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

Takashi Takeda, Yoko Imoto, Hiroyo Nagasawa, Atsuko Takeshita, Masami Shiina

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. Epidemiological surveys have shown that the frequency of premenstrual symptoms is high (80–90%). Approximately 5% of women experience symptoms so severe that they interfere with personal or social relationships. 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).

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. Judging from the fact that the suppression of ovarian activity diminishes these symptoms, the ovarian function of patients with PMS/PMDD is normal.

In the past 40 years, athletic participation by women has increased dramatically, particularly at high school and collegiate levels. Along with the increasing competition, intensive training has caused unique health problems for female athletes, known as the female athlete triad.
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/m²) was calculated by dividing weight by height squared. Underweight was defined as BMI <18.5 kg/m². 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±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 dysmenorrhea, 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’ (82.2%), ‘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. 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%). 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. Dysemorrhoea 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/m²), mean±SD                               | 20.5±1.76 |
| BMI <18.5 kg/m², 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) |

| 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) |

Takeda T, et al. BMJ Open 2016;6:e013103. doi:10.1136/bmjopen-2016-013103
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 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. 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, 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. It may be possible that disturbed motion by premenstrual physical symptoms caused gawkiness 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 3 Prevalence rates of menstrual pain, premenstrual symptoms and interference with work, usual activities or relationships with degrees of severity

| Symptoms                                      | Not at all | Mild | Moderate | Severe |
|------------------------------------------------|------------|------|----------|--------|
| Menstrual pain, number (%)                     | 66 (16.8)  | 137 (34.8) | 156 (39.6) | 35 (8.9) |
| 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.

*p=0.031

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 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                 | 189 (58.9)      | 85 (26.5)       | 33 (10.3)       | 14 (4.4)        | 0.586           |
| Number (%)                     | 42 (63.6)       | 13 (19.7)       | 10 (15.2)       | 1 (1.5)         |                 |
| Anxiety or tension             | 107 (33.3)      | 129 (40.2)      | 69 (21.5)       | 16 (5.0)        | 0.361           |
| Number (%)                     | 20 (30.3)       | 24 (36.4)       | 18 (27.3)       | 4 (6.1)         |                 |
| Tearful                        | 183 (57.0)      | 94 (29.3)       | 29 (9.0)        | 15 (4.7)        | 0.645           |
| Number (%)                     | 40 (60.6)       | 16 (24.2)       | 10 (15.2)       | 0 (0.0)         |                 |
| Anger or irritability          | 110 (34.3)      | 139 (43.3)      | 58 (18.1)       | 14 (4.4)        | 0.686           |
| Number (%)                     | 29 (43.9)       | 17 (25.8)       | 18 (27.3)       | 2 (3.0)         |                 |
| Decreased interest in work     | 216 (67.3)      | 69 (21.5)       | 29 (9.0)        | 7 (2.2)         | 0.502           |
| Number (%)                     | 42 (63.6)       | 14 (21.2)       | 9 (13.6)        | 1 (1.5)         |                 |
| Difficulty concentrating       | 129 (40.2)      | 150 (46.7)      | 37 (11.5)       | 5 (1.6)         | 0.989           |
| Number (%)                     | 29 (43.9)       | 25 (37.9)       | 9 (13.6)        | 3 (4.5)         |                 |
| Fatigue or lack of energy      | 105 (32.7)      | 137 (42.7)      | 59 (18.4)       | 20 (6.2)        | 0.821           |
| Number (%)                     | 22 (33.3)       | 25 (37.9)       | 16 (24.2)       | 3 (4.5)         |                 |
| Overeating or food cravings    | 123 (38.3)      | 100 (31.2)      | 77 (24.0)       | 21 (6.5)        | 0.015           |
| Number (%)                     | 16 (24.2)       | 23 (34.8)       | 17 (25.8)       | 10 (15.2)       |                 |
| Insomnia or hypersomnia        | 181 (56.4)      | 75 (23.4)       | 50 (15.6)       | 15 (4.7)        | 0.903           |
| Number (%)                     | 37 (56.1)       | 18 (27.3)       | 7 (10.6)        | 4 (6.1)         |                 |
| Feeling overwhelmed            | 231 (72.0)      | 67 (20.9)       | 18 (5.6)        | 4 (1.2)         | 0.190           |
| Number (%)                     | 42 (63.6)       | 19 (28.8)       | 4 (6.1)         | 1 (1.5)         |                 |
| Physical symptoms              | 159 (49.5)      | 99 (30.8)       | 45 (14.0)       | 18 (5.6)        | 0.008           |
| Number (%)                     | 24 (36.4)       | 18 (27.3)       | 16 (24.2)       | 8 (12.1)        |                 |
| Interference with work         |                 |                 |                 |                 |                 |
| Work efficiency                | 173 (53.9)      | 112 (34.9)      | 34 (10.6)       | 2 (0.6)         | 0.878           |
| responsibility, number (%)    | 34 (51.5)       | 26 (39.4)       | 6 (9.1)         | 0 (0.0)         |                 |
| Social life activities         | 275 (85.7)      | 29 (9.0)        | 11 (3.4)        | 6 (1.9)         | 0.571           |
| Number (%)                     | 58 (87.9)       | 7 (10.6)        | 1 (1.5)         | 0 (0.0)         |                 |
| Relationships with coworkers   | 148 (74.0)      | 39 (19.5)       | 10 (5.0)        | 3 (1.5)         | 0.200           |
| family, number (%)             | 75 (67.0)       | 28 (25.0)       | 8 (7.1)         | 1 (0.9)         |                 |
| Performance in training        | 197 (61.4)      | 87 (27.1)       | 31 (9.7)        | 6 (1.9)         | 0.006           |
| or competition, number (%)     | 29 (43.9)       | 24 (38.4)       | 10 (15.2)       | 3 (4.5)         |                 |
| Severity of PMS/PMDD           |                 |                 |                 |                 |                 |
| No/mild PMS                    | 287 (89.4)      | 29 (9.0)        | 6 (1.9)         | 5 (1.6)         | 0.251           |
| Moderate-to-severe PMS         | 62 (93.9)       | 4 (6.1)         | 0 (0.0)         |                 |                 |
| PMDD                           |                 |                 |                 |                 |                 |

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

PMDD, premenstrual dysphoric disorder; PMS, premenstrual syndrome.
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 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. 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.

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/m²                                   | 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 |

Prenomenstrual symptoms

- Depressed mood: 0.75 (0.32 to 1.72) p = 0.498
- Anxiety or tension: 1.88 (0.90 to 3.98) p = 0.092
- Tearful: 0.70 (0.31 to 1.54) p = 0.381
- Anger or irritability: 0.66 (0.30 to 1.45) p = 0.301
- Decreased interest in work, home or social activities: 1.13 (0.54 to 2.36) p = 0.739
- Difficulty concentrating: 1.06 (0.49 to 2.32) p = 0.880
- Fatigue or lack of energy: 0.87 (0.43 to 1.73) p = 0.696
- Overeating or food cravings: 1.04 (1.75 to 1.89) p = 0.447
- Insomnia or hypersomnia: 0.74 (0.39 to 1.33) p = 0.326
- Feeling overwhelmed: 1.85 (0.78 to 4.54) p = 0.165
- Physical symptoms: 1.66 (1.06 to 2.62) p = 0.026

Induced interference with work, usual activities or relationships

- Work efficiency or productivity, home responsibility: 0.70 (0.32 to 1.48) p = 0.357
- Social life activities: 0.45 (0.08 to 1.54) p = 0.228
- Relationships with coworkers or family: 0.54 (0.22 to 1.19) p = 0.128
- Performance in training or competition: 1.29 (0.76 to 2.17) p = 0.349

BMI, body mass index.
Competing interests None declared.

Patient consent Obtained.

Ethics approval Institutional Review Board at Kindai University (approval number 26-193).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

REFERENCES

1. Yonkers KA, O’Brien PM, Eriksson E. Premenstrual syndrome. Lancet 2008;371:1200–10.
2. Angst J, Sellaro R, Merikangas KR, et al. The epidemiology of perimenstrual psychological symptoms. Acta Psychiatr Scand 2001;104:110–16.
3. Dimmock PW, Wyatt KK, Jones PW, et al. Efficacy of selective serotonin-reuptake inhibitors in premenstrual syndrome: a systematic review. Lancet 2000;356:1131–6.
4. Association AP. Diagnostic and statistical manual of mental disorders: DSM-5. Arlington: American Psychiatric Association, 2013.
5. Grady-Weliky TA. Clinical practice. Premenstrual dysphoric disorder. N Engl J Med 2003;348:433–8.
6. Segebladh B, Borgström A, Nyberg S, et al. Evaluation of different add-back estradiol and progesterone treatments to gonadotropin-releasing hormone agonist treatment in patients with premenstrual dysphoric disorder. Am J Obstet Gynecol 2009;201:138.e1–8.
7. Javed A, Tebben PJ, Fischer PR, et al. Female athlete triad and its components: toward improved screening and management. Mayo Clin Proc 2013;88:996–1009.
8. Chen YT, Tenforde AS, Fredericson M. Update on stress fractures in female athletes: epidemiology, treatment and prevention. Curr Rev Musculoskelet Med 2013;6:173–81.
9. Milgrom C, Giladi M, Simkin A, et al. An analysis of the biomechanical mechanism of tibial stress fractures among Israeli infantry recruits. A prospective study. Clin Orthop Relat Res 1988;231:216–21.
10. Bennell KL, Malcolm SA, Thomas SA, et al. Risk factors for stress fractures in female track-and-field athletes: a retrospective analysis. Clin J Sport Med 1996;5:229–36.
11. Snyder RA, Koester MC, Dunn WR. Epidemiology of stress fractures. Clin Sports Med 2006;25:37–52, viii.
12. Nattiv A. Stress fractures and bone health in track and field athletes. J Sci Med Sport 2000;3:268–79.
13. Constantinii NW, Dubnov G, Lebrun CM. The menstrual cycle and sport performance. Clin Sports Med 2005;24:e51–82, xii-xiv.
14. Takeda T, Imoto Y, Nagasawa H, et al. Premenstrual syndrome and premenstrual dysphoric disorder in Japanese collegiate athletes. J Pediatr Adolesc Gynecol 2015;28:215–8.
15. Takeda T, Imoto Y, Nagasawa H, et al. Fish consumption and premenstrual syndrome and dysphoric disorder in Japanese collegiate athletes. J Pediatr Adolesc Gynecol 2016;29:386–9.
16. Fridén C, Hirschberg AL, Saartok T, et al. The influence of premenstrual symptoms on postural balance and kinesthesia during the menstrual cycle. Gynecol Endocrinol 2003;17:433–9.
17. Readon CL, Factor RM. Sport psychiatry: a systematic review of diagnosis and medical treatment of mental illness in athletes. Sports Med 2010;40:961–80.
18. Nattiv A, Armsey TD. Stress injury to bone in the female athlete. Clin Sports Med 1997;16:197–224.
19. Takeda T, Tasaka K, Sakata M, et al. Prevalence of premenstrual syndrome and premenstrual dysphoric disorder in Japanese women. Arch Womens Ment Health 2006;9:209–12.
20. Steinier M, Maccouglit M, Brown E. The premenstrual symptoms screening tool (PSST) for clinicians. Arch Womens Ment Health 2006;9:203–9.
21. Field AE, Gordon CM, Pierce LM, et al. The experience of breast pain (mastalgia) in female runners of the 2012 London Marathon and its effect on exercise behaviour. Br J Sports Med 2014;48:220–5.
22. Feldmann JM, Belsha JP, Elissa MA, et al. Female adolescent athletes’ awareness of the connection between menstrual status and bone health. J Pediatr Adolesc Gynecol 2011;24:311–14.
23. Thys-Jacobs S. Micronutrients and the premenstrual syndrome: the case for calcium. J Am Coll Nutr 2000;19:220–7.
24. Thys-Jacobs S, McMahon D, Bliszczak JP. Cyclical changes in calcium metabolism across the menstrual cycle in women with premenstrual dysphoric disorder. J Clin Endocrinol Metab 2007;92:2952–9.