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The Comparison of Bone Mineral Content (BMC) and Bone Area in Professional Water Polo Players and Non-Athletes

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Abstract

The purpose of this study was to investigate the differences between bone mineral content (BMC) and bone area of the lumbar vertebral and femur in professional water polo players and their non-athlete male counterparts. This investigation was in the form of a comparative and cause-effect study. 17 professional male water polo players presence in the national team of Iran with having average age (23.06±1.70 yr), height (179.73±4.25 cm), weight (78.92±9.94 kg), participating background in water polo (8±1.2 yr) together with 17 healthy male non-athletes with having average age (25.83±2.59 yr), height (168.94±8.06 cm), and weight (65.84±9.69 kg). BMC and bone area were measured with Dual energy X-Ray Absorptiometry (DXA). Data analysis was done by descriptive and inferential (T-test) statistical methods using Statistical Package for the Social Sciences (SPSS) software (version 16). The obtained results in this study showed that there is significant difference between lumbar vertebral and femur BMC of the participants, respectively (T=4.15, P=0.001 and T=7.63 P=0.001). Also, significant difference for bone area of the lumbar vertebral and femur was observed among participants, respectively (T=4.04, P=0.001 and T=4.45, P=0.001). But there was no significant difference between L_4 bone area of the participants (T=1.86, P=0.072). The results of this research clarified that Water polo exercise can be an effective factor on BMC and bone area increase.

Keywords: BMC, Bone area, Lumbar vertebral, Femur, Water polo.

Introduction

Bone tissue, much like muscle, shows a high plasticity and through a continuous modeling and remodeling adapts to meet the strain demands that may be imposed by either external or internal forces (Lanyon, 1984; Wilmet, 1995). It has been documented that immobilization and weightlessness are associated with a decrease in bone mass, osteopenia, and in extreme cases, lead to osteoporosis with an increased risk of fractures (Wilmet, 1995; Raisz, 1971). Conversely, most cross-sectional (Nilsson, 1971; Kannus, 1994) and longitudinal studies (Dalsky, 1988; Peterson, 1991) have demonstrated that physical activity is associated with an increased bone mineral content (BMC) and bone mineral density (BMD), although some have failed to establish such a relationship (Jacobson, 1984; Suominen, 1993; Gleeson, 1990). BMC is either defined as the mass of mineral contained in an entire bone (g) or as the mass of mineral per unit bone length (g/cm). Although mineral mass can be expected to be a good surrogate of bone stability, BMC obviously is a size-dependent parameter (Schoenau, 2002). In other words, BMC refers to the absolute amount of hydroxyapatite-calcium and phosphate salts that are responsible for the hardness of the bone matrix-measured in grams (Plowman, 2008). There are several known determinants of bone mass, bone non-modifiable and modifiable. Non-modifiable factors consist of heredity (Kelly, 1993; Krall, 1993), race, and gender (Aloia, 1989). These factors account for approximately 50%-70% of the variation in total body BMC and BMD. Modifiable factors account for the remaining 20%-50% variation in bone mass including body composition, pubertal status, nutrition, and sports history (Edelstein, 1993; Hunt, 2005). Bone tissue, also called osseous tissue, is a dynamic, living tissue that is constantly undergoing change. In fact, adults recycle 5%-7% of their bone mass every week (Marieb, 2001). Bone remodeling refers to the continual process of bone breakdown (resorption) and formation (deposition of new bone). Bone remodeling plays an important role in regulating blood calcium levels and in replacing old bone with new bone to ensure the integrity of the skeletal system. The mass and shape of the bones depend largely on the stress placed on them. The more the bones are stressed (by mechanical loading in the form of activity), the more they increase in volume and mass, specifically at the site of mechanical loading. The concept that bone adapts to changes in mechanical loading is referred to as Wolff's Law (Beck, 1999). There is skeletal adaptation to exercise training; therefore, logic implies that there must also be an exercise response occurring within the skeletal system to bring about training adaptations. Unfortunately, researchers have not yet found a way to quantify the acute effects of exercise on the skeletal system. Some research has been conducted on the effects of exercise on biochemical markers of bone activity and the response of hormones known to be involved with bone remodeling (Lindsay, 1993; Nishiyama, 1988). However, human research in this area is limited. Although it is well established that bone responds to mechanical stress, notably to physical activity, the mechanisms by which bone responds to exercise are not fully understood. Water polo has several unique features. Roughly, it may be regarded as a combination of short-distance swimming and handball playing. The water polo player moves the length of the pool in quick swim sprints, following the course of the ball. The overhead throw is similar to that of a handball player, yet the water polo player lacks the advantage of firm ground and the ability to use the legs and torso to help generate power, as the athlete's feet do not reach the bottom of the pool while playing (Kavouras, 2006). Since a large portion of body weight is exerted on lumbar vertebral and femur, and on the other hand the highest probability of osteoporosis-induced fracture is seen in these limbs, the limbs can be considered as an index for evaluating the BMD and BMC (Ebrahimi, 2012). The purpose of this study, therefore, was to investigate lumbar vertebral and femur BMC/bone area of professional water polo players in comparison to non-athletes.

Methodology

Subjects

Professional water polo players

This investigation was in the form of a comparative and cause-effect study. 17 professional male water polo players presence in the national team of Iran with having average age (23.06±1.70 yr), height (179.73±4.25 cm), weight (78.92±9.94 kg), and participating background in water polo (8±1.2 yr) took part in this study. All athletes competed at the national level and had been training for at least the last 7 years before the study was carried out (> 3 h/day, 6 days/week, < 9 workouts/week, 11 months/year). More than 80% of their total training regimen was sport-specific from which approximately 40% was general fitness (swimming for the water polo players), 15% weight-lifting/strength-training exercises (both upper and lower limbs, 3-4 times/week of 1 h each), and the remaining 45% sport-specific drills and games, all being part of their typical training schedule.

Healthy non-athletes

17 healthy male non-athletes with having average age (25.83±2.59 yr), height (168.94±8.06 cm), and weight (65.84±9.69 kg) took part in this study. They were inactive and did not engage in any regular structured physical activity. The participants' in our study after filling out a written consent letter voluntarily. First, the participants were familiarized with the study conditions and the various aims needed for data collection. Participants were chosen based on lacking factors effecting BMC and bone area such as not having experienced bone fractures, not having heritable osteoporosis or former diabetes, cardiovascular diseases, and so forth. Also people with a background of smoking or taking drugs affecting BMC and bone area such as corten or anticonvulsant medicines (Ebrahimi, 2012) were not chosen to take part in the study. This screening was based on the questionnaires answered by the participants and confirmed by a specialist physician.

BMC and bone area measurements

The data were recorded by a specialist using Dual Energy X-ray Absorptiometry (DXA; HOLOGIC® Company, Russia), scales, a height meter and a medical questionnaire. Participants' weight was measured using digital scales (Beurer Company, German) having an accuracy of 100 grams and their height was measured using a wall height meter (Beurer Company, German) with an accuracy of 1 mm. To evaluate the BMC, BMD, T score, and Z score of the participants using DXA methods, the BMC and BMD values were measured in densitometry center by a specialist. In this study, two-body parts of professional water polo players and non-athletes, namely lumbar spine (lumbar 2nd, 3rd, 4th vertebral and L_{Total}) and hip bone (F_{Neck}, F_{Inter}, F_{Ward}, and F_{Total}); each having its own clinical values of BMC and bone area were investigated (Ebrahimi, 2012; Malandish, 2011). The results of each part were recorded in the computer individually, and the final data and colourful photograph were printed and analyzed by a lab specialist. The total values for each participant is calculated by the authors'.

Statistical analysis

Results are reported as means±standard deviations (SD). Normality of the distribution was assessed using the Kolmogorov-Smirnov test. Differences between BMC and bone area values of the lumbar vertebral and femur of professional water polo players and healthy non-athlete counterparts were evaluated by independent T test. All analyzes were carried out using SPSS 16.00 for Windows. Statistical significance was set at P<0.05.

Results

The data presented in table 1, indicate that participants were significantly different in lumbar vertebral and femur BMC ($P<0.05$) and also bone area of the lumbar vertebral and femur ($P<0.05$), with the exception of L_4 bone area of the participants ($P>0.05$).

Table 1. The comparison of BMC and bone area of the lumbar vertebral and femur in the participants.

Participants	Water polo players N= 17	Non-athletes N= 17	t	P
Variables	Mean±SD	Mean±SD		
Bone Mineral Content (g)				
L_1	17.35±2.54†	12.23±3.42	4.23	*0.001
L_2	18.58±2.83	13.73±3.39	4.18	*0.001
L_3	20.12±3.04	14.97±3.90	3.94	*0.001
L_4	20.94±3.13	16.10±5.01	3.02	*0.005
L_{Total}	76.98±10.98	56.82±14.73	4.15	*0.001
F_{Neck}	6.29±0.88	3.74±1.02	8.36	*0.001
F_{Inter}	38.20±5.32	22.06±5.09	8.59	*0.001
F_{Ward}	1.17±0.36	0.54±0.16	6.40	*0.001
F_{Total}	54.04±6.02	35.21±7.69	7.63	*0.001
Bone Area (cm^2)				
L_1	15.97±1.14	13.36±1.64	5.18	*0.001
L_2	16.54±1.19	14.12±1.85	4.34	*0.001
L_3	17.74±1.17	15.86±1.99	3.20	*0.003
L_4	19.15±1.40	17.68±2.79	1.86	0.072
L_{Total}	69.41±4.30	61.04±6.97	4.04	*0.001
F_{Neck}	5.55±0.51	4.18±0.89	5.22	*0.001
F_{Inter}	29.95±4.06	21.17±3.21	6.92	*0.001
F_{Ward}	1.08±0.26	0.75±0.18	4.12	*0.001
F_{Total}	46.62±5.51	38.50±4.78	4.45	*0.001

† Data are expressed as Mean ± SD, *Significant difference, $p<0.05$.

Discussion and Conclusion

Based on results obtained in this study, Water polo exercise can be an effective factor on BMC and bone area increase in the lumbar spine and femur. In other words, all of the professional water polo players were healthy. While among non-athletes, 10 (58.8%) and 1 (5.8%) had osteopenia in lumbar spine and femur, respectively. And also 1 (5.8%) non-athlete had osteoporosis in lumbar spine. According to our study hypothesis – there is different between BMC and bone area of the lumbar vertebral and femur in professional water polo players and their non-athlete male counterparts-BMC and bone area values of the lumbar spine and femur were significantly higher than that of the non-athletes ($P<0.05$), with the exception of L_4 bone area of the participants ($P>0.05$), however BMC and bone area values both lumbar spine and femur were higher than that of non-athletes. This finding concords with the results reported by Block et al (1989) and Kavouras et al (2006), but with the results reported by Andreoli et al (2001) disagreement.

The bone response to exercise is site-specific and load-dependent. Recent evidence suggests that the effects of physical activity at the whole body level may be regulated in a reciprocal manner, so that loaded skeletal sites may benefit from exercise, at the expense, however, of unloaded ones (Kavouras, 2006). Previous research with respect to the effects of water polo on bone mass is scarce. Block et al (1989) measured bone density at the spine and hip in 20 young adult male water polo players. Spinal trabecular, spinal integral, and hip bone densities were reported to be significantly higher in the athletes than in sedentary referents, by approximately 15.5, 10.3, and 10.5%, respectively. Andreoli et al (2001) used DXA to measure total and regional BMC and aBMD in 24 male water polo athletes (aged 22.4 years). Compared to sedentary subjects, athletes were reported to have higher aBMD at the arms (+ 9%), but similar values at the legs, trunk, and total body (Andreoli, 2001). Recently, Kavouras et al (2006) reported that water polo players had higher upper limbs BMC, bone area, and aBMD (by 22.2, 11.1, and 10.5%, respectively) relative to non-athletes. Bone mass is effectively under the influence of mechanical pressures exerted on the skeletal system (Plowman, 2008; Ebrahimi, 2012; Malandish, 2011). Since some special movements in water polo exercise such as start, jumping, salto, exerting pressure by lower limbs, on to pool wall strength impacts of ball and use of the arms (upper limbs), confers a generalized positive effect on the skeleton as a result of impact and/or active loading at multiple sites (Andreoli, 2001). Mechanical pressure on the bone mass, through tendons and muscle influences bone formation (Ebrahimi, 2012; Malandish, 2011; Binbridge, 2004). In addition, the bone is considered as a piezoelectric crystal in which, mechanical pressure is converted to electrical energy and electrical changes along with the time when bone is under mechanical pressure, stimulates Osteoblast cells and increases calcium formation in professional water polo athletes (Plowman, 2008; Ebrahimi, 2012; Malandish, 2011). Impact and colliding activities like Water polo produce higher osteogenic stimulations on bone tissue than that of regular and light activities such as cycling (Plowman, 2008; Ebrahimi, 2012; Malandish, 2011; Medelli, 2009). On the other hand, we observed that, water polo athletes had increased BMC and bone area at both the lumbar vertebral and femur. Probably factors such as intensity, direction, and magnitude of the forced exerted on the bones are effective on BMC and bone area increases and among these, magnitude of the pressure is the chief factors (Ebrahimi, 2012; Malandish, 2011), and because in water polo exercise exerted high pressure on the skeleton system by suddenly direction changes and lead to increasing BMC and bone area of professional water polo athletes compared to non-athletes.

Our results indicated that the majority of non-athletes had abnormal bone mass in the lumbar vertebral, according to WHO definition. In other words, walking-induced pressures on lower limbs, especially hip bone of non-athletes lead to higher pressure than that of lumbar vertebral and cause more stimulation of osteoblasts in femur region (Ebrahimi, 2012; Malandish, 2011), justifying normal bone mass of non-athletes' femur in this investigation. These results indicated that the overall bone response in control groups is reciprocal in nature, with the lower limbs being favored at the expense of the upper limbs.

In conclusion, the present study has examined BMC and bone area of the lumbar vertebral and femur in water polo players and non-athletes. Compared to control groups, water polo athletes had higher BMC, bone area, and BMD at all regions and for total body. This seemed to be independent of their increased weight and height. These results suggest that the overall bone response to water polo is positively and clearly in nature and lead to increasing BMC, bone area, and BMD of both the upper limbs and lower limbs.

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