【Original Article】

Influences of exercise habits during growth period and in college on changes in bone mass of female college students – A longitudinal study –

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Summary

To prevent osteoporosis, maintenance of the perk bone mass (PBM) is important, and exercise is beneficial for this. However, in recent years, a decrease in the daily physical activities of young females has become a concern. Therefore, we performed a longitudinal study of the influences of exercise habits in the past and in college on changes in the bone mass of female college students. The subjects consisted of 134 female college students aged 19.22 ± 0.29 years. Bone mass parameters were annually measured in the right calcaneus using the ultrasound bone densitometry (A-1000 EXPRESS, Lunar Co., USA). As a result, the calcaneus Stiffness value was higher in the group with than in that without past exercise habits in the first investigation year and after 1 and 2 years ($p<0.01$, 0.01, and 0.05, respectively). Concerning changes in Stiffness, a significant decrease was observed in the group with past exercise habits ($p<0.001$). However, students with exercise habits both in the past and after entering college showed the maintenance of Stiffness. These results suggest the usefulness of exercise for maintaining bone mass.
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Keywords: Quantitative ultrasound, exercise, annual changes of bone mass

Introduction

For the prevention of osteoporosis, the acquisition of a high peak bone mass (PBM) during youth and the inhibition of a postmenopausal decrease in bone mass are important. Osteoporosis is markedly affected by genetic factors[1)], but can be prevented by improving lifestyle-related factors[2)]. Thus, attention has been directed from secondary prevention during the senile period to the acquisition of a high PBM and its maintenance during youth as active preventive measures. With such a background, studies in the young have been extensively performed, and have suggested the importance of exercise habits during the growth period in maintaining a high bone mass[3,4)]. In addition, longitudinal studies in female college students have shown the influence of exercise habits after entering college on changes in the bone mass[5-7)].

However, in recent years, a decrease in daily physical activities during youth has become a concern. A survey by the Ministry of Education, Culture, Sports, Science and Technology showed the presence of exercise habits in 68.1% of female junior high school students, 42.4% of female high school students, but only 15.0% of females aged 19 years[8)]. Thus, exercise habits are lost after graduation from high school. It is possible that a high bone mass cannot be maintained until menopause for this reason. Therefore, we

evaluated the influences of exercise habits during the growth period and in college on changes in the bone mass of female college students.

Subjects and methods

The subjects consisted of 134 (19.22 ± 0.29 years) female college students who entered our college in 2006 and 2007. The study was approved by the Ethics Committee of the Wayo Women's University. All participants provided written informed consent.

In this study, a quantitative ultrasound bone densitometry (A-1000 EXPRESS, Lunar Co., USA) was used for measurement. Employing this system, the broadband ultrasound attenuation (BUA) and speed of sound (SOS) are measured. The BUA reflects the bone mass structure, and SOS represents the bone mineral density[9], and Stiffness is calculated based on these items using the following equation:

$$\text{Stiffness} = 0.67 \times \text{BUA} + 0.28 \times \text{SOS} - 420$$

These 3 items were regarded as QUS parameters. Measurement was performed in the right calcaneus. Before measurement in the subjects, the same examiner performed 5 consecutive measurements, and confirmed the coefficient of variation (CV) to be < 2%.

The height, weight, and body fat percentage (TBF-102, Tanita Co., Japan) were determined, and the body mass index (BMI), fat mass (FM), and lean body mass (LBM) were calculated. For determination of the body weight and body fat percentage, constant measurement conditions were maintained to minimize errors. The anthropometric parameters of the subjects obtained in the first measurement (baseline) are shown in Table 1.

Lifestyle and past and present exercise habits were surveyed using a questionnaire. Subjects without past exercise habits such as sports club activities in junior and senior high school were included in the group without past exercise habits (n=36), and those with such habits during this period were included in the group with past exercise habits (n=98).

The first measurement and survey were performed in November-December in the first year of college. Subsequently, similar measurement was annually performed.

The possible correlations between the QUS parameters and each anthropometric parameter were analyzed using Pearson's single correlation coefficient. For comparison between the groups, the unpaired t-test was used. Annual changes in each parameter were evaluated using analysis of variance, and, for parameters showing significant differences, multiple comparison was performed using the Bonferroni method. The significance level was set at $p<0.05$. All statistical analyses were performed with SPSS version 18.0 for Windows (SPSS, Inc., Japan).

Results

1. Relationship between the anthropometric and QUS parameters

The height and weight of the subjects did not differ from the mean values in Japanese at their age[10]. Table 2 shows the relationship between the anthropometric and QUS parameters. stiffness was positively correlated with the body weight and BMI ($p<0.05$ for each). BUA was positively correlated with the body weight, BMI, body fat percentage, FM, and LBM ($p<0.01$ for all parameters excluding the LBM, $p<0.001$ for LBM).

2. Annual changes in the anthropometric and QUS parameters

Annual changes in the anthropometric and QUS parameters of subjects are shown in Table 3. The anthropometric parameters did not change. Among QUS parameters, Stiffness decreased after 1 and 2 years compared with the baseline ($p<0.001$). BUA decreased after 2 years compared with the baseline ($p<0.001$), while SOS decreased after

1 year compared with the baseline ($p<0.001$) but increased after 2 years compared with the value after 1 year ($p<0.05$).

3. Changes in the QUS parameters according to the presence/ absence of past exercise habits

The anthropometric parameters according to the presence/ absence of past exercise habits are shown in Table 4. No parameter significantly differed between the two groups. A two-way ANOVA repeated measures analysis of variance using time as a repeated factor, past exercise habits as a grouping factor, and changes in Stiffness as a dependent variable. No significant interaction was observed, but each factor shown a significant main effect (time, $p<0.001$; past exercise habits, $p<0.01$). As a multiple comparison test, the stiffness value was significantly higher in the group with than that without past exercise habits. In the group with past exercise habits, the stiffness values after 1 and 2 years were significantly lower than in the baseline ($p<0.001$ for each; Fig. 1). In the group without past exercise habits, no significant change were observed. BUA and SOS showed similar results.

4. Changes in the QUS parameters according to the presence/ absence of exercise habits in college

The two groups with or without past exercise habits were further classified into a total of 4 groups according to the presence/ absence of exercise habits after entering college, and changes in the QUS parameters were evaluated (Table 5). In the group with past exercise habits but without such habits after entering college (Yes/ No group, n=71), the stiffness value decreased both after 1 and 2 years ($p<0.001$). In 31 subjects with exercise habits after entering college, who constituted the group without past exercise habits but with such habits in college (No/ Yes group, n=4) or that with both past exercise habits and exercise habits

Table 1 Anthropometric parameters of the subjects(n=134).

Items	Unit	Means ± S D	95% CI
Age	years	19.22 ± 0.29	19.17 − 19.27
Age at menartche	years	12.32 ± 1.33	12.09 − 12.55
Height	cm	157.99 ± 5.11	157.12 − 158.86
Weight	kg	51.97 ± 6.92	50.78 − 53.15
BMI	kg/m^2	20.81 ± 2.58	20.37 − 21.25
%Fat	%	24.95 ± 4.82	24.12 − 25.77
FM	kg	13.23 ± 4.18	12.52 − 13.95
LBM	kg	38.73 ± 3.47	38.14 − 39.32

Table 2 Correlation coefficients between anthropometric and QUS parameters.

Itetms	Stiffness	BUA	SOS
Age	-0.049	-0.065	-0.029
Age at menartche	-0.162	-0.165	-0.116
Height	-0.009	0.141	-0.149
Weight	0.175 *	0.330 **	-0.016
BMI	0.192 *	0.277 **	0.064
%Fat	0.154	0.223 **	0.054
FM	0.162	0.269 **	0.022
LBM	0.154	0.355 ***	-0.059

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 3 Annual changes in the anthropometric and QUS parameters (n=134)

Items	Unit	Baseline	After 1 year	After 2 years
《 Anthropometric parameters 》				
Height	cm	157.99 ± 5.11	158.08 ± 5.10	158.07 ± 5.21
Weight	kg	51.97 ± 6.92	51.96 ± 6.89	52.01 ± 6.55
BMI	kg/m^2	20.81 ± 2.58	20.80 ± 2.65	20.81 ± 2.48
%Fat	%	24.95 ± 4.82	25.34 ± 4.91	25.21 ± 4.80
FM	kg	13.23 ± 4.18	13.43 ± 4.35	13.35 ± 4.18
LBM	kg	38.73 ± 3.47	38.53 ± 3.43	38.66 ± 3.32
《 QUS prameters 》				
Stiffness		102.16 ± 14.15	98.72 ± 13.39 ***	98.90 ± 13.36 ***
BUA	dB/MHz	116.77 ± 11.98	114.93 ± 12.01	113.43 ± 11.59 ***
SOS	m/sec	1587.54 ± 29.47	1579.36 ± 28.90 ***	1583.73 ± 28.06 †

*** p<0.001 VS Baseline
† p<0.05 VS After 1 year

Table 4 Difference between subjects without or with past exercise habits.

Items	Unit	Exercise habits in junior and senior high school	
		No (n=36)	Yes (n=98)
Age	years	19.22 ± 0.27	19.22 ± 0.29
Age at menartche	years	12.31 ± 1.48	12.32 ± 1.28
Height	cm	157.45 ± 4.74	158.19 ± 5.24
Weight	kg	51.79 ± 7.54	52.03 ± 6.71
BMI	kg/m^2	20.90 ± 3.01	20.78 ± 2.41
%Fat	%	25.31 ± 5.78	24.82 ± 4.44
FM	kg	13.47 ± 5.01	13.15 ± 3.86
LBM	kg	38.32 ± 3.30	38.88 ± 3.54

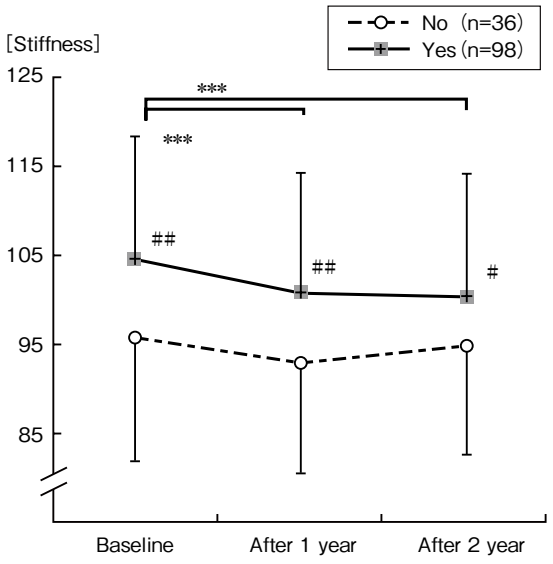

Fig.1 Stiffness changes in two groups.
# p<0.05, ## p<0.01 VS No group
*** p<0.001 VS Baseline

in college (Yes/ Yes group, n=27), no change in stiffness were observed. The BUA and SOS showed similar results.

Discussion

We evaluated the influences of past exercise habits in junior and senior high school and those in college on change in the bone mass parameters of the calcaneus in female college students. Dual-energy X-ray absorptiometry (DXA) is a golden standard for measuring the bone mass, but involves exposure to a small amount of radiation. Therefore, we measured bone mass parameters in the calcaneus using a QUS system, allowing noninvasive measurement, annually for 3 consecutive years. A correlation between the bone mass measured using the QUS method and that

Table 5 Changes in Stiffness according past and curent exercise habits.

Exercise habits		n	Stiffness			*P*-value
Junior and senior high school	In college		Baseline	After 1 year	After 2 years	
No	No	32	95.81 ± 13.60	92.97 ± 12.00	94.84 ± 12.20	n.s
No	Yes	4	95.25 ± 16.78	93.00 ± 16.27	95.25 ± 12.09	n.s
Yes	No	71	104.72 ± 13.96 #	100.13 ± 13.91 ***	100.11 ± 14.29 ***	p<0.001
Yes	Yes	27	103.96 ± 12.99	102.70 ± 11.23 #	101.07 ± 11.71	n.s

*** p<0.001 VS Baseline
# p<0.05 VS No/No group

using the DXA method has been reported[11], and the relationship between the QUS parameters and risk of fracture has also been clarified with this method[12,13].

Evaluation of the possible correlation between the QUS and anthropometric parameters (Table 2) showed a positive correlation between the stiffness and body weight as well as BMI. The BUA was positively correlation with anthropometric parameters excluding height and most strongly correlated with the LBM. The BUA is affected by anthropometric parameters, and is more strongly affected by the LBM composed mainly of skeletal muscle than by body weight[14-16]. The results of our study supported the importance of the LBM as a factor associated with the bone mass.

Evaluation of the annual changes in QUS parameters revealed significant decreases in stiffness after 1 and 2 years compared with the baseline (Table 3). There have been only a few studies on changes in the bone mass of female college students, and their conclusions have been inconsistent due to differences in the measurement area and observation years[5-7]. Therefore, in this study, the subjects were classified into two groups according to the presence or absence of past exercise habits in junior and senior high school, and the bone mass was evaluated. In all years in college, the stiffness value was higher in the group with (n=98) than in that without (n=36) past exercise habits (Fig. 1). These results were consistent with the results of previous cross-sectional studies on the relationship between the bone mass and past exercise habits in young females[3,17], supporting the importance of exercise habits during the growth period in acquiring a high bone mass.

As a result of the evaluation of changes in Stiffness in the groups with or without past exercise habits, Stiffness did not change in the group without but significantly decreased in the group with past exercise habits (Fig. 1). Bone formation is promoted when stress is affected a certain level due to mechanical loads such as exercise, and is terminated by bone resorption caused by a decrease in loading due to bed rest[19] or zero gravity[20]. Thus, bone is constantly affected by mechanical loading. In this study, stiffness did not change in the group without past exercise habits, which suggests no changes in mechanical loading after entering college. In the group with past exercise habits, stiffness decreased after 1 year, which suggests a decrease in mechanical loading after entering college.

Evaluation of the influences of exercise habits after entering college revealed decreases in the QUS parameters in the group with exercise habits in the past but not in college, but no changes in the other groups. Wu et al.[5] and Yokouchi et al.[6] reported an increase in the bone mass of students with exercise habits both in the past and after entering college. However, in this study, no changes in bone mass were observed in such students. This may be because many subjects with exercise habits in this study performed exercise only for about 60 minutes once weekly. Exercise

once weekly may not have been a sufficient enough load to increase the bone mass. However, this subjects who lost exercise habits showed a decrease in the bone mass, which suggests that exercise about once weekly can inhibit such a decrease.

In this study, since there were a few subjects who continued exercise after entering college, evaluation according to the type of sport could not be performed. In addition, the association between changes in the bone mass and Ca intake was not evaluation. In the future, it will be necessary to evaluate the influences of the quality and amount of exercise or Ca intake on changes in the bone mass in a larger number of subjects.

Conclusion

We evaluated the influence of past exercise habits on changes in the bone mass after entering college in female college students. As a result, the stiffness value was higher in the group with than in that without past exercise habits, suggesting the effectiveness of exercise habits during the growth period for increasing the bone mass. Concerning changes in stiffness, the stiffness significantly decreased in the group with past exercise habits, but was maintained in the group with exercise habits both in the past and after entering college. Thus, the bone mass may be the continuation of exercise.

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成長期および大学在学中の運動経験が女子大学生の骨量変化に及ぼす影響
―縦断的研究―

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要　旨

骨粗鬆症の予防には最大骨量 (Peak Bone Mass：PBM) を維持することが重要である。骨量を維持するには運動が重要であるが、近年、若年女性の運動習慣減少が問題となっている。そこで本研究では、女子大学生を対象に過去および大学在学中の運動習慣が骨量変化に及ぼす影響を縦断的に検討した。134 名（19.22 ± 0.29 歳）の女子大学生を被験者とし、右踵骨を超音波法（Lunar 社，A-1000 EXPRESS）にて年 1 回、縦断的に測定した。その結果、初年度、1 年後および 2 年後とも過去運動経験あり群はなし群に比べ踵骨骨量 (Stiffness) が高値を示した（各 $p<0.01$、$p<0.01$、$p<0.05$）。骨量変化は過去運動経験あり群が有意に低下した（$p<0.001$）。しかし、その中でも大学入学後も運動習慣を有していた者は骨量を維持していた。このことから、運動は骨量維持の可能性が示唆された。

キーワード：超音波法、運動、骨量年間変化

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