



Effects of High-Intensity Circuit Training on Calcaneal Bone Status in Collegiate Women

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Abstract

Objective: The purpose of this study was to examine the effects of high-intensity circuit training (HICT) using body weight as resistance on calcaneal bone status in sedentary collegiate women.

Methods: The subjects were 24 healthy sedentary collegiate women and were randomly divided into 2 groups: 12 in the HICT group and 12 in the control group. The HICT group performed 14-min HICT, 2 d[•]wk⁻¹ for 10 weeks. Quantitative ultrasound measurements of the right calcaneus were performed to measure speed of sound (SOS), broadband ultrasound attenuation (BUA), and stiffness index (SI). Nutrient intake was assessed with a food frequency questionnaire.

Results: After the training period, the HICT group showed significantly lower body weight, fat mass and %Fat, whereas there were no significant changes in the control group. There were no significant differences between the 2 groups in energy or nutrient intake before or after the training period. After the training period, the HICT group exhibited significant increases of SOS and SI, whereas the controls did not show any significant changes.

Conclusion: Performing 14-min of HICT, 2 d[•]wk⁻¹, for 10 weeks has positive effects on calcaneal bone status.

Keywords

Quantitative ultrasound; Calcaneal bone status; Calcium; Vitamin D; Circuit training

Introduction

Incidence of osteoporosis is higher in women than in men [1,2]. The estimated number of osteoporotic patients aged 40 or over in Japan is 3,000,000 men and 9,800,000 women [3]. Because a high peak bone mass in early adulthood is an important protective factor against osteoporotic fractures in later life [4,5], and peak bone mass occurs in approximately in the third or fourth decade of life [6], maximizing peak bone mass before menopause may be important in preventing osteoporosis in premenopausal women.

Cross-sectional studies have been shown that athletes involved in sports that increase the mechanical stress placed on the bone (i.e., weight-bearing activities and/or strength training) have greater bone mineral densities (BMD) than swimmers or non-active controls

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Received: February 4, 2021 Accepted: February 19, 2021 Published: February 26, 2021

[7-9]. Longitudinal studies of strength training in premenopausal women showed conflicting results. Some studies found increased BMD [10-12], while others did not [13-15]. Furthermore, the above mentioned studies [10-15] have some limitations for working people. They need special equipment to perform strength training and may not be realistic for time-conscious adults due to the amount of time necessary to complete each program [16].

Klika and Jordan [16] introduced high-intensity circuit training (HICT) using body weight as resistance, which combines aerobic and resistance training into a single exercise session lasting approximately 7 min. Participants can repeat the 7-min circuit 2 to 3 times, depending on the amount of time they have. Because body weight is the only form of resistance, the program can be done anywhere, without special equipment. It has been shown that the HICT can decrease body weight and body fat, as well as increase maximal oxygen uptake [17-19].

When examining the effects of physical exercise on BMD, the bones in the foot are an important region for evaluation, as they bear the greatest effects of gravity during exercise [20]. Quantitative ultrasound (QUS) is a portable and practical machine that measures bone status and involves no x-ray exposure [20]. To our knowledge, the effects of HICT on calcaneal bone status in sedentary young women have not been investigated. The purpose of this study was to examine the effects of HICT using body weight as resistance on calcaneal bone status in sedentary collegiate women.

Methods

Subjects

The study protocol was approved by the Ethics Committee of the University. Informed consent was obtained from each subject.

The subjects were 24 healthy sedentary collegiate women and were randomly divided into 2 groups: 12 in the HICT group and 12 in the control group. All subjects were non-smokers, drank alcohol less than once a week, and were not taking any contraceptive medication.

Experimental design

All participants were asked not to make any changes to their diets or regular life style during the 10-week experimental period. The HICT group performed HICT 2 d[•]wk⁻¹. During the orientation session, an investigator instructed the participants how to properly perform all HICT exercises. Upon arrival to the exercise facility, HICT participants performed 5 min of stretching. Following the stretching, the participants completed the 7-min HICT protocol introduced by Klika and Jordan [16], which included 30 sec of exercise with 10 sec of active rest. The exercises were as follows: (1) Jumping jacks, (2) Wall sit, (3) Push-up, (4) Abdominal crunch, (5) Step-up, (6) Squat, (7) Triceps dip on chair, (8) Plank, (9) High knees/running in place, (10) Lunge, (11) Push-up and rotation, and (12) Side plank (see reference # 16 which show these exercises with photos). The participants completed all exercises in the order from 1 to 12, and then repeated the process for a total of 2 times (i.e. 2 sets).

Training intensity

Blood lactate was obtained immediately after the first and the last

14-min HICT sessions. Shortly after, 5 µl of blood lactate sample was drawn from an ear lobe, and analyzed with the Lactate Pro Analyzer (Akroy, Tokyo, Japan). The Lactate Pro is supplied with a Check Strip to confirm that the analyzer is operating correctly and a Calibration Strip that provides a non-quantitative indication of instrument accuracy. The reported correlations between the Lactate Pro and the ABL 700 Series Acid-Base analyzer, YSI 2300, and Accusport were $r=0.98$, $r=0.99$, and $r=0.97$, respectively [21].

Measurements and dietary information

Body weight and height, as well as dietary information, were obtained before and after the 10-week training period. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. The body mass index (BMI) was calculated as $\text{weight}/\text{height}^2$ (kg/m^2). Percentage of body fat (%fat), fat mass, and lean body mass were evaluated with a bioelectric impedance analyzer (BC-519, Tanita, Tokyo, Japan).

QUS measurements of the right calcaneus were performed (A-1000 EXP II, Lunar, GE Health Care, Tokyo, Japan). After cleaning the skin with alcohol, each subject's heel was positioned in a small measurement device. An ultrasonic wave is transmitted through the heel and detected by a receiving transducer. Speed of sound (SOS), which is the velocity of the ultrasonic wave as it passes through the heel, and broadband ultrasound attenuation (BUA), which reflects the frequency dependence of ultrasound attenuation [22], were measured using the QUS device. The stiffness index (SI) was derived from both the SOS and BUA, where, as defined by the manufacturer, $\text{SI}=(0.67 \times \text{BUA})+(0.28 \times \text{SOS})-420$. The coefficient of variation for measurements reported by the manufacturer was approximately 2%.

All subjects were interviewed by experienced dietitians using a food frequency questionnaire (FFQ), which is based on 29 food groups and 10 types of cooking, to estimate the energy and nutrient intakes of each subject during the past 1 to 2 months [23]. The FFQ was validated by a comparison with weighed dietary records for 7 continuous days [24]. Using the results from the FFQ, the mean daily intake of total energy and nutrients was calculated according to the Tables of the Japanese Foodstuff Composition [25]. Information on nutrient supplement and/or diet was obtained via a self-administered questionnaire. The accuracy of the questionnaire was checked through individual interviews.

Analysis

The SPSS statistical software 22.0J (Chicago, IL) was used to analyze the data. Values were expressed as means and SD. Because sample size in each group was small, non-parametric statistics were used. The mean differences between HICT group and control groups were analyzed by non-paired Mann-Whitney U test. The mean differences before and after the training period were analyzed by paired Mann-Whitney U test. Two-sided $p<0.05$ was considered to be significant.

Results

The mean blood lactate values obtained immediately after the first and the last 14-min HICT sessions were 7.6 ± 1.9 and 8.6 ± 2.5 mmol.l^{-1} , respectively.

The characteristics of the subjects are shown in Table 1. After the training period, the HICT group showed significantly lower body weight, %fat, and fat mass, whereas there were no significant changes in the control group.

The selected energy and nutrient intakes of the subjects are shown in Table 2. There were no significant differences between the 2 groups in energy or nutrient intake before or after the training period. Also, they did not significantly change after the training period in either group.

The calcaneal bone status of the subjects is shown in Figures 1 and 3. After the training period, the HICT group exhibited significant increases of SOS (Figure 1) and SI (Figure 3), whereas the control group did not show any significant changes. The BUA did not show any significant changes in both groups (Figure 2).

Discussion

The main finding of the present study was the positive effects of performing HICT 14-min/session, 2 d $\cdot\text{wk}^{-1}$, for 10 weeks on calcaneal bone status in sedentary collegiate women, while the control group did not show such changes. According to Yung et al. [26], the BUA value is related to the bone structure, whereas the SOS and SI values are correlated to bone density and elasticity. In the HICT group, SI and SOS significantly increased, but BUA did not significantly change. Thus, the significant increase in SI could mainly be due to the significant increase in SOS. As far as we are aware, this is the first study to show the positive effects of performing HICT on calcaneal bone status in sedentary young women.

Although we did not measure maximal oxygen uptake during performance of HICT, the training intensity, in terms of mean blood lactate values (7.6 ± 1.9 and 8.6 ± 2.5 mmol.l^{-1} , respectively), appears to be high in the present study. These values are higher than the reported maximal value obtained by a maximal treadmill test (6.7 ± 1.9 mmol.l^{-1}) in collegiate women of similar age [27].

It has been reported that body height, LBM, and BMI were positively associated with BMD [28,29]. In the present study, however, the HICT group showed significant improvement in calcaneal bone status (SOS

Table 1: Characteristics of the subjects.

	HICT group				Control group			
	Pre-training		Post-training		Pre-training		Post-training	
Age (years)	20.8	\pm 0.7			20.6	\pm 0.5		
Height (cm)	157.0	\pm 3.3	157.0	\pm 3.5	158.7	\pm 6.3	158.9	\pm 6.0
Weight (kg)	56.6	\pm 6.4	55.7	\pm 6.0 *	53.8	\pm 7.3	53.4	\pm 8.0
%Fat	31.9	\pm 3.5	31.1	\pm 3.5 *	28.7	\pm 4.6	28.0	\pm 4.8
Fat mass (kg)	18.2	\pm 4.0	17.5	\pm 3.8 *	15.7	\pm 4.5	15.2	\pm 4.8
Lean body mass (kg)	38.3	\pm 2.8	38.3	\pm 2.5	38.1	\pm 3.4	38.2	\pm 3.9

Mean \pm SD.

Abbreviations=HICT: High-Intensity Circuit Training, %Fat: percentage of body fat
* $p<0.05$ (compared with pre training)

Table 2: Energy and selected micronutrient intakes of the subjects.

	HICT group				Control group			
	Pre-training		Post-training		Pre-training		Post-training	
energy (kcal)	1589	\pm 340	1626	\pm 497	1526	\pm 333	1566	\pm 303
calcium (mg)	429	\pm 111	419	\pm 171	374	\pm 187	353	\pm 145
vitamin D (μg)	3.2	\pm 1.8	3.7	\pm 2.4	3.7	\pm 2.0	3.9	\pm 2.3
vitamin K (μg)	153	\pm 46	147	\pm 51	151	\pm 72	145	\pm 78

Mean \pm SD.

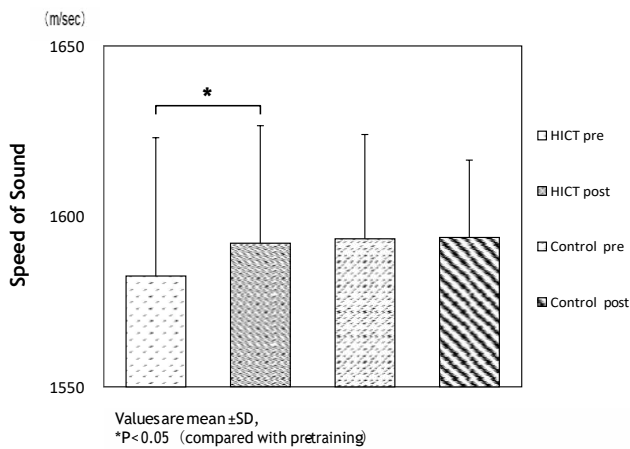


Figure 1: Speed of sound of the subjects.

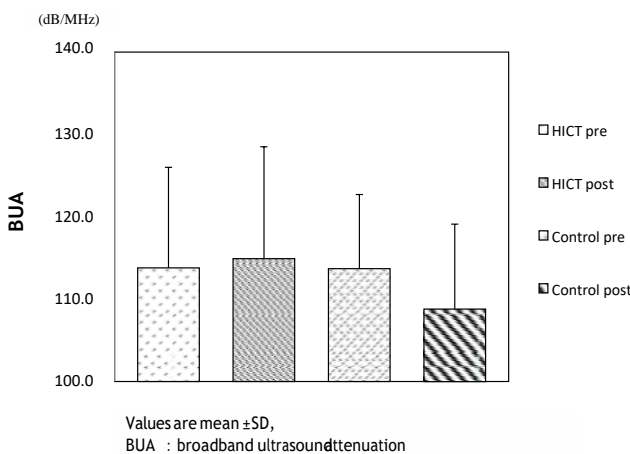


Figure 2: Broadband ultrasound attenuation of the subjects.

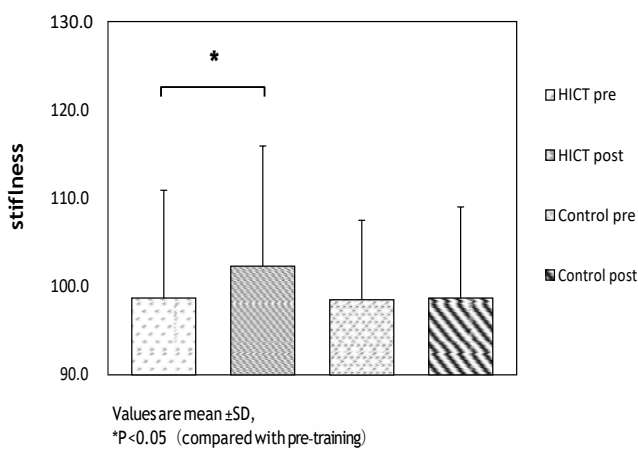


Figure 3: Stiffness index of the subjects.

and SI), despite the significant decrease in mean body weight, fat mass, and % fat. In contrast, there were no significant changes in calcaneal bone status, mean body weight, fat mass or % fat in the control group.

Calcium, vitamin D, and vitamin K intakes are key elements in the promotion and maintenance of bone health, as well as preventing bone loss [30,31]. A poor intake of calcium increases fracture risk via low BMD [30]. When vitamin D is low, parathyroid hormone increases, resulting in increased bone resorption in order to satisfy the body's demand for calcium [32]. It has been shown that vitamin K improves bone quality and reduces the risk of fracture [33]. In the present study, the mean values of calcium, vitamin D, and vitamin K intakes did not differ significantly between the 2 groups. Furthermore, these intakes did not change significantly after the experimental period in either group. Thus, the influence of these nutrients appears to be limited.

Longitudinal studies of strength training in premenopausal women showed conflicting results. Some studies [10-12] showed positive effects of strength training on BMD, while others did not [13-15]. The divergent results obtained in these studies could be due to the differences in the subjects' characteristics, such as age, body height, weight, BMI and body composition, genetic and hormonal factors, smoking, drinking, and dietary habits. Other possible confounding factors include variation in the training program's intensity, frequency, duration of each exercise, or duration of the experimental period. These studies [10-15] have some limitations for working people. They need special equipment to perform strength training. We instead used HICT, which uses body weight as resistance, and combines aerobic and resistance training into a single exercise session lasting approximately 7 min.

One limitation of our study needs to be mentioned. In the studies of strength training on BMD in premenopausal women [10-15], various sites of BMD were measured with dual energy X-ray absorptiometry (DXA), which remains the optimal method for evaluating BMD. We evaluated calcaneal bone status using a QUS device, as opposed to conventional measurement by DXA, for the following reasons: First, QUS is a portable and practical machine that measures bone status and involves no x-ray exposure [20]. Second, relatively high correlation coefficients between SOS and BMD ($r=0.76$) and BUA and BMD ($r=0.81$) at the heel assessed at the location corresponding to that of the QUS measurement have been reported, and SOS values were significantly lower in fracture patients than in participants without fractures [34]. Third, it has further been shown that calcaneal SOS is comparable with DXA in identifying subjects with vertebral fractures [35,36].

Conclusion

This study revealed that performing HICT at 14-min/session, 2 d•wk⁻¹, for 10 weeks can improve calcaneal bone status in sedentary young women.

Acknowledgements

This study was supported by grants from Beppu University and Nagasaki International University.

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
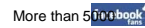

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