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Analysis of Regional Differences in Bone Mineral Density Acquisition Factors in Young Women

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Abstract

Purpose: Obtaining high peak bone mass (PBM) and maintaining bone mass is important for the prevention of osteoporosis. This study aimed to examine the regional differences in bone mineral density and factors associated with its acquisition from exercise. **Design:** The study population included 75 women of 18 - 22 years of age in East Japan and 104 women of 18 - 27 years of age in West Japan. The speed of sound (SOS) of the calcaneus was measured, and the young adult mean (%YAM) was calculated from the SOS. The subjects' medical history, family history of osteoporosis, and exercise habits were examined using a self-administered questionnaire. **Results:** There were a significantly greater number of subjects with low %YAM in West Japan. The exercise history and exercise time were significantly higher in West Japan, and the exercise intensity score tended to be higher in East Japan during junior high and high school. A multiple regression analysis by region revealed that the following factors had a significant positive association with the SOS: exercise intensity at elementary school and outdoor sports at junior high school in East Japan; and exercise time at elementary school, muscle mass, and outdoor sports at junior high school in West Japan. On the other hand, exercise time in junior high school in West Japan showed a negative association with the SOS. **Conclusions:** Regional differences in bone mineral density existed, suggesting a trend toward lower bone mineral density in West Japan. Exercise history and time tended to be higher in West Japan, and exercise intensity scores tended to be higher in East Japan, suggesting that exercise intensity may be more important than exercise time for obtaining bone mineral density.

Keywords

Bone Mineral Density, Exercise Intensity, Region Differences, Young Women

1. Introduction

Osteoporosis was defined as "a skeletal disorder characterized by compromised bone strength predisposing to an increased risk of fracture" at a consensus conference by the National Institutes of Health in 2000 [1]. Bone mineral density increased through puberty. Thereafter, with menopause and aging, bone resorption by osteoclasts exceeds bone formation by osteoblasts, and bone density declines. To prevent osteoporosis, it is necessary to obtain a higher peak bone mass (PBM) and maintain bone mass at a young age. Increasing PBM is considered important because it has been reported that an increase in PBM prolongs the onset of osteoporosis [2].

Environmental factors have been described in several reports on the effects of exercise [3] [4] [5], but no unified view has been obtained [6] [7] [8] [9]. In addition, exercise intensity, which takes into account the impact on bones, has been reported to be important [9] [10] [11], but few studies quantifying exercise intensity have been found.

Regional studies of bone mineral density in Japan have been conducted in Kochi Prefecture, which analyzed urban districts, mountainous towns and villages, and coastal towns and villages [12], but the factors responsible for the regional differences have not been examined. Furthermore, there are no studies investigating differences in bone mineral density and factors for acquiring bone mineral density by region in Japan.

The purpose of this study was to examine regional differences in bone mineral density and its factors associated with acquiring bone mineral density from exercise in young age with the highest PBM and in women with a high risk of developing osteoporosis.

2. Methods

2.1. Subjects

The survey was conducted in the East Japan region and the West Japan region, and comparisons were made. In East Japan, 136 women of 18 - 22 years of age were surveyed in June 2019. After excluding responses with missing or abnormal data and subjects with a history of renal disease, which is thought to be involved in bone metabolism, 75 valid responses remained. In West Japan, 115 women of

18 - 27 years of age were surveyed in November 2018, after applying the above-mentioned exclusion criteria 104 valid responses remained. The present study was approved by the Ethics Committee of Epidemiological Studies at Yamagata Prefectural Yonezawa University of Nutrition Sciences.

2.2. Survey Description

The survey was conducted between November 2018 and June 2019. The subjects' medical history, family history of osteoporosis, exercise history and exercise time were investigated using a self-administered questionnaire survey. In the East Japan Survey, height and weight were ascertained by responses to a self-administered questionnaire survey, and sports tests, including grip strength measurement, squat jump (SJ), and counter movement jump (CMJ). SJ consisted of jumping upward from a knee flexion angle of 90˚. In the CMJ, the participants jumped upward from a standing position with a recoil motion. In the West Japan survey, height, weight, muscle mass, and body fat percentage were measured. In the exercise survey, the subjects were divided into the following categories: elementary school/junior high school/high school/high school graduate and onward, and asked to indicate the type of exercise and exercise time (hours/day, times/week, and months of continuous exercise) during each period. Exercise time and intensity scores were analyzed after the exclusion of data after high school graduation. In addition, to further explore the influence of vitamin D production from the duration of sunshine, exercise activities were classified into two groups: outdoor sports and other sports (**Table 1**). Exercise activities were classified into five categories according to the intensity of impact on the bone, based on the article by Gotzone Hervas *et al.* [13] [14] (**Table 2**). In that classification, the exercise event group with the highest intensity of exercise was quantified as 5 points, and the exercise event group with the lowest intensity of exercise was quantified as 1. The scores were defined as follows: 5 points, high-impact events involving vertical jumps and ground impact; 4 points, events involving rapid turns and stops with ground impact; 3 points, events involving slow and well-coordinated movements that apply maximal muscle force without ground impact; 2 points, events involving ground impact during long-lasting performances at a relatively constant speed; 1 point, a prolonged exercise event with no impact. For those who performed more than one type of exercise, a point scoring system was used.

Table 1. Outdoor sports classification.

	Sports event
Outdoor Sports	athletics, tennis, skiing, softball or baseball, soccer, cycling, golf, farming, archery, rowing, futsal
Other Sports	swimming, badminton, volleyball, basketball, karate, judo, kendo, handball, gymnastics, fencing, dance, beauty and flexibility exercises, muscle training, naginata, classical ballet, ballet, rhythmic gymnastics, Japanese dance, table tennis, cheerleading, yoga, theater, light exercise, Japanese drumming, yosakoi, aerobics, shorinjikenpo, aikido

Table 2. Exercise intensity classification.

Exercise intensity points	Exercise events
5	volleyball, basketball, handball, classical ballet, ballet, rhythmic gymnastics, cheerleading
4	soccer, tennis, badminton, karate, judo, kendo, softball/baseball, gymnastics, fencing, dance, naginata, yosakoi, futsal, syourinzikenpo, aikido
3	—
2	athletics, golf, farming, Japanese drumming, table tennis, aerobics
1	swimming, skiing, beauty and flexibility, muscle training, cycling, yoga, theater, light exercise, archery, rowing, Japanese drum

Bone mineral density was measured using a CM-200 bone ultrasonometer of quantitative ultrasound measurement (FURUNO, Japan), and the speed of sound (SOS) was measured. In addition, the young adult mean (YAM) was calculated from the SOS. The SOS was analyzed using the median value for each region, dividing the population into two groups: above the median (high SOS group) and below the median (low SOS group). The YAM was analyzed in two groups, >100 (high YAM group), and <100 (low YAM group).

2.3. Statistical Analysis

Data were analyzed using BellCurve for Excel and SPSS version 25 (IBM Corp. JPN). Correlation coefficients were calculated for the relationship between the two variables. A t-test was used to test for differences in means between groups. The χ-square test was used to test for differences in frequency. Multiple regression analysis was also performed with SOS as the dependent variable and factors related to SOS as explanatory variables. All significance levels in the tests were less than 5%.

3. Results

3.1. Subject Characteristics

The age of the subjects was 19.0 ± 0.7 years in East Japan and 20.8 ± 1.9 years in West Japan. The SOS was 1557.1 ± 29.7 m/sec (median 1554 m/sec) in East Japan and 1549.2 ± 37.2 m/sec (median 1544 m/sec) in West Japan. YAM was 110.4% ± 16.7% in East Japan and 106.3% ± 20.5% in West Japan. The SOS and YAM in East and West Japan did not differ to a statistically significant extent. On the other hand, the χ^2 test of the high YAM and low YAM groups, showed that a significantly higher number of subjects were classified into the low YAM group in West Japan ($p < 0.01$) (Table 3).

There were no significant regional differences in family history of osteoporosis. However, the proportion of respondents with a family history of osteoporosis was higher in West Japan than in East Japan (Table 3). The analysis of the correlation between the SOS and survey items showed a significant positive correlation for SJ and CMJ in East Japan ($p < 0.05$), and for muscle mass in West Japan ($p < 0.01$) (Table 3).

Table 3. Subject characteristics and correlation with SOS (East/West Japan).

	East Japan (n = 75)		West Japan (n = 104)	
		SOS correlation		SOS correlation
Age	19.0 ± 0.7	−0.007	20.8 ± 1.9**	−0.175
Height (cm)	157.5 ± 4.9	0.001	157.9 ± 5.1	0.001
Body weight (kg)	51.0 ± 7.1	0.082	53.0 ± 7.2	0.137
BMI (kg/m^2)	20.5 ± 2.5	0.098	21.3 ± 2.8	0.137
SJ (cm)	21.6 ± 4.6	0.280*	—	
CMJ (cm)	23.2 ± 5.0	0.273*	—	
Right hand grip strength average (kg)	25.2 ± 4.4	0.1	—	
Left hand grip strength average (kg)	23.2 ± 4.6	0.184	—	
Muscle mass (kg)	—		36.0 ± 3.0	0.283**
Body fat percentage (%)	—		27.3 ± 5.4	−0.063
SOS (m/sec)	1557.1 ± 29.7		1549.2 ± 37.2	
%YAM (%)	110.4 ± 16.7		106.3 ± 20.5	
%YAM ≥ 100	58 (77.3)		61 (58.7)††	
<100	17 (22.7)		43 (41.3)	
No family history of osteoporosis	54 (96.4)		95 (91.3)	
Family history of osteoporosis	2 (3.6)		9 (8.7)	

Average ± standard deviation t-test and correlation *p < 0.05 **p < 0.01; %YAM n (%) χ-square test ††p < 0.01.

3.2. Relationship between Bone Density and Exercise

3.2.1. SOS/YAM and Exercise History

The number of respondents in East Japan and West Japan, respectively, who had a history of exercise was as follows: elementary school, 36 (48.0%) and 64 (61.5%); junior high school, 31 (41.3%) and 77 (74.0%); high school, 20 (26.7%) and 49 (47.1%); and after graduation from high school, 9 (12.0%) and 34 (32.7%). Overall, 47(62.7%) and 92 (88.5%) respondents had a history of exercise in East Japan and West Japan, respectively. The results of the χ^2 test for the presence/absence of a history of exercise in East and West Japan showed that significantly more respondents in West Japan had a history of exercise from junior high school to after high school graduation (p < 0.01) (Table 4).

The χ^2 test was performed separately for each region, dividing the respondents into two groups: high SOS/low SOS and high YAM/low YAM. The results showed that neither the SOS nor YAM was significantly associated in East Japan (Table 5). In West Japan, there were significantly more individuals with a history of physical activity in the high SOS group in junior high school and high school (p < 0.05). The high YAM group had a significantly higher percentage of respondents with a history of exercise in high school (p < 0.05) (Table 6).

Table 4. Experience of exercise/Outdoor sports experience/Exercise time/Exercise intensity (East and West Japan).

	East Japan (n = 75)	SOS correlation	West Japan (n = 104)	SOS correlation
Experience of exercise				
history of exercise in elementary school	36 (48.0)	—	64 (61.5)	—
no history of elementary school exercise	39 (52.0)	—	40 (38.5)	—
history of exercise in junior high school	31 (41.3)	—	77 (74.0)††	—
no history of junior high school exercise	44 (58.7)	—	27 (26.0)	—
history of exercise in high school	20 (26.7)	—	49 (47.1)††	—
no history of high school exercise	55 (73.3)	—	55 (52.9)	—
history of exercise after graduating from high school	9 (12.0)	—	34 (32.7)††	—
no exercise history after graduating from high school	66 (88.0)	—	70 (67.3)	—
history of exercise	47 (62.7)	—	92 (88.5)††	—
no history of exercise	28 (37.3)	—	12 (11.5)	—
Outdoor sports experience				
history of outdoor sports in elementary school	14 (18.7)	—	11 (10.6)	—
no outdoor sports history in elementary school	61 (81.3)	—	93 (89.4)	—
history of outdoor sports in junior high school	14 (18.7)	—	24 (23.1)	—
no outdoor sports history in junior high school	61 (81.3)	—	80 (76.9)	—
history of outdoor sports in high school	9 (12.0)	—	16 (15.4)	—
no outdoor sports history in high school	66 (88.0)	—	88 (84.6)	—
history of outdoor sports after graduation from high school	1 (1.3)	—	7 (6.7)	—
no outdoor sports history after graduation from high school	74 (98.7)	—	97 (93.3)	—
history of outdoor sports	25 (33.3)	—	39 (37.5)	—
no history of outdoor sports	50 (66.7)	—	65 (62.5)	—
Exercise time (h)				
Elementary school	106.6 ± 209.2	0.04	253.8 ± 325.6**	0.364**
Junior high school	199.4 ± 293.8	0.011	484.9 ± 409.9**	0.151
High school	122.0 ± 274.9	0.154	282.8 ± 348.9**	0.394**
Total	428.0 ± 592.1	0.091	1021.5 ± 828.9**	0.383**
Exercise intensity points				
Elementary school	2.7 ± 3.6	0.206	2.7 ± 2.7	0.260**
Junior high school	4.1 ± 5.9	0.088	2.9 ± 2.2	0.308**
High school	2.4 ± 4.8	0.126	1.8 ± 2.1	0.412**
Total	9.2 ± 11.1	0.169	7.4 ± 5.2	0.435**

n (%) $^{††}p < 0.01$; average ± standard deviation $^{**}p < 0.01$.

Table 5. Experience of exercise/Outdoor sports experience/Exercise time/Exercise intensity (East Japan).

	SOS		%YAM	
	≥Median (n = 38)	<Median (n = 37)	≥100 (n = 58)	<100 (n = 17)
Experience of exercise				
history of exercise in elementary school	20 (55.6)	16 (44.4)	28 (77.8)	8 (22.2)
no history of elementary school exercise	18 (46.2)	21 (53.8)	30 (76.9)	9 (23.1)
history of exercise in junior high school	16 (51.6)	15 (48.4)	23 (74.2)	8 (25.8)
no history of junior high school exercise	22 (50.0)	22 (50.0)	35 (79.5)	9 (20.5)
history of exercise in high school	11 (55.0)	9 (45.0)	14 (70.0)	6 (30.0)
no history of high school exercise	27 (49.1)	28 (50.9)	44 (75.9)	11 (20.0)
history of exercise after graduating from high school	4 (44.4)	5 (55.6)	7 (77.8)	2 (22.2)
no exercise history after graduating from high school	34 (51.5)	32 (48.5)	51 (77.3)	15 (22.7)
history of exercise	25 (53.2)	22 (46.8)	34 (72.3)	13 (27.7)
no history of exercise	13 (46.4)	15 (53.6)	24 (85.7)	4 (14.3)
Outdoor sports of experience				
history of outdoor sports in elementary school	9 (64.3)	5 (35.7)	10 (71.4)	4 (28.6)
no outdoor sports history in elementary school	29 (47.5)	32 (52.5)	48 (78.7)	13 (21.3)
history of outdoor sports in junior high school	11 (78.6)	3 (21.4) †	12 (85.7)	2 (14.3)
no outdoor sports history in junior high school	27 (44.3)	34 (55.7)	46 (75.4)	15 (24.6)
history of outdoor sports in high school	5 (55.6)	4 (44.4)	6 (66.7)	3 (33.3)
no outdoor sports history in high school	33 (50.0)	33 (50.0)	52 (78.8)	14 (21.2)
history of outdoor sports after graduation from high school	0 (0.0)	1 (100.0)	0 (0.0)	1 (100.0)
no outdoor sports history after graduation from high school	38 (51.4)	36 (48.6)	58 (78.4)	16 (21.6)
history of outdoor sports	17 (68.0)	8 (32.0)†	19 (76.0)	6 (24.0)
no history of outdoor sports	21 (42.0)	29 (58.0)	39 (78.0)	11 (22.0)
Exercise time (h)				
Elementary school	85.1 ± 151.8	128.7 ± 255.5	108.8 ± 217.8	99.1 ± 182.3
Junior high school	198.5 ± 276.5	200.4 ± 314.4	205.6 ± 304.3	178.6 ± 262.2
High school	136.0 ± 266.6	107.5 ± 286.1	114.6 ± 264.6	147.2 ± 315.1
Total	419.6 ± 514.4	436.6 ± 669.7	428.9 ± 635.6	424.8 ± 427.0
Exercise intensity points				
Elementary school	3.3 ± 4.1	2.1 ± 3.1	2.9 ± 3.8	2.3 ± 3.0
Junior high school	4.4 ± 6.4	3.6 ± 5.4	4.0 ± 6.0	4.1 ± 5.4
High school	2.6 ± 5.2	2.2 ± 4.5	2.3 ± 4.9	2.9 ± 4.7
Total	10.4 ± 12.4	8.0 ± 9.5	9.2 ± 12.0	9.4 ± 7.3

n (%) $^{\dagger}p < 0.05$; average ± standard deviation.

Table 6. Experience of exercise/Outdoor sports experience/Exercise time/Exercise intensity (West Japan).

	SOS		%YAM	
	≥Median (n = 53)	<Median (n = 51)	≥100 (n = 61)	<100 (n = 43)
Experience of exercise				
history of exercise in elementary school	34 (53.1)	30 (46.9)	39 (60.9)	25 (39.1)
no history of elementary school exercise	19 (47.5)	21 (52.5)	22 (55.0)	18 (45.0)
history of exercise in junior high school	44 (57.1)	33 (42.9)†	48 (62.3)	29 (37.7)
no history of junior high school exercise	9 (33.3)	18 (66.7)	13 (48.1)	14 (51.9)
history of exercise in high school	31 (63.3)	18 (36.7)†	34 (69.4)	15 (30.6)†
no history of high school exercise	22 (40.0)	33 (60.0)	27 (49.1)	28 (50.9)
history of exercise after graduating from high school	20 (58.8)	14 (41.2)	23 (67.6)	11 (32.4)
no exercise history after graduating from high school	33 (47.1)	37 (52.9)	38 (54.3)	32 (45.7)
history of exercise	49 (53.3)	43 (46.7)	55 (59.8)	37 (40.2)
no history of exercise	4 (33.3)	8 (66.7)	6 (50.0)	6 (50.0)
Outdoor sports of experience				
history of outdoor sports in elementary school	8 (72.7)	3 (27.3)	9 (81.8)	2 (18.2)
no outdoor sports history in elementary school	45 (48.4)	48 (51.6)	52 (55.9)	41 (44.1)
history of outdoor sports in junior high school	15 (62.5)	9 (37.5)	17 (70.8)	7 (29.2)
no outdoor sports history in junior high school	38 (47.5)	42 (52.5)	44 (55.0)	36 (45.0)
history of outdoor sports in high school	8 (50.0)	8 (50.0)	9 (56.3)	7 (43.8)
no outdoor sports history in high school	45 (51.1)	43 (48.9)	52 (59.1)	36 (40.9)
history of outdoor sports after graduation from high school	3 (42.9)	4 (57.1)	3 (42.9)	4 (57.1)
no outdoor sports history after graduation from high school	50 (51.5)	47 (48.5)	58 (59.8)	39 (40.2)
history of outdoor sports	20 (51.3)	19 (48.7)	22 (56.4)	17 (43.6)
no history of outdoor sports	33 (50.8)	32 (49.2)	39 (60.0)	26 (40.0)
Exercise time (h)				
Elementary school	296.7 ± 367.5	209.2 ± 271.9	291.4 ± 351.7	200.4 ± 279.7
Junior high school	512.0 ± 403.2	456.8 ± 418.9	491.1 ± 405.0	476.2 ± 421.5
High school	379.9 ± 386.0	181.8 ± 274.7**	355.9 ± 376.9	179.0 ± 277.3**
Total	1188.7 ± 918.3	847.7 ± 691.3*	1138.5 ± 901.3	855.5 ± 690.1
Exercise intensity points				
Elementary school	2.9 ± 2.7	2.5 ± 2.6	3.0 ± 2.7	2.3 ± 2.6
Junior high school	3.2 ± 2.0	2.5 ± 2.4	3.1 ± 2.2	2.6 ± 2.2
High school	2.4 ± 2.3	1.1 ± 1.7**	2.2 ± 2.3	1.1 ± 1.7**
total	8.5 ± 5.3	6.1 ± 4.8*	8.3 ± 5.4	6.0 ± 4.5*

n (%) $^{\dagger}p < 0.05$; average ± standard deviation $^{*}p < 0.05$ $^{**}p < 0.01$.

3.2.2. SOS/YAM and History of Outdoor Sports Activity

The number of respondents in East Japan and West Japan, respectively, who had a history outdoor sports activity was as follows: elementary school, 14 (18.7%) and 11 (10.6%); junior high school, 14 (18.7%) and 24 (23.1%); high school, 9 (12.0%) and 16 (15.4%); and after graduation from high school, 1 (1.3%) and 7 (6.7%). Overall, 25 (33.3%) of respondents in East Japan, and 39 (37.5%) of respondents in West Japan had a history of outdoor sports activity. The results of the χ^2 test for the presence or absence of a history of outdoor sports activity showed no significant differences (**Table 4**).

The χ^2 test was performed separately for each region, dividing the respondents into two groups: high SOS/low SOS and high YAM/low YAM. In East Japan, the high SOS group had significantly higher percentages of respondents with a history of outdoor sports activity in junior high school and comprehensive outdoor sports activity ($p < 0.05$). No significant relationship was found for YAM (**Table 5**). And no significant relationship was found for either the SOS or YAM in West Japan (**Table 6**).

3.2.3. SOS/YAM and Exercise Time

The total exercise time for each period of schooling in East Japan and West Japan, respectively, was as follows: elementary school, 106.6 ± 209.2 h and 253.8 ± 325.6 h; junior high school, 199.4 ± 293.8 h and 484.9 ± 409.9 h; and high school, 122.0 ± 274.9 h and 282.8 ± 348.9 h. Total exercise time was 428.0 ± 592.1 h in East Japan and 1021.5 ± 828.9 h in West Japan. West Japan had significantly more exercise time than East Japan in all age groups ($p < 0.01$) (**Table 4**). In addition, a significant positive correlation was found between the SOS and exercise time in West Japan for all age groups except junior high school ($p < 0.01$) (**Table 4**).

The results of the regional analysis of differences in the duration of physical activity in the high SOS/low SOS and high YAM/low YAM groups showed no significant differences in either the SOS or YAM in East Japan (**Table 5**). The high SOS group in West Japan had significantly more exercise time in high school and significantly more overall exercise time ($p < 0.01$, $p < 0.05$). The high YAM group had significantly more exercise time in high school than the low YAM group ($p < 0.01$) (**Table 6**).

3.2.4. SOS/YAM and Exercise Intensity Scores

The exercise intensity scores in East Japan and West Japan, respectively, were as follows: elementary school, 2.7 ± 3.6 and 2.7 ± 2.7; junior high school, 4.1 ± 5.9 and 2.9 ± 2.2; and high school, 2.4 ± 4.8 and 1.8 ± 2.1. The total scores were 9.2 ± 11.1 in East Japan and 7.4 ± 5.2 in West Japan. A comparison of the exercise intensity scores between East and West Japan showed no significant differences (**Table 4**). In West Japan a significant positive correlation with the SOS was observed in all age groups ($p < 0.01$) (**Table 4**).

The results of the regional analysis of differences in the duration of physical activity in the high SOS/low SOS and high YAM/low YAM groups showed no significant differences in either the SOS or YAM in East Japan (**Table 5**). In

West Japan, the high SOS and high YAM groups had significantly higher exercise intensity scores in high school and overall in comparison to the respective low groups ($p < 0.01$, $p < 0.05$) (**Table 6**).

3.3. Analysis of Factors Influencing Bone Density

A multiple regression analysis was conducted to comprehensively examine factors affecting the SOS by region. For the explanatory variables, we selected items that were correlated and items that were considered to be related to the SOS.

In East Japan, there were 10 explanatory variables: SJ, CMJ, history of outdoor sports activity in junior high school, history of comprehensive outdoor sports activity/elementary school exercise time, junior high school exercise time, high school exercise time, elementary school exercise intensity scores, junior high school exercise intensity scores, and high school exercise intensity scores. These were analyzed using the forced entry method. Elementary school exercise intensity scores and history of outdoor sports activity in junior high school showed a significant positive association with the SOS ($p < 0.05$). Elementary school exercise intensity scores had the most influence on the SOS (**Table 7**).

In West Japan, there were 10 explanatory variables: body fat percentage, muscle mass, history of outdoor sports activity in junior high school, elementary school exercise time, junior high school exercise time, high school exercise time, elementary school exercise intensity scores, junior high school exercise intensity scores, and high school exercise intensity scores. These were analyzed using the forced entry method. Results showed that elementary school exercise time had the greatest influence on the SOS ($p < 0.01$). Next, muscle mass and a history of outdoor sports activity in junior high school were positively associated with the SOS, in that order ($p < 0.05$). On the other hand, junior high school exercise time was negatively associated with the SOS ($p < 0.05$) (**Table 8**).

Table 7. Multiple Regression Analysis for SOS (East Japan).

Explanatory variables	Non-standardized coefficient	Standardized coefficient	t-value	p-value	95.0% confidence interval	
					Lower limit	Upper limit
SJ	1.713	0.268	1.154	0.253	−1.253	4.679
CMJ	−0.22	−0.037	−0.156	0.876	−3.032	2.592
Junior high school outdoor sports history	24.509	0.324	2.001	0.050*	0.043	48.974
Outdoor sports history	−6.087	−0.097	−0.578	0.566	−27.136	14.963
Elementary school exercise time	−0.029	−0.204	−1.343	0.184	−0.072	0.014
Junior high school exercise time	−0.037	−0.37	−1.426	0.159	−0.09	0.015
High school exercise time	0.046	0.428	1.917	0.06	−0.002	0.094
Elementary school exercise intensity scores	2.942	0.36	2.154	0.035*	0.214	5.671
Junior high school exercise intensity scores	1.062	0.21	0.797	0.428	−1.599	3.722
High school exercise intensity time	−2.13	−0.346	−1.524	0.132	−4.923	0.663

Adjusted $R^2 = 0.121$, $F = 2.017$ *$p < 0.05$.

Table 8. Multiple Regression Analysis for SOS (West Japan).

Explanatory variables	Non-standardized coefficient	Standardized coefficient	t-value	p-value	95.0% confidence interval	
					Lower limit	Upper limit
Body fat percentage	−0.267	−0.039	−0.432	0.667	−1.496	0.961
Muscle mass	2.565	0.204	2.138	0.035*	0.183	4.948
Junior high school exercise of history	16.914	0.192	2.032	0.045*	0.383	33.445
Elementary school exercise time	0.04	0.346	2.738	0.007**	0.011	0.068
Junior high school exercise time	−0.025	−0.275	−2.077	0.041*	−0.049	−0.001
High school exercise time	0.017	0.164	1.008	0.316	−0.017	0.052
Elementary school exercise intensity	−1.122	−0.081	−0.669	0.505	−4.451	2.208
Junior high school exercise intensity	2.563	0.152	1.114	0.268	−2.006	7.131
High school exercise intensity	2.94	0.168	1.028	0.307	−2.739	8.619

Adjusted $R^2 = 0.263$, $F = 5.089$ *$p < 0.05$ **$p < 0.01$.

4. Discussion

In this study, we compared regional differences in bone mineral density based on the SOS and YAM values of young women in East and West Japan using the QUS method. Since the same device was used for measurement, the values obtained are considered to be highly reliable for comparison. The results of the χ square test between the YAM high and low groups showed that low values were significantly more common in West Japan than in East Japan. Therefore, it was suggested that there may be regional differences in calcaneal bone mineral density value between East and West Japan. In a study by Tamaki *et al.* [15] that investigated the incidence of hip fractures by prefecture, regional differences were reported which indicated that higher rates of hip fractures were observed in western areas than in eastern areas of Japan, and those findings are consistent with the results of this study.

We examined factors contributing to bone density gain based on exercise history, history of outdoor sports activity, exercise intensity by exercise category, and exercise time. A positive correlation trend was found between the SOS and exercise time and intensity in both regions, confirming that exercise is important for increasing bone density, as was reported in previous studies. The multiple regression analysis of factors influencing the SOS in each region showed that in East Japan, intensity of exercise during elementary school and history of outdoor sports activity during junior high school influenced the SOS. In West Japan, the most influential factor was the duration of physical activity in elementary school. As a factor on bone mineral density gain, the influence of a history of outdoor sports activity was greater in East Japan than in West Japan. There is a difference in the amount of sunlight in winter between the East Japan and West Japan regions covered in this study, with the amount of sunlight being lower in the former. According to a study by the National Institute for Environmental studies

[16], it takes 20 minutes to obtain 10 μg of vitamin at noon in December in Cape Hedo, Okinawa Prefecture, about 60 minutes in Tsukuba, and more than 100 minutes in Cape Ochishi, Hokkaido, suggesting that there are regional differences in vitamin D production in the skin from UV light due to differences in latitude. Therefore, it is possible that the difference in sunlight hours due to outdoor sports in East Japan may have had a more pronounced effect on bone mineral density gain than in West Japan. However, a limitation of this study may be that in collecting subjects from eastern and western Japan regions in this study, there may have been a seasonal bias in factors affecting bone mineral density, such as exercise time and sunshine duration, because the subjects' research study dates straddled the fiscal year.

In addition, the results showed that physical activity during elementary school had a positive effect on bone in both regions. It has been reported that exercise before menarche is important for increasing bone density [17] [18], and the results of this study suggest that it is important to conduct exercise at a time when bone density is increasing. Furthermore, the results suggest that exercise intensity during elementary school is important for the SOS in East Japan. In bone formation, there have been multiple reports on the effects of physical impact on bone [19], and the stimulation of bone by exercise may be effective. Recently, the impact on the bone caused by physical activity causes the flow of interstitial fluid in the bone, and the Cas protein translocated into the nucleus by mechanical stimulation of bone cells promotes the maturation of osteoclasts and bone resorption. The mechanism of suppressing the expression of the ligand molecule RANKL and thereby suppressing osteoclast differentiation has also been elucidated [20]. Therefore, it is considered important to conduct high-intensity exercise or a combination of several exercises to increase bone stimulation. In contrast, a multiple regression analysis revealed that exercise time in elementary school had the greatest influence on the SOS in West Japan. This suggests that too many hours of exercise can negatively affect the acquisition of bone mineral density. Previous studies have reported that excessive exercise can lead to endocrine abnormalities, menstrual irregularities [21], and fatigue fractures [22]. Therefore, exercise intensity is more important than exercise duration for obtaining bone mineral density, and the reason why more people in East Japan have a high YAM in comparison to West Japan may be that more people in East Japan engage in high intensity exercise for an appropriate duration. In addition, the proportion of individuals with a family history of osteoporosis in West Japan tended to be higher than that in East Japan. This suggests that genetic factors may have been involved in the smaller effect of exercise on bone mineral density acquisition in West Japan, which may have led to the differences in bone mineral density.

The present study was associated with some limitations, including the fact that although multiple factors are involved in the acquisition of bone mineral density, this study focused only on exercise factors and did not take into account dietary intake, hormone levels, or genetic traits. Furthermore, bone and calcium metabolism are related to parathyroid hormone, serum vitamin D concentration, serum albumin concentration, and serum phosphorus concentration. It is necessary to examine selection methods that enable the grouping of subjects and to conduct follow up surveys.

This study suggested that there are regional differences in bone mineral density in East and West Japan. Suggestions for osteoporosis prevention measures for each region include the implementation of outdoor sports in East Japan, and exercise that provides a load to the bones while paying attention to the duration of exercise in order to prevent overtraining in West Japan. In addition, it is thought that exercise during elementary school, which is a period when bone density increases, is useful for preventing osteoporosis, regardless of region. In this study, we think that in addition to identifying measures to increase bone density that are suitable for each region, we can also find new preventive measures against osteoporosis and bone density loss based on regional differences. Further studies are required to identify factors involved in bone density gain based on multiple factors, such as food intake surveys, in addition to exercise.

5. Conclusion

The results showed a significant difference in YAM between East and West Japan, suggesting that more women in West Japan have lower bone mineral density in comparison to East Japan. As a preventive measure against osteoporosis, it is considered important to implement exercise during elementary school—a period of increased bone density—in both regions. In particular, it is important to conduct outdoor sports in East Japan, and in West Japan, exercises that provide a load to the bones while paying attention to the duration of exercise in order to prevent overtraining.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] National Institutes of Health Consensus Development Conference Statement (2001) Osteoporosis Prevention, Diagnosis, and Therapy. *JAMA*, **285**, 785-795.

[2] Hernandez, C.J., Beaupré, G.S. and Carter, D.R. (2003) A Theoretical Analysis of the Relative Influences of Peak BMD, Age-Related Bone Loss and Menopause on the Development of Osteoporosis. *Osteoporosis International*, **14**, 843-847. https://doi.org/10.1007/s00198-003-1454-8

[3] Faienza, M.F., Lassandro, G., Chiarito, M., Valente, F., Ciaccia, L. and Giordano, P. (2020) How Physical Activity across the Lifespan Can Reduce the Impact of Bone Ageing: A Literature Review. *International Journal of Environmental Research and Public Health*, **17**, Article 1862. https://doi.org/10.3390/ijerph17061862

[4] Specker, B., Thiex, N.W. and Sudhagoni, R.G. (2015) Does Exercise Influence Pe-

diatric Bone? A Systematic Review. *Clinical Orthopaedics and Related Research*, **473**, 3658-3672. https://doi.org/10.1007/s11999-015-4467-7

[5] Daly, R.M. (2007) The Effect of Exercise on Bone Mass and Structural Geometry during Growth. *Medicine and Sport Science*, **51**, 33-49. https://doi.org/10.1159/000103003

[6] Nagase, H., Hayashi, K., Nakamura, H., Yamada, A. and Ogino, K. (1999) Cross-Sectional Study of Factors Related to Achilles Bone Mineral Density Measured by an Ultrasound System. *Japanese Journal of Public Health*, **46**, 799-810.

[7] Mase, T. (2005) Effects of Past Exercise Habits on Bone Mineral Density in Female Students—Examination by the Characteristics of the Exercise Type. *Japan Journal of Test and Evaluation of Physical Education and Sports*, **5**, 15-20.

[8] Miyamoto, S. and Ishiko, T. (1993) Effect of Pubescent Habitual Exercise on Bone Mineral Density of University Students. *Japanese Journal of Physical Fitness and Sports Medicine*, **42**, 37-45. https://doi.org/10.7600/jspfsm1949.42.37

[9] Tachi, Y., Sakamoto, Y., Sasaki-Fukatsu, K., Koike, A., Kita, T., Iida, K. and Wang, P.L. (2018) Impact of Exercise on Bone Mass in Female University Students. *Bulletin of the Tokyo College of Domestic Science*, **58**, 71-77.

[10] Nakatani, A., Yoshida, T., Shimizu, C., Yoshioka, A. and Yamaguchi, K. (2020) Effects of Different Sports on Bone Mineral Density in Female College Students. *The Journal of Kansai University of Social Welfare*, **23**, 75-79.

[11] Scofield, K.L. and Hecht, S. (2012) Bone Health in Endurance Athletes: Runners, Cyclists, and Swimmers. *Current Sports Medicine Reports*, **11**, 328-334. https://doi.org/10.1249/JSR.0b013e3182779193

[12] Hirai, M., Watanabe, N., Yamasaki, T., *et al.* (1998) Regional Differences of Bone Density. *Official Journal of Japan Society of Ningen Dock*, **13**, 29-32.

[13] Hervás, G., Ruiz-Litago, F., Irazusta, J., *et al.* (2019) Bone Health and Its Relationship with Impact Loading and the Continuity of Physical Activity throughout School Periods. *International Journal of Environmental Research and Public Health*, **16**, Article 2834. https://doi.org/10.3390/ijerph16162834

[14] Nikander, R., Kannus, P., Rantalainen, T., Uusi-Rasi, K., Heinonen, A. and Sievänen, H. (2010) Cross-Sectional Geometry of Weight-Bearing Tibia in Female Athletes Subjected to Different Exercise Loadings. *Osteoporosis International*, **21**, 1687-1694. https://doi.org/10.1007/s00198-009-1101-0

[15] Tamaki, J., Fujimori, K., Ikehara, S., *et al.* (2019) Estimates of Hip Fracture Incidence in Japan Using the National Health Insurance Claim Database in 2012-2015. *Osteoporosis International*, **30**, 975-983. https://doi.org/10.1007/s00198-019-04844-8

[16] Nakajima, H. (2020) Vitamin D Synthesis in Human Body by Solar Ultraviolet-B (UV-B) Radiation. *Vitamins*, **94**, 469-491.

[17] Ducher, G., Bass, S.L., Saxon, L. and Daly, R.M. (2011) Effects of Repetitive Loading on the Growth-Induced Changes in Bone Mass and Cortical Bone Geometry: A 12-Month Study in Pre/Peri- and Postmenarcheal Tennis Players. *Journal of Bone and Mineral Research*, **26**, 1321-1329. https://doi.org/10.1002/jbmr.323

[18] Kohri, T., Kaba, N., Murakami, T., *et al.* (2012) Search for Promotion Factors of Ultrasound Bone Measurement in Japanese Males and Pre/Post-Menarcheal Females Aged 8-14 Years. *Journal of Nutritional Science and Vitaminology*, **58**, 263-271. https://doi.org/10.3177/jnsv.58.263

[19] Rosa, N., Simoes, R., Magalhães, F.D. and Marques, A.T. (2015) From Mechanical

Stimulus to Bone Formation: A Review. *Medical Engineering & Physics*, **37**, 719-728. https://doi.org/10.1016/j.medengphy.2015.05.015

[20] Miyazaki, T., Zhao, Z., Ichihara, Y., *et al*. (2019) Mechanical Regulation of Bone Homeostasis through p130Cas-Mediated Alleviation of NF-κB Activity. *Science Advances*, **5**, eaau7802. https://doi.org/10.1126/sciadv.aau7802

[21] Maïmoun, L., Georgopoulos, N.A. and Sultan, C. (2014) Endocrine Disorders in Adolescent and Young Female Athletes: Impact on Growth, Menstrual Cycles, and Bone Mass Acquisition. *The Journal of Clinical Endocrinology & Metabolism*, **99**, 4037-4050. https://doi.org/10.1210/jc.2013-3030

[22] Sosa, D.D. and Eriksen, E.F. (2016) Women with Previous Stress Fractures Show Reduced Bone Material Strength. *Acta Orthopaedica*, **87**, 626-631. https://doi.org/10.1080/17453674.2016.1198883