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ORIGINAL RESEARCH

Risk of female athlete triad development in Japanese collegiate athletes is related to sport type and competitive level

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Introduction: Menstrual dysfunction, musculoskeletal injury, and poor nutrition combine to form the female athlete triad (FAT), which results in serious health consequences for affected athletes. To this point, the risk factors of this phenomenon have not been fully explored in Japanese female college athletes. Additionally, the effect of competitive level on FAT risk factors has also not been reported. Therefore, we aimed to examine FAT risk factors in Japanese female athletes of various sports as well as examine the impact of competitive level on FAT.

Methods: A Japanese-language survey was completed by 531 athletes and 20 nonathletes at two Japanese universities and answers with regard to menstrual status, musculoskeletal injury, nutrition, and other variables were analyzed based on classification of the sports into nine distinct groups based on activity type. Sport intensity, training volume, and competitive levels were used to further classify each sport. One-way ANOVA and the Bonferroni post hoc test using SPSS were carried out to analyze significance for relationships between sport intensity and FAT risk factors. Additionally, the relationship between competitive level and FAT risk factors was analyzed by ANOVA and Bonferroni post hoc tests.

Results: Sport intensity was positively correlated with a delay in menarche as well as dysmenorrhea and poor nutrition while musculoskeletal injury was correlated with repetitive, high-training volume sports. Lower competitive levels increased dysmenorrhea but did not impact injury status or nutrition.

Conclusion: Sport intensity and training volume, but not competitive level, are the critical factors affecting FAT risk in Japanese female college athletes.

Keywords: athletes, dysmenorrhea, FAT, female, Japanese, triad

Plain language summary

Female athletes suffer a higher rate of menstrual problems, muscle and/or skeletal injuries, and poor nutrition intake than non-athletic women. We investigated the link between these problems, known as the female athlete triad (FAT) and the intensity, training amount, and competitive level of college sports in Japanese women. First, we used a classification system that grouped sports by intensity types. Then, we used a Japanese-language questionnaire that 531 athletes and 20 nonathletes responded to. We used ANOVA to find the relationships between intensities, volume, competitive levels, and FAT risk. After analyzing the responses, we found that higher sport intensities caused menstrual problems and poor nutrition intake but higher sports training volume caused more injuries. Competitive level only affected menstrual problems but not as much as intensity. Therefore, we recommend that coaches in high-intensity or high-training volume sports take special care to monitor their athletes for FAT risk.

Introduction

Athletes rely on regular and constant physical training to build and maintain stamina and skill but the training requirements of high-intensity sports put them at a significant risk of microtrauma.[1] However, as improvement in athletic performance is highly correlated with training load,[2,3] athletes suffering from non-mobility-threatening conditions (eg, menstruation) may feel pressured to continue their high workload, leading to a significant risk of injury in both male and female athletes. We previously reported on mild edema in the calf muscles of female athletes due to ovarian hormone fluctuations that led to reductions in static balance ability and agility.[4] Such a connection between training intensity and variation in body condition points to an intimate link between menstrual status and injury risk. Previously, the connection between menstrual dysfunction, musculoskeletal injury, and eating disorders in female athletes has been investigated and reported as the female athlete triad (FAT). FAT is a unique combination of eating disorders, amenorrhea, and osteoporosis in female athletes and results in low energy, functional hypothalamic amenorrhea, and isolated or combined osteoporosis.[5] To address this crucial issue, the American College of Sports Medicine first published recommendations for screening, diagnosis, prevention, and treatment of FAT in 1997 (updated in 2007) to reduce health risks, maximize the benefits of exercise, and allow athletes to compete in their best condition.[5] In Japan, the FAT problem has only recently been recognized: in 2013, the Japan Institute of Sports Sciences (JISS) initiated programs to study specific FAT-related issues,[6] but until recently, these studies have mainly been conducted only in top-level athletes. Conversely, data on collegiate female athletes are lacking, with only few reports on small groups of Japanese students or students in other countries.[7–9] There have also been no reports linking FAT to the competitive level of Japanese athletes; higher competitive requirements at the college level (or above) can be reasonably expected to produce more intensive training requirements and exacerbate the effect of injury risk in female athletes affected by hormone fluctuations.[10–14] Therefore, the aim of this study was to investigate correlations between the individual risk factors for FAT (amenorrhea, injury, nutrition) and sport intensity in Japanese college athletes. We then extended the parameters to include competitive level under the hypothesis that higher competitive levels will increase menstrual irregularities, increase injury risk, and affect nutrition intake.

Materials and methods

Subjects and data collection

From April to May 2017, a specific questionnaire developed by our research team was distributed among the collegiate athletes at the University of Tsukuba and the Japan Women's College of Physical Education. Questionnaires were in the Japanese language (section explanations and answer choices were translated into English for this manuscript). All questionnaires were collected at the same time point and were completely filled in by 551 female collegiate students, including 531 individual athletes, who participated in school-sponsored sports such as basketball, volleyball, track and field, artistic gymnastics, modern dance, swimming, soccer, lacrosse, rescue swimming, cheerleading, sport dance, badminton, fencing, and tennis. A control group consisted of 20 students (2.3%) with no sports activity experience since elementary school. Students were recruited under informed consent during practices and with the permission of coaches and athletic staff. Students were given both oral and written explanations of the study, and written consent was obtained from them. Prior to questionnaire distribution, general instructions were given to each participant. The athletes answered on their menstrual status, recent and past injury history, eating habits and behavior, as well as other demographic information.

This study was in accordance with the latest revision of Declaration of Helsinki and was approved by the Ethics Committees of both the University of Tsukuba (approval #28–85) and the Japan Women's College of Physical Education (approval #2016–23).

Menstrual status questions included menarche age, current menstrual status (a: recently had a regular menstrual cycle, b: delayed for ~ month(s), current menstrual cycle (a: the cycle is between 25 and 38 days, b: the cycle is less than 24 days, c: the cycle is more than 39 days, d: the cycle duration is over ±7 days), past menstrual status (a: having a cyclic menstruation from menarche till now, b: experienced a delay of any kind up to 1–2 months ago, c: experienced a delay of any kind more than 3 months ago), experience of taking oral contraception (a: taking it now, b: have an experience in the past though not taking recently, c: never had it).

Musculoskeletal injury was defined as an injury (either from direct trauma or overuse) which was the direct result of sports participation and resulted in a training stoppage of more than 3 days. This questionnaire form included details of prior musculoskeletal injuries such as date of the injury occurrence, time lost from practice or competition (days), body part injured, presence/absence of stress fractures, and menstrual status at the time of stress fractures (a: had menses every month, b: had menses with irregular cycle, c: menses delayed more than 3 months).

Eating habits and behavior were analyzed as frequency and nutritive choice of meals per day (a: always eat three times per day and well balanced, b: always eat three times per day though not always well balanced, c: usually eat three times per day though not always, d: usually eat less than two times per day), body weight reduction (a: intentional weight loss of more than 5 kg, b: intentional weight loss of 1–4 kg, c: never experienced an intentional weight reduction).

Demographic information questions addressed age, height, weight, sport type, training volume (training hours per week), the highest recent or past competitive level (a: national team level, b: national convention level, c: regional convention level, d: subregional convention level), years of experience, and the names of any and all sports experienced in elementary school, junior high school, high school, and college. Sports that were done in gym or physical education classes were excluded as activities prescribed by the nationalized Japanese curriculum served as a common baseline for both the experimental and control groups.

Sports intensity classifications

To investigate the effect of intensity level to FAT risk, we used the sports type classification by Jere et al[15] and divided all athletes into nine groups (Figure 1). Cheerleading, modern dance, and sports dance (which were not included in the Jere classification) have been reported to require higher degrees of flexibility, strength, coordination, and physical fitness levels.[16–21] Additionally, rescue swimming (also not included in the Jere classification) is recognized as an official competitive sport that combines such elements as swimming and running, with previous reports showing rescue swimming velocity matching competitive swimmers in the first 50 m of freestyle swimming.[22] Therefore, we decided to classify cheerleading, modern dance, and sport dance to Group IIIA (similar to gymnastics) and rescue swimming to group IIC (similar to swimming) (Figure 1). Competitive levels were divided into two groups: "high competing level" to represent national team and national convention level, and "low competing level" which stood for the regional and subregional convention levels. With respect to current menstrual status and cycle regularity, we divided these categories into two groups, including "On Time" (recent menses) or "Delayed" (menstrual delay of 40 or more days) with the additional qualifier of "Regular" (cyclic menstruation every 25–38 days) and "Irregular" (irregular cycle). In cases of amenorrhea, we subdivided the previous menstrual status into two groups: "Yes" (menstrual delay of greater than 3 months) and "No" (menstrual delay of less than 2 months).

Statistical data analysis

SPSS version 24.0 (IBM Corporation, Armonk, NY, USA) and the one-way ANOVA with Bonferroni post hoc test were used to evaluate differences between each of the quantitative indexes in classification groups, current menstrual cycle, mealtimes, and weight reduction. Pearson's correlation coefficient was used to investigate the relationship in the quantitative index in each classification group. Non-paired *t*-testing was done to evaluate the differences between the quantitative index and competitive levels, current menstrual statuses, histories of amenorrhea, histories of musculoskeletal injury, and histories of bone stress fractures in each sports type. One-way ANOVA with Bonferroni post hoc test was performed to evaluate the differences between the quantitative index and mealtimes and weight reduction in each sports team.

Chi-squared testing was done to determine the relationship between nominal variables in all athletes, groups, and each sports type. Relationships between competitive levels, current menstrual statuses, histories of amenorrhea, mealtimes, weight reduction, histories of injuries, and histories of bone stress fractures were all compared, and Fisher's exact test was also performed in a small sample size. Mean values of age, height, weight, menarche age, training hours per week, and starting age are shown as ±SD and alpha values of less than 0.05 were considered significant.

Within each sport, comparisons were made between low and high competition status while additional analyses (with respect to competitive level) looked at comparisons of each sport type to its group as well as between each of the groups. For low-to-high (LTH) competitive comparisons within each sport type, no normalization was done. However, for sport-to-group (STG) comparisons, the specific sport's results (average LTH values) were normalized to the average LTH scores of that entire group. For group-to-group (GTG) comparisons, average LTH values were used. All values reported were mean±SD and alpha values of less than 0.05 were considered significant.

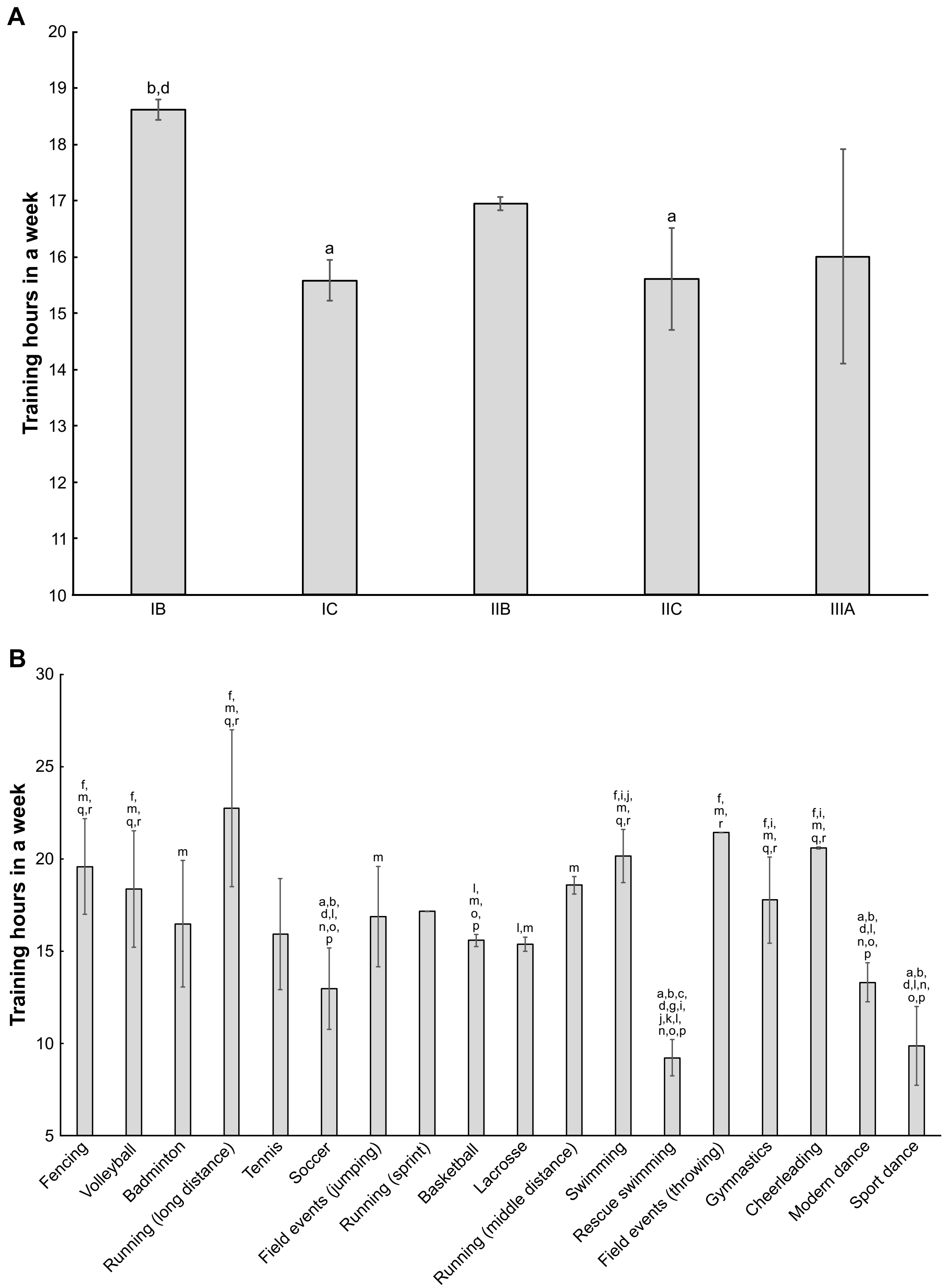

Figure 1 (**A**) Comparison of training hours by sports type classification followed by Jere et al.[15] Training hours per week were compared between Groups IB, IC, IIB, IIC, and IIIA. a) $P<0.05$ in Group IB, b) $P<0.05$ in Group IC, and d) $P<0.05$ in Group IIC. (**B**) Training volume (training hours per week) in each sports team. $P<0.05$ is found when compared with a) fencing, b) volleyball, c) badminton, d) running (long distance), f) soccer, g) field events (jumping), i) basketball, j) lacrosse, k) running (middle distance), l) swimming, m) rescue swimming, n) field events (throwing), o) gymnastics, p) cheerleading, q) modern dance, and r) dance sport.

Results

Classification results, demographics, and the number of athletes meeting one or more of the FAT criteria

The results of the classification and demographics of athletes who returned our questionnaire are shown in Tables 1–3. Group IIC had the highest intensity within all sports and Group IIIA had the highest training volume. As for FAT criteria, 270 (49%) athletes had menstrual dysfunction, 15 (2.7%) had low energy availability, and 108 (20%) had low bone density. These athletes therefore met only one of the three criteria. As for two of the three criteria, 58 (11%) athletes had both menstrual dysfunction and low bone density, 3 (<1%) had both menstrual dysfunction and low energy availability, and 1 (<1%) had both low energy availability and low bone density. There were only 4 (<1%) athletes who met all three criteria.

High-intensity sports delay menarche and contribute to menstrual irregularities in Japanese college athletes

Age of menarche was significantly lower in the control group compared with Groups IB, IIB, IIC, and IIIA, while Group IIIA was significantly higher than Groups IB, IC, IIB, IIC, and control group (Table 1; Figure 2). There was a significant negative correlation between the age of menarche

Table 1 Demographic information of athletes and control

	Number of athletes			Age (years)	Height (cm)	Weight (kg)	Age of menarche (years)	Training volume (hours/week)
	All	High competing level	Low competing level					
Group IB								
Fencing	14	14	0	19.3±0.5	159.3±4.8	55.2±5.7	13.1±1.9	19.6±2.6
Volleyball	65	58	7	19.6±1.1	164.3±6.6	60.3±7.3	13.0±1.6	18.4±3.2
All	79	72	7	19.5±1.0	163.4±6.5[b,e]	59.4±7.3[b,c,d,e,f]	13.1±1.6[e,f]	18.6±0.2[b,d]
Group IC								
Badminton	17	6	11	20.1±1.0	159.3±3.9	54.4±4.4	12.5±1.3	16.5±3.4
Running (long distance)	8	1	7	19.9±0.8	157.0±2.5	47.7±5.4	13.3±1.5	22.8±4.3
Race walking	1	1	0	19.0±0	149.7±0	47.6±0	12.0±0	18.0±0
Tennis	11	0	11	19.6±1.4	160.0±4.5	55.5±5.5	12.2±1.0	15.9±0
Soccer	32	2	30	19.6±1.0	158.7±4.1	53.0±4.2	12.9±1.9	12.9±2.2
All	69	10	59	19.7±1.0	158.7±4.1[a,c,d]	53.1±5.0[a,d]	12.7±1.6[e]	15.6±0.4[a]
Group IIB								
Field events (jumping)	30	18	12	19.4±0.9	164±7.1	53.8±5.6	12.9±1.3	16.9±2.7
Running (sprint)	7	4	3	19.9±1.3	162.6±5.1	52.5±6.0	12.9±1.5	17.1±2.7
All	37	22	15	19.5±1.0	163.7±6.8[b,e]	53.6±5.6[a,d]	12.9±1.3[e,f]	16.9±0.1
Group IIC								
Basketball	113	27	86	19.7±0.9	163.2±5.7	58.9±5.4	13.1±1.3	15.8±4.0
Lacrosse	29	5	24	19.9±0.9	160.3±5.0	54.3±4.9	13.3±1.3	15.4±4.3
Running (middle distance)	8	2	6	19.9±1.0	159.9±3.9	50.9±3.7	13.1±1.5	18.8±6.1
Swimming	33	26	7	19.7±0.7	160.5±5.5	54.3±5.9	13.0±1.1	20.8±8.5
Rescue swimming	25	7	18	20±1.1	159.7±5.4	57.1±6.7	12.9±1.6	9.4±4.8
All	208	67	141	19.8±0.9	161.8±5.7[b,e]	57.0±6.0[a,b,c,e,f]	13.1±1.3[e,f]	15.6±0.9[a]
Group IIIA								
Field events (throwing)	7	3	4	19.1±0.7	162.5±3.5	66.5±7.5	12.1±1.5	21.4±2.4
Gymnastics	43	22	21	19.7±1.0	153.9±4.3	50.7±4.0	14.5±1.4	19.9±1.1
Cheerleading	24	19	5	19.5±0.8	157.7±5.2	53.9±6.8	13.5±1.6	20.6±1.6
Modern dance	40	32	8	19.4±1.1	159.0±4.9	51.1±5.5	13.4±1.6	13.4±6.0
Dance sport	20	9	11	19.8±0.6	159.2±4.2	52.0±4.8	13.4±1.1	11.4±9.9
All	134	85	49	19.6±0.9	157.4±5.2[a,c,d]	52.4±6.3[a,d]	13.7±1.6[a,b,c,d,f]	16.0±1.9
Group IIIC								
Hepathlon	4	4	0	19.8±0.5	166.2±6.3	59.3±4.2	12.3±1.7	18.8±0.5
All athletes	531	258	273	19.7±1.0	160.7±6.1	56.5±3.9	13.1±1.5	16.8±1.6
Control	20	–	–	20.9±1.7[a,b,c,d,e]	159.7±4.5	51.9±5.1[a,d]	11.7±1.0[a,c,d,e]	–

Note: $P<0.05$ with [a]Group IB, [b]Group IC, [c]Group IIB, [d]Group IIC, [e]Group IIIA, [f]control group.

Table 2 Correlation of variable indexes in all athletes

	Age (years)	Height (cm)	Weight (kg)	Age of menarche (years)	Training hours (hours)	Training frequency (days/week)	Training hours in 1 week (hours)	Age starting sports (years)
Age	1							
Height	0.026	1						
Weight	–0.032	0.674**	1					
Age of menarche	0.016	–0.054	–0.114	1				
Training hours	–0.037	–0.071	–0.029	0.082	1			
Training frequency	–0.035	0.149**	0.101	0.488	0.255**	1		
Training hours in 1 week	–0.046	0.008	0.016	0.096*	0.861**	0.663**	1	
Age starting sports	0.021	0.06	0.079	–0.099*	–0.088*	–0.054	0.106*	1

Note: *$P<0.05$, **$P<0.01$.

Table 3 Number of athletes who met the FAT criteria

	No criteria	One criterium			Two criteria			Three criteria
		MD	LE	LBD	MD×LE	MD×LBD	LE×LBD	
Group IB								
Fencing	6	4	0	3	0	1	0	0
Volleyball	31	16	4	7	0	6	0	1
All	37	20	4	10	0	7	0	1
Group IC								
Badminton	12	1	0	1	0	3	0	0
Running (long distance)	2	4	0	0	0	2	0	0
Race walking	0	1	0	0	0	0	0	0
Tennis	2	8	0	0	0	1	0	0
Soccer	8	15	0	5	0	4	0	0
All	24	29	0	6	0	10	0	0
Group IIB								
Field events (jumping)	6	13	0	4	0	7	0	0
Running (sprint)	2	1	0	2	0	2	0	0
All	8	14	0	6	0	9	0	0
Group IIC								
Basketball	47	43	0	12	2	8	0	1
Lacrosse	14	11	1	3	0	0	0	0
Running (middle distance)	1	2	0	1	0	4	0	0
Swimming	18	14	0	0	0	1	0	0
Rescue swimming	13	10	0	2	0	0	0	0
All	93	80	1	18	2	13	0	1
Group IIIA								
Field events (throwing)	6	0	0	0	0	1	0	0
Gymnastics	12	22	1	2	0	5	0	1
Cheerleading	6	11	0	0	1	4	1	1
Modern dance	15	17	1	2	0	5	0	0
Dance sport	6	12	0	0	0	2	0	0
All	45	62	2	4	1	17	1	2
Group IIIC								
Hepathlon	1	0	0	1	0	2	0	0
All athletes	208	205	7	45	3	58	1	4

Notes: Athletes who have met at least one of the following were defined as MD: 1) Athletes who have answered their current menstrual status as b: delayed for ~ month(s). 2) Athletes who have answered their current menstrual cycle as b: the cycle is less than 24 days, c: the cycle is more than 39 days, or d: the cycle duration is over ~ ±7 days). 3) Athletes who have answered their past menstrual status as b: experienced a delay of any kind up to 1–2 months ago, c: experienced a delay of any kind more than 3 months ago). Athletes who have answered to have their meal usually less than two times per day and frequently lose their weight intentionally were defined to have a risk of LE availability. LBD was defined as athletes who have answered to have an experience of bone stress fracture.
Abbreviations: FAT, female athlete triad; MD, menstrual dysfunction; LE, low energy; LBD, low bone density.

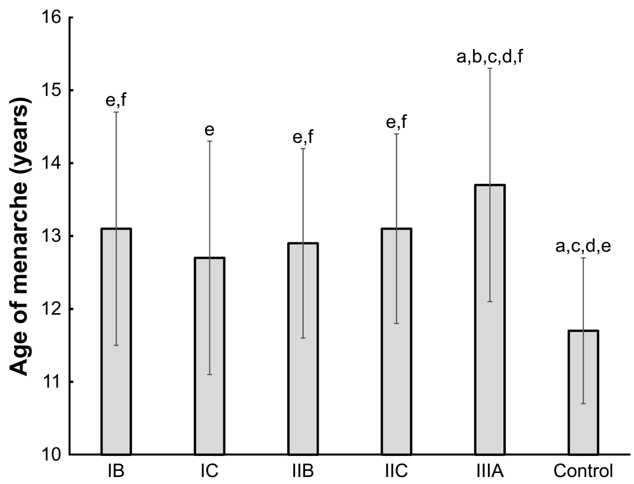

Figure 2 Age of menarche in each group. *P*<0.05 is shown as compared with a) Group IB, b) Group IC, c) Group IIB, d) IIC, e) Group IIIA, and f) control.

and the age of starting sports as well as weight among all athletes (rs=–0.099 and –0.114, respectively; Table 2), which was also seen only in Group IIIA (rs=–0.230 and –0.181, respectively; Table 4).

Highly repetitive, high-training volume sports increase risk of musculoskeletal injury and high-intensity sports negatively impact nutrition choices

Intensity number did not affect the number of athletes who experienced musculoskeletal injury severe enough to require rest for more than 3 days. Group IIB showed significantly higher numbers of athletes who had experienced stress fractures while Group IIC showed significantly lower athlete numbers with regard to stress fractures (*P*=0.038; Table 5).

Group IIIA reported a significantly lower number of athletes who usually have well-balanced meals three times per day, while Group IIB and IIC reported significantly higher numbers. Furthermore, in weight reduction, Group IIIA reported a significantly higher number of athletes who frequently reduce their weight over 5 kg or around 1–2 kg for improvement of sports performance (Table 5).

Classification of competitive levels and numbers of athletes in each by intergroup and group-to-group comparisons

The results of LTH (Table 6), STG (Tables 7–9), and GTG (Table 11) comparisons contained differences. In LTH (low competitive level vs high competitive level) classifications within each sport, basketball and modern dance showed significantly higher training volumes in high competitive level than in low, a trend reflected in all athletes. According to the classification of intensity level/training volumes in STG comparisons (comparisons of individual sports to the others within their respective groups), there was no significant difference in competing level and sports type in Groups IB and IIB (Table 7). However, within the groups, there were differences in athlete numbers with respect to competitive levels. In Group IC, badminton had a significantly higher number of athletes at the high competing levels. In Group IIC, swimming had a significantly higher number of athletes in a high competing level while basketball had a significantly higher number of athletes at a low competing level. In Group IIIA, modern dance had a significantly higher number of athletes in a high competing level while gymnastics had a significantly higher number of athletes in low competing levels. Through variable indexes, there was no significant difference seen within Group IB (Table 7). Groups IC, IIC, and IIIA showed significant higher training volumes at the high competing level than in low. With regard to nominal indexes, no significant relationship between competitive level and other nominal indexes was

Table 4 Correlation of variable indexes in Group IIIA

	Age (years)	Height (cm)	Weight (kg)	Age of menarche (years)	Training hours (hours)	Training frequency (days/week)	Training hours in 1 week (hours)	Age starting sports (years)
Age	1							
Height	0.166	1						
Weight	–0.031	0.551**	1					
Age of menarche	0.125	–0.144	–0.181*	1				
Training hours	–0.093	–0.174	0.147	0.073	1			
Training frequency	0.083	0.019	–0.02	0.051	0.482**	1		
Training hours in 1 week	–0.025	–0.128	0.071	0.083	0.912**	0.778**	1	
Age starting sports	–0.004	0.034	0.066	–0.230**	–0.149	–0.223**	0.205*	1

Note: *$P<0.05$, **$P<0.01$.

Table 5 Relationships by sports intensity classifications (Mitchell JH, 2005)

			Group				
			IB (n=79)	IC (n=69)	IIB (n=37)	IIC (n=208)	IIIA (n=134)
Experience of amenorrhea	Yes	Count	11	15	19	33	26
		% Within total	2.10%	2.80%	3.60%	6.30%	4.90%
		Adjusted residual	−1.4	0.4	5.0*	−1.8	−0.1
	No	Count	68	54	18	175	108
		% Within total	12.90%	10.20%	3.40%	33.20%	20.50%
		Adjusted residual	1.4	−0.4	−5.0*	1.8	0.1
Meal attitude	3 meals/day, well balanced	Count	21	25	18	81	33
		% Within total	3.98%	4.74%	3.42%	15.37%	6.26%
		Adjusted residual	−1.5	0.5	2.0*	2.0*	−2.6*
	Just 3 meals/day	Count	29	26	8	48	41
		% Within total	5.50%	4.93%	1.52%	9.11%	7.78%
		Adjusted residual	1.7	1.7	−1	−2.4*	0.5
	Mainly 3 meals/day, sometimes 2 meals	Count	24	17	11	66	52
		% Within total	4.55%	3.23%	2.09%	12.52%	9.87%
		Adjusted residual	−0.4	−1.5	−0.3	−0.2	1.9
	Mainly less than 2 meals/day	Count	5	1	0	13	8
		% Within total	0.95%	0.19%	0.00%	2.47%	1.52%
		Adjusted residual	0.5	−1.5	−1.5	0.9	0.5
Weight reduction	Frequently over 5 kg	Count	0	1	1	2	6
		% Within total	0.00%	0.19%	0.19%	0.38%	1.14%
		Adjusted residual	−1.3	−0.3	0.4	−1.3	2.5*
	Frequently around 1–2 kg	Count	33	28	20	76	83
		% Within total	6.26%	5.31%	3.80%	14.42%	15.75%
		Adjusted residual	−0.7	−0.9	1.1	−3.4*	4.4*
	Never tried	Count	46	40	16	130	45
		% Within total	8.73%	7.59%	3.04%	24.67%	8.54%
		Adjusted residual	1.1	1	−1.2	3.7*	−5.7*
History of stress fracture	Yes	Count	18	16	15	32	24
		% Within total	3.42%	3.04%	2.85%	6.07%	4.55%
		Adjusted residual	0.7	0.7	3.3*	−2.1*	−0.7
	No	Count	61	53	22	176	110
		% Within total	11.57%	10.06%	4.17%	33.40%	20.87%
		Adjusted residual	−0.7	−0.7	−3.3*	2.1*	0.7

Note: *$P<0.05$. Data from Mitchell et al.[15]

seen in Groups IB, IIC, and IIIA (Tables 8 and 9). Within GTG comparisons (comparisons between each of the groups), a significantly higher number of athletes were in the high competitive level in Groups IB and IIIA while Groups IC and IIC were significantly lower (Table 10).

Competitive level does not specifically increase menarche age at higher levels in groups, but lower competitive levels experience more amenorrhea

With respect to age of menarche, there was a general increase as competitive level increased which was seen only in overall comparisons but not in our intensity-classified groups.

Within each sport, there was no significant relationship seen between current menstrual status and competitive level. However, in comparisons through classification of intensity level groups, Groups IC and IIC showed a significant relationship between menstrual status and the competitive level (Table 11). The number of athletes in all groups but IIC who currently had a regular menstrual cycle was significantly higher at high competing levels while the number of low competing level athletes was significantly higher in menstrual irregularities (including oligomenorrhea, amenorrhea, and polymenorrhea). Additionally, the number of athletes with past experience of amenorrhea was significantly higher in lower competing levels while the number of athletes in high competing levels was significantly lower in all athletes (Fisher's exact test, $P<0.001$; Table 12). A notable exception to this finding exists: Athletes in the high competing level of Group IC had significantly higher numbers of athletes who experience amenorrhea (Fisher's

Table 6 Comparison in LTH

	Competing level	Number of athletes	Age (years)	Height (cm)	Weight (kg)	Age of menarche (years)	Training hours in 1 week (hours)	Age of starting sports (years)
All	High	258	19.7±0.9	161.1±6.3	55.8±7.1	13.3±1.6*	18.1±6.1*	7.4±1.9*
	Low	273	19.7±1.0	160.3±5.8	55.2±6.2	13.0±1.4*	15.1±6.1*	8.0±2.1*
Volleyball	High	58	19.7±1.1	164.0±6.5	60.0±7.1	13.1±1.6	18.4±3.2	8.1±1.6
	Low	7	18.7±0.8	167.0±6.6	62.8±8.6	12.3±1.4	18.0±3.5	7.7±1.5
Badminton	High	6	19.5±0.8*	159.0±2.5	58.1±5.4*	12.2±1.7	18.0±3.8	8.7±0.5
	Low	11	20.4±1.0	159.5±4.6	52.4±2.1*	12.7±1.0	15.6±3.1	7.5±2.9
Soccer	High	2	19.5±0.7	157.1±2.7	49.7±5.2	12.5±0.7	12.0±0	6.0±0
	Low	30	19.6±1.0	158.8±4.2	53.2±4.1	12.9±1.9	13.0±2.3	7.4±2.0
Field events (jumping)	High	18	19.3±0.6	166.3±7.1*	54.2±6.4	13.1±1.3	17.1±2.5	8.0±2.4
	Low	12	19.6±1.2	160.6±5.9*	53.2±4.4	12.8±1.4	16.5±3.1	9.2±3.6
Running (sprint)	High	4	19.3±1.5	163.8±6.1	53.6±6.4	13.3±1.5	17.5±2.9	6.8±3.6
	Low	3	20.7±0.6	160.9±4.1	51.1±6.4	12.3±1.5	16.7±2.9	9.0±1.0
Basketball	High	27	20.2±1.0	164.1±7.0	60.5±5.5	13.3±1.7	17.2±3.4*	8.1±1.2
	Low	86	19.6±0.9	162.9±5.3	58.3±5.4	13.0±1.1	15.3±4.0*	8.1±1.5
Lacrosse	High	5	19.8±1.1	158.4±3.7	54.4±3.5	13.4±1.5	18.0±4.5	8.6±2.8
	Low	24	20.0±0.9	160.7±5.3	54.5±5.3	13.4±1.3	15.1±4.3	9.5±2.1
Running (middle distance)	High	2	20.5±0.7	159.0±4.2	49.7±2.3	13.5±2.1	12.5±3.5	8.5±0.7
	Low	6	19.7±1.0	160.2±4.2	51.3±4.1	13.0±1.4	20.8±5.4	8.5±2.4
Swimming	High	26	19.8±0.7	160.4±5.5	54.3±6.0	13.1±1.1	22.1±8.2	6.2±0.8
	Low	7	19.3±0.8	161.1±5.7	54.1±6.1	12.6±1.4	15.7±8.0	6.7±1.5
Rescue swimming	High	7	19.7±1.0	160.7±4.5	57.1±9.3	13.1±1.1	7.6±4.2	7.6±2.1
	Low	18	20.1±1.1	159.3±5.7	57.1±5.8	12.8±1.8	10.1±5.0	8.5±2.1
Field events (throwing)	High	3	19.0±1.0	162.7±3.2	71.3±7.8	12.0±1.0	21.7±2.9	7.7±2.1
	Low	4	19.3±0.5	162.3±4.2	62.8±5.6	12.3±1.9	21.3±2.5	6.8±1.0
Gymnastics	High	22	19.8±1.0	155.0±4.4	51.2±4.3	14.6±1.5	22.0±9.4	5.4±1.8*
	Low	21	19.6±1.0	152.7±3.8	50.2±3.6	14.3±1.3	17.7±12.4	7.6±2.8*
Cheerleading	High	19	19.6±0.8	158.4±4.3	53.1±6.3	13.7±1.6	20.5±1.4	7.3±2.1
	Low	5	19.0±0.0	154.9±7.7	57.0±8.7	12.4±1.1	21.0±2.2	7.8±2.8
Modern dance	High	32	19.6±1.1*	159.0±4.6	50.9±5.2	13.3±1.7	14.6±5.4*	6.7±1.5
	Low	8	18.6±0.5*	159.3±6.4	52.0±6.8	13.8±0.7	8.6±6.2*	6.8±1.4
Sport dance	High	9	19.0±0.5	161.1±4.1*	54.8±4.3*	13.4±1.4	14.1±11.8	7.7±2.2
	Low	11	19.9±0.7	157.6±3.6*	49.7±3.9*	13.3±0.9	9.1±7.8	7.0±1.9

Note: *$P<0.05$ between high and low competing level in each sports.
Abbreviation: LTH, low-to-high.

exact test, $P=0.026$), which was completely opposite to the result seen in all athletes.

Higher competitive levels do not generally correlate to musculoskeletal injuries or stress fractures and do not impact nutrition choices

Generally, the effect of competitive level on musculoskeletal injuries, especially stress fractures, was not significant in all athletes. However, in Group IIC (Table 9), lower competitive levels had higher numbers of athletes with injuries, but not stress fractures, and in Group IIB (Table 8), athletes who did have injuries were more likely to have stress fractures. This counterintuitive relationship between low and high competitive level was seen only in Group IIC sports.

From the intensity-based classifications, Group IIC was the only group to show a significant relationship between competing level and meal attitude (Table 9). Athletes in the high competing level in this group had a significantly higher number of athletes who usually have well-balanced meals, while the number of athletes in low-level competition significantly chose less well-balanced meals ($P=0.017$).

Competitive levels within each sport significantly affect other variables such as starting age and height

In high competitive level Group IB and IIIA sports, Group IIIA was significantly lower in starting age compared with other groups including the control group. Within Group IIIA, we found that the starting age in artistic

Table 7 Comparison in STG

			Competing level		*P*-value
			High	**Low**	
Group IB	Fencing	Count	14	0	0.24
		% Within Group IB	17.70%	0.00%	
		Adjusted residual	1.3	−1.3	
	Volleyball	Count	58	7	
		% Within Group IB	73.40%	8.90%	
		Adjusted residual	−1.3	1.3	
Group IC	Badminton	Count	6	11	0.017
		% Within Group IC	8.80%	16.20%	
		Adjusted residual	3.1*	−3.1*	
	Running (long distance)	Count	1	7	
		% Within Group IC	1.50%	10.30%	
		Adjusted residual	−0.1	0.1	
	Tennis	Count	0	11	
		% Within Group IC	0%	16.20%	
		Adjusted residual	−1.4	1.4	
	Soccer	Count	2	30	
		% Within Group IC	2.90%	44.10%	
		Adjusted residual	−1.6	1.6	
Group IIB	Field events (jumping)	Count	18	12	0.606
		% Within Group IIB	48.60%	32.40%	
		Adjusted residual	0.1	−0.1	
	Running (sprint)	Count	4	3	
		% Within Group IIB	10.80%	8.10%	
		Adjusted residual	−0.1	0.1	
Group IIC	Basketball	Count	27	86	<0.001
		% Within Group IIC	13.00%	41.30%	
		Adjusted residual	−2.8*	2.8*	
	Lacrosse	Count	5	24	
		% Within Group IIC	2.40%	11.50%	
		Adjusted residual	−1.9	1.9	
	Running (middle distance)	Count	2	6	
		% Within Group IIC	1%	2.90%	
		Adjusted residual	−0.4	0.4	
	Swimming	Count	26	7	
		% Within Group IIC	12.50%	3.40%	
		Adjusted residual	6.2*	−6.2*	
	Rescue swimming	Count	7	18	
		% Within Group IIC	3.40%	8.70%	
		Adjusted residual	−0.5	0.5	
Group IIIA	Field events (throwing)	Count	3	4	0.006
		% Within Group IIIA	2.20%	3.00%	
		Adjusted residual	−1.2	1.2	
	Gymnastics	Count	22	21	
		% Within Group IIIA	16.40%	15.70%	
		Adjusted residual	−2.0*	2.0*	
	Cheerleading	Count	19	5	
		% Within Group IIIA	14%	3.70%	
		Adjusted residual	1.8	−1.8	
	Modern dance	Count	32	8	
		% Within Group IIIA	23.90%	6.00%	
		Adjusted residual	2.6*	−2.6*	
	Dance sports	Count	9	11	
		% Within Group IIIA	6.70%	8.20%	
		Adjusted residual	−1.9	1.9	

Note: *$P<0.05$.
Abbreviation: STG, sport-to-group.

Table 8 Comparison in STG in variable indexes

	Group									
	IB (n=79)		IC (n=69)		IIB (n=37)		IIC (n=208)		IIIA (n=134)	
	High	Low	High	Low	High	Low	High	Low	High	Low
Age (years)	19.6±1.0	18.7±0.8	19.5±0.7	19.8±1.1	19.3±0.8	19.8±1.2	20.0±0.1	19.7±0.1	19.6±1.0	19.4±0.9
Height (cm)	163.1±6.5	167.0±6.6	157.6±3.5	158.9±4.2	165.8±6.8*	160.6±5.5	161.7±0.8	161.9±0.5	158.2±4.8*	155.9±5.6
Weight (cm)	59.1±7.1	62.8±8.6	54.9±6.1	52.8±4.8	54.1±6.3	52.8±4.7	57.0±0.8	57.0±0.5	52.6±6.4	52.1±6.2
Training volume (hours/week)	18.6±3.1	18.0±3.5	16.8±3.8*	15.3±4.3	17.2±2.5	16.5±3.0	18.0±0.9*	14.9±0.4	18.0±7.7*	14.9±10.4
Age of menarche (years)	13.1±1.6	12.3±1.4	12.3±1.3	12.8±1.6	13.1±1.3	12.7±1.3	13.2±0.2	13.0±0.1	13.7±1.7	13.6±1.4
Age starting sports	8.2±1.6	7.7±1.5	8.4±1.7	7.6±2.2	7.8±2.6	9.1±3.2	7.4±0.2*	8.4±0.2	6.6±2.0	7.3±2.3

Note: *$P<0.05$ between high and low competing levels in each group.
Abbreviation: STG, sport-to-group.

gymnastics was significantly lower than that in volleyball (IB), badminton, tennis and soccer (IC), jumping (IIB), basketball (IIC), swimming and rescue swimming (IIC), throwing (IIIA), and controls. Additionally, Groups IIB and IIIA showed a significantly higher height at the higher competing level than at the lower level.

Discussion

In this study, we surveyed 531 Japanese collegiate athletes against 20 non-active control students to investigate the risk of FAT with regard to sports intensity level, sports type, and competing level. We aimed to identify which of the accepted FAT risk factors were correlated to the intensity and training volume of various sports in a Japanese collegiate female population. Additionally, as there are no current reports of the effect of competitive level on FAT risk at the college level in Japan, our secondary aim was to see how this variable impacted FAT risk factors in our respondents.

Comparisons across different sports can be treacherous; however, similarities in movement, objective, and kinesthetic demand can be exploited to create groups of roughly similar sports. We took advantage of this by grouping our sports according to the Jere classification method.[15] We were then able to effect analyses with regard to intensity and training volume to see if correlations with FAT risk factors existed. However, to avoid bias from the limitations of GTG comparisons, we also looked at each sport compared to the others within its group and added a comparative category in which competitive levels (low or high) in each sport could be analyzed for links to FAT risk factors. Our results in sports intensity and training volume are in line with other reports. One previous study reported that the training volume (hours per week) was highest in athletes who are competing in esthetic sports (which includes Group IIIA in our study) compared with power, technical, anti-gravitation, and ball game sports.[23] However, Group IIB sports types (which showed the highest training volume in our study) were classified into different groups in this previous report, showing swimming and lifesaving as anti-gravitation sports, and basketball as ball game sports.[23] Group IIIA showed a significantly higher age of menarche compared with other groups, including controls, and the control group was significantly lower than Groups IB, IIB, IIC, and IIIA. These results are in line with previous reports that the average menarche age in athletes is higher than nonathletes.[24] With regard to menarche age by sport types, the earliest was tennis (12.2±1.0 years old) while the latest was artistic gymnastics (14.5±1.4 years old). These esthetic sports are high-intensity sports which place

Table 9 Competing level and the history of amenorrhea in Group IC

			Competing level	
			High	Low
History of amenorrhea	Yes	Count	9	31
		% Within Group IC	13.00%	44.90%
		Adjusted residual	2.2*	–2.2*
	No	Count	1	28
		% Within Group IC	1.40%	40.60%
		Adjusted residual	–2.2*	2.2*

Note: *$P<0.05$.

Table 10 Significant relationship with competing level in Group IIC

			Competing level	
			High	Low
Current menstrual cycle	Regular	Count	58	134
		% Within Group IIC	27.90%	64.40%
		Adjusted residual	–2.1*	2.1*
	Delayed	Count	9	7
		% Within Group IIC	4.30%	3.40%
		Adjusted residual	2.1*	–2.1*
Meal attitude	3 meals/day, well balanced	Count	36	45
		% Within Group IIC	17.30%	21.60%
		Adjusted residual	3.0*	–3.0*
	Just 3 meals/day	Count	14	34
		% Within Group IIC	6.70%	16.30%
		Adjusted residual	–0.5	0.5
	Mainly 3 meals/day, sometimes 2 meals	Count	15	51
		% Within Group IIC	7.20%	24.50%
		Adjusted residual	–2.0*	2.0*
	Mainly less than 2 meals/day	Count	2	11
		% Within Group IIC	1.00%	5.30%
		Adjusted residual	–1.3	1.3
History of injuries	Yes	Count	46	114
		% Within Group IIC	22.10%	54.80%
		Adjusted residual	–2.0*	2.0*
	No	Count	21	27
		% Within Group IIC	10.10%	13.00%
		Adjusted residual	2.0*	–2.0*

Note: *$P<0.05$.

excessive demands on athletes to maintain low body fat, weight restriction, and heavy intensity training from a very young age.[25–28] Similarly, a study in female top competing level athletes reported that the menarche age of athletes in esthetic sports (14.5±2.0 years old) was higher than other sport types such as technical skill/endurance sports, ball sports, power sports, and weightlifting sports.[29]

In our study, the starting age in artistic gymnastics (Group IIIA) was significantly lower than that in volleyball, field events (jumping), basketball, lacrosse, and lifesaving, while the starting age in cheerleading and sports dance was significantly higher than that in lacrosse, and that in modern dance was significantly lower than in field events (throwing), basketball, and lacrosse, which strongly supports information from previous reports.[30,31] Esthetic and near-esthetic sports such as artistic gymnastics, rhythmic gymnastics, dance, figure skating, modern dance, and swimming are generally known as "early-entry sports"[30,31] which typically require early specialization and high intensity during prepubescent stages.[32] Group IIB (which includes jumping and sprint) showed a higher level of amenorrhea compared with other groups. There are some reports on sports that require horizontal (eg, running and long jump) or vertical (eg, high jump, gymnastics) movements of the body where excessive fat

Table 11 Competing level in GTG

			Groups				
			IB (n=79)	IC (n=69)	IIB (n=37)	IIC (n=208)	IIIA (n=134)
Competing level	High	Count	72	10	22	67	85
		% Within group	13.60%	1.90%	4.10%	12.60%	16.00%
		Adjusted residual	8.2*	–6.1*	1.4	–6.1*	4.0*
	Low	Count	7	59	15	141	49
		% Within group	1.30%	11.10%	2.80%	26.60%	9.20%
		Adjusted residual	–8.2*	6.1*	–1.4	6.1*	–4.0*

Note: *$P<0.05$.
Abbreviation: GTG, group-to-group.

Table 12 Relationship between menstrual status and competing level

			Competing level		***P*-value (Fisher's exact test)**
			High	**Low**	
Current menstrual cycle	Regular	Count	206	196	0.034
		% Within competing level	51.20%	48.80%	
		Adjusted residual	2.2*	–2.2*	
	Irregular	Count	52	77	
		% Within competing level	40.30%	59.70%	
		Adjusted residual	–2.2*	2.2*	
Experience of amenorrhea	Yes	Count	89	122	0.017
		% Within competing level	16.80%	23.00%	
		Adjusted residual	–2.4*	2.4*	
	No	Count	169	151	
		% Within competing level	31.80%	28.40%	
		Adjusted residual	2.4*	–2.4*	

Note: *$P<0.05$.

mass is considered a disadvantage,[33,34] which may lead to low body fat, weight, and menstrual irregularities.[23] As a highly dynamic sport, it could negatively affect regular menstrual periods, especially in young Japanese women.[35]

Taken together, these results indicate a significant relationship between intensity and delay of menarche; training volume is less a factor than the actual intensity of the sport type itself. Interestingly, starting age is negatively correlated to menstrual irregularities, meaning that intensity of the sport type is more important.

With regard to injuries, both the intensity of training and the amount of training time may affect susceptibility, even without menstrual irregularities. Musculoskeletal injuries may be either traumatic (broken bones, torn muscles) or chronic injuries brought about by repetitive motion and insufficient recovery time. We found that sports which are relatively restricted in dynamic movement (running, jumping, etc.) had a significantly higher reporting of severe musculoskeletal injuries. We also found that the overwhelming type of injury for athletes who have experienced severe musculoskeletal injury requiring more than 3 days of rest is the stress fracture (Fisher's exact test, $P<0.01$). This is troubling, as this type of injury is highly indicative of repetitive motion injury. In almost all sports, with the exception of the heptathlon, the range of motion is restricted by the demand of the sport itself and it is possible that the cross-training schemes of heptathletes is somehow protective against stress fractures. These data indicate that, in sports with lower dynamic movement demands, cross-training methods (eg, plyometrics) involving complimentary musculoskeletal groups may serve a protective role against repetitive motion injuries.

Nutrition is the cornerstone of sports and many diets, both fad and medically approved, that exist to provide the optimum concentration of nutrition and calories to build strength, stamina, and recovery. However, the culture and attitudes of the athletes within each sport will determine overall nutrition. In Japan, sports nutrition has been poorly studied among collegiate female students[36,37] and while there are also a few English-language reports on the impact of nutrition in athletes, they are not at the university level.[38–41] Furthermore, it has been reported in Japan (and other countries) that the actual level of support in sports nutrition is still poor and the awareness of the importance of nutrition intake among athletes and coaching staff is not always sufficient.[42–44] Fortunately, as Japan's nationalized school system teaches Ministry of Health-approved guidelines on meal composition and frequency, we were able to assume that all survey participants were aware of "healthy" nutrition guidelines and that any deviation from them was a conscious choice brought about by either the culture of the sport/coaches or a personal decision based on athletic goals. In general, we found that intense sports (Group IIIA) had lower frequencies of well-balanced meals while endurance athletes (Groups IIB and IIC) reported higher levels of well-balanced mealtimes. Additionally, Group IIIA athletes were found to have more frequently tried intentional weight loss diets. As Group IIIA sports are primarily short-twitch, energy burst-type sports that demand maximum strength-to-weight ratios, it could be that this kinesthetic pressure, in addition to pressure from peers and coaching staff, results in skipped or unbalanced meals.[45–47] Likewise, the intensive need for long-twitch endurance and sustained energy release in Group IIB and

IIC sports, coupled with long training sessions, drive those athletes toward well-balanced mealtimes.[48] These results are in line with reports from other countries. In Australian female elite athletes, endurance sports participants (including distance runners and swimmers) showed a higher energy intake against weight-conscious groups (including gymnasts) reporting low energy intakes.[49] In a study among elite Greek female aquatic athletes reported to have inadequate energy intake, the poor diets were considered to be healthy and well balanced.[50] Furthermore, athletes in non-lean sports tend to be healthier and have fewer eating problems than did nonathletes.[51] However, it has been also reported that race/ethnicity is related to eating disorder classifications[52] as ethnic/cultural perceptions of ideal body shapes and desire for thinness may vary highly.[53]

The trend of potential malnutrition in Group IIIA athletes is troubling, as skeletal, neurological, endocrine, reproductive, and muscular development could impact Group IIIA athletes at a much greater frequency than the general population. Based on our data, we would recommend that coaching staff retrain and focus Group IIIA athletes on the fundamentals of nutrition in an accountable manner.

The effects of competitive level on FAT factor risks

After finding that our intensity/training volume effects on FAT factor risk were in line with reports from other countries, we next sought to establish previously unreported links between competitive levels and menarche age/amenorrhea, musculoskeletal injury, and nutrition choices. A study in Japan reported that the rate of amenorrhea was 6% in female top competing level athletes and was higher than in nonathletes.[6] Other studies in Japanese female top competing level athletes reported that 59.3% athletes had regular menstrual cycles while 32.9% of athletes had menstrual dysfunction (including 7.8% athletes with secondary amenorrhea).[54] In our study, athletes with irregular menstrual status were up to nearly 30% and athletes with secondary amenorrhea were 5.6%, which was quite similar to the previous reports. As our own data were similarly reflective of this phenomenon, we then made comparisons based solely on competitive level. To avoid bias that would come from simply evaluating groups, we also used comparisons within each sport (LTH), each sport to its own group (STG), and each group to other groups (GTG). In this way, we hoped to establish a baseline of identification for sport types and groups in which competitive influence on FAT exists.

With regard to menarche and competitive level, we found an overall trend of higher competitive level resulting in higher menarche ages though this effect disappeared in the group comparisons. We believe this is due to sport intensity and the aforementioned hormonal imbalances associated with intense/high-volume training being the key factors in delayed menarche.[55] Competitive level, in the face of intense training and possible nutritive deficiencies, may simply be a complicating secondary factor.

However, with respect to competitive levels and amenorrhea, we found that the lower levels within groups had more menstrual irregularities as opposed to their highly competitive counterparts (with the exception of IC, where high competition correlated to more menstrual irregularities). We theorize that this unusual finding may be due to a "veteran effect," where higher levels of competition effectively filter out athletes whose bodies experience amenorrhea; these unadaptable athletes would be then forced to compete either at low levels or quit entirely. In Group IC, which includes endurance sports such as running and race walking, the effect of constant body fat mobilization may induce hormonal cascades that adversely affect menstruation at the higher competitive levels.

Next, we looked at the effect of competitive levels on musculoskeletal injuries and found no general correlation between them. However, we did see that, in Group IIC, the lower competitive levels had higher injury numbers (but not stress fractures) and, in Group IIB, the preponderance of injuries suffered was stress fractures. As field events like jumping and sprinting cause microfractures that may worsen due to the repetitive nature of those sports, it has been reported that these athletes are at a higher risk of stress fractures.[56] Group IIC sports included team sports such as basketball and lacrosse as well as swimming and rescue swimming. At the lower level in these sports, higher injuries might be due to the relative inexperience of the athletes but the fact that the stress fracture is less common than other types of injuries could be explained by either the lack of impact (eg, swimming) or the constant, low-level motion required to follow the ball (basketball, lacrosse) or stay with the pack (mid-distance running).

As nutrition and body fat percentage are thought to be key factors in developing FAT,[5] we analyzed possible relationships between competitive level and nutrition choices. Within the groups, only IIC showed a correlation between competing level and positive nutrition choices. Within the individual sports, lacrosse players were most likely to often eat well-balanced meals. This could be explained by the need for a large store of energy to draw from while running at medium distances. Lacrosse and basketball sports in particular have a stop-and-go model where high-intensity bursts are interspersed into long bouts of lower level physical motion; research has shown these athletes have a high requirement for easily utilized carbohydrate energy.[57]

Interestingly, competitive levels did affect variables such as starting ages of sports and the average heights of the athletes. Higher starting ages were seen in higher levels of competition in Groups IB and IIIA sports. Within these groups, Group IIIA sports such as artistic gymnastics had a much higher starting age than had other sports such as volleyball or basketball. The musculoskeletal demands of gymnastics may require a higher starting age as coordination and motor skills are selective pressures in this sport.[58] As for height, fencing, volleyball, and throwing naturally require either longer reach (fencing), ability to reach over the net (volleyball), or body height/weight as leverage (throwing) but the scoring demands of Group IIIA sports may mean that, within the sport itself, the competitive pressure selects for taller and more "graceful" athletes.[59] Interestingly, basketball, which would be expected to have taller athletes, was not enough to lift Group IIC into significance when compared with other groups. However, as basketball is a team sport, shorter athletes who have power and skill may be able to compensate for height disadvantage and not every position on the team requires exceptional height in women's basketball. In fact, Japanese female athletes, in general, would not be expected to be more than 169 cm at maturity (only 0.3% of the population would exceed this mark), thereby selecting more for power and skill than pure height.[60]

Limitations

Several limitations of this must be acknowledged. First, no actual diagnoses of FAT risk factors were clinically conducted; relationships to risk factors were calculated based solely on survey responses. Second, surveys were not collected at the immediate end of each season and medical records for each of the athletes were not consulted to verify answers. Overreliance on the recollections and self-reports of athletes may have introduced errors into our data. We also did not measure menstrual cycles or monitor estrogen levels within athletes during the study, relying solely on questionnaires, which may not capture a complete picture of injury risk during the various phases of the cycle. Finally, comparisons that isolate relationships between variables may conceal multivariable relationships. However, to the best of our knowledge, this is the first report of its kind with a large sample size that examines the parameters of Japanese female collegiate athletes with respect to FAT and will serve as a foundational report upon which to build future prospective studies featuring clinical validation of FAT risk factors.

Conclusion

We found that Japanese collegiate athletes experience the FAT risk factors (delayed menarche/amenorrhea, musculoskeletal injury, and poor nutrition) in a manner correlated with the intensity of their sport types and, to a lesser extent, the volume of training endured. Of particular note is the trend of repetitive motion injury in endurance/non-dynamic sports. Additionally, we also found some correlation between lower competitive levels and delayed menarche/amenorrhea. However, in general, competitive level had no effect on musculoskeletal injury or nutrition choice. Taken together, our results highlight the need for coaching staff and universities to adjust sport rules and expectations to compensate for the higher risks of FAT in athletes subjected to high intensity, high training volume, and highly competitive sports.

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Author contributions

All authors contributed towards data analysis, drafting and revising the paper and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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