Science & Sports (2019) 34, e259—e269

Disponible en ligne sur
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

ORIGINAL ARTICLE

What happens to bone mineral density, strength and body composition of ex-elite female volleyball players: A cross sectional study

Étude transversale sur le devenir de la densité minérale osseuse, de la force et de la composition corporelle d'anciennes joueuses de volleyball féminines d'élite

N. Küçükkubaş[a,*], **F. Korkusuz**[b]

[a] *Sports Management Department, School of Physical Education and Sports, Bozok University, 66100 Yozgat, Turkey*
[b] *Sports Medicine, Hacettepe University Hospitals, Ankara, Turkey*

Received 23 December 2017; accepted 5 November 2018
Available online 19 December 2018

KEYWORDS
Bone Mineral Density;
Ex-elite volleyball players;
Sedentary women;
Strength;
Body composition

Summary
Background and aim. — Bone Mineral Density (BMD) and effects of exercise have been extensively studied for prevention and treatment. However, little is known as what happens to body composition, bone, and strength in a long period of time after quitting. The aim of this study was to compare BMD of ex-elite volleyball players (Ex-eVP) and sedentary women (SW) at the age of 40 and over regarding to their body composition, muscle strength.
Materials and methods. — Thirty-three Ex-eVP and 33 sedentary women SW volunteers at the ages of 40 and over participated in the present study. BMD was measured by Dual Energy X-Ray Absorptiometry (DXA, Lunar Model DPX). Body composition compartments were obtained from total body scans. Takei Physical Fitness Test Dynamometers were used to measure subjects' leg, back and hand grip static strength.
Results. — Findings revealed that all sites of BMD values of ex-eVP (except for distal forearm values) were higher than that of SW. Body composition were examined in part, body weight of ex-eVP (67.9 ± 8.3 kg) were not significantly higher than SW (65.2 ± 9.2 kg), and

* Corresponding author.
E-mail addresses: nigar.kucukkubas@hotmail.com, nigar.kucukkubas@gmail.com (N. Küçükkubaş).

https://doi.org/10.1016/j.scispo.2018.11.006

lean body mass were significantly higher (41.59 ± 4.96 $P < 0.01$) than SW (37.80 ± 3.46) in their older ages. Gained bone mass remained higher significantly ($P < 0.01$) at major sites for total body scan of leg and regional body scan of $L_{2\text{-}4}$, in Ex-eVP (1.247 ± 0.170 and 1.217 ± 0.118 respectively) than SW (1.140 ± 0.132 and 1.144 ± 0.092 respectively) (Fig. 2). There was no significant difference in any of the left or right/dominant or non-dominant forearm and hip BMD values. Ex-eVP's static back, leg, left hand grip and right-hand grip strength (64.7 ± 11.7; 107.6 ± 27.2; 28.0 ± 3.4 $P < 0.001$ and 29.3 ± 4.3 $P < 0.01$ respectively) were significantly higher than that of SW (51.8 ± 12.1; 81.4 ± 25.0; 24.2 ± 3.6 $P < 0.001$ and 25.6 ± 4.3 $P < 0.01$ respectively) (Fig. 3). There was a significant but low relationship between Total Body BMD with FW for ex-eVP and total subjects ($r = 0.369$ and 0.311 $P < 0.05$ respectively).
Conclusion. — Playing volleyball at young ages helps to prevent osteoporosis and/or reverse bone loss, due to the possibilities of having less age-related bone loss and/or/both achieved higher peak bone mass than that of the sedentaries, notwithstanding age-related bone loss.

MOTS CLÉS
Densité minérale osseuse ;
Anciennes joueuses d'élite de volleyball ;
Femmes sédentaires ;
Force ;
Puissance ;
Composition corporelle

Résumé
Objectif. — Les effets de l'exercice sur la densité minérale osseuse (DMO) ont été largement étudiés en termes de prévention et de soins. Toutefois, on connaît mal les effets d'une longue période d'arrêt sur la composition corporelle, les os et la force de ces athlètes. Le but de cette étude est de comparer la DMO, la force et la composition corporelle d'anciennes joueuses d'élite de volleyball et de femmes sédentaires (FS) de 40 ans et plus.
Matériel et méthodes. — Trentre-trois anciennes joueuses d'élite de volleyball (JEVB) et 33 volontaires FS ont participé à cette étude. La DMO a été mesurée par absorptiométrie biphotonique (DEXA), qui donnait aussi la mesure des compartiments corporels. Des dynamomètres Takei ont été utilisés pour mesurer la force statique des jambes, du dos et de la poignée des volontaires.
Résultats. — Les résultats de l'étude ont montré que toutes les évaluations de la DMO (à l'exception des valeurs distales des avant-bras) des anciennes joueuses étaient plus hautes que celles des FS. Il y avait des corrélations signicatives et non significatives entre la composition corporelle et les sites de la DMO.
Conclusion. — Jouer au volleyball à un jeune âge aide à prévenir l'ostéoporose et/ou à inverser la perte osseuse, en raison des possibilités d'avoir moins de perte osseuse liée à l'âge et/ou d'atteindre une masse osseuse maximale plus élevée que celle des sédentaires, malgré la perte osseuse naturelle liée à l'âge.

1. Introduction

High BMD is a common result after long-term weight-bearing activity in the early ages. In recent years, due to modern lifestyle changes and lack or very low intensity of physical activity, the importance of maintaining skeletal health has been increasing. Regular exercise in adolescence [1], early adulthood [2] and premenopausal period [3] increases peak bone mass. In addition to physical activity, different body compartments provide mechanical loading and stress on bones. The factors appear beneficial for enhancing bone health in the early life particularly during the process of growth and development to deposit bone mineral. Achieving peak bone mass by using physical activity becomes important to reduce bone loss with aging to protect age-related loss in bone and muscle tissues. Regular exercise throughout life, furthermore, prevents bone loss [4,5]. Moreover, investigations of bone mass and body composition (BC) have arisen out of the common assumptions that BC is associated with bone mass [6,7]. There are also results about relationship between bone mass and strength of the adjacent muscles [8,9].

Most of the cross sectional and longitudinal studies answered the question of what happened after the predetermined exercise protocols or sports branches with different age groups and menopausal status for women [4,10—12]. Playing volleyball as a weight-bearing activity imposes one of the highest impact and weight-bearing load upon the axial skeleton and neck of the femur [6,13]. There is a need to know more about the real benefits of specific exercises in order to select those that are effective for optimizing bone mass and prevention of osteoporosis and fracture risk at the level of the skeletal segments of maximum interest, such as the lumbar spine and hip.

Findings examining the relationship of BMD and playing volleyball were clearly determined. Volleyball players have

higher BMD values than most of the weight-bearing athletes and sedentary or controls at the specific bone sites [6,14]. However, after giving up intensive training of the competitive athletes and having sedentary lifestyle is not answered. For this reason, the purpose of the study is to compare bone mineral density of ex-elite volleyball players and sedentary women at the later years of life and over regarding to their BC, muscle strength and BMD. Furthermore, the study was also designed to investigate the possible relationships between body composition, strength and BMD.

2. Materials and methods

2.1. Subjects

Thirty-three ex-elite volleyball players (ex-eVP) and 33 sedentary women (SW) volunteers at the ages of 40 and over were participated in the present study. The subjects' sports participation asked via telephone if they participated volleyball training (1st League and Turkish National Team Volleyball Players) at least 8 hours/week and 4 years of duration while they were at the young ages, plus they had given up sports participation (regular training with at least 8 hours/week and 3 days/week any sport branches which increase the heart rate and cause heavy sweating) The data collected from the all ex-eVP who are achieved to obtain their information and addresses and volunteer to participate for the study. SW volunteers did not participate in any regular exercise program in their lifelong. The study carried out in accordance with the World Medical Association Declaration of Helsinki, covering the latest revision date. Patient confidentiality protected according to the universally accepted guidelines and rules.

2.2. Data collection

The questionnaire was applied to the subjects before beginning of the measurements to inquiry the retrospective exercise/sports activity history [15]. Anthropometry, BMD and strength measurements were taken respectively.

2.2.1. Anthropometric measurement

Height, body weight, and arm span were taken between the 08.00—10.00 am. Arm span was measured by using ±0.1 cm sensitive gulickmeter. Body weight (BW) was measured using ±0.1 kg sensitive scale with the subject's light clothing and without shoes. Height (Ht) was measured to the ±0.1 cm sensitive fixed-rod stadiometer with bare-foot.

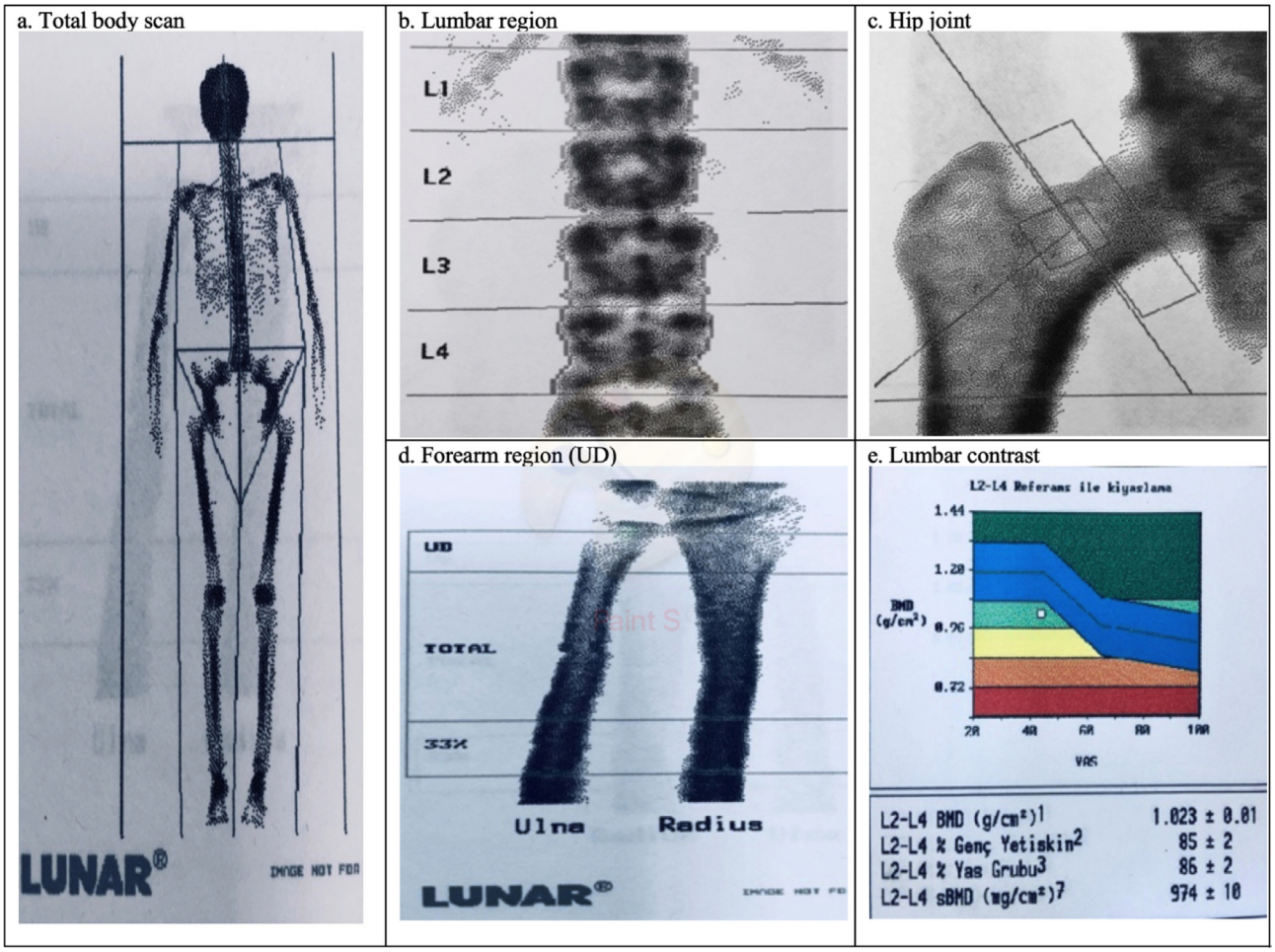

Figure 1 Bone mineral density measurements and analysis by DXA. a: total body scan; b: lumbar region; c: hip joint; d: forearm region (UD); e: lumbar contrast evaluation.

2.2.2. Bone Mineral Density (BMD) measurement

Dual Energy X-Ray Absorptiometry (DXA) (Lunar DPX Dual X-Ray Absorptiometry) was used to measure BMD of total body (arms, legs, trunk, and ribs), non-dominant and dominant femur (neck, wards, trochanter, shaft, and total), dominant and non-dominant distal part of radius (UD), lumbar spine 1, 2, 3, 4 (L_1, L_2, L_3, L_4 respectively) (Fig. 1). All the measurements were taken at the medium mode. Body Fat Percentage (BF%), Fat Weight (FW) and Lean Body Mass (LBM) were obtained from total body scan by DXA.

2.2.3. Strength measurements

Static muscle strengths were measured by Takei Physical Fitness Test Dynamometers. Grip, Leg and Back Strength testing procedures were applied as described in Takei Fitness Test Instructional Manual.

2.2.4. Statistical analysis of data

Physical parameters of ex-eVP and SW were compared by using independent samples *t* test. BMD of ex-eVP and SW were compared using MANOVA. MANOVA's assumptions were tested and there was no impediment to run MANOVA. All the assumptions of MANOVA were satisfied. Pearson Product Moment Correlation was also used to see the correlation between BMD specific regions and related regions' static muscle strength and physical parameters of ex-eVP and SW.

3. Results

Thirty-three females ex-elite volleyball players (ex-eVP) and 33 sedentary women (SW) at the ages of 40 and over were participated voluntarily in the study. The average age of the ex-eVP was 46.7 ± 3.2 years ranging from 40 to 55 years and 46.5 ± 3.4 years ranging from 41 to 55 for SW. Ex-eVP played volleyball for an average of 11.1 ± 5.0 years at elite level ranging from 4 to 23 years and they trained at least 8 hours/week at an average of 9.3 ± 1.8 hours/week. Demographic data of the subjects participated in the study are shown in the Table 1. Results showed that ex-eVP were significantly taller (164.8 ± 7.5; 159.3 ± 6.2 $P < 0.01$ respectively). Their arm span/Ht ratio was significantly lower (ratio = 0.991 ± 0.0195; ratio = 1.0025 ± 0.0271 $P < 0.05$) than SW, whereas their arm span-Ht difference was higher than SW group (difference = −1.52 ± 3.26; difference = 0.38 ± 4.34 respectively). BF% of ex-e VP was also significantly (36.7 ± 6.2; 39.8 ± 5.7 $P < 0.05$) lower and LBM was higher significantly than that of SW (LBM = 41.59 ± 4.96; 37.80 ± 3.46 $P < 0.01$) despite the fact that FW and BW was not significantly different (FW = 24.59 ± 6.06; 25.62 ± 6.64 $P > 0.05$ and BW = 67.9± kg respectively) (Table 1).

Table 1 Physical Parameters of ex-eVP ($n = 33$) compared to SW ($n = 33$).

Physical parameters	Ex-elite VP Mean ± SD	SW Mean ± SD
Age (years)	46.7 ± 3.2	46.5 ± 3.4
Height (cm)[b]	164.8 ± 7.5	159.3 ± 6.2
Body Weight (kg)	67.9 ± 8.3	65.2 ± 9.2
BMI (kg/m^2)	25.1 ± 3.1	25.8 ± 4.0
Arm Span (cm)	163.3 ± 8.1	159.6 ± 7.2
Arm Span/Ht[a]	0.991 ± 0.0195	1.0025 ± 0.0271
Arm Span-Ht (cm)[a]	−1.52 ± 3.26	0.38 ± 4.34
BF%[a]	36.7 ± 6.2	39.8 ± 5.7
LBM (kg)[b]	41.59 ± 4.96	37.80 ± 3.46
FW (kg)	24.59 ± 6.06	25.62 ± 6.64

[a] Significant at 0.05 level.
[b] Significant at 0.01 level.

Table 2 BMD of Ex-eVP ($n = 33$) compared to SW ($n = 33$).

BMD site	Ex-eVP Mean ± SD	SW Mean ± SD
L_1[a]	1.154 ± 0.152	1.045 ± 0.119
L_2[a]	1.223 ± 0.149	1.115 ± 0.126
L_3	1.261 ± 0.178	1.185 ± 0.177
L_4[a]	1.250 ± 0.197	1.140 ± 0.155
$L_{2\text{-}4}$[b]	1.247 ± 0.170	1.140 ± 0.132
Right hip		
Neck	0.973 ± 0.130	0.941 ± 0.102
Wards	0.853 ± 0.148	0.808 ± 0.119
Trochanter	0.844 ± 0.150	0.801 ± 0.122
Shaft	1.197 ± 0.185	1.178 ± 0.167
Total	1.013 ± 0.153	0.977 ± 0.128
Left hip		
Neck	0.986 ± 0.141	0.933 ± 0.106
Wards	0.869 ± 0.142	0.814 ± 0.109
Trochanter	0.844 ± 0.152	0.796 ± 0.118
Shaft	1.208 ± 0.192	1.154 ± 0.146
Total	1.017 ± 0.157	0.964 ± 0.117
Total body scan (regional)		
Arms	0.856 ± 0.085	0.830 ± 0.062
Legs[b]	1.217 ± 0.118	1.144 ± 0.092
Trunk[a]	0.960 ± 0.088	0.917 ± 0.072
Ribs[a]	0.715 ± 0.075	0.680 ± 0.058
Pelvis	1.114 ± 0.093	1.077 ± 0.095
Spine	1.234 ± 0.162	1.175 ± 0.136
Total body	1.164 ± 0.089	1.127 ± 0.073
Hip and forearm		
Right forearm (UD)	0.522 ± 0.058	0.520 ± 0.058
Left forearm (UD)	0.515 ± 0.057	0.517 ± 0.058
Dominant hip (Total)	1.010 ± 0.151	0.977 ± 0.128
Non-dominant Hip Total	1.020 ± 0.157	0.964 ± 0.117
Dominant forearm (UD)	0.523 ± 0.059	0.520 ± 0.058
Non-dominant forearm (UD)	0.515 ± 0.057	0.517 ± 0.058

[a] Significant at 0.05 level.
[b] Significant at 0.01 level.

BMD results of subjects are presented in Table 2. Although all the Ex-eVP's BMD values were higher than that of SW, significant differences exist in L_1, L_2, L_4, $L_{2\text{-}4}$, legs, trunk, and ribs (Fig. 2).

There was no significant difference in any of the forearm and hip BMD values. In addition to that, except for left and non-dominant forearm value, all the BMD results of the ex-eVP are higher than that of SW (Table 2).

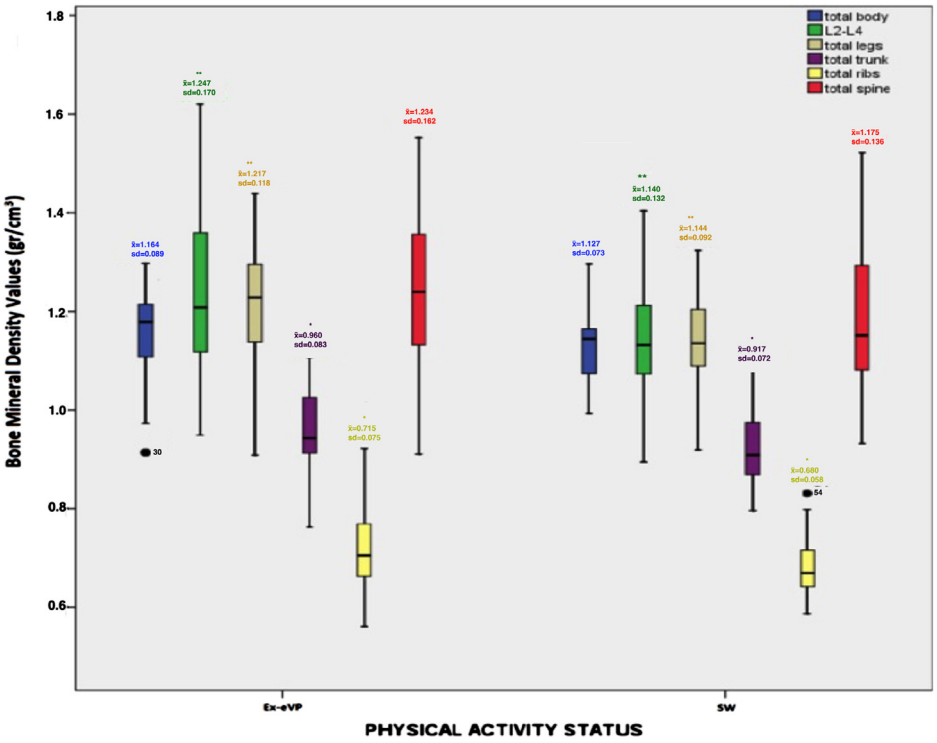

Figure 2 Box-plot graphs for bone mineral density of L_2—L_4 and some major site comparisons by total body scan. Bone mineral density means and sd of total body; L_2—L_4; total legs; total trunk; total ribs; total spine respectively. Ex-eVP = 1.164 ± 0.089; 1.247 ± 0.170**; 1.217 ± 0.118**; 0.960 ± 0.088*; 0.715 ± 0.075*; 1.234 ± 0.162. SW = 1.127 ± 0.073; 1.140 ± 0.132**; 1.144 ± 0.092**; 0.917 ± 0.072*; 0.680 ± 0.058*; 1.175 ± 0.136. *Significant at 0.05 level; **significant at 0.01 level.

As can be seen in Fig. 3, ex-eVP's static back, leg, left hand grip and right-hand grip strength were ($P < 0.001$) significantly higher than the SW.

In Table 3, the results obtained through Pearson product moment correlations are given for ex-eVP and SW. The significant positive relationships between the variables for ex-eVP were as follows; $L_{2\text{-}4}$ — BMI, $L_{2\text{-}4}$ — Mean BMD of hip total, mean BMD of hip total — BMI, mean BMD of hip total (dominant) — BW, and mean BMD of Hip Total (non-dominant) — BW. The significant positive relationships between the variables for SW were as follows; mean BMD of hip total — BMI, BMD of hip total (dominant) — BW, BMD of hip total (non-dominant) — BW, and mean BMD of hip total-arm span/Ht. There is no significant relationship between BMD of $L_{2\text{-}4}$ or total body and arm span — Ht difference.

In Table 3, there were significant relationships between Total Body BMD and BC in BMI of FW of SW and BMI of all subjects ($r = 0.352$ and 0.298 $P < 0.05$ respectively). There were also significant but low relationship between Total Body BMD with FW of ex-eVP and total subjects ($r = 0.369$ and 0.311 $P < 0.05$ respectively). Another critical BMD point can be seen there is no significant relationship between BMD of $L_{2\text{-}4}$ and BC except significant low relationship ($r = 0.348$) of BMI of ex-eVP.

4. Discussion

Mechanical forces (physical activity and weight-bearing exercise) through gravity or muscle pull are major factors in bone modeling and remodeling maintaining bone mass and strength [4,16,17]. Exercise has a beneficial effect on the growing skeleton by acting to maximise peak bone mass. Physical training and weight-bearing activity prevent or reverse the involutional loss of bone with age [16,17]. Most effective type of exercise, frequency and intensity must be stated for different population characteristics in order to use exercise for different purposes of achieving peak bone mass, prevention and/or treatment for osteoporosis. Many researchers concluded that intervention studies show a positive effect of exercise on bone mass [5,18]. However, conflicting results are also reported [19,20]. Notwithstanding the above reported results, most of the cross sectional studies show larger positive exercise effects on BMD [20,21].

Physical parameters of ex-eVP and those of SW results showed that height of the ex-eVP (164.8 ± 7.5) was significantly ($P < 0.01$) higher than SW group (159.3 ± 6.2). Although, both groups' BWs did not differ significantly ($P > 0.05$), ex-eVP (67.9 ± 8.3) heavier than SW (65.2 ± 9.2). Sleivert et al. [22] conducted a study to determine the neuromuscular differences of volleyball players, middle distance runners and non-athletes. They found that volleyball players were taller, and heavier than runners and non-athletes. Fehling et al. [23] also found similar results for young university athletes that volleyball players were significantly taller and heavier than all gymnasts, swimmers, and control group. Lee et al. [24] provided some information about the physical characteristics of young athletes to determine volleyball, basketball, soccer and swimming programs' association with site-specific differences. In their

Table 3 Correlation Coefficients between BMD and possible related variables.

Variables	EX-EVP ($n=33$)	SW ($n=33$)	∑subjects ($n=66$)
L_{2-4} — Back strength	0.165	0.204	0.310[a]
L_{2-4} — BMI	0.348[a]	0.059	0.151
L_{2-4} — Arm span	−0.169	−0.039	−0.027
L_{2-4} — Arm span/Ht	−0.003	−0.023	−0.093
L_{2-4} — Arm span-Ht	−0.009	−0.030	−0.091
Total BMD — Arm span-Ht	−0.018	0.268	0.065
UD (right) — Arm span-Ht	−0.037	0.135	0.053
UD (left) — Arm span-Ht	−0.022	0.125	0.065
BMD of leg (total body scan) — Leg strength	0.224	0.241	0.342[b]
Mean BMD of hip tTotal — Leg strength	0.140	0.208	0.221
Mean BMD of hip total — BMI	0.439[a]	0.569[b]	0.465[b]
Mean BMD of hip total — BW	0.389[a]	0.482[b]	0.441[b]
BMD of hip total (dominant) — BW	0.410[a]	0.518[b]	0.468[b]
BMD of hip total (non-dominant) — BW	0.365[a]	0.430[a]	0.406[b]
Mean BMD of hip total — Arm span/H	0.191	0.481[b]	0.276
Mean BMD of hip total — Arm span H	0.196	0.476[b]	0.275[a]
Total Body BMD — BMI	0.325	0.352[a]	0.298[a]
Total Body BMD — FW	0.369[a]	0.316	0.311[a]
Total Body BMD — LBM	0.077	0.163	0.189
BMD of L_{2-4} — BMI	0.348[a]	0.059	0.151
BMD of L_{2-4} — FW	0.320	0.069	0.162
BMD of L_{2-4} — LBM	0.084	0.001	0.184

[a] Significant at 0.05 level.
[b] Significant at 0.01 level.

study, the results showed that, active volleyball players were significantly taller and heavier than sedentaries. Volleyball players were heavier than sedentary or controls in their young active ages [23—25]. In addition, BMI values of ex-eVP did not differ significantly from SW. The results of the present study are in line with the results of Fehling [23] and Alfredson [25] studies. In the Johnell's [26] Medos Study, there is no linear relationship between BMI and risk factor for fracture, however, in the study, it was stated that BMI of 26 kg/m^2 or more (or a weight of over 70 kg) was not associated with a further decrease in fracture risk and a significant threshold was found at a BMI of 26.2 (or weight of over 70) that for each unit decrease in BMI, the fracture risk increased. In the present study, the BMI results of ex-eVP (25.1 ± 3.1) and SW (25.8 ± 4.0) did not fall at the risk group values.

Whether or not, ex-eVP, have not significantly higher BW, FW and and BMI, LBM of ex-eVP were significantly higher (41.59 ± 4.96 kg) than that of SW ($37.80 \pm$ kg) in their older ages (Table 1). Similar results were obtained that active volleyball players were heavier BW and LBM than non-active female in the study of Alfredson [25] might affect BMD as an impact loading in their young ages might be the possible result of higher BMD. The end result supports that Ex-eVP' previously achieved bone mass remains higher BMD. Althougth ex-eVP gave up their active elite level exercise period, the result of their sedentary life style after their active intensive training period could make them gained and age-related bone loss rate higher. They also would have taken the advantage of high BMD along their life.

Due to the fact that osteoporosis results in a reduction of height and arm span remains unchanged, arm span-Ht difference have been used to predict osteoporosis [27]. One of the findings of the present study was that the arm span/Ht ratio ($P=0.049$) was significantly higher for SW (1.0025 ± 0.0271) than ex-eVP (0.991 ± 0.0195). In addition, their arm span-Ht difference significantly higher for SW (0.379 ± 4.339) than that of the ex-eVP (-1.515 ± 3.263 $P<0.05$). In spite of the findings, BMD of the SW was not significantly higher in any of the BMD results of ex-eVP. In contrast, significant difference was found in BMD of ex-eVP in L_1, L_2, L_4, L_{2-4} as compared to SW favoring the former group. Therefore, according to the results it could be stated that arm span/Ht or arm span-Ht difference was not the marker of BMD. Although arm span was not significantly different in ex-eVP (163.3 ± 8.1) it was still higher than that of the SW (159.6 ± 7.2) ($P=0.056$). The result might be ex-eVP had taller than SW significantly whereas their arm span was not. Moreover, there was no significant high relationship between BMD of total body, L_{2-4}, UD (right and left), mean hip total and arm span/Ht or arm span-Ht difference for either group or all subjects. Arm span and Ht relationships have been studied for vertebral deformities or fracture risks for the postmenapausal women [28,29] and predict height for clinical usage [29,30]. To state a relationship between arm span/Ht rate or arm span-Ht difference and BMD needs to be further analyzed with a larger group and different population characteristics.

Despite the fact that BMD values of volleyball players and sedentary controls at the younger ages are not known, the results gave chance to compare the effects of the playing

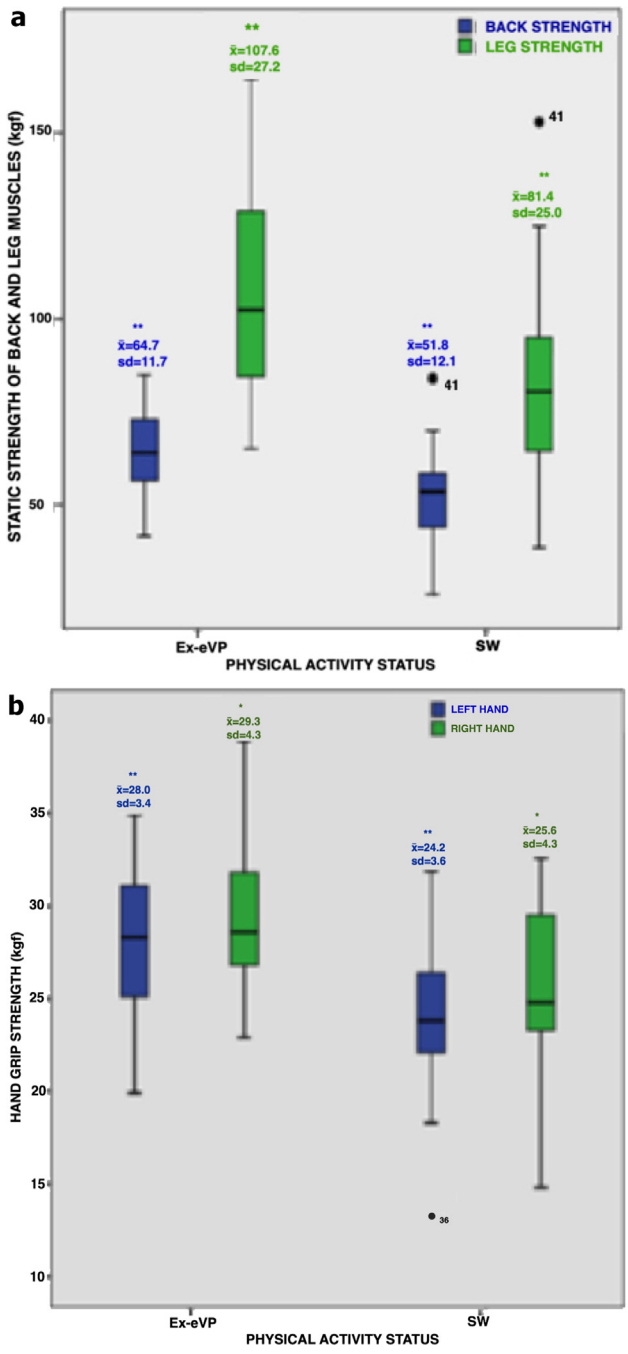

Figure 3 Static strength of the muscles; a. back and legs, b. left and right-hand grips. a: means and sd of the back and leg muscles respectively. Ex-e VP = 64.7 ± 11.7; 107.6 ± 27.2; SW = 51.8 ± 12.1; 81.4 ± 25.0. b: means and sd of the left and right-hand grip strength respectively; Ex-eVP = 28,0 ± 3,4; 29,3 ± 4,3. SW = 24,2 ± 3,6; 25,6 ± 4,3. *Significant at 0,01 level **significant at 0.001 level.

volleyball. The findings of the present study showed that ex-eVP had higher BMD values than SW. All the BMD results (except non-dominant and left forearm) were higher than SW provided that only L_1, L_2, L_4, L_{2-4}, legs, trunk, and ribs were statistically significant in favour of the ex-eVP. This could reflect systemic effects of exercise. Heinonen et al. [9] and Suominen's review [16] supported the results of the present study.

Nichols et al. [31] gave BMD results of the young volleyball, basketball, tennis players, and non-athletes in the study. Nichols' study [31] showed that young volleyball players BMD values were higher than non-athletes, other athletic group (except for basketball players total hip value = 1.226 ± 0.075 and gymnasts arm value = 0.907 ± 0.065), ex-eVP and SW group of the present study. Due to the fact that subjects of the Nichols' study [31] were active young volleyball players, whom of the present study were not. For both studies, comparing the results of the volleyball group with ex-eVP and sedentary group with non-athlete groups' L_{2-4}, neck, total, leg, arm bone density, not only young the volleyball players but also the control group were higher in the young group except arm site. Young volleyball players (1.197 ± 0.106) and non-athletes (1.050 ± 0.126) hip neck BMD results are higher than ex-eVP (right hip neck = 0.973 ± 0.130; left hip neck = 0.986 ± 0.141) and SW (right hip neck = 0.941 ± 0.102; left hip neck = 0.933 ± 0.106). Young volleyball players (1.221 ± 0.044) and non-athletes (1.110 ± 0.066) total hip BMD results are higher than ex-eVP (BMD of right hip total = 1.013 ± 0.153; BMD of left hip total = 1.017 ± 0.157) and SW (right hip total = 0.977 ± 0.128; left hip total = 0.964 ± 0.117). Total leg BMD values are higher in young volleyball players (1.320 ± 0.067) than SW (1.144 ± 0.092) or non-athlete (1.147 ± 0.090) group in the Nichols study [31] and in the present study, however, ex-eVP leg BMD value (1.217 ± 0.118) was higher than young non-athletes (1.147 ± 0.090). In addition to that results, ex-eVP arm value (0.856 ± 0.085) was lower than Nichols study's [31] volleyball players (0.872 ± 0.026), whereas higher than young non-athlete group (0.807 ± 0.051) of Nichol's study [31]. The result showed that the positive effect of playing volleyball and the reason of the difference may be the result of the age-related bone loss. In order to compare the values of both groups in different studies by giving details older group has age-related bone loss. The present study showed a considerable result that arm BMD value show a different result from the other site for the SW (0.830 ± 0.062), which is higher than young non-athletes (0.807 ± 0.051). The reason could be the result of the sample size or other factors effecting BMD values.

As the results showed the same findings, it could be claimed that by playing volleyball, as a regular intensive weight-bearing exercise, in adolescence and young adulthood, one can achieve the higher peak bone mass [6,7,14,23–25,31,32]. Although BMD of L_1, L_2, L_4, and L_{2-4} of ex-eVP were significantly higher than SW, L_3 was not significantly different. This result was also in line with the Alfredson's [25] study. He found out that, although the BMD of the volleyball group was higher than that of the sedentary during their active life, the bone loss also occurred in the volleyball players group during their sedentary life. On the basis of the above findings, Risser et al. [32] also found similar results in that bone densities of lumbar spine (L_{2-4}) were higher in female volleyball and basketball players than control group; these sports seem to place stress on the heel. In addition to this studies Lee et al. [24] also supported the results of the present study. They found that volleyball and basketball players had significantly higher total body and lumbar values

than sedentaries, and volleyball players' neck of femur had significantly higher values than sedentaries. There seemed to be a consensus reached by Suominen [16] and Risser et al. [32] in that positive relations between weight-bearing exercise and BMD, they also stated in their study that, having engaged in a continuous physical exercise for many years reveals the effect of it on the BMD more clearly.

When we compare the BMD results of arms, pelvis, spine of the two groups, they weren't significantly different. It should be noted that, ex-eVP' total body BMD results were higher although not statistically significant but still higher than that of the SW. However, BMD of legs, trunk and ribs of ex-eVP were significantly higher than that of the SW. Those results were also supported by Alfredson [25] and Risser et al. [32] for lumbar, Nichols, [31] for arm and leg; Lee, [24] for the lumbar, arm, spine, leg, pelvis values, Fehling [23] for lumbar, arms, legs, and pelvis.

Lee at al. [24] indicated that volleyball and basketball players had significantly higher BMD of total body measurements than that of sedentary. Lee at al. [24] concluded that higher intensity activities involving multiple sites of impact and weight-bearing movements throughout the skeleton required for volleyball and basketball players may have greater influence on total body bone density than the cyclical loading of running that is specific to the lower limbs. Those results were also in line with the findings of present study. In that, BMD of total body measurements of volleyball players were to be significantly different from non-athletic group. In addition, Heinonen et al. [9] and Heinrich [33] found out that active athletes had higher BMD and bone mineral content than in control group. Another review conducted by Gutin and Kasper [18] revealed that previously active older people had higher BMD.

Although in all region analysis (except UD part of non-dominant forearm and left forearm), BMD results of ex-eVP were higher than those of the SW. Jacobsons study [34] analyzed different adult age groups of athletes (20—40; 40—55; 55—75 yrs old) and controls. The values of the same age group between 40—55 years with the present study, dominant arm (UD) of Ex-eVP (0.523 ± 0.059) and SW (0.520 ± 0.058) are higher than that of the Jacobsons' [34] control group (0.406 ± 0.007) and athletes (0.424 ± 0.008) in spite of that latter study adult group is active athletes. BMD of lumbar spine of Jacobson study [34] athletes (1.386 ± 0.053) and controls (1.252 ± 0.021) had higher BMD values than ex-eVP (1.247 ± 0.170) and SW (1.140 ± 0.132). Higher lumbar spine results in the active athletes in the study of Jacobson [34] could be because of maintaining active regular exercise program although much less rigorous than that of the intercollegiate athletes.

It could be concluded that female volleyball players seem to have less age-related bone loss or achieve higher peak bone mass than that of the sedentaries based on the results of the present study. However, in order to confirm this conclusion, a longitudinal study must be conducted comparing the age-related bone loss of ex-eVP and that of SW and with different larger samples on a long-term basis. In the present study, ex-eVP were no longer active, whereas achieved higher peak bone mass at the younger ages for the ex-elite volleyball players might behave like a bank account. Although ex-eVP has age-related bone loss whatsoever, they have higher BMD at the older ages. While playing volleyball as a weight-bearing activity, high mechanical loading that stresses the skeleton at the young ages is the probable result of cause-effect relationship for the older ages.

Most of the BMD result was significantly higher in ex-eVP than that of SW. Although having sedentary life after intensive weight-bearing activity, the result also supports volleyball playing as an active loading or weight-bearing physical activity at the young ages helps to reach peak bone mass and/or less age-related bone loss. Furthermore, whether or not same age-related bone loss happens, the result of BMD will remain higher bone mass for volleyball players. It could be stated that, in spite of age-related bone loss, ex-eVPs have higher bone density than SW. According to Wolff's meta-analysis [5] playing volleyball regarded as a weight-bearing exercise, has a preventative and reversing effects on bone density. Furthermore, it might be recommended that the BMD of volleyball players must be monitored on a long-term basis and comparative studies must be conducted in order to see the effect of their sport specific life for different sport branches.

According to the theoretical hypothesis, if specific muscle group was stronger, it is expected that related bone's mineral density would be higher. Heinonen's [9] conclusion about the site-specific effect of the training stimulus was that weight-bearing exercises increase BMD as a site-specific response. The results of the present study showed that back, leg, and hand grip static strengths of ex-eVP were significantly higher than that of SW (Fig. 3), however, BMD of L_3, forearm (right and left) and hip (right and left) of both groups were not significantly different (Table 2). In addition to those results, there was no significant high correlation between static strengths and adjacent bone sites for both group and total subjects (Table 3). Furthermore, there was no significant high correlation between leg strength and BMD of leg (total body scan) values for both groups and total subjects (Table 3). It should be noted that Beverly et al. [35] found inconsistent results that there would be a close correlation between grip strength and forearm BMC in women. According to those results it could be generalized that static grip strength was not a marker for BMD of forearm for both groups, and also static leg strength was not a marker of hip (left and right) BMD. Pocock et al. [36] studied 73 females aged 20—75 and found that muscle strength (biceps, quadriceps, grip) was an independent predictor of bone density proximal femur, lumbar spine, and forearm. The results of the present study were also not in line with their study for forearm relation.

BMD of lumbar spine of ex-eVP results were significantly higher (except L_3) than SW (Table 2). This could be attributed to the specific weight-bearing site of volleyball playing, not due to the reason of statistically higher static back strength of the volleyball players than that of the SW (Fig. 3). Those results of the present study might be related with the site-specific loading or the nature of the volleyball sport. Although all the static strength of the ex-eVP were higher significantly that of the SW (Fig. 3), none of the hip and forearam (dominant and non-dominant BMD results) were significantly different from each other (Table 2). In addition to that ex-eVP were not active at all, however they have already had significantly higher BMD values and static strength results. The findings could be concluded that having

higher BMD in the older ages might be the result of systemic effect of nature of sport due to achieving peak bone mass in the young ages despite age-related bone loss during adulthood.

In the study of Bevier et al. [8], grip strength was correlated with radial bone density in both sexes, supporting the hypothesis of a local effect. Contrary to this hypothesis, however, was their finding in women that the relation of grip strength to spinal bone density reached significance, while the relation of back strength to spinal bone density did not. In this study grip strength and spinal bone density is inconsistent while the correlation between back strength and spinal bone is consistent with the present study. In the Beviers [8] and Snow [37] studies found similar results of the present study. It was stated that there was no significant relationship between grip strength and radial bone density. The specific bone density sites were not always related to the strength of the muscles attached to those bones.

Haapasalo [38] and Kannus [39] control group's non-dominant arm BMD value was higher than tennis and squash players, although the difference was not significant. The result was also parallel to the present study as considering BMD values. In addition to that Heinonen [40] found similar results that distal radius result showed (except squash players) sedentary reference had higher BMD value than aerobic dancers, speed skaters and physically active reference. Haapasalo at al. [41] also found no significant difference BMD values of distal radius in junior tennis players and controls, whereas, distal radius BMD of tennis players' dominant arm significantly higher than that of non-dominant arm. Jacobson [34] summarized that distal radius of dominant arm of tennis players and swimmers had higher bone density than controls. Jacobson [34] stated that bone mineral content of radius in the athletes was accompanied by an increase in bone width. According to the statement, and the formula of bone density ($g/cm^2 \times 10^{-3}$/bone width), bone width increases results in the decrease of bone density. Athletes radial bone density may not be increased due to the increase in the denominator of formula.

Most of the researches showed that BC is related with BMD [7,42—45]. In the present study, there were no significant relationship between BMD of $L_{2\text{-}4}$ or total body and body compartments (Table 3). BW was not significantly different from each other (Table 1), BMD of $L_{2\text{-}4}$ of ex-eVP was significantly higher than that of SW (Table 2). Therefore, BW couldn't be a predictor for BMD of the $L_{2\text{-}4}$ and total body. The present result of the study is in correlation with that of Reid et al. [43], Slemenda and Johnson [44], and Cummings et al. [45] supported the results of the present study. In contrast to prementioned studies, Welten [7] found that BW is a significant predictor for BMD.

Significant low relationship was found between BW and non-dominant hip, and BW and dominant hip for both groups and all subjects (Table 3). Those results supported by As Reid et al. [43], Slemenda and Johnson [44], and Cummings et al. [45]. They stated that mechanical loading of the skeleton reflects some combination of BW and exercise patterns and without taking into account this aspect of skeletal development and maintenance. On the other hand, in SW weight alone, which is strongly correlated with fatness, may be primary in loading the skeleton. However, in active women, it is more probable both BW and LBM relating with the types and intensity of the exercise (previous and current) determine skeletal loading. In addition to that result, there was no high significant relationship between BMD of total body and $L_{2\text{-}4}$ and other body compartments (Table 3). BW measurements were not statistically significant for both groups, while LBM in favouring ex-eVP and BF% in favoring SW were significantly higher than the other group. This most basic tie between skeletal and non-skeletal mass deserves further study and its implications for the study of other mechanisms is important as well.

Ex-eVP's LBM (41.59 ± 4.96) was significantly higher than that of SW (37.80 ± 3.46). It is worth reiterating the fact that the BMD measures of the ex-eVP were higher than those of the SW. Having not statistically significant BMI and FW difference between the groups a few high favoring SW, and having significantly higher LBM favoring very high Ex-eVP (Table 1), showed that, BMI shouldn't be a direct predictor in evaluating BMD. Likewise, the strength results of ex-eVP were higher than the SW. Although there is no certain scientific evidence to claim that LBM and BMD measures are directly related, it could still be stated that the higher the LBM the higher the BMD.

This needs to be further analyzed. In conclusion, although in all region analysis (except UD part of non-dominant forearm), BMD results of ex-eVP were higher than those of the SW; BF% ($P = 0.043$) and FW were higher in SW group. According to the results of higher FW or BF% for both BC measurement methods in SW group, BMD results were higher in ex-eVP. It could be concluded that fat mass as a mechanical load is not related to the BMD of the subjects. It is considerable to note that mechanical loading factors are gravity and muscles pull in bone modelling and remodelling. LBM might have considerable role to have higher BMD value as the function of muscle pull. Further longitudinal studies are needed to determine whether changes in BMD are sensitive to changes in BC compartments and furthermore, to describe precisely the mechanism of such an association.

BF% was significantly higher in SW (39.8 ± 5.7) than ex-eVP (36.7 ± 6.2) ($P < 0.05$). In addition, the reasons of significant difference of present study could be their previous physical activity status or life style.

In the light of the results of this study, BMD of ex-eVP were higher than sedentary in spite of other factors. It could be concluded that playing volleyball have a positive effect on BMD and beneficial to prevent osteoporosis and/or reverse bone loss, maximise bone mass early in life as well as slow the rate of age-related bone loss. This paper also one of the first to know the difference between after quitting elite level sports participation with being sedentary and being lifelong sedentary. Further study is needed to answer the question if the level of higher bone mass in athletes' due to the lower age-related bone loss or higher bone loss in the sedentary. In addition to that longitudinal study is needed to answer the gained bone mass maintained lifelong or same rate decrease comparing with the controls after cessation of the intensive training period. Longitudinal follow up is needed to determine the rate of decrease in the BMD for ex-athlete and sedentary adults. To conclude the effect of exercise or site-specific stimulus on specific bone site should be studied longitudinally adding high intensity stimulus plus giving up or tapering effect of the loading to investigate the effect of strengthening the muscle and bone.

Not only as a health problem, preventive caution has to be taken into consideration but also the effect of specific exercise intensity, frequency, and volume must be examined.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Tenforde AS, Fredericson M. Influence of sports participation on bone health in the young athlete: a review of the literature. PM&R 2011;3:861—7.

[2] Bass SL, Saxon L, Daly RM, Turner CH, Robling AG, Seeman E, et al. The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: a study in tennis players. J Bone Miner Res 2002;17:2274—80.

[3] Kelley GA, Kelley KS, Kohrt WM. Review article, exercise and bone mineral density in premenopausal women: a meta-analysis of randomized controlled trials. Int J Endocrinol 2013;2013:1—16 [Article ID 741639].

[4] Drenjančević I, Davidović CE. Influence of physical activity to bone metabolism. Med Glas Ljek Komore Zenicko-Doboj Kantona 2013;1:12—9.

[5] Wolff I, Croonenborg JJ, van Kemper HCG, Kostense PJ, Twisk JWR. The effect of exercise training programs on bone mass: a meta analysis of published controlled trials in pre-postmenopausal women. Osteoporos Int 1999;9:1—12.

[6] Calbet JA, Herrera PD, Rodriguez LP. High bone mineral density in male elite professional volleyball players. Osteoporos Int 1999;10:468—74.

[7] Welten DC, Kemper HC, Post GB, Van Mechelen W, Twisk J, Lips P, et al. Weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. J Bone Miner Res 1994;9:1089—96.

[8] Bevier WC, Wiswell RA, Pyka G, Kazak KC, Newhall KM, Marcus R. Relationship of body composition, muscle strength, and aerobic capacity to bone mineral density in older men and women. J Bone Miner Res 1989;4:421—32.

[9] Heinonen A, Oja P, Kannus P, Sievänen H, Mänttäri A, Vuori I. Bone mineral density of female athletes in different sports. Bone Miner 1993;23:1—14.

[10] Burrows M, Nevill AM, Bird S, Simpson D. Physiological factors associated with low bone mineral density in female endurance runners. Br J Sports Med 2003;37:67—71.

[11] Johannsen N, Binkleya T, Englert V, Neiderauer G, Specker B. Bone response to jumping is site-specific in children: a randomized trial. Bone 2003;33:533—9.

[12] Stengel SV, Kemmler W, Lauber D, Kalender WA, Engelke K. Differential effects of strength versus power training on bone mineral density in postmenopausal women: a 2-year longitudinal study. Br J Sports Med 2007;41:649—55.

[13] Laconi P, Melis F, Crisafulli A, Sollai R, Lai C, Concu A. Field test for mechanical efficiency evaluation in matching volleyball players. Int J Sports Med 1998;19:52—5.

[14] Ito M, Nakamura T, Ikeda S, Tahara Y, Hashmi R, Tsurusaki K, et al. Effects of lifetime volleyball exercise on bone mineral densities in lumbar spine, calcaneus and tibia for pre-, peri- and postmenopausal women. Osteoporos Int 2001;12:104—11.

[15] Friedenreich CM, Courneya KS, Bryant HE. The lifetime total physical activity questionnaire: development and reliability. Med Sci Sports Exerc 1998;30:266—74.

[16] Suominen H. Bone mineral density and long term exercise. Sports Med 1993;16:316—30.

[17] Sinaki M, Offord K. Physical activity in postmenopausal women effect of back muscle strength and bone mineral density of the spine. Arch Phys Med Rehab 1988;69:277—80.

[18] Gutin B, Kasper MJ. Can vigorous exercise play a role in osteoporosis prevention? A review. Osteoporos Int 1992;2:55—69.

[19] Bassey EJ, Ramsdale SJ. Increase in femoral bone density in young women following high-impact exercise. Osteoporos Int 1994;4:72—5.

[20] Nelson ME, Fisher CE, Dilmanian FA, Dallal GE, Evans WJ. A 1-y walking program and increased dietary calcium in postmenopausal women: effects on bone. Am J Clin Nutr 1991;53:1304—11.

[21] Heinonen A, Sievänen H, Kyröläinen H, Perttunen J, Kannus P. Mineral mass, size, and estimated mechanical strength of triple jumpers lower limb. Bone 2001;29:279—85.

[22] Sleivert GG, Backus RD, Wenger HA. Neuromuscular differences between volleyball players, middle distance runners and untrained controls. Int J Sports Med 1995;16:390—8.

[23] Fehling PC, Alekel L, Clasey J, Rector A, Stillman RJ. A comparison of bone mineral densities among female athletes in impact loading sports. Bone 1995;17:205—10.

[24] Lee EJ, Long KA, Risser WL, Poindexter HBW, Gibsons WE, Goldzieher J. Variations in bone status of contralateral and regional sites in young athletic women. Med Sci Sports Exerc 1995;27:1354—61.

[25] Alfredson H, Nordström P, Lorentzon R. Bone mass in female volleyball players: a comparison of total and regional bone mass in female volleyball players and non active females. Calcif Tissue Int 1997;60:338—42.

[26] Johnell O, Gullberg B, Kanis JA, Allander E, Elffors L, Deoueker J, et al. Risk factors for hip fracture in european women: the MEDOS study. J Bone Miner Res 1995;10:1802—15.

[27] Verhaar HJJ, Koele JJ, Neijzen T, Dessens JAG, Duursma SA. Are arm span measurements useful in the prediction of osteoporosis in postmenopausal women? Osteoporos Int 1998;8:174—6.

[28] Versluis RG, Petri H, van de Ven CM, Scholtes AB, Broerse ER, Springer MP, et al. Usefulness of armspan and height comparison in detecting vertebral deformities in women. Osteoporos Int 1999;9:129—33.

[29] Mohanty SP, Babu SS, Sreekumaran NN. The use of arm span as a predictor of height: a study of South Indian women. J Orthop Surg 2001;9:19—23.

[30] Tan MP, Wynn NN, Umerov M, Henderson A, Gillham A, Junejo S, et al. Arm span to height ratio is related to severity of dyspnea, reduced spirometry volumes, and right heart strain. Chest 2009;135:8—454.

[31] Nichols DL, Sanborn CF, Bonnick SL, Gench B, DiMarco N. Relationship of regional body composition and bone mineral density in college females. Med Sci Sports Exerc 1995;27:178—82.

[32] Risser WL, Lee EJ, LeBlanc A, Poindexter HBW, Risser JMH, Schneider V. Bone density in eumenorrheic female college athletes. Med Sci Sports Exerc 1990;22:570—4.

[33] Heinrich CH, Going S, Pamenter RW, Perry CD, Boyden TW, Lohman TG. Bone mineral content of cyclically menstruating female resistance and endurance trained athletes. Med Sci Sports Exerc 1990;22:558—63.

[34] Jacobson PC, Beaver W, Grubb SA, Taft TN, Talmage RV. Bone density in women: college athletes and older. Orthop Res Soc 1984;2:328—32.

[35] Beverly MC, Rider TA, Evans MJ, Smith R. Local bone mineral responce to brief exercise that stresses the skeleton. Br Med J 1989;299:233—5.

[36] Pocock N, Eisman J, Gwinn T, Sambrook P, Kelly P, Freund J, et al. Muscular strength, physical fitness, and weight but not age predict femoral neck bone mass. J Bone Miner Res 1989;4:441—8.

[37] Snow-Harter C, Bouxsein M, Lewis B, Charette S, Weinstein P, Marcus R. Muscle strength as a predictor of bone mineral density in young women. J Bone Miner Res 1990;5:589—95.
[38] Haapasalo H, Kannus P, Sievfinen H, Heinonen A, Oja P, Vuori I. Long-term unilateral loading and bone mineral density and content in female squash Players. Calcif Tissue Int 1994;54:249—55.
[39] Kannus P, Haapasalo H, Sankelo M, Sievanen H, Pasanen M, Heinonen A, et al. Effect of starting age of physical activity on bone mass in the dominant arm of tennis and squash players. Ann Intern Med 1995;123:27—31.
[40] Heinonen A, Oja P, Kannus P, Sievänen H, Haapasalo H, Mänträri A, et al. Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone 1995;17:197—203.
[41] Haapasalo H, Kannus P, Sieänen H, Pasanen M, Uusi-Rasi K, Heinonen A, et al. Effect of long-term unilateral activity on bone mineral density of female junior tennis players. J Bone Miner Res 1998;13:310—9.
[42] Reid IR, Ames R, Evans MC, Sharpe S, Gamble G, France JT, et al. Determinants of total body and regional bone mineral density in normal post-menopausal women — A key role for fat mass. J Clin Endocrinol Metab 1992;75: 45—51.
[43] Reid IR, Legge M, Stapleton JP, Evans MC, Grey AB. Regular exercise dissociates fat mass and bone density in premenopausal women. J Clin Endocrinol Metabolism 1995;80:1784—8.
[44] Slemenda WC, Johnson CC. High impact activities in young women: site specific bone mass effects among female figure skaters. Bone Miner 1993;20:125—32.
[45] Cumming SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, et al. Risk factors for hip fracture in white women. N Engl J Med 1995;332:767—73.