6.1)	
Tearful, no. (%)	183 (57.0)	94 (29.3)	29 (9.0)	15 (4.7)	0.645
	40 (60.6)	16 (24.2)	10 (15.2)	0 (0.0)	
Anger or irritability, no. (%)	110 (34.3)	139 (43.3)	58 (18.1)	14 (4.4)	0.686
	29 (43.9)	17 (25.8)	18 (27.3)	2 (3.0)	
Decreased interest in work, home, or social activities, no. (%)	216 (67.3)	69 (21.5)	29 (9.0)	7 (2.2)	0.502
	42 (63.6)	14 (21.2)	9 (13.6)	1 (1.5)	
Difficulty concentrating, no. (%)	129 (40.2)	150 (46.7)	37 (11.5)	5 (1.6)	0.989
	29 (43.9)	25 (37.9)	9 (13.6)	3 (4.5)	
Fatigue or lack of energy, no. (%)	105 (32.7)	137 (42.7)	59 (18.4)	20 (6.2)	0.821
	22 (33.3)	25 (37.9)	16 (24.2)	3 (4.5)	
Overeating or food cravings, no. (%)	123 (38.3)	100 (31.2)	77 (24.0)	21 (6.5)	0.015
	16 (24.2)	23 (34.8)	17 (25.8)	10 (15.2)	
Insomnia or hypersomnia, no. (%)	181 (56.4)	75 (23.4)	50 (15.6)	15 (4.7)	0.903
	37 (56.1)	18 (27.3)	7 (10.6)	4 (6.1)	
Feeling overwhelmed, no. (%)	231 (72.0)	67 (20.9)	18 (5.6)	4 (1.2)	0.190
	42 (63.6)	19 (28.8)	4 (6.1)	1 (1.5)	
Physical symptoms, no. (%)	159 (49.5)	99 (30.8)	45 (14.0)	18 (5.6)	0.008
	24 (36.4)	18 (27.3)	16 (24.2)	8 (12.1)	
Interference with work, usual activities, or relationships					
Work efficiency or productivity, home	173 (53.9)	112 (34.9)	34 (10.6)	2 (0.6)	0.878
	34 (51.5)	26 (39.4)	6 (9.1)	0 (0.0)	

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responsibility, no. (%)					
Social life activities, no. (%)	275 (85.7)	29 (9.0)	11 (3.4)	6 (1.9)	0.571
	58 (87.9)	7 (10.6)	1 (1.5)	0 (0.0)	
Relationships with coworkers or family, no. (%)	148 (74.0)	39 (19.5)	10 (5.0)	3 (1.5)	0.200
	75 (67.0)	28 (25.0)	8 (7.1)	1 (0.9)	
Performance in training or competition, no. (%)	197 (61.4)	87 (27.1)	31 (9.7)	6 (1.9)	0.006
	29 (43.9)	24 (36.4)	10 (15.2)	3 (4.5)	

Severity of PMS/PMDD	No/mild PMS	Moderate-to-severe PMS	PMDD	
	287 (89.4)	29 (9.0)	5 (1.6)	0.251
	62 (93.9)	4 (6.1)	0 (0.0)	

Upper line, stress fracture (-) (n=321); lower line, stress fracture (+) (n=66).

PMDD: premenstrual dysphoric disorder, PMS: premenstrual syndrome.

Table 4. Multivariate analysis of risk factors for stress fracture

Risk factors	OR (95% CI)	P
School year	1.15 (0.63–2.08)	0.646
BMI <18.5 kg/m^2	2.55 (0.81–7.67)	0.108
Age at menarche (years)	1.03 (0.76–1.40)	0.844
Menstrual pain	0.96 (0.60–1.53)	0.861
Age at commencing training (years)	1.03 (0.91–1.16)	0.673
Participation of national or international competition	1.55 (0.65–3.70)	0.325
Restriction of body weight	2.47 (1.12–5.41)	0.025
Weekly training duration (hrs/week)	1.06 (1.01–1.13)	0.015
Premenstrual symptoms		
Depressed mood	0.75 (0.32–1.72)	0.498
Anxiety or tension	1.88 (0.90–3.98)	0.092
Tearful	0.70 (0.31–1.54)	0.381
Anger or irritability	0.66 (0.30–1.45)	0.301
Decreased interest in work, home, or social activities	1.13 (0.54–2.36)	0.739
Difficulty concentrating	1.06 (0.49–2.32)	0.880
Fatigue or lack of energy	0.87 (0.43–1.73)	0.696
Overeating or food cravings	1.19 (0.75–1.89)	0.447
Insomnia or hypersomnia	0.74 (0.39–1.33)	0.326
Feeling overwhelmed	1.85 (0.78–4.54)	0.165
Physical symptoms	1.66 (1.06–2.62)	0.026
Induced interference with work, usual activities, or relationships		
Work efficiency or productivity, home responsibility	0.70 (0.32–1.48)	0.357
Social life activities	0.45 (0.08–1.54)	0.228
Relationships with coworkers or family	0.54 (0.22–1.19)	0.128
Performance in training or competition	1.29 (0.76–2.17)	0.349

BMI: body mass index, OR: Odds ratio, 95% CI: 95% confidence interval.

24

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7,8,9
Bias	9	Describe any efforts to address potential sources of bias	*9*
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9,10
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	11
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11
		(b) Indicate number of participants with missing data for each variable of interest	11
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13,14,15,16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Stress fracture and premenstrual syndrome in Japanese adolescent athletes: a cross-sectional study

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1 **Stress fracture and premenstrual syndrome in Japanese adolescent athletes: a**

2 **cross-sectional study**

3

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15 Word count; 3087 words

16

1 **ABSTRACT**

2 **Objectives:** To investigate the relationship between the occurrence of stress fracture and

3 premenstrual syndrome (PMS)/premenstrual dysphoric disorder (PMDD) in Japanese

4 adolescent athletes.

5 **Design:** Cross-sectional study.

6 **Setting:** Osaka, Japan

7 **Participants:** A school-based survey on menstruation and school life was conducted

8 using a sample of 1818 Japanese female students who belonged to two public high

9 schools in Japan. Among them, we recruited 394 athletes who had regular menstrual

10 cycles (25–38 days) and completed a questionnaire about their premenstrual symptoms

11 and their competitive career.

12 **Main outcome measure:** Premenstrual symptoms and the occurrence of stress fracture.

13 **Results:** The prevalences of moderate-to-severe PMS and PMDD were 8.9% and 1.3%

14 respectively, which were the same as in collegiate athletes in a previous study.

15 Premenstrual symptoms disturbed 'Work efficiency or productivity, home

16 responsibilities', 'Relationships with coworkers or family', and 'Athletic performance

17 in training or competition' more severely than menstrual pain ($P = 0.031$, $P = 0.004$,

18 and $P<0.001$, respectively). Sixty-six athletes (16.8%) reported having experienced a

1   stress fracture. The severity of 'Overeating or food cravings', 'Physical symptoms', and

2   'Performance in training or competition' in athletes with previous stress fracture were

3   much higher than in those without a history of stress fracture (P=0.015, P=0.008, and

4   P=0.006, respectively). In terms of premenstrual symptoms, 'Physical symptoms' was

5   associated with an increased risk of stress fractures in athletes (odds ratio 1.66, 95%

6   confidence interval: 1.06–2.62).

7   **Conclusions:** The results from this study indicated that premenstrual symptoms may

8   affect not only athletic performance but also the risk of stress fractures in adolescent

9   athletes.

10

11 **Running title:** PMS and stress fracture in athletes

12

13 **Key words:** PMS, PMDD, Athlete, Stress fracture, High school student

14

15 **Strength and limitations of this study**

16 ● This is the first study on the relationship between the symptoms of PMS/PMDD

17 and stress fractures in athletes.

3

1 ● A key strength of this study is that we collected data from the female athletes with

2 regular menstruation to evaluate PMS/PMDD status precisely.

3 ● It may not be possible to generalize the findings to all female athletes in Japan, but

4 we analyzed the data from female athletes who participated in authorized high

5 school sports clubs and not elite athletes.

6 ● Due to the cross-sectional design, it is impossible to determine causality, that is,

7 whether these risk factors were a cause or effect of stress fracture

8

4

1 **INTRODUCTION**

2 Premenstrual syndrome (PMS) is a complex constellation of mood, behavioral, and

3 physical changes that are limited to the premenstrual phase. These symptoms recover

4 within a few days after the start of menstruation [1]. Epidemiologic surveys have shown

5 that the frequency of premenstrual symptoms is high (80–90%) [2]. Approximately 5%

6 of women experience symptoms so severe that they interfere with personal or social

7 relationships [3]. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5;

8 American Psychiatric Association 2013) has defined such a severe form of PMS as

9 premenstrual dysphoric disorder (PMDD) [4].

10   The precise pathogenic mechanisms of PMS/PMDD are as yet unknown, but several

11 possible causes have been suggested, including hormonal changes, neurotransmitters,

12 diet, stress, and lifestyle [5]. Judging from the fact that the suppression of ovarian

13 activity diminishes these symptoms, the ovarian function of patients with PMS/PMDD

14 is normal [6].

15   In the last 40 years, female athletic participation has increased dramatically,

16 particularly at high school and collegiate levels [7]. Along with the increasing

17 competition, intensive training has caused unique health problems for female athletes,

18 known as the female athlete triad [7]. The triad includes a spectrum of health problems

5

1   related to energy availability, menstrual function, and bone mineral density. They show

2   the symptoms of eating disorders, amenorrhea, and nontraumatic stress fractures. There

3   has been extensive research on this triad at high school and collegiate levels. Among the

4   triad components, stress fractures are one of the most serious health problem for athletes,

5   because of the interruption caused to training and their potential to end sporting careers

6   in extreme cases [8]. The pathogenic mechanisms of nontraumatic stress fractures are

7   thought to stem from microdamage to the bone caused by repetitive mechanical load

8   that goes beyond the biological capacity of the bone [9]. Risk factors for stress

9   fractutres identified in female athletes include late menarche, menstrual dysfunction,

10 low bone density, and eating disorders, which are related to the female athlete triad

11 [10-12]. On the other hand, many female athletes experience stress fractures without

12 these risk factors.

13   Many reports have documented that the premenstrual phase is associated with

14 decreased performance [13], but there are few reports about PMS/PMDD in athletes.

15 Previously, we reported that PMS and PMDD are common menstrual problems in

16 female collegiate athletes, and almost half of athletes felt a negative effect of

17 premenstrual symptoms on athletic performance [14 15]. One previous report has

18 demonstrated that women with PMS had a significantly greater postural sway than those

6

1   without PMS. This may contribute to the higher rates of injury during the luteal phase

2   [16]. Our previous data also showed that among the PMS/PMDD symptoms in

3   collegiate athletes, the prevalence of "Overeating or food cravings" was very high [14].

4   It has been reported that eating disorders appear to be the most common psychiatric

5   problem in athletes [17]. Several reports showed that restrictive eating patterns were

6   associated with increased risk of stress fracture [10] [18]. Restrictive eating patterns

7   induce biased nutrition and may lead to a lowering in bone mineral density.

8   The aim of this study was to investigate the relationship between the risk of stress

9   fractures and PMS/PMDD in Japanese adolescent athletes.

10

7

1 **METHODS**

2 **Ethics**

3 The study was carried out in accordance with the principles outlined in the Declaration

4 of Helsinki. Our institutional review board at Kindai University approved the study

5 (approval number 26-193).

6

7 **Study population**

8 A school-based cross-sectional survey was conducted in December 2013 using a sample

9 of 1818 Japanese female students who belonged to two public high schools in Sendai,

10 the largest city in northeastern Japan. A total of 1578 students completed the

11 questionnaire with written informed consent. We selected 506 female students who

12 belonged to authorized high school sports clubs and were active athletes. Among these,

13 we further selected 394 students who had regular menstrual cycles (25–38 days) without

14 hormonal therapy.

15

16 **Questionnaire**

17 We used the Premenstrual Symptoms Questionnaire (PSQ), which was developed in our

18 previous study [19], to screen for premenstrual symptoms. The PSQ translates DSM-4

8

1   criteria into a rating scale with degrees of severity described in Japanese and is

2   essentially identical to the Premenstrual Symptoms Screening Tool [20]. The PSQ asked,

3   "Within the last three months have you experienced the following premenstrual

4   symptoms starting during the week before menses and remitting a few days after the

5   onset of menses?" The premenstrual symptoms listed on the PSQ are 'Depressed mood',

6   'Anxiety or tension', 'Tearful', 'Anger or irritability', 'Decreased interest in work,

7   home, or social activities', 'Difficulty concentrating', 'Fatigue or lack of energy',

8   'Overeating or food cravings', 'Insomnia or hypersomnia', 'Feeling overwhelmed', and

9   'Physical symptoms such as tender breasts, feeling of bloating, headache, joint or

10   muscle pain, or weight gain'. The PSQ also asked whether such premenstrual symptoms

11   interfered with 'Work efficiency or productivity, or home responsibilities', 'Social life

12   activities', or 'Relationships with coworkers or family'. The PSQ asked the students to

13   rate the severity of premenstrual symptoms as 'Not at all', 'Mild', 'Moderate', or

14   'Severe'. We divided students with premenstrual symptoms into three groups: 'PMDD',

15   'moderate-to-severe PMS', and 'no/mild PMS' according to the criteria reported

16   previously [15,16]. In addition to the PSQ, we asked whether such premenstrual

17   symptoms interfered with 'Performance in training or competition'. This additional

18   question also asked the students to rate the severity as 'Not at all', 'Mild', 'Moderate',

9

1 or 'Severe'. We asked the students about their severity of pain during menses with the

2 categories of 'Not at all', 'Mild', 'Moderate', and 'Severe'. We also asked whether such

3 menstrual pain interfered with 'Work efficiency or productivity, or home

4 responsibilities', 'Social life activities', 'Relationships with coworkers or family', or

5 'Performance in training or competition'.

6 We further collected additional information about their age, body weight, height, age

7 at menarche, age at commencing training, history of stress fracture diagnosed by a

8 medical doctor, participation of national or international competition, weekly training

9 duration, and restriction of body weight. These data were also assessed using a

10 self-reported questionnaire. Body-mass index (BMI) (kg/m^2) was calculated by dividing

11 weight by height squared. Underweight was defined as BMI <18.5 kg/m^2. Athletes were

12 grouped into six groups: ball games, gymnastics, track, swimming, fighting sports, and

13 other sports.

14

15 **Statistical analyses**

16 Statistical analysis was performed using JMP 11.2.1 (SAS, Cary, NC, USA). Data are

17 expressed as the means ± S.D. Statistical significance was set at $P < 0.05$. Wilcoxon

18 signed-ranks test was applied to test the difference in interference with work, usual

10

1   activities, or relationships between premenstrual symptoms, and menstrual pain.

2   Mann–Whitney's U test was applied to test the difference in prevalence of

3   dysmenorrhea, premenstrual symptoms, and severity of PMS/PMDD. Multivariate

4   analysis was applied to analyze the factors that were significantly associated with stress

5   fracture. We selected school year, BMI<18.5, age at menarche, menstrual pain, age at

6   commencing training, participation in national or international competition, restriction

7   of body weight, weekly training duration, and 15 premenstrual symptoms and put these

8   variables into the model.

9

11

1　**RESULTS**

2　The characteristics of the study population are presented in Table 1. Considering that a

3　quarter of the athletes participated in national or international competitions, some of

4　these clubs have a high ranking in Japanese high school sport. Sixty-six athletes

5　(16.8%) with regular menstrual cycles reported having experienced a stress fracture.

6　According to the type of sport, the prevalence of stress fracture in 'Track' and

7　'Gymnastics' participants was high (43.5% and 31.6%, respectively) (Table 2).

8　　The prevalence of menstrual pain and each premenstrual symptom is shown in Table

9　3. More than half reported 'menstrual pain' (83.2%), 'Anxiety or tension' (67.3%),

10　'Anger or irritability' (63.7%), 'Difficulty concentrating' (59.4%), 'Fatigue or lack of

11　energy' (67.5%), 'Overeating or food cravings' (64.0%), and 'Physical symptoms'

12　(53.0%). We further compared the difference in the degree of disturbance to social and

13　life activities by menstrual pain or premenstrual symptoms. Premenstrual symptoms

14　disturbed 'Work efficiency or productivity, home responsibilities', 'Relationships with

15　coworkers or family', and 'Athletic performance in training or competition' more

16　severely than menstrual pain ($P = 0.031$, $P = 0.004$, and $P < 0.001$, respectively, by

17　Wilcoxon signed-ranks test). The 'PMDD' group consisted of 5 athletes (1.3%), the

18　'moderate to severe PMS' group of 35 girls (8.9%); and the 'no/mild PMS' group of 354

12

1   girls (89.8%).

2   Next, we analyzed the prevalence difference of menstrual pain and premenstrual

3   symptoms with or without a history of stress fracture (Table 4). The severity of

4   'Overeating or food cravings' and 'Physical symptoms' in athletes with previous stress

5   fracture were much higher than those of without such a history (*P*=0.015 and *P*=0.008,

6   respectively, by Mann–Whitney's U test). The severity of the effect on 'Performance in

7   training or competition' in athletes with previous stress fracture was much higher than

8   that of athletes without a history of stress fracture (*P*=0.006 by Mann–Whitney's U

9   test).

10   The results of multivariate analysis of the factors that were significantly associated

11   with stress fractures are shown in Table 5. 'Restriction of body weight' and 'Weekly

12   training duration' showed an increased risk of stress fractures in athletes. Regarding

13   premenstrual symptoms, 'Physical symptoms' was associated with an increased risk of

14   stress fractures.

15

13

1 **DISCUSSION**

2 Our data showed that premenstrual symptoms impaired athletic performance in 41.1%

3 of adolescent athletes. This rate was almost the same as that reported previously with

4 regard to performance impairment in collegiate athletes [14 15]. In our previous report

5 about Japanese collegiate athletes, the 'PMDD' group consisted of 5 female athletes

6 (2.9%), the 'moderate to severe PMS' group of 15 female athletes (8.6%) and the

7 'No/Mild PMS' group of 154 female athletes (88.5%) [14]. The rates of PMDD and

8 moderate-to-severe PMS in the current study population were the same as those in the

9 collegiate athletes population (P =0.596 by Mann-Whitney's U test). It may be possible

10 that premenstrual symptoms in collegiate athletes have been disturbing their athletic

11 performance since high school. Dysmenorrhea is the commonest disease among

12 adolescent girls, and clinicians tend to focus only on dysmenorrhea and underestimate

13 PMS/PMDD. Our data showed the high prevalence rate of menstrual pain in athletes,

14 but premenstrual symptoms disturbed their athletic performance more severely than

15 menstrual pain. It is important to give proper attention to PMS/PMDD in younger

16 women.

17 Our data showed that the incidence of stress fracture in female athletes with regular

18 menstrual cycles was 16.8%. It is well established that the female athlete triad is a

14

1   significant risk factor for stress fractures in female athletes. For this reason, there have

2   been no previous studies about stress fractures in female athletes with regular

3   menstruation. It is difficult to compare our data with other data in similar populations.

4   The pathogenic mechanism of stress fractures is thought to involve microdamage to

5   the bone caused by repetitive mechanical loads that go beyond the biological capacity of

6   the bone. Multivariate analysis revealed that 'Weekly training duration' was correlated

7   with an increased risk of stress fractures. It stands to reason that longer training times

8   increase the risk of developing stress fractures. A prospective study reported that the

9   hours per week of participation in sports could be a risk factor for stress fracture in

10   adolescent females [21]. Our data on 'Weekly training duration' were in accordance

11   with this. Our data showed a relationship between stress fracture and premenstrual

12   physical symptoms in athletes. Water retention symptoms, especially edema, may

13   disturb the motion of athletes. Physical activity induces excessive breast motion and

14   resulting in breast pain [22], and PMS worsens preexisting mastalgia and further

15   disturbs the motion of athletes. These symptoms will also be exacerbated by athletic

16   behavior and athletes feel much more load. One previous report demonstrated that

17   women with PMS had a significantly greater postural sway than women without PMS

18   [16]. It may be possible that disturbed motion by premenstrual physical symptoms

15

1   caused gawky movement and placed an unnecessary burden on athletes' bone.

2   Accordingly, physical symptoms of PMS possibly contribute to the higher risk of stress

3   fracture.

4   Multivariate analysis also revealed that 'Restriction of body weight' showed an

5   increased risk of stress fractures in athletes with regular menstruation. 'Restriction of

6   body weight' will lead to energy insufficiency and trigger menstrual dysfunction. It

7   should be noted that 'Restriction of body weight' could be an independent risk factor for

8   stress fractures without ovarian insufficiency. Energy insufficiency could induce chronic

9   malnutrition and result in bone deterioration [8]. The female athlete triad and its

10   negative effects on bone health has been well recognized through research, but most

11   female high school athletes still remain unfamiliar with this relationship [23].

12   Our data showed that the severity of 'Overeating or food cravings' with previous

13   stress fracture were much higher than those of without a history of stress fracture. Not

14   only energy insufficiency but also biased nutrition leads to a lowering in bone mineral

15   density [10]. Along with an adequate energy intake, a variety of micronutrients in the

16   diet is also important. Calcium and vitamin D are the most important micronutrients for

17   bone mass. Of note, it has been reported that both factors are dysregulated in

18   PMS/PMDD patients [24][25]. It may be possible that inadequate intake of calcium and

16

1   vitamin D in PMS/PMDD patients affects their bone health. Our data further

2   emphasized the paramount importance of nutrition in bone health.

3   Our study had several limitations. The main limitation was that the study was of a

4   cross-sectional design. It was impossible to determine causality whether these risk

5   factors were a cause or effect of stress fracture. Based on the results of this study, we are

6   now studying the relationship between stress fracture and PMS/PMDD by using cohort

7   data in a prospective setting. Longitudinal evaluation of these students will enable us to

8   clarify causal links between stress fracture and PMS/PMDD. The second limitation was

9   that all our data were based on self-reporting; therefore, the study was susceptible to

10   recall bias. The third limitation was that this study was conducted only in Japan. It is

11   possible that our data may not be applicable to other countries. The proportion of

12   students in the third year was low in our study. This could be explained by the fact that

13   school entrance examinations are extremely difficult in Japan, so most students give up

14   their club activity in their third year. The further limitation was that we have only

15   checked the history of stress fracture by self-reported of data and a detailed description

16   such as location and age at onset was lacking. We could not exclude the possibility that

17   the self-reported stress fractures were caused by traumatic accidents. To collect more

18   accurate information as far as possible, we took a past history of stress fractures

17

1 diagnosed by medical doctor.

2 Despite these limitations, the findings from our study have several strengths. We

3 analyzed the data from female athletes who participated in authorized high school sports

4 clubs and not elite athletes. This will increase the generalizability of the study in this

5 population. In addition, we collected data from female athletes with regular

6 menstruation. This will enable the evaluation of PMS/PMDD status precisely.

7 Research into female athletes has focused on menstrual dysfunction, so

8 ovulation-induced PMS/PMDD symptoms have been generally overlooked. After

9 overcoming the female athlete triad, PMS/PMDD could be a major health concern in

10 female athletes. Our previous data showed that almost half of athletes felt a negative

11 effect of PMS/PMDD symptoms on their performance [14 15]. Moreover, our data

12 suggested that premenstrual symptoms may increase the risk of stress fractures in

13 female athletes. Further research using intervention for PMS/PMDD is warranted to

14 confirm their importance for the health of female athletes.

15 To the best of our knowledge, this is the first study on the relationship between the

16 symptoms of PMS/PMDD and stress fractures in athletes. Premenstrual symptoms

17 disturbed social life activity and athletic performance more severely than menstrual pain.

18 The incidence of stress fracture in female athletes with regular menstrual cycles was

18

1 16.8%. 'Restriction of body weight', 'Weekly training duration', and 'Physical

2 symptoms of PMS' were associated with an increased risk of stress fractures. We should

3 monitor premenstrual symptoms not only for athletic performance but also stress

4 fractures.

5 **Conflict of interest**

6 The authors have no conflict of interest.

7 **Acknowledgments**

11 **Contributors**

12 TT contributed to the drafting of the manuscript. TT, YI, HN, AT and MS contributed to

13 data collection and analyzed the data. TT was main contributor to the study design and

14 conception. All authors were agreed with the integrity of the study and gave their

15 approval.

16 **Data Sharing**

17 No additional data available.

18

19

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1   Table 1. Characteristics of study participants (N=394)

Characteristic	
Age (years), mean ± SD	16.4 ± 0.78
School year, no. (%)	
First year	197 (50.0)
Second year	153 (38.8)
Third year	44 (11.2)
BMI (kg/m^2), mean ± SD	20.5 ± 1.76
BMI <18.5 kg/m^2, no. (%)	47 (11.9)
Age at menarche (years), mean ± SD	12.5 ± 1.34
Age at commencing training (years), mean ± SD	11.1 ± 3.80
Type of sport, no. (%)	
Ball games	212 (53.8)
Gymnastics	19 (4.8)
Track	23 (5.8)
Swimming	17 (4.3)
Fighting sports	26 (6.6)
Others	97 (24.6)
Participation in national or international competition, no. (%)	102 (25.9)
Weekly training duration (hrs/week), mean ± SD	15.4 ± 8.4
Restriction of body weight, no. (%)	88 (22.3)
Stress fracture, no. (%)	66 (16.8)

2   BMI: body mass index, SD: standard deviation.

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1   Table 2. Prevalence of stress fracture according to type of sport.

Type of sport	no. (%)
Ball games (N=212)	42 (19.8)
Gymnastics (N=19)	6 (31.6)
Track (N=23)	10 (43.5)
Swimming (N=17)	0 (0.0)
Fighting sports (N=26)	0 (0.0)
Others (N=97)	8 (8.2)

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1   Table 3. Prevalence rates of menstrual pain, premenstrual symptoms, and interference with work,

2   usual activities, or relationships with degrees of severity. N=394

Symptoms	Not at all	Mild	Moderate	Severe
Menstrual pain, no. (%)	66 (16.8)	137 (34.8)	156 (39.6)	35 (8.9)
Premenstrual symptoms				
Depressed mood, no. (%)	235 (59.6)	100 (25.4)	43 (10.9)	16 (4.1)
Anxiety or tension, no. (%)	129 (32.7)	155 (39.3)	89 (22.6)	21 (5.3)
Tearful, no. (%)	228 (57.9)	111 (28.2)	39 (9.9)	16 (4.1)
Anger or irritability, no. (%)	143 (36.3)	158 (40.1)	76 (19.3)	17 (4.3)
Decreased interest in work, home, or social activities, no. (%)	262 (66.5)	85 (21.6)	38 (9.6)	9 (2.3)
Difficulty concentrating, no. (%)	160 (40.6)	178 (45.2)	47 (11.9)	9 (2.3)
Fatigue or lack of energy, no. (%)	128 (32.5)	166 (42.1)	75 (19.0)	25 (6.3)
Overeating or food cravings, no. (%)	142 (36.0)	125 (31.7)	95 (24.1)	32 (8.1)
Insomnia or hypersomnia, no. (%)	221 (56.1)	94 (23.9)	58 (14.7)	21 (5.3)
Feeling overwhelmed, no. (%)	277 (70.3)	89 (22.6)	23 (5.8)	5 (1.3)
Physical symptoms, no. (%)	185 (47.0)	121 (30.7)	62 (15.7)	26 (6.6)
Interference with work, usual activities, or relationships	Upper line, by menstrual pain			
	Lower line, by premenstrual symptoms			
Work efficiency or productivity, home responsibilities, no. (%)	230 (58.4)	131 (33.2)	27 (6.9)	6 (1.5)
	211 (53.6)	139 (35.3)	41 (10.4)	3 (0.8)
	†p=0.031			
Social activities, no. (%)	331 (84.0)	52 (13.2)	8 (2.0)	3 (0.8)
	339 (86.0)	36 (9.1)	13 (3.3)	6 (1.5)
	†p=0.891			
Relationships with coworkers or family, no. (%)	341 (86.5)	42 (10.7)	9 (2.3)	2 (0.5)
	330 (83.8)	43 (10.9)	17 (4.3)	4 (1.0)
	†p=0.004			
Athletic performance in training or competition, no. (%)	261 (66.2)	104 (26.4)	25 (6.3)	4 (1.0)
	232 (58.9)	111 (28.2)	42 (10.7)	9 (2.3)
	†p<0.001			
Severity of PMS/PMDD	No/mild PMS	Moderate-to-severe PMS	PMDD	
	354 (89.8)	35 (8.9)	5 (1.3)	

3   † By Wilcoxon signed-ranks test.

4   PMDD: premenstrual dysphoric disorder, PMS, premenstrual syndrome.

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1   Table 4. Prevalence rates of menstrual pain, premenstrual symptoms, and induced interference

2   with work, usual activities, or relationships with or without stress fracture

	Not at all	Mild	Moderate	Severe	*P* (Mann–Whitney *U* test)
Menstrual pain, no. (%)	52 (16.2)	115 (35.8)	124 (38.6)	30 (9.3)	0.781
	14 (21.2)	18 (27.3)	30 (45.5)	4 (6.1)	
Premenstrual symptoms					
Depressed mood, no. (%)	189 (58.9)	85 (26.5)	33 (10.3)	14 (4.4)	0.586
	42 (63.6)	13 (19.7)	10 (15.2)	1 (1.5)	
Anxiety or tension, no. (%)	107 (33.3)	129 (40.2)	69 (21.5)	16 (5.0)	0.361
	20 (30.3)	24 (36.4)	18 (27.3)	4 (6.1)	
Tearful, no. (%)	183 (57.0)	94 (29.3)	29 (9.0)	15 (4.7)	0.645
	40 (60.6)	16 (24.2)	10 (15.2)	0 (0.0)	
Anger or irritability, no. (%)	110 (34.3)	139 (43.3)	58 (18.1)	14 (4.4)	0.686
	29 (43.9)	17 (25.8)	18 (27.3)	2 (3.0)	
Decreased interest in work, home, or social activities, no. (%)	216 (67.3)	69 (21.5)	29 (9.0)	7 (2.2)	0.502
	42 (63.6)	14 (21.2)	9 (13.6)	1 (1.5)	
Difficulty concentrating, no. (%)	129 (40.2)	150 (46.7)	37 (11.5)	5 (1.6)	0.989
	29 (43.9)	25 (37.9)	9 (13.6)	3 (4.5)	
Fatigue or lack of energy, no. (%)	105 (32.7)	137 (42.7)	59 (18.4)	20 (6.2)	0.821
	22 (33.3)	25 (37.9)	16 (24.2)	3 (4.5)	
Overeating or food cravings, no. (%)	123 (38.3)	100 (31.2)	77 (24.0)	21 (6.5)	0.015
	16 (24.2)	23 (34.8)	17 (25.8)	10 (15.2)	
Insomnia or hypersomnia, no. (%)	181 (56.4)	75 (23.4)	50 (15.6)	15 (4.7)	0.903
	37 (56.1)	18 (27.3)	7 (10.6)	4 (6.1)	
Feeling overwhelmed, no. (%)	231 (72.0)	67 (20.9)	18 (5.6)	4 (1.2)	0.190
	42 (63.6)	19 (28.8)	4 (6.1)	1 (1.5)	
Physical symptoms, no. (%)	159 (49.5)	99 (30.8)	45 (14.0)	18 (5.6)	0.008
	24 (36.4)	18 (27.3)	16 (24.2)	8 (12.1)	
Interference with work, usual activities, or relationships					
Work efficiency or productivity, home	173 (53.9)	112 (34.9)	34 (10.6)	2 (0.6)	0.878
	34 (51.5)	26 (39.4)	6 (9.1)	0 (0.0)	

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responsibility, no. (%)					
Social life activities, no. (%)	275 (85.7)	29 (9.0)	11 (3.4)	6 (1.9)	0.571
	58 (87.9)	7 (10.6)	1 (1.5)	0 (0.0)	
Relationships with coworkers or family, no. (%)	148 (74.0)	39 (19.5)	10 (5.0)	3 (1.5)	0.200
	75 (67.0)	28 (25.0)	8 (7.1)	1 (0.9)	
Performance in training or competition, no. (%)	197 (61.4)	87 (27.1)	31 (9.7)	6 (1.9)	0.006
	29 (43.9)	24 (36.4)	10 (15.2)	3 (4.5)	

Severity of PMS/PMDD	No/mild PMS	Moderate-to-severe PMS		PMDD	
	287 (89.4)	29 (9.0)		5 (1.6)	0.251
	62 (93.9)	4 (6.1)		0 (0.0)	

1 Upper line, stress fracture (-) (n=321); lower line, stress fracture (+) (n=66).

2 PMDD: premenstrual dysphoric disorder, PMS: premenstrual syndrome.

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1   Table 5. Multivariate analysis of risk factors for stress fracture

Risk factors	OR (95% CI)	P
School year	1.15 (0.63–2.08)	0.646
BMI <18.5 kg/m^2	2.55 (0.81–7.67)	0.108
Age at menarche (years)	1.03 (0.76–1.40)	0.844
Menstrual pain	0.96 (0.60–1.53)	0.861
Age at commencing training (years)	1.03 (0.91–1.16)	0.673
Participation of national or international competition	1.55 (0.65–3.70)	0.325
Restriction of body weight	2.47 (1.12–5.41)	0.025
Weekly training duration (hrs/week)	1.06 (1.01–1.13)	0.015
Premenstrual symptoms		
Depressed mood	0.75 (0.32–1.72)	0.498
Anxiety or tension	1.88 (0.90–3.98)	0.092
Tearful	0.70 (0.31–1.54)	0.381
Anger or irritability	0.66 (0.30–1.45)	0.301
Decreased interest in work, home, or social activities	1.13 (0.54–2.36)	0.739
Difficulty concentrating	1.06 (0.49–2.32)	0.880
Fatigue or lack of energy	0.87 (0.43–1.73)	0.696
Overeating or food cravings	1.19 (0.75–1.89)	0.447
Insomnia or hypersomnia	0.74 (0.39–1.33)	0.326
Feeling overwhelmed	1.85 (0.78–4.54)	0.165
Physical symptoms	1.66 (1.06–2.62)	0.026
Induced interference with work, usual activities, or relationships		
Work efficiency or productivity, home responsibility	0.70 (0.32–1.48)	0.357
Social life activities	0.45 (0.08–1.54)	0.228
Relationships with coworkers or family	0.54 (0.22–1.19)	0.128
Performance in training or competition	1.29 (0.76–2.17)	0.349

2   BMI: body mass index, OR: Odds ratio, 95% CI: 95% confidence interval.

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4   **STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***
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Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7,8,9
Bias	9	Describe any efforts to address potential sources of bias	*9*
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9,10
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	11
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11
		(b) Indicate number of participants with missing data for each variable of interest	11
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13,14,15,16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.