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Original research article

DIFFERENCES IN THE PARAMETERS OF CALCANEAL BONE MINERAL DENSITY BEETWEN ELITE TRACK AND FIELD ATHLETES, ELITE HANDBALL PLAYERS AND SEDENTARY MALE CONTROLS

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Abstract. *The aim of this study was to determine the differences between the parameters of dominant calcaneal bone mineral density of elite track and field athletes, elite handball players and sedentary male controls, as well as the values of these differences. A total of 90 healthy men, aged 18 to 30 took part in this study, elite track and field athletes (n=30), elite handball players (n=30) and sedentary controls (n=30). Bone mineral density measurements of the dominant calcaneus were done by using an ultrasound densitometer "Sahara" (Hologic, Inc., MA, USA). The following parameters were measured: Speed of sound (SOS), Broadband ultrasound attenuation (BUA), the aStiffness index (SI) and Bone mineral density (BMD). MANOVA revealed a significant difference between the group of elite athletes and the control group in all measured parameters of bone mineral density (p=0.00). There was no significant difference in measured parameters between track and field athletes and handball players, yet bone mineral density arithmetic mean of elite track and field athletes was higher (0.732 g/cm²) than it was in elite handball players (0.690 g/cm²), as well as all the other measured parameters. The results of this study shows that there is no difference between the values of bone mineral density parameters in highly trained track and field and handball male athletes. In addition to this, practicing these two high-impact sports has a significant impact on the values of the calcaneal bone density parameters compared to sedentary male controls.*

Key words: *bone density, calcaneus, track and field, handball, non-athlete*

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INTRODUCTION

Osteoporosis is characterized by low bone mass and deterioration of bone tissue leading to fragility and increased risk of fracture (Drinkwater, 1994). Although aging is inevitable, mechanical loading, such as the kind which might occur in physical exercise, has been shown to alter or delay the reduction in bone mass associated with the aging process (Beck, Daly, Singh, & Taaffe, 2017; Smith & Gilligan, 1991). Data from numerous cross-sectional studies demonstrate a positive association between BMD and physical activity (Hanham et al., 2017; Tenforde & Fredericson, 2011; Barry & Kohrt, 2008). Peak bone mass is obtained during the second and third decade of life (Weaver et al., 2016). Active participation in sport during the years that peak bone mass is being acquired may lead to adaptive changes that improve bone architecture through increased density and enhanced geometric properties (Gabel, Macdonald, Nettlefold, & McKay, 2017; Tenforde & Fredericson, 2011). Mechanical loading with weight-bearing activity produces strain on the bone that provides the stimulus for bone remodeling and structural adaptation (Milgrom et al., 2000). In athletes, high impact activity has been associated with positive bone adaptation responses (Harding, & Beck, 2017; Andreoli et al., 2001).

Research has shown that BMD in athletes is significantly greater than it is in sedentary controls (Lara et al., 2016) and that it is the highest in athletes who participate in high- impact exercises, defined as activities involving running, jumping and weight lifting (Yung et al., 2005; Pettersson, Nordström, Alfredson, Henriksson-Larsén, & Lorentzon, 2000; Bennell et al., 1997).

The aim of this study was to determine the extent of the differences between the parameters of dominant calcaneal bone mineral density of elite track and field athletes and elite handball players, and how these parameters values vary in relation to the population of non-athletes. There are some assumptions that this kind of study was conducted for the first time on the territory of Serbia.

METHODS

Participants

The survey was conducted on a sample of 90 men, aged 18 to 30. Three groups were studied: members of the national junior and senior track and field team of Serbia (n=30), the members of the national junior and senior handball team of Serbia (n=30) and sedentary male controls (n=30). In the group of track and field athletes there were sprinters (n=15), jumpers (n=6) throwers (n=5), middle and long-distance runners (n=3) and a decathlon athlete (n=1). The average age of the track and field participants was 24.04 (median 23.5, SD 3.32), of the handball participants was 24.0 (median 23, SD 3.37) and of sedentary male controls was 24.13 (median 24.5, SD 3.46).

The first part of the research was conducted in Bar (Montenegro), in April 2015, in the official training camp for the national track and field team of Serbia. The second part was conducted in Novi Sad, in May 2015, during a handball Super League competition. At the end, the third group, the group of sedentary male controls, who volunteered to participate in research, were measured also in Novi Sad, in May 2015.

The principal inclusion criteria for this study for elite athletes were age, gender, sport history (a minimum of five years of active sports occupation in track and field and handball, *i.e.* training and an elite athlete was defined as one who qualified for one of the national teams) and absence of diseases. The principal inclusion criteria for this study for sedentary male controls were age, gender, absence of diseases and non-sport history (a minimum of five years of inactive sports occupation).

Measurements

Ultrasound bone densitometry was performed for each participant. We used the device Sahara (Hologic, Inc., MA 02154, USA) clinical sonometer that uses a non-ionizing ultrasound for assessing bone density. The results obtained by this method are sufficiently correlated to the other methods and from other body locations (Hans & Baim, 2017; Faulkner, McClung, Coleman, & Kingston-Sandahle, 1994). We decided to use this device because it is easily portable, so we could scan each participant quickly, without disturbing their daily routine training/competition and because the calcaneus is the most common measurement site due to its accessibility, suitable shape and high trabecular content (Stewart & Reid, 2002).

Bone mineral density of the participants (BMD - Bone Mineral Density, in g/cm^2) was evaluated on the basis of three following measured parameters: Broadband ultrasound attenuation: take-off leg calcaneus (BUA, in dB/MHz), Speed of sound: take-off leg calcaneus (SOS, in m/s) and the Stiffness index: take-off leg calcaneus (SI: stiffness index of bone). Measurements were taken while the participants were seated with the dominant foot resting in the heel bath of the instrument. Ultrasound gel was applied as a coupling medium to ensure good contact. Inaudible high frequency sound waves, produced by one of the sound transducers, are transmitted through the heel and received by the opposite transducer. Patient examination time is short, with a measurement time (excluding patient positioning) of less than ten seconds. Quantitative parameters describing the speed and attenuation of the sound waves in the heel were measured. The device is calibrated daily using a model (phantom). All scans were performed by the same technician.

The survey did not include the hormonal status of participants or trial on the use of supplements in the diet, but it was rather focused on the differences in the above mentioned parameters of bone mineral density between the top athletes, i.e.. track and field athletes and handball players and sedentary male controls.

Statistical analysis

Data were analyzed using SPSS software (Statistical Package for the Social Sciences, V.20; SPSS Inc, Chicago, Illinois, USA). The Shapiro-Wilk Test was used in assessing normality data distribution. Standard descriptive statistical methods were used to calculate means, range and standard deviation. The Multivariate Analysis of Variance (MANOVA) was used for the determination of inter-group differences, while the differences between the groups were determined with the Analysis of Variance (ANOVA) for every measured parameter. The Bonferroni correction is used to reduce the chances of obtaining false-positive results or type I errors, so the level of significance was set at $p<0.017$.

The study was approved by the School of Sports and Physical Education at the University of Novi Sad. The trainers and athletes received a detailed explanation of the purpose of the study, the selected method, the benefits and potential risks or discomforts. All of the participants signed an informed consent form to participate in the study.

RESULTS

Statistical diagnostic tests revealed no violations of the assumptions of normality and homogeneity of variance for any of the dependent variables. The Shapiro-Wilk test was used in assessing the normality data distribution. It was observed that the distribution of the data, of all the variables applied in this study, in all the groups does not deviate significantly from the normal distribution (SOS: p=0.19; BUA: p=0.13; SI: p= 0.08; BMD: p=0.09). Shapiro-Wilk test values for each variable within each tested group are shown in Table 1.

Table 1 Descriptive statistics and the normality distribution of the applied variables

Parameter	Sport	Min	Max	AM	S	Shapiro-Wilk
SOS (m/s)	Track and field	1526,72	1665,60	1603,46	35,10	0,38
	Handball	1543,49	1627,57	1586,10	24,53	0,21
	Controls	1508,16	1595,89	1553,36	20,51	0,95
BUA (dB/MHz)	Track and field	62,57	140,17	100,72	22,37	0,05
	Handball	76,90	124,85	100,36	14,21	0,33
	Controls	50,03	99,61	71,38	12,90	0,47
SI index	Track and field	80,61	169,36	127,71	22,97	0,10
	Handball	93,36	150,96	121,27	16,97	0,31
	Controls	70,94	117,53	95,16	12,77	0,58
BMD (g/cm^2)	Track and field	0,433	0,99	0,73	0,14	0,08
	Handball	0,514	0,88	0,69	0,11	0,31
	Controls	0,372	0,67	0,52	0,08	0,57

Legend: MIN – minimal values of the measured results, MAX – maximal values of the measured results, AM – arithmetic mean, S – standard deviation of the arithmetic mean; Shapiro-Wilk – significance of the Shapiro-Wilk test of normality for each variable, SOS – Speed of sound, BUA – Broadband ultrasound attenuation, SI – Stiffness index of bone, BMD – Bone Mineral Density

Descriptive statistics for ultrasound parameters SOS, BUA, SI and BMD of elite track and field athletes, elite handball players and sedentary male controls are presented in Table 1. By calculating the significance of the difference between the levels of arithmetic mean values for all the tests between elite track and field athletes, elite handball players and sedentary male controls (Table 4), a statistically significant difference was determined, as Wilks' Lambda test equals .41, which shows the significance of the differences at the P-level = .000 with a unit F-ratio of 11.83. Therefore, the results indicate statistically significant differences between three study groups, in the means of each of the applied variable, i.e. SOS, BUA, SI and BMD.

Table 2 The Multivariate Analysis of Variance between elite track and field athletes, elite handball players and sedentary male controls

Wilks' Lambda	F	Partial Eta Squared	p
0.41	**11.83**	**0.36**	**0.000**

The analysis of individual difference variables on the basis of univariate analysis of variance (ANOVA) determined a significant difference, for SOS, in all groups at a statistical significant level. BUA results also show significant differences in all groups as for the SI variable and BMD variable at the P-level = .000 (Table 3). The importance of the impact of the tested groups is the biggest for the BUA variable, and group explaining 40,3% (Eta Squared 0,403) of variance in the results of the BUA parameter.

Table 3 Statistical difference between the mean values of the parameters of bone mineral density in three tested groups according to ANOVA

Parameters	F	p
SOS (m/s)	25,83	**.000**
BUA (dB/MHz)	29,36	**.000**
SI index	27,31	**.000**
BMD (g/cm^2)	27,72	**.000**

Legend: F – univariate F test; p – statistical significance of univariate F test; SOS – Speed of sound, BUA – Broadband ultrasound attenuation, SI – Stiffness index of bone, BM – Bone Mineral Density.

Multiple comparisons (MANOVA) with Bonferroni correction (p<0,017) revealed the differences between each pair of tested groups. As shown in Table 4, there is a statistically significant difference between the transmitted Speed of sound (SOS) through the heel in elite track and field athletes and sedentary male controls (Mean Difference 50.99; p=0.000) as between elite handball players and sedentary male controls (Mean Difference 32.74; p=0.000). There is no statistically significant difference between the elite track and field athletes and elite handball players (Mean Difference 17.36; p=0.05) despite the fact that track and field athletes had higher values of SOS mean (Table 1) i.e., as the results are expressed in m/s, so the ultrasound wave was the slowest through the calcaneus of these athletes. There are also the same results of significance for each parameter of bone mineral density. For BUA, SI and BMD, there is a statistically significant difference between the elite track and field athletes and sedentary male controls (BUA: Mean Difference 29.34; p=.000; SI: Mean Difference 32.55; p=.000; BMD: Mean Difference 0.21; p=.000), as between elite handball players and sedentary male controls (BUA: Mean Difference 28.98; p=.000; SI: Mean Difference 26.11; p=.000; BMD: Mean Difference 0.16; p=.000). There is no statistically significant difference between the elite track and field athletes and elite handball players in BUA, SI and BMD parameters (BUA: Mean Difference 0.36; p=1.00; SI: Mean Difference 6.44; p=0.51; BMD: Mean Difference 0.04; p=0.48).

Table 4 Differences between the groups in bone mineral density parameters according to MANOVA

Parameter	**p**		
	a*b	a*c	b*c
SOS (m/s)	0,05	**.000**	**.000**
BUA (dB/MHz)	1,00	**.000**	**.000**
SI index	0,51	**.000**	**.000**
BMD (g/cm^2)	0,48	**.000**	**.000**

Legend: p – level of statistical significance, a*b comparison between track and field and handball athletes, a*c comparison between track and field athletes and sedentary male controls, b*c comparison between handball players and sedentary male controls, SOS – Speed of sound, BUA – Broadband ultrasound attenuation, SI – Stiffness index of bone, BM – Bone Mineral Density

DISCUSSION

The main goal of this study was to examine and compare the values of bone mineral density parameters of elite track and field athletes, elite handball players and inactive controls. The results of our study are consistent with the results of numerous studies between elite athletes and non-athletes (Arasheben, Barzee, & Morley, 2011; Kaštelan et al., 2007) and support the fact that elite athletes have greater bone mineral density than sedentary controls. In our study elite athletes had higher values for all the measured parameters of BMD at a statistically significant level, comparing with sedentary male controls. Research done on athletes shows that they have higher bone mass than non-athletes and that bone density increases during periods of intensive training (Bajić, Ponorac, Rašeta, & Bajić, 2010). In the 12-month longitudinal cohort study, Benell et al. (1997) were comparing bone mass and bone turnover in elite and sub-elite track and field athletes and less active controls, aged 17-26. The final results showed that power athletes had a higher regional BMD at lower limb, lumbar spine, and upper limb sites compared with controls ($p<0.05$) and endurance athletes had higher BMD than controls in lower limb sites only ($p < 0.05$). Furthermore, the cross-sectional study of Andreoli et al. (2001) has shown that athletes, especially those engaged in high-impact sports, have significantly higher total BMD than controls so it was suggested that the type of sport activity may be an important factor in achieving high peak bone mass and reducing osteoporosis risk.

The first measured parameter in our study was the Speed of sound (SOS) and it refers to the division of transmission time of the sound waves by the length of the body part studied (Kok-Yong & Ima-Nirwana, 2013). Measurements of the SOS parameter revealed a statistically significant difference between groups of athletes (track and field athletes and handball players) and sedentary male controls, and there is no difference between two high-impact sports participants (Table 3). Studies which examined the relationship between calcaneal parameters and bone properties found that SOS was closely related to BMD (Hans et al., 1999; Töyräs, Nieminen, Kröger, & Jurvelin, 2002; Cavani et al., 2008). Toyras et al. (2002) indicated that this relationship was strong, with a coefficient of correlation (r) of 0.888. The bone biomechanical study of Cavani et al. (2008) revealed that SOS was significantly correlated to bone volume, total volume ratio and Young's modulus. These results show that SOS is strongly influenced by volumetric mineral bone density and bone elasticity. Besides that, Töyräs, Kröger, & Jurvelin (1999) found that ultimate strength was significantly associated with SOS. It has been demonstrated that strength training can increase bone mineral density and content.

Training activities in handball have a very similar pattern as training activities in sprint, jump and throw events, because they include intensive training with load or with weights. This training pattern differs from the one used in the training of middle and long-distance runners, because the requirements in the game of handball and mentioned track and field events differ based on their structure from the demands which are set in long-distance running.

Because of this fact and the similarities between two impact sports, it can be expected that values of bone density parameters between elite track and field and handball athletes are very close to each other. Besides that, it is important to point out the differences of BMD between the athletes who practice different track and field events. Whittington et al. (2009) concluded that throwers have greater BMDs than non-athletes and most other athletes. Only the middle and long-distance events (in track and field) are not high impact activities. Long-distance running produces a regular pattern of repetitive loading consisting of moderately high ground reaction forces (2.0–3.0 body weight) (Cavanagh & Lafortune, 1980) and repetitive low-impact activity, such as distance running, is associated with favorable changes in bone geometry (Tenforde & Fredericson, 2011). In our study, there were just three athletes who practice middle and long-distance events. All the other participants in the track and field group were sprinters, jumpers and throwers who practice high-impact exercises. SOS mean of elite athletes in this study was the highest in track and field athletes respectively, the ultrasound wave was the slowest through their calcaneus because of calcaneal bone density.

The second measured bone density parameter was BUA - Broadband attenuation of sound which refers to the slope between attenuation of sound signals and its frequency. Attenuation occurs because the energy is absorbed by the soft tissue and bone when the sound waves travel through them (Kok-Yong & Ima-Nirwana, 2013). Bouxsein and Radloff (1997) concluded that BUA and densitometric measurements were independently associated with elastic modulus, but not with ultimate strength of the bones. In most track and field events, as it is in handball, the training process except distance running includes various types of jumps, in height, plyometric jumps and the long jump (Bouxsein & Radloff, 1997). As bone tissue responds to dynamic rather than static loading (Lanyon & Rubin, 1984) the maximum effect on BMD is believed to be achieved by weight-bearing physical activity including jumping actions, explosive actions (such as turning and sprinting), and fairly few repetitions rather than endurance or nonweight-bearing activities (Heinonen et al., 1995; Taaffe et al., 1995; Nikander, Sievänen, Heinonen, & Kannus, 2005; Nikander et al., 2009). As handball participation is associated with improved physical fitness, increased lean and bone masses, and enhanced axial and appendicular BMD in young handball players (Vicente-Rodriguez et al., 2004) and the regular practice of handball seems to be an osteogenic factor, it may be advisable in adolescents during the growth period to optimize the bone (Mrabet Bahri et al., 2013). Furthermore, Taaffe, Suominen, Ollikainen, & Cheng (2001) support all the previously said, indicating that bone mineral content and density of the calcaneus are substantially higher in jumpers than individuals engaged in nonweight-bearing or regular weight-bearing activities.

The level of significance showed that elite track and field athletes and elite handball players had BMD at a statistically significant level (Table 3) comparing to sedentary male controls, but there was no difference between the groups of athletes. These results are equal with the Stiffness index, which is a combination of two previous parameters, calculated by the computer from the BUA and SOS, and for BMD. In the group of elite track and field athletes mean of BMD value was the highest, but there was no difference between the groups of elite athletes because there are the same or similar forms of the training process involved in these activities, and some research has noted that the type of physical activity and the accompanying dynamic activity are very important (Turner, 1998; Kontulainen, Sievanen, Kannus, Pasanen, & Vuori, 2002; Nilsson, Ohlsson, Mellstrom, & Lorentzon, 2009).

The track and field study group was mainly a group of participants who practice high – impact activity, so it is necessary to point out the fact that if in the track and field study group were more middle and long distance runners, perhaps the results would indicate the lower mean of bone density parameters and the value of BMD in these athletes and which would lead to a significant difference between two high-impact study groups.

This study supports previous research, indicating a positive effect of high-impact sports on BMD in elite athletes.

CONCLUSION

The results of this study show that there is no difference between the values of bone mineral density parameters in highly trained track and field and handball male athletes, yet bone mineral density arithmetic mean of elite track and field athletes was higher than it was in elite handball players, as well as all other measured parameters. In addition, all of the measured parameters of bone mineral density, SOS, BUA, SI and BMD had significantly higher values in the group of elite athletes compared to sedentary male controls. Furthermore, practicing these two high-impact sports have a significant impact on the values of the calcaneal bone density parameters compared to sedentary male controls.

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RAZLIKE U PARAMETRIMA GUSTINE PETNE KOSTI IZMEĐU VRHUNSKIH ATLETIČARA, VRHUNSKIH RUKOMETAŠA I NESPORTISTA

Cilj ove studije je bio da se utvrde razlike između parametara mineralne gustine petne kosti dominantne noge kod vrhunskih atletičara, vrhunskih rukometaša i nesportista, kao i kolike su vrednosti tih razlika. U studiji je učestvovalo ukupno 90 zdravih muškaraca, od 18 do 30 godina starosti, vrhunski atletičari (n=30), vrhunski rukometaši (n=30) i nesportisti (n=30). Merenja parametara mineralne gustine petne kosti dominantne noge su izvršena upotrebom ultrazvučnog denzitometra "Sahara" (Hologic, Inc.,MA, USA). Mereni su sledeći parametri: brzina ultrazvučnog signala (SOS), slabljenje ultrazvučnog signala (BUA), stifnes indeks (SI) i mineralna gustina kosti (BMD). MANOVA metodom je utvrđena statistički značajna razlika između grupe vrhunskih sportista i kontrolne grupe u svim merenim parametrima mineralne gustine kosti (p = 0.00). Između vrhunskih atletičara i vrhunskih rukometaša nije utvrđena statistički značajna razlika u merenim parametrima, iako su atletičari imali veću prosečnu mineralnu gustinu kosti (0.732 g/cm²) nego rukometaši (0.690 g/cm²), kao i sve ostale merene parametre mineralne gustine kosti. Rezultati ove studije pokazuju da nema razlike između vrednosti parametara mineralne gustine kosti kod vrhunskih atletičara i rukometaša. Pored toga, treniranje ova dva sporta visoko - udarnog karaktera ima značajan uticaj na vrednosti parametara mineralne gustine kosti u odnosu na vrednosti ovih parametara kod nesportista.

Ključne reči: *gustina kosti, petna kost, atletika, rukomet, nesportisti*