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Original Research

Dominant and non-dominant arm bone mineral density of racquet athletes

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Abstract

Background and Purpose: The upper extremities, especially the arms and shoulders, are used intensively in racquet sports. In this work, our primary aim is to compare bone mineral densities (BMDs) between dominant and non-dominant arms in racquet athletes. We then compare BMDs between athletes playing racquet sports and non-athletes. **Methods**: A total of 24 racquet sports male athletes active for at least 10 years (age, 22.46 $\pm$ 2.41 years) and 22 non-athletes (age, 21.45 $\pm$ 1.74 years) voluntarily participated in this study. The BMDs of the humerus, radius, and ulna of the dominant and non-dominant arms of both groups were measured by dual energy X-ray absorptiometry. **Results**: The BMDs of the proximal humerus and humeral shaft of dominant arms were significantly higher than those of non-dominant arms in athletes (19.85% vs. 12.02%); while statistically, no statistically significant difference in BMDs was found in non-athletes ($P > 0.05$). The BMDs of the dominant proximal humerus and humeral shaft of athletes were higher than those of non-athletes ($P < 0.05$). Non-dominant arm BMDs did not differ between the two groups ($P > 0.05$). **Conclusion**: BMD differences observed between the right and left arms of athletes indicate that, rather than confounding factors like genotype, right-/left-handedness, participation in racquet sports may influence BMDs in the related extremities.

Keywords

Athletes; Bone mineral density; DEXA; Dominance

1. Introduction

The relationship between bone mineral density (BMD) and exercise has been studied for many years. One of the most effective methods of maintaining ones BMD is exercise [1]. Well, it is clear that individuals who live a sedentary lifestyle most likely have lower bone mass than those who do physical activity regularly, and moderate exercise increases bone tissue [2]. As stated in many studies, exercising is a factor that significantly increase the development of bone mass in young people and prevents natural bone mass loss in adults [1, 3–6].

The exercises youth perform greatly influence their ability to live healthier as they age. Physical activity and mechanical strain are important factors determining bone mass, structure, and strength [7]. Besides increasing BMD, regular exercise plays an important role in the development of bone density during adolescence and young adulthood and maintenance of this level with the least loss in subsequent years [8, 9]. There are conflicting results regarding the intensity, type, frequency, and duration of physical activity that are optimal for an increase in bone mineral density [10]. A previous study indicated positive effects of a high-impact physical activity and sports (i.e. artistic gymnastics) on BMD. At the same time, the BMD values of swimmers indicated small or no effects of low-impact-activities and hypo gravity on bone development [11].

Many variables are considerable examing the effect of exercise on bone density. For example, nutrition, genetic factors, age, climate, gender, and smoking, among others, are believed to affect BMD. In addition to these, the bone mineral density of the dominant and non-dominant arm of the athletes involved in racket sports may be another factor that reveals the effect of the sport on BMD. There are studies with different results regarding side to side differences. In the results of a previous study, higher BMD of the right arm compared with the left arm for all teams, with the most pronounced differences observed in male and female tennis players and baseball male players [12]. In another study, BMD in the dominant hip was significantly higher for the low-impact sports and lower in the high-impact sports; however, differences were not clinically relevant [13].

The upper extremities, particularly the arms and shoulders, are extensively used in racquet sports. With more load applied to the athletes' dominant hand and because of the specific motor movement patterns of the sports performed, certain sports-specific adaptations can be observed in the musculoskeletal system of elite athletes. In racquet sports, such as badminton, tennis, and table tennis, the dominant hand holds the racquet; thus, differences in the BMDs of the holding and non-holding arms may be observed. The main purpose of this study was to compare BMDs between the dominant and non-dominant arm of racquet athletes. Besides, BMDs of the dominant and non-dominant arms of non-athletes were compared. The BMD values of the left and right arms of athletes compared to non-athletes were also examined. We hypothesized that (1) the BMD of the dominant arm will be higher than that of the non-dominant arm in racquet athletes and (2) the BMD of the dominant arm of racquet athletes will be higher than that of non-athletes.

2. Methods

2.1 Study design

This is a cross-sectional observational study.

2.2 Subjects

A control group of 22 non-athletes males and 24 male athletes engaged in racquet sports for at least ten years, participated in this study. Distributing the athletes by branches, the sample consists of 12 table tennis players, 6 badminton players, and 6 tennis players. The average training frequency of the athletes was five times a week for at least 2 hours a day. All athletes and non-athletes were clinically healthy and had no history of any upper extremity fractures. No one from the non-athletes group was engaging in physical activity. All subjects were informed of the study procedure, and informed consent permissions were obtained. The study was organized and conducted in accordance with Helsinki protocol. The ethical approval was taken by the Clinical Research Committee of Ondokuz Mayıs University, number 2017/270.

2.3 International physical activity questionnaire (IPAQ)

The short-form of IPAQ was used to determine the physical activity level of individuals in 7 questions concerning the subject's activity patterns a week earlier [14]. The physical activity level of athletes was found to be "adequate" ($>$ 3000 MET min/week), while non-athletes was found to be "inactive" ($<$ 600 MET min/week).

2.4 Anthropometric measurements

Height and body weight of athletes and non-athletes were measured with the Gaia 359 Plus BodyPass analyzer. Lean body mass was calculated as [15]:

$$eLBM = 0.407W + 0.267H - 19.2$$

2.5 Bone mineral density

The BMD at multiple skeletal sites (i.e., humerus, radius-ulna, lumbar spine L1-L4, and femur neck) were measured. A dual energy X-ray absorptiometry device (DEXA Hologic QDR 2000, Discovery Series; Hologic, Inc., Waltham, MA, SUA). With BMD calculated as (g/cm^2). Specifically, proximal humerus (metaphysis), humeral shaft (diaphysis), distal humerus (metaphysis), radial shaft, and distal radius. Coefficients of variation (CV) for the parameters were less than 1%. Display of the measured BMD areas is illustrated in Fig. 1.

2.6 Statistical analysis

The mean percentage difference between the dominant and non-dominant side in BMD was calculated as [16]:

$$\text{side to side difference in } BMD(\%) = \frac{\text{dominant arm } BMD - \text{nondominant arm } BMD}{\text{nondominant arm } BMD} \times 100 \quad (1)$$

The mean percentage difference between athletes and non-athletes in BMD was calculated as:

$$\text{mean \% difference in } BMD(\Delta\%) = \frac{\text{Athletes } BMD - \text{Non} - \text{athletes } BMD}{\text{non} - \text{athletes } BMD} \times 100 \quad (2)$$

In the G power analysis conducted to determine the number of subjects, the results indicated that 20 people for each group is needed to accomplish this study (actual power: 0.85); however, 24 participants in the athlete group and 22 participants for non-athletes joined in the study. The data were analyzed using SPSS version 21 (SPSS, Inc., Chicago, IL, USA). Variables were checked for normality using the Kolmogorov-Smirnov test with distribution was found to be normal. Side-to-side differences in BMDs between the dominant and non-dominant arm of athletes and non-athletes were determined using paired *t*-test. BMDs across the two study groups (athletes versus non-athletes) were analyzed using the analysis of covariance, including body mass and lean body mass as covariates. The results then expressed as mean $\pm$ standard deviation with a 95% confidence interval.

TABLE 1. Characteristics of subjects.

	Athletes	Non-athletes
	Mean (SD)	**Mean (SD)**
Age (year)	22.46 (2.41)	21.45 (1.74)
Height (cm)	177.54 (4.81)	178.82 (6.47)
Weight (kg)	77.12 (9.19)	77.59 (18.11)
Lean body mass (kg)	59.60 (4.38)	60.11 (8.36)
Sports age (year)	10.96 (0.85)	-

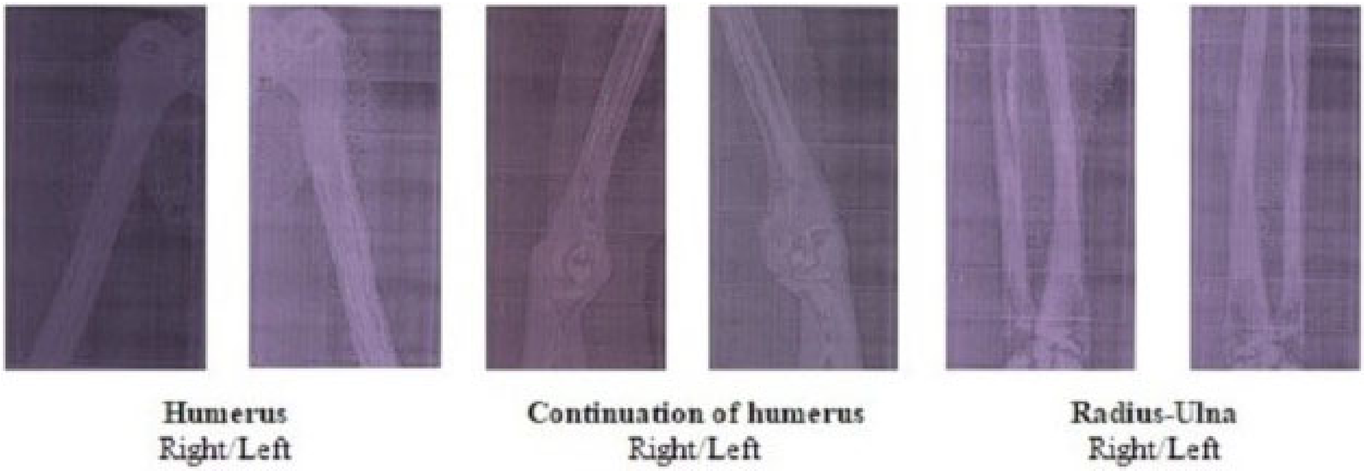

FIG. 1. Display of the measured BMD areas.

TABLE 2. Dominant versus non-dominant arm BMD values.

BMD (g/cm^2)	Athletes			Non-athletes		
	Dominant Mean (SD)	Non-dominant Mean (SD)	Side to side difference (%)	Dominant Mean (SD)	Non-dominant Mean (SD)	Side to side difference (%)
HUMERUS						
Proximal	1.0 (0.15)* (P = 0.02)	0.91 (0.16)	19.85‡ (P = 0.003)	0.93 (0.15)	0.87 (0.13)	9.39
Humeral shaft	1.27 (0.09)* (P = 0.03)	1.18 (0.21)	12.02† (P = 0.02)	1.17 (0.19)	1.17 (0.12)	1.48
Distal	0.98 (0.22)	0.96 (0.22)	6.32	0.93 (0.18)	0.89 (0.16)	7.22
RADIUS/ULNA						
Radial Shaft	0.62 (0.05)	0.61 (0.05)	1.66	0.66 (0.22)	0.60 (0.04)	8.93
Distal	0.47 (0.03)	0.46 (0.04)	1.79	0.46 (0.05)	0.45 (0.04)	2.38

Difference between dominant and non-dominant arm: $^‡P < 0.01$, $^†P < 0.05$.
*Difference between athletes and non-athletes in dominant arm ($P < 0.05$).

3. Results

Group characteristics are shown in Table 1. No significant differences in age, height, weight, or lean body mass was observed between the two groups.

Dominant and non-dominant arm BMDs were given in Table 2. The proximal humerus (19.85%, $P < 0.01$) and humeral shaft (12.02%, $P < 0.05$) were higher in dominant arm compared to non-dominant arm in athletes. No significant difference between dominant and non-dominant arm was observed in non-athletes ($P > 0.05$).

When dominant arm BMDs were compared between athletes and non-athletes, statistically significant differences between the two groups were observed only in terms of the proximal humerus and humeral shaft ($P < 0.05$). Non-dominant arm BMDs were not significantly different between the two groups ($P > 0.05$).

Mean, SD, percentage difference, and P values for comparisons in BMD between athletes and non-athletes are shown in Table 3. Athletes had significantly higher BMDs of the lumbar spine (L1-L4) and femoral neck compared with non-athletes ($P < 0.01$ and $P < 0.05$, respectively). No significant differences in the BMDs of the radius and ulna between the two groups were observed ($P > 0.05$). The mean percentage difference in BMDs between groups was 8.08% in the lumbar spine and 14.28% in the femur neck in favor of athletes.

4. Discussion

The study shows that the BMD of racket athletes differs between dominant and non-dominant arms in favour of the dominant arm. However, such a difference was not seen in non-athletes. Besides, athletes' dominant arm BMD is higher than non-athletes. Another finding is that athletes' routine BMD values are better than non-athletes.

Comparing dominant and non-dominant arm BMDs was the main aim of our study. When differences were examined side-to-side, the dominant arm BMDs of racquet athletes were approximately 19.85% greater at the proximal humerus and 12.02% greater at the humeral shaft compared with their non-dominant arm BMDs. However, BMDs between dominant and non-dominant arm in non-athletes did not differ. These findings are consistent with those of previous studies [17–20]. Calbet *et al.* (1998) reported that the arm tissue mass (bone mineral content [BMC] + fat + lean mass) of tennis players is approximately 20% greater in the dominant arm compared with that in the contralateral arm because of a greater muscle mass and BMC [17]. The authors also observed no significant difference in BMC or BMD between contralateral arms in the control group, which is similar to our present findings. Ducher *et al.* (2011) reported that BMC in the playing arm is 16%-18% higher than that in the non-playing arm of tennis players [18].

Also, a previous study compared whole and segmental body

TABLE 3. Bone mineral density values of athletes and non-athletes in routine assessment.

BMD (g/cm^2)	Athletes Mean (SD)	Non-athletes Mean (SD)	$\Delta\%^a$	95% CI
Lumbar Spine (L1 to L4)	1.07 (0.12)	0.99 (0.15)	8.08, $P < 0.003^‡$	0.00 to 0.16
Femur Neck	1.12 (0.17)	0.98 (0.16)	14.28, $P < 0.032^†$	0.04 to 0.25
Radius/Ulna	0.75 (0.04)	0.77 (0.09)	-2.6	-0.06 to 0.02

^{a}mean% difference ($\Delta\%$) = (Athletes-Non-athletes) / Non-athletes *100.
$^‡P < 0.01$, $^†P < 0.05$.

composition variables of trained Brazilian table tennis players according to different performance levels and genders. In this study, BMDs were higher in the dominant arm than in the non-dominant arm in all competition levels [19]. Sanchis-Moysi *et al.* (2010a) revealed that the BMD of the dominant arm in tennis players is higher than their non-dominant arm BMD [21]. Warden *et al.* (2017) demonstrated that throwers within each maturity group have magnificent throwing-to-non-throwing arm differences in BMC [20].

Ducher *et al.* (2011) characterized geometric changes in the dominant radius in response to long-term tennis playing while assessed the influence of muscle forces on bone tissue by investigating the muscle-bone relationship. BMDs were slightly higher on the dominant side (+3.3%) than on the non-dominant side. This study indicated that the greater BMC at the dominant radius induced by long-term tennis playing is associated with a marked increase in bone size and slight improvements in volumetric BMD [18].

Furthermore, the effects of genetic, hormonal, and nutritional factors on bone formation in dominant and non-dominant arms to some extent are similar, that the higher BMD observed in the dominant arms could only be attributed to the unilateral loading that occurs with racquet sports. It also seems that the vibration of the racquet contributes causing recurrent mechanical stresses, muscle contraction, and torsional forces in the dominant arm [22, 23]. Thus, long-term participation in racquet sports causes significant osteogenic effects on arm bones [21, 24, 25]. These reasons may explain differences in BMDs between dominant and non-dominant arm in our athletes.

After that, we also compared dominant arm BMDs between athletes and non-athletes. In this comparison, only the BMDs of the proximal humerus and humeral shaft showed significant differences in favour of athletes. Non-dominant arm BMDs were similar between the two groups. Our results are concordant with cross-sectional studies showing that athletes have greater BMDs compared with the control groups [26–28]. These findings also go with Ahmadi & Amraei (2013) when compared the arm BMC and BMD of volleyball players and non-athletes and found that the dominant arm BMD is higher in volleyball players than in non-athletes, which is similar to our findings in the present study [26]. Whilst, Haapasalo *et al.* (1996) compared tennis players with controls and determined that relative side-to-side differences in BMD (range, + 5.8 to + 22.5%) were significantly larger in all measured humeral sites in players than in non-players [28]. The novel results of Nordström *et al.* (2008) suggested that playing badminton might be associated with higher gains in bone mass and size compared with ice hockey after puberty in men [27]. The differences observed by the authors may be associated with higher strains on the bones from badminton plays, which would explain why the BMDs of racquet athletes are higher than that of non-athletes in our study.

In this study, we evaluated routine BMDs of the participants finding that routine BMDs for the lumbar spine (L1-L4) and femoral neck were higher in athletes than in non-athletes. Whereas, we observed no significant differences in the BMDs of the radius and ulna between the two groups. Examining mean percentage differences in BMDs between athletes and non-athletes, we have observed the corresponding values of 8.08% at the lumbar spine and 14.28% at the femur neck in favour of athletes. This finding coincide with the results of the previous studies [3, 17, 20–22]. Also, Warden *et al.* (2017) works had explored physical activity-induced bone adaptations at different stages of growth. Results involved categorizing total of 90 baseball throwers and 51 controls into five matured groups. This study found that rowers in the post-mid group have a higher spine and hip BMDs than their opponent controls while throwers in the post-late group have greater total mass, lean mass, and hip BMDs than their controls [20].

Just as Ermin *et al.* (2012) investigated differences in BMD among adolescent female tennis and non-tennis players and found that lumbar spine and total hip BMD are higher for tennis players than for non-tennis players. However, these differences were not statistically significant. Tennis players had significantly greater femoral neck BMDs than non-tennis players. The authors thus hypothesized that this difference may play a substantial role in preventing osteoporosis and decreasing the risk of hip fractures later in life post sport career [29]. Ducher *et al.* (2005) also concluded that, among adults and children, all side-to-side differences are higher in the tennis group than in the control group [22]. Tennis players showed higher inter-arm asymmetry in the bone parameters, BMC, BMD, and lean mass compared with soccer players and the corresponding control group [17, 21]. These finding indicate that participation in tennis is associated with increased BMDs in the lumbar spine and femoral neck.

Besides, Nagata *et al.* (2002) investigations of the effect of exercise practice on the radius BMD of 480 women at the age of perimenopause and later on which divided the subjects into a group performing regular exercise and a control group not exercising regularly. Differences in mean radius BMDs were not statistically significant between the control and the exercising (i.e., tennis, ping-pong, golf, and volleyball) groups [30]. This study supports our current finding that radius-ulna BMD levels are not different between racquet athletes and non-athletes.

In another study, Tervo *et al.* (2010) investigated the influence of different types of weight-bearing physical activities on the BMD of 19 badminton players, 48 ice hockey players, and 25 controls. During their active career, where badminton players gained significantly more BMD compared with ice hockey players at all sites tested, including the femoral neck, humerus, lumbar spine, and legs. BMD gains in badminton players were also higher compared with those in the controls at all sites [31]. Tervo *et al.* (2010) thus suggested that badminton is a more osteogenic activity than ice hockey that could maximize peak BMDs in men. Interestingly, the former benefits of racquet sports in BMD appeared to be partly maintained at multiple sites up to 7 years after the end of the athlete's active career [31].

Kontulainen *et al.* (2003) in their study as well explained that the structural adaptation of the humeral shaft to long-term loading might be occurring due to periosteal reaction causing enlargement of the bone cortex; however, this adaptation is better in young starters than in older individuals [32]. From the other side, it has been determined that mechanical loading might be the dominant factor affecting bone mineral acquisition throughout life [33]. Especially in badminton and tennis, by which the force applied to the floor by player's jump is primarily absorbed by their feet and joints and causes high strain in the surrounding area, this situation reveals a strong marker to increased BMD. Studies on athletes have shown that exercise-induced stress in the skeleton generally causes a higher degree of mineralization in the bones [34]. This observation may explain why athletes have a higher BMD than non-athletes in our study.

More or less, our results differ from those of Sanchis-Moysi *et al.* (2010a), who reported no significant differences in the lumbar spine or femoral neck BMC or BMD between tennis players and the control group. Contradictions in results between studies are possibly related to age variation. In our study, the athletes' mean age was 22 years; by contrast, the mean age of subjects in the study of Sanchis-Moysi *et al.* (2010a) was 10 years [21].

Our study includes several limitations that may affect the interpretation of our results. Although all of the participants involved in racquet sports, the physical requirements of badminton, tennis, and table tennis remarkably differed. By which, it involved 24 subjects playing only these three racquet sports. Thus, despite our promising observations, evaluating other racquet sports separately with more participants might have affected the final results confirming our findings.

In conclusion, no significant difference was obtained between right and left arms' BMD values in the non-athletes, unlike the considerable difference found in athletes. This result suggests that, rather than genotype, or any other confounding factors such as being right/left-handed, playing racquet sports can have a crucial role in increasing bone mineral density in the related extremity. The BMDs of the dominant arm of athletes was found higher than those of the dominant arms of non-athletes. Finally, it is recommended that racket athletes also train their non-dominant arms to increase bone mineral density.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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