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THE SIDE-TO-SIDE DIFFERENCES IN BONE MINERAL STATUS AND CROSS-SECTIONAL AREA IN RADIUS AND ULNA IN TEENAGE TAIWANSES FEMALE VOLLEYBALL PLAYERS

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Abstract: Regular physical training has been shown to affect bone development. It has been shown in Caucasians that athletes participated in sports involving long-term unilateral mechanical loading showed significantly larger dominant-to-nondominant differences in BMC and BMD in humerus and radius than those in sedentary subjects. However, racial differences do exits in bone metabolism and no information was available regarding the effect of unilateral mechanical loading on bone development in teenage Asian females. The differences in bone mineral content (BMC), mineral density (BMD), and cross section area of distal radius and ulna between dominant and non-dominant limbs were investigated in teenage female volleyball players. Thirty-nine volleyball players (VOL group) from junior national team and a high school and thirty gender-, height-, weight- and age-matched sedentary subjects (CON group) were recruited. The bone parameters were measured with a dual-energy X-ray absorptiometry bone densitometer. In VOL group, dominant radius BMC and ulna BMC and cross-sectional area were significantly higher than those of non-dominant hand. In CON group, dominant ulna BMC and cross-sectional area were significantly higher than those of non-dominant hand. All bone parameters measured were significantly higher in VOL group than those in the respective sites in CON group. The percent side-to-side differences were not significantly different in any parameters measured between the 2 groups. This study suggested that long-term regular volleyball training did not result in more significant bilateral difference in BMC, BMD, and cross-sectional area in radius and ulna in Taiwanese teenage females.

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Key words: Exercise - Bone development - Mechanical loading

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Introduction

Regular physical activity, especially weight-bearing types, has been shown to increase bone mineral content (BMC) and bone mineral density (BMD) in adolescents [17] and young and older adults [12,21]. Furthermore, the role of physical activity in preventing osteoporosis has long been recognized [3,9,21].

Athletes participated in sports involving long-term unilateral mechanical loading, such as tennis and squash, showed significantly larger dominant-to-nondominant differences in BMC and BMD in humerus and radius than those in sedentary subjects [6,7,10]. The side-to-side differences were approximately two times larger when the subjects started playing these sports at or before menarche than did 1 year or more after it [6,10]. Furthermore, in a study involving 7- to 17-year-old female tennis players, Haapasalo *et al.* revealed that the dominant-to-nondominant differences in BMC and BMD in humerus and radius were not significant until the third Tanner stage [7]. These results indicated the importance of weight-bearing physical activity in promoting bone mineralization at childhood and puberty, coinciding with the natural rapid increase in bone mass. However, the data from Caucasians may not be applicable to Asians as the racial differences do exist in bone metabolism [2,16,18,20]. No information was available regarding the effect of unilateral mechanical loading on bone development in teenage Asian females. The aim of this study is to investigate the effect of long-term unilateral mechanical loading on side-to-side differences in BMC, BMD, and cross-sectional area in radius and ulna in Taiwanese teenage female volleyball players.

Materials and Methods

Subjects: Thirty-nine female volleyball players (VOL group) were recruited from Taiwan’s junior national team and a high school in southern Taiwan. The school constantly ranks among the top four in the country. The basic characteristics, age of menarche, history of regular volleyball training, and training program during the previous year were collected with a questionnaire. The subjects have participated in 10 to 14 volleyball and weight training sessions a week throughout the year. These subjects have undergone regular volleyball training for 7.1±1.2 (mean±SD, range 4-10) years.

Thirty gender- and age-matched sedentary controls (CON group) were recruited from Fooyin University, Kaohsiung, Taiwan. The controls have not conducted any regular physical activity for at least a year, other than regular physical education classes 2 hours per week.

All subjects were nonsmokers and nondrinkers and not using any oral contraceptives. The procedures followed were approved by Fooyin University and in accordance with the Helsinki Declaration of 1977, as revised in 1983. All subjects signed an informed consent after the procedure and possible risk were clearly explained.

Bone and body composition measurements: BMC, BMD, and cross-sectional area in distal radius and ulna of both forearms of subjects were measured with Osteometer DTX-100 dual-energy X-ray absorptiometry bone densitometer (Osteometer MediTech, Inc., Hawthorne, CA, USA). All subjects were measured by the same qualified professional. Body composition was measured in early morning after an overnight fast with bioelectrical impedance analysis (Bodystat 1500, Bodystat Limited, Isles of Man, U.K.).

Statistical analysis: The differences in BMC, BMD, and cross-sectional area between dominant and nondominant limbs were analyzed by paired t-test. The percent side-to-side differences, calculated as (dominant-nondominat)/ nondominat x 100%, between the 2 groups were compared by t-test. All analysis was performed using SPSS 11.0 for Windows (Chicago, IL, USA). A p-value less than 0.05 were considered statistically significant. All data are expressed as mean ±SD.

Results

The two groups had similar age (VOL: 16.9±0.9, CON: 16.1±0.4 years), height (VOL: 1.68±0.06, CON: 1.66±0.02 m), and weight (VOL: 62.7±5.8, CON: 61.6±8.1 kg). VOL group had significantly lower body fat than CON group (VOL: 18.13±2.62, CON: 21.79±3.97%, $p<0.01$), possibly due to the regular exercise training. The age of menarche was 12.2±1.3 years (range 11-17 years) in VOL group and 12.5±0.8 years (range 12-14 years) in CON group.

BMC, BMD, and cross-sectional area of radius and ulna of both arms are presented in Table 1. In VOL group, dominant radius BMC and ulna BMC and cross-sectional area were significantly higher than those of nondominant arm. In CON group, dominant ulna BMC and cross-sectional area were significantly higher than those of nondominant arm. Radius and ulna BMC, BMD, and cross-sectional area of both dominant and nondominant arms were significantly higher in VOL group, compared to those of the respective regions in CON group. The percent side-to-side differences were not significantly different in any parameters measured between the 2 groups.

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Table 1
BMC, BMD, and cross sectional area of radius and ulna of both arms in VOL and CON groups

	VOL			CON		
	Dominant	Non-dominant	Difference (%)	Dominant	Non-dominant	Difference (%)
Radius						
BMC (g)	2.13 ±0.25*,¶¶¶	2.10 ±0.26¶¶¶	1.73 ±4.03	1.76 ±0.21	1.74 ±0.20	1.85 ±8.13
BMD (g/cm^2)	0.53 ±0.04¶¶¶	0.53 ±0.04¶¶¶	0.53 ±3.63	0.47 ±0.03	0.47 ±0.03	0.62 ±4.16
Cross-sectional area (cm^2)	4.00 ±0.31¶¶	3.96 ±0.35¶	1.25 ±3.84	3.72 ±0.33	3.68 ±0.31	1.20 ±0.63
Ulna						
BMC (g)	1.30 ±0.16***,¶¶¶	1.24 ±0.15¶¶¶	4.51 ±6.04	1.06 ±0.12*	0.98 ±0.12	8.35 ±10.13
BMD (g/cm^2)	0.46 ±0.04¶¶¶	0.46 ±0.04¶¶¶	-0.09 ±6.73	0.40 ±0.03	0.38 ±0.04	4.48 ±10.14
Cross-sectional area (cm^2)	2.86 ±0.27***,¶	2.73 ±0.26¶	4.77 ±4.86	2.65 ±0.18*	2.56 ±0.18	3.84 ±4.86

*p<0.05, **p<0.01, ***p<0.001, compared to non-dominant within the group; ¶p<0.05,
¶¶p<0.01,¶¶¶p<0.001, compared to the same region of CON

Discussion

Our study suggested that regular volleyball training results in similar percent side-to-side differences in BMC, BMD, and cross-sectional area in radius and ulna in Taiwanese teenage females, compared to sedentary controls. This is in agreement with Alfredson *et al.* who suggested that side-to-side difference in humerus BMD was similar in Caucasian adult female volleyball players and sedentary controls [1]. However, these results were different from Calbet *et al.*, who revealed that Caucasian adult male volleyball players had greater BMC and BMD in dominant arm and leg, while sedentary controls did not [4]. The disagreement could due to the gender, racial, and/or age difference in bone development and/or mineralization.

In VOL group, the side-to-side differences in BMC and cross-sectional area were more significant in ulna than in radius. The BMC and cross-sectional area in dominant ulna were more than 4% higher than those in the nondominant. BMC and cross-sectional area in dominant radius were only 1.73% and 1.25%, respectively, higher than those in the nondominant. However, there was no side-to-side difference in BMD in either radius or ulna as the increase in BMC was in the similar magnitude as that in cross-sectional area. The comparable trend in side-to-side differences was also seen in CON group, as radius and ulna BMD were similar between dominant and nondominant arms. In female Finnish squash players, the side-to-side differences in BMC and BMD of various parts of radius and ulna ranged between 5.6% to 17.8%, compared to 1.6% to 4.1% in nonactive controls [6]. In another study on female Finnish tennis and squash players, the side-to-side differences in BMC of radial shaft and distal radius were 8.5% and 12.5%, respectively, compared to 3.2% and 3.9% in nonactive controls [10]. In male Finnish tennis players, the side-to-side differences in BMC and BMD of various parts of radius and ulna ranged between 3.1% to 15.4%, compared to 0% to 3.4% in nonactive controls [11]. The disagreement between the current study and those using Caucasians as subjects suggested the possible existence of racial difference in bilateral bone development and the effect of physical training in bone metabolism. This viewpoint is further supported by Yang *et al.* [22], who revealed the lack of side-to-side difference in proximal femur BMD in Chinese women, compared to up to 23% (average 5%) in various parts of femur in Caucasians [8]. However, we cannot rule out the effect of different types of physical training. Volleyball competition is consisted of one-handed spike and serve and two-handed forearm and overhand passes. The unilateral mechanical loading in volleyball may not be as significant as that in tennis or squash.

BMC, BMD, and cross-sectional area of dominant and nondominant radius and ulna in VOL group were significantly higher than those in the respective region in CON group. It suggested that volleyball training could enhance forearm bone mineralization. Females participated in sports in which ground reaction forces were several times of body weight, such as volleyball and basketball, showed significantly higher BMD in upper and lower extremities than those participated in low-impact sports or nonactivity [5,13,19]. The difference could result from the greater rate of bone formation in high-impact sport participants [5].

It has been revealed that the younger the unilateral loading started, the more significant side-to-side difference in BMC in Finnish female tennis and squash players [10]. The side-to-side difference in forearm BMC was significantly higher in those who started playing before or at menarche. Menarche is one of the first signs that bone mass development starts to slow down, with little increase in bone mass after 2 years of beginning menses in Caucasians [14,15]. Many of our female subjects participated in regular volleyball training from age 10 or even younger. All but 3 subjects started regular volleyball training before menarche. The exclusion of these 3 subjects produced the similar results. The disagreement between our study and Kannus *et al.* [10], in which Caucasians were investigated, suggested possible racial difference in the timing of physical training effect on bone development.

This study suggested that long-term regular volleyball training did not result in more significant side-to-side difference in BMC, BMD, and cross-sectional area in radius and ulna in Taiwanese teenage females. In addition, the effect of physical training in bone development may have racial differences. The effect of starting biological age of physical training on side-to-side difference in bone development in Asians warrants further investigation.

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