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The Comparison of BMC, BMD, T score, and Z score of the Lumbar Spine and Femur between Professional Swimmers and Non- athletes

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Abstract

Purpose: The purpose of this study was to investigate the differences between bone mineral content (BMC), bone mineral density (BMD), T score, and Z score of the lumbar spine and femur in professional swimmers and their non-athlete male counterparts.

Material and Methods: This investigation was a comparative, cause-effect study. 17 professional, male swimmers from Iran's national swimming team (age 23.59±2.34 yr, height 176.76±6.68 cm, weight 68.70±7.40 kg, swimming background 10±2.5 yr) and 17 non-athlete, healthy males (age 25.83±2.59 yr, height 168.94±8.06 cm, weight 65.84±9.69 kg) participated in this study. Data were evaluated using BMC and BMD assessing device, Dual energy X-Ray Absorptiometry (DXA). A medical history questionnaire was also filled out for each participant by a specialist physician. In this research bone density of femur and second to fourth lumbar vertebrae were evaluated. Data analysis included descriptive and inferential (T-test) statistics ($p \leq 0/05$) and was done using SPSS-16 software.

Results: Results from the present study showed that BMC and BMD of femur, BMC, BMD, T score, and Z score of lumbar vertebrae did not differ significantly in professional swimmers and non-athletes ($P > 0.05$); while T score and Z score of femur were significantly different between professional swimmers and non-athletes ($P < 0.05$).

Discussion and Conclusion: Results of this research clarified that exercise and sport activity, on their own, cannot be an effective factor in increasing BMC and BMD; and that, type of the exercise and the way it is performed may probably be counted as significant factors in professional swimmers' BMC and BMD. Accordingly, in order to increase their BMC and BMD and to prevent osteopenia or osteoporosis in old age, it is recommended to professional swimmers to try other physical activities such as weight-bearing exercises, choose appropriate methods of exercising, and use a balanced diet supplemented with calcium and dairy products.

Key words: BMC, BMD, T score, Z score, Swimming

Introduction

Bone is a metabolically active tissue with continuous remodeling occurring throughout its life [1]. Different kinds of physical loading might have different effects on bone mineral density (BMD). The influence of exercise and mechanical loading on skeleton peak bone mass has been studied extensively in humans [2, 3]. Peak bone mass is defined as the highest level of BMD or bone mineral content (BMC) or bone mass (BM) reached during life [4]. These are all estimations of the amount of mineralised bone. BMD is a more generalized term when describing the amount of mineral, BMC the amount of mineral measured within the scanned skeletal region and BMD the amount of mineral measured within the scanned skeletal region but partially adjusted for the bone size [4, 5]. If growing children built a skeleton with a lower peak bone mass than 50 years ago, then the fracture risk ought to have increased during the same period. It seems possible that this has occurred, as today we live a more sedentary life than some decades ago, although no long-term studies are available to support this assumption [5]. If we could implement changes in the current lifestyle by increasing levels of physical activity,

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we could possibly also increase the accrual of bone mineral so that young individuals of today reach a high peak bone mass. A higher peak bone mass would then probably reduce the number of fractures, as 50% of the BMD in old age is attributed to the peak bone mass [6]. Epidemiological studies have convincingly shown that BMC and BMD are closely associated with the risk of sustaining a fracture [4, 7]. A 10% decrease in BMD (corresponding to one standard deviation; SD) is associated with a doubled fracture risk [7].

Bone mass and density are influenced by a number of factors, some being modifiable and others not. Although the genetic background of an individual is a major determinant of one's bone mass [8], many environmental and lifestyle factors may exert a physiologically significant effect, or even modify the outcome of genetic predisposition [9]. Physical activity is a modifiable factor that has attracted much interest throughout the years and, despite evidence being inconclusive, regular exercise has been advocated for maximizing bone accretion during childhood, optimizing peak bone mass, and maintaining bone mass or delaying its loss later in life [10, 11]. The skeletal response to exercise appears complex in nature, but some underlying principles have been identified, such as overload and specificity: only the bones directly loaded by physical activity will increase their mass appreciably, and for this to happen, imposed mechanical loads must exceed normal loading patterns [12]. According to the mechanostat theory (Figure 1), an externally applied load (stress) causes some degree of bone deformation (strain), and the latter has to exceed a threshold (minimum effective strain) to effect changes in the bone remodeling cycle [13]. Initiating sport activities in childhood and teens is an important basis of health and personal sanitary during middle and old age [14]. Exercise training and physical activities are necessary for formation and maintenance of stout and powerful bones. Activities capable of stimulating osteoblasts are those which influence all bones and accelerate calcium absorption. These activities are only achieved through weight-bearing-exercises [15]. A large number of authors have investigated the effect of physical activities on BMD and BMC. According to these investigations, osteoblasts exhibit response to mechanical stimuli resulting from exercise training and consequently increase bone formation significantly [16, 17]. Physical activities and exercise training as conserving and stimulating factor of osteoblasts that – through accumulating minerals – improve muscle power and person balance and besides, reduce the risk of bone fracture. Moreover, initiating sport activities at different rates and severities before maturation accompanied by taking suitable amounts of calories and calcium, increase BMC and lateral growth of the bones [18].

Some investigators have claimed that athletes participating in non-weight-bearing exercises such as swimming, cycling, and rowing possess lower BMD compared to those participate in sports like football, wrestling, gymnastics and Ping-Pong enduring body weight [19]. In general, performing sport training on hard and stiff surface along with more jumping, beating and shearing activities exerts more pressure on the bones and increases BMD [19, 20]. Creighton et al (2001) showed that for exercise training and physical activity to improve BMD and BMC, ground response force should be at least three times as much as body weight so that high pressure is exerted on the bones [21]. Through two methods of gravitational force and muscle tension, physical activity and sport training lead to force transmitting toward the bones and as a consequence of the forced exerted, BMD is improved [19].

Orwoll et al (1989) studied the BMD of swimmers and non-athletes and found that the BMD of lumbar vertebrae was higher in swimmers compared to their non-athletes counterparts [24]. In contrast, Nichols et al (1995), comparing BMD of swimmers and their non-athlete counterparts, reported that the BMD of lumbar vertebral and hip bone was 12.1% and 17.1% lower than that of the non-athletes, respectively [25]. Taaffe et al (1995) compared the effect of swimming on BMD among females. They found that swimming does not have a significant effect on BMD and BMC in females [26]. contradictory results are reported regarding the effects of non-weight bearing exercises on BMC and BMD. In addition, as identifying osteoporosis risk factors in professional swimmers is of great importance , the aim of the present study was to investigate the differences in BMC, BMD, T score, and Z score of the lumbar spine and femur of professional swimmers and their non-athlete counterparts.

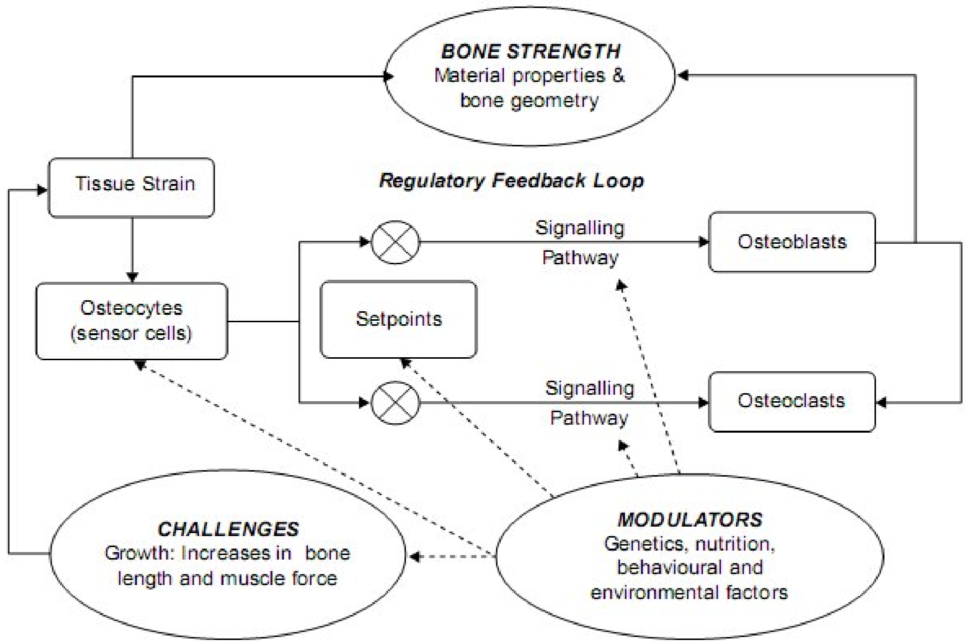

Figure 1: A functional model of bone development based on the mechanostat theory [22] and related approaches [23]. The central component of the regulation of bone development and adaptation is the feed-back loop between bone deformation (tissue strain) and bone strength. During growth, this homeostatic system must continually adapt to external challenges (increases in bone length and muscle force) to keep tissue strain close to a preset level (setpoint). Various modulating factors influence aspects of the regulatory system as indicated by the dashed arrows.

Material and Methods

Subjects

Professional Swimmers

This investigation was a descriptive (comparative, cause-effect) study. 17 professional male swimmers, all of them members of Iran's national swimming team (age 23.59±2.34 yr, height 176.76±6.68 cm, weight 68.70±7.40 kg, swimming background 10±2.5 yr) took part in this study. Professional swimmers had been training professional swimming at least for eight years, seven sessions a week, and 2 to 3 hours per session.

Healthy non-athletes

17 healthy, , non-athlete males (age 25.83±2.59 yr, height 168.94±8.06 cm, weight 65.84±9.69 kg) took part in this study. They were inactive and did not engage in any regular structured physical activity. All the participants took part in this study after filling out a written consent form voluntarily. All the participants were familiarized with the study conditions and data collection procedures before the start of the study. Exclusion criteria included having factors effecting BMC and BMD, such as bone fractures experiences, heritable Osteoporosis, former Diabetes, or cardiovascular diseases, a background of smoking or taking drugs affecting BMC and BMD, such as Corten or anticonvulsant medicines [19, 20].

This screening was done based on the questionnaires answered by the participants and was confirmed by a specialist physician.

BMC, BMD, T score, and Z score 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' weights were measured using digital scales (Beurer Company, Germany) with an accuracy of 100 grams and their heights were measured using a wall height meter (Beurer Company, Germany) with an accuracy of 1 mm. To evaluate the BMC, BMD, T score, and Z score of the lumbar spine and femur 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 swimmers and non-athletes, namely lumbar spine (lumbar 2^{nd}, 3^{rd}, 4^{th} vertebral and L_{Total}) and hip bone (F_{Neck}, F_{Troch}, F_{Inter}, F_{Ward}, and F_{Total}), each having its own clinical values of BMC and BMD, were investigated [19]. The results from studying each part were separately recorded in a computer, and the final data and colored photographs were printed and analyzed by a lab specialist. total values for each participant was calculated by the authors.

Statistical methods

Standard statistical methods were used to calculate means and standard deviations (± SD). Kolmogorov–Smirnov test was used to normalize the data. Independent T-test was used to compare BMC, BMD, T score, and Z score values of the lumbar vertebral and hip bone of professional swimmers and their healthy non-athlete counterparts. The data were analyzed using SPSS software (version 16). The level of significance was set at $P < 0.05$.

Results

As data presented in Table 1 show, there was no significant difference in BMC and BMD of femur, and BMC, BMD, T score, and Z score of lumbar vertebral between professional swimmers and non-athletes ($P > 0.05$); while T score and Z score of femur was significantly different between professional swimmers and non-athletes ($P < 0.05$).

Table 1: The comparison between BMC, BMD, T score, and Z score of the lumbar vertebral and femur in the participants.

Participants / Variables	Swimmers n= 15 Mean±SD	Non-athletes n= 18 Mean±SD	T	P
Bone Mineral Density (gr/cm^2)				
L_2	0.933±0.15	0.957±0.13	0.46	0.643
L_3	0.969±0.13	0.930±0.16	0.71	0.480
L_4	0.95±0.15	0.895±0.17	0.89	0.379
L_{Total}	0.946±0.10	0.915±0.14	0.60	0.548
F_{Neck}	0.946±0.10	0.874±0.18	1.27	0.212
F_{Troch}	0.833±0.10	0.660±0.15	3.47	*0.002
F_{Inter}	1.270±0.12	1.028±0.21	2.09	*0.049
F_{Ward}	0.830±0.09	0.662±0.16	3.27	*0.003
F_{Total}	0.943±0.14	0.882±0.18	0.98	0.335
Bone Mineral Content (gr)				
L_2	12.56±3.26	13.73±3.39	-0.956	0.347
L_3	14.22±3.22	14.97±3.90	-0.566	0.575
L_4	15.97±3.91	16.10±5.01	-0.077	0.939
L_{Total}	47.12±15.78	56.82±14.73	-1.757	0.090
F_{Neck}	3.90±1.19	3.74±1.02	0.401	0.692
F_{Troch}	10.57±3.99	8.99±2.82	1.300	0.204
F_{Inter}	34.67±5.53	21.49±5.49	4.333	*0.000
F_{Ward}	1.11±0.19	0.52±0.17	8.646	*0.000
F_{Total}	26.99±15.85	34.23±8.54	-1.642	0.111
T score				
L_2	-0.79±1.11	-1.16±0.96	0.988	0.332
L_3	-0.80±1.02	-1.24±1.18	1.074	0.292
L_4	-1.04±1.15	-1.30±1.34	0.549	0.587
L_{Total}	-0.91±1.05	-1.22±1.07	0.818	0.420
F_{Neck}	0.74±0.91	-0.29±1.34	2.419	*0.022
F_{Troch}	0.17±0.82	-1.35±1.14	3.964	*0.000
F_{Inter}	0.52±0.53	-1.13±1.40	2.292	*0.033
F_{Ward}	0.36±0.62	-1.01±1.27	3.464	*0.002
F_{Total}	0.52±0.63	-1.11±1.25	4.329	*0.000
Z score				
L_2	-0.79±1.11	-1.22±0.93	1.174	0.250
L_3	-0.80±1.02	-1.27±1.17	1.160	0.256
L_4	-1.03±1.14	-1.31±1.35	0.588	0.561
L_{Total}	-0.90±1.05	-1.25±1.07	0.898	0.377
F_{Neck}	0.58±0.84	-0.38v1.34	2.292	*0.029
F_{Troch}	2.08±0.82	-1.38±1.13	3.636	*0.001
F_{Inter}	0.52±0.53	-1.12±1.40	2.278	*0.034
F_{Ward}	0.05±0.66	-1.02±1.29	2.647	*0.013
F_{Total}	0.31±0.63	-1.13±1.25	3.803	*0.001

***** Significant difference, $p < 0.05$.

Discussion and Conclusion

Our results indicated that professional swimmers have higher BMD compared to healthy non-athletes at lumbar vertebral and femur regions, while BMC values of the lumbar vertebral and femur of healthy non-athletes were higher than that of the professional swimmers. However no significant differences were observed in BMD and BMC values between the groups (P > 0.05). Johnov (1994) hypothesized that since a large portion of body weight is exerted on lumbar vertebral and femoral neck, and on the other hand the highest probability of Osteoporosis-induced fracture is seen in these limbs, these regions can be considered as an index for evaluating the BMD and BMC [19].

Thus, participants' BMC and BMD values that in the femur (F_{Total}) no significant difference was observed; probably, due to femoral neck that there is not a significant difference.

T scores were calculated based on statistical measurements called standard deviations (SD) that reflect the difference between one's bone density and the normal bone density of the reference population, whose T scores and not z scores, are based on the World Health Organization (WHO) norms (Figure 1).[19, 20, 27]. As shown in Table 2, 100% of professional swimmers had normal bone mass status in their femur, while 47.05% of them had osteopenia (7 athletes) and osteoporosis (1 athlete) in lumbar vertebral.

64.7% of healthy non-athletes had osteopenia (10 non-athletes) and osteoporosis (1 non-athlete) in lumbar vertebral while only 1 (5.8%) professional swimmer had osteopenia in his femur (see Table 2). Based on the results presented in Table 1, BMD values of professional swimmers in the lumbar vertebral and femur were higher than that of the non-athletes, while BMC values of professional swimmers were lower than that of the healthy non-athletes. However no significant difference was observed between professional swimmers and non-athletes, regarding their BMC and BMD values of the lumbar vertebral and femur(P>0.05). This finding is in agreement with the results reported by Taaffe et al (1995), Fehling et al (1995), Cassell et al (1996), and Taaffe et al (1999) [26, 28, 29, 30]. In contrast, Nichols et al (1995) and Moral et al (2001) reported that the BMD of professional swimmers was lower than that of non-athletes. On the other hand Orwoll et al (1989) and Dereman et al (2008) reported that the BMD of the lumbar vertebral and femur were higher in swimmers compared to non-athletes, which contradicts the results of the present research [24, 32]. Factors such as professional level of athletes (amateur, elite, professional), intensity and duration of exercise, and age of the participants [19, 20,] can be considered as probable reasons for this lack of consensus.

Using T-Scores to Define Bone Health			
Osteoporosis	**Osteopenia**	Normal Bone Mass	High Normal Bone Mass
...-4.0 through -2.5	-2.5 through -1.0	-1.0 through +1.0	+1.0 through +4.0...

Figure 1: Diagnosis of bone mass status based on the WHO norms
T scores are based on statistical measurements called standard deviations (SD) that reflect the difference between one's bone density and normal bone density in the reference population.

Table 2: The participants' bone mass status based on the WHO norms (T score) and Z score.

Participants	**Swimmers n=17**		**Non-athletes n=17**	
Bone mass status	**Lumbar vertebral**	**Femur**	**Lumbar vertebral**	**Femur**
T score (WHO)				
Normal	9*	17	6	16
Osteopenia	7	0	10	1
Osteoporosis	1	0	1	0
Z score				
Normal	9	17	6	16
Osteopenia	7	0	10	1
Osteoporosis	1	0	1	0

*Numbers indicate the number of participants.

bone response to exercise is site-specific and load-dependent [33]. Volf law indicated that the mechanical pressure or stress on the bones, through tendons and muscle, influences bone formation and transformation [19, 20, 34]. In addition, the bone is considered as a piezoelectric crystal in which, mechanical pressure is converted to electrical energy and when bone is under mechanical pressure these electrical changes stimulate Osteoblasts and finally results in calcium formation [19, 20]. In addition, physical activities affect bone tissue substructures. Bone structure is effectively under the influence of mechanical pressures exerted on the skeletal system [20, 27]. Since some special movements such as start, jumping, salto and exerting pressure and strength force by lower limbs to pool's wall are common in swimming, this can be the probable cause of osteoblasts stimulation, justifying normal bone mass of swimmers' femur in this investigation. In both men and women, BMC and BMD increase throughout childhood and adolescence and reach a peak, usually in the third decade of their life. About 90% of the peak BMC accrues within the period of skeletal maturation [19, 20, 27]. It has been proved that weight–bearing–activities are more Osteogenic than non–weight bearing exercises and increase BMC and BMD to a greater extent [20]. Since swimming is a non–weight–bearing–exercise it probably does not influence osteoblast cells in the lumbar vertebral region. In our study, no differences were observed in the BMC and BMD of the lumbar vertebral (L_{Total}) and femur (F_{Total}) between professional swimmers and non-athletes. Probably factors such as intensity, direction and magnitude of the forced exerted on the bones are effective on BMC and BMD increases and among these, magnitude of the pressure is the chief factor [19, 20]. In general, one probable reason for the abnormality of lumbar vertebral BMD in professional swimmers might be that they had less contact with the ground for 2 to 3 hours per day which may reduce osteoblasts stimulation and BMD of professional swimmers [35]. In addition, because during swimming less reduction force is exerted on the lumbar vertebral as compared to the femur, the osteoblasts in lumbar spine are less stimulated and do not influence BMD of professional swimmers[27, 35]. Considering that nutrition and living status during growth periods are two of the limiting factors in our study, these may also be among the probable factors resulting in the reduction of professional swimmers' lumbar vertebral BMD. In other words, over consumption of protein and shortage of calcium lead to osteopenia and osteoporosis [19, 36]. Over consumption of protein has a higher effect on osteopenia and osteoporosis, compared to calcium shortage. Since professional swimmers have a balanced diet, over consumption of proteins in professional swimmers make their body unable to store or immediately metabolize the extra protein. Consequently, liver converts the amino acids to organic acids and these organic acids can be used for energy production, or be converted to lipids acidifying the blood. To compensate this acidification, kidney absorbs a large amount of calcium from the bones dissipating it through urine, the result of which may be professional swimmers' lumbar vertebral BMD reduction [19, 35, 36]. results of this study showed that swimming can by itself explain the abnormal low BMD values in professional swimmers. Therefore, we recommend that professional swimmers: (1) supplement their swimming with a kind of cross-training such as resistance training or impact exercise in order to improve their BMD and BMC of the lumbar vertebral and/ or BMD of the total body and to prevent osteopenia or osteoporosis in middle and old ages ; (2) consume a balanced diet with adequate calcium and vitamin D intake; and (3) avoid energetic foods (such as protein supplementations) which reduce BMD

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