

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

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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 $p<0.001$, respectively). 66 athletes (16.8%) reported having experienced a stress fracture. The severity of 'Overeating or food cravings', 'Physical symptoms' and 'Performance in training or competition' in athletes with previous stress fractures were much higher than in those without a history of stress fractures ($p=0.015$, $p=0.008$ and $p=0.006$, respectively). In terms of premenstrual symptoms, 'Physical symptoms' was associated with an increased risk of stress fractures in athletes (OR 1.66, 95% CI 1.06 to 2.62).

Conclusions: The results from this study indicated that premenstrual symptoms may affect athletic performance and has the risk of stress fractures in adolescent athletes.

INTRODUCTION

Premenstrual syndrome (PMS) is a complex constellation of mood, behavioural and physical changes that are limited to the premenstrual phase. These symptoms recover within a few days after the start of menstruation.¹

Strengths and limitations of this study

- This is the first study on the relationship between the symptoms of premenstrual syndrome premenstrual dysphoric disorder (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 generalise the findings to all female athletes in Japan, but we analysed the data from female athletes who participated in authorised high school sports clubs and not elite athletes.
- Owing to the cross-sectional design, it is impossible to determine causality, that is, whether these risk factors were a cause or effect of stress fracture

Epidemiological 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 Fifth Edition (DSM-5; American Psychiatric Association 2013) has defined such a severe form of PMS as premenstrual dysphoric disorder (PMDD).⁴

The precise pathogenic mechanisms of PMS/PMDD are as yet unknown, but several possible causes have been suggested, including hormonal changes, neurotransmitters, diet, stress and lifestyle.⁵ Judging from the fact that the suppression of ovarian activity diminishes these symptoms, the ovarian function of patients with PMS/PMDD is normal.⁶

In the past 40 years, athletic participation by women has increased dramatically, particularly at high school and collegiate levels.⁷ Along with the increasing competition, intensive training has caused unique health problems for female athletes, known as the female athlete triad.⁷ 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, amenorrhoea and non-traumatic stress fractures. There has been extensive research on this triad at high school and collegiate levels. Among the triad components, stress fractures are one of the most serious health problems for athletes, because of the interruption caused to training and their potential to end sporting careers in extreme cases.⁸ The pathogenic mechanisms of non-traumatic 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.⁹ Risk factors for stress fractures identified in female athletes include late menarche, menstrual dysfunction, low bone density and eating disorders, which are related to the female athlete triad.^{10–12} 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,¹³ 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.^{14–15} 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.¹⁶ Our previous data also showed that among the PMS/PMDD symptoms in collegiate athletes, the prevalence of 'Overeating or food cravings' was very high.¹⁴ It has been reported that eating disorders appear to be the most common psychiatric problem in athletes.¹⁷ Several reports showed that restrictive eating patterns were associated with increased risk of stress fracture.^{10–18} Restrictive eating patterns induce biased nutrition and may lead to a lowering in bone mineral density.

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.

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 authorised high school sports clubs and were active athletes. Among these, 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,¹⁹ to screen for premenstrual symptoms. The PSQ translates DSM-4 criteria into a rating scale with degrees of severity described in Japanese and is essentially identical to the Premenstrual Symptoms Screening Tool.²⁰ 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' 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 starting training, history of stress fracture diagnosed by a medical doctor, participation of national or international competition, weekly training duration and restriction of body weight. These data were also assessed using a self-reported questionnaire. Body-mass index (BMI) (kg/m^2) was calculated by dividing weight by height squared. Underweight was defined as $\text{BMI} < 18.5 \text{ kg}/\text{m}^2$. 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, North Carolina, USA). Data are expressed as the means \pm 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. Mann-Whitney's U test was applied to test the difference in prevalence of dysmenorrhoea, premenstrual symptoms and severity of PMS/PMDD. Multivariate analysis was applied to analyse the factors that were significantly associated with stress fracture. We selected school year, BMI <18.5, age at menarche, menstrual pain, age at starting training, participation in national or international competition, restriction of body weight, weekly training duration and 15 premenstrual symptoms and put these variables into the model.

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. According to the type of sport, the prevalence of stress fracture in 'Track' and 'Gymnastics' participants was high (43.5% and 31.6%, respectively; [table 2](#)).

The prevalence of menstrual pain and each premenstrual symptom is shown in [table 3](#). 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 $p<0.001$, respectively, 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%).

Next, we analysed the prevalence difference of menstrual pain and premenstrual symptoms with or without a history of stress fracture ([table 4](#)). The severity of 'Overeating or food cravings' and 'Physical symptoms' in athletes with previous stress fracture were much higher than those without such a history ($p=0.015$ and $p=0.008$, respectively, 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 5](#). 'Restriction of body weight' and 'Weekly training duration' showed an increased risk of stress fractures in athletes. Regarding premenstrual symptoms, 'Physical symptoms' were associated with an increased risk of stress fractures.

DISCUSSION

Our data showed that premenstrual symptoms impaired athletic performance in 41.1% of adolescent athletes. This rate was almost the same as that reported previously with regard to performance impairment in collegiate athletes.^{14 15} In our previous report about Japanese collegiate athletes, the 'PMDD' group consisted of 5 female athletes (2.9%), the 'moderate to severe PMS' group of 15 female athletes (8.6%) and the 'No/Mild PMS' group of 154 female athletes (88.5%).¹⁴ 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). It may be possible that premenstrual symptoms in collegiate athletes have been disturbing their athletic performance since high school. Dysmenorrhoea is the commonest

Table 1 Characteristics of study participants (N=394)

Characteristic	
Age (years), mean±SD	16.4±0.78
School year, number (%)	
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 starting training (years), mean±SD	11.1±3.80
Type of sport, number (%)	
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, number (%)	102 (25.9)
Weekly training duration (hours/week), mean±SD	15.4±8.4
Restriction of body weight, number (%)	88 (22.3)
Stress fracture, number (%)	66 (16.8)
BMI, body mass index.	

Table 2 Prevalence of stress fracture according to type of sport

Type of sport	Number (%)
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)

Table 3 Prevalence rates of menstrual pain, premenstrual symptoms and interference with work, usual activities or relationships with degrees of severity

Symptoms	Not at all 66 (16.8)	Mild 137 (34.8)	Moderate 156 (39.6)	Severe 35 (8.9)
Menstrual pain, number (%)				
Premenstrual symptoms				
Depressed mood, number (%)	235 (59.6)	100 (25.4)	43 (10.9)	16 (4.1)
Anxiety or tension, number (%)	129 (32.7)	155 (39.3)	89 (22.6)	21 (5.3)
Tearful, number (%)	228 (57.9)	111 (28.2)	39 (9.9)	16 (4.1)
Anger or irritability, number (%)	143 (36.3)	158 (40.1)	76 (19.3)	17 (4.3)
Decreased interest in work, home or social activities, number (%)	262 (66.5)	85 (21.6)	38 (9.6)	9 (2.3)
Difficulty concentrating, number (%)	160 (40.6)	178 (45.2)	47 (11.9)	9 (2.3)
Fatigue or lack of energy, number (%)	128 (32.5)	166 (42.1)	75 (19.0)	25 (6.3)
Overeating or food cravings, number (%)	142 (36.0)	125 (31.7)	95 (24.1)	32 (8.1)
Insomnia or hypersomnia, number (%)	221 (56.1)	94 (23.9)	58 (14.7)	21 (5.3)
Feeling overwhelmed, number (%)	277 (70.3)	89 (22.6)	23 (5.8)	5 (1.3)
Physical symptoms, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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)

N=394.

*By Wilcoxon signed-ranks test.

PMDD, premenstrual dysphoric disorder; PMS, premenstrual syndrome.

disease among adolescent girls, and clinicians tend to focus only on dysmenorrhoea 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 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 studies about stress fractures in female athletes with regular menstruation. It is difficult to compare our data with other data in similar populations.

The pathogenic mechanism of stress fractures is thought to involve microdamage to the bone caused by repetitive mechanical loads that go beyond the biological capacity of the bone. Multivariate analysis revealed that 'Weekly training duration' was correlated with an increased risk of stress fractures. 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 sports could be a risk factor for stress fracture in adolescent females.²¹ Our data on 'Weekly training duration' were in accordance with this. Our data showed a relationship between stress fracture and premenstrual physical symptoms in athletes. Water retention symptoms, especially oedema, may disturb the motion of athletes. Physical activity induces excessive breast motion and resulting in breast pain,²² and PMS worsens pre-existing mastalgia and further disturbs the motion of athletes. These symptoms will also be exacerbated by athletic behaviour and athletes feel much more load. One previous report demonstrated that women with PMS had a significantly greater postural sway than women without PMS.¹⁶ It may be possible that disturbed motion by premenstrual physical symptoms caused gawky movement and placed an unnecessary burden on athletes' bone. Accordingly, physical symptoms of PMS possibly contribute to the higher risk of stress fracture.

Multivariate analysis also revealed that 'Restriction of body weight' showed an increased risk of stress fractures

Table 4 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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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, number (%)	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 responsibility, number (%)	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)	
Social life activities, number (%)	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, number (%)	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, number (%)	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.

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. Energy insufficiency could induce chronic malnutrition and result in bone deterioration.⁸ The female athlete triad and its negative effects on bone health has been well recognised through research, but most female high school athletes still remain unfamiliar with this relationship.²³

Our data showed that the severity of ‘Overeating or food cravings’ with previous stress fractures were much higher than those of without a history of stress fracture. Energy insufficiency and biased nutrition leads to a

lowering in bone mineral density.¹⁰ Along with an adequate energy intake, a variety of micronutrients in the diet is also important. Calcium and vitamin D are the most important micronutrients for bone mass. Of note, it has been reported that both factors are dysregulated in patients with PMS/PMDD.^{24–25} It may be possible that inadequate intake of calcium and vitamin D in patients with PMS/PMDD affects their bone health. Our data further emphasised the paramount importance of nutrition in bone health.

Our study had several limitations. The main limitation was that the study was of a cross-sectional design. It was impossible to determine causality whether these risk factors were a cause or effect of stress fracture. Based on the results of this study, we are now studying the

Table 5 Multivariate analysis of risk factors for stress fracture

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

BMI, body mass index.

relationship between stress fracture and PMS/PMDD by using cohort data in a prospective setting. Longitudinal evaluation of these students will enable us to clarify the causal links between stress fracture and PMS/PMDD. The second limitation was that all our data were based on self-reporting; therefore, the study was susceptible to recall bias. The third 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 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 only checked the history of stress fracture by self-reported of data and a detailed description such as location and age at onset was lacking. 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 history of stress fractures diagnosed by medical doctor.

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

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 the athletes felt a negative effect of PMS/PMDD symptoms on their performance.^{14 15} 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 for both athletic performance and stress fractures.

Contributors TT contributed to the drafting of the manuscript. TT, YI, HN, AT and MS contributed to data collection and analysed the data. TT was the main contributor to the study design and conception. All authors agreed with the integrity of the study and gave their approval.

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Patient consent Obtained.

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