

**DIFFERENCES IN PARAMETERS OF BONE MINERAL DENSITY BETWEEN
ELITE ATHLETES AND NON ATHLETES**

Anita Šolaja, Milan Šolaja and Borislav Obradovi

Faculty of sport and physical education – University of Novi Sad

Correspondence to:
Anita Šolaja

Address: Bulevar cara Lazara 7, 21000 Novi Sad

Telephone: 06505350054

E-mail address: anitasolaja@yahoo.com

Abstract

The aim of this study is to investigate the differences in parameters of bone mineral density in elite track and field athletes and sedentary male controls, respectively non-athletes. The research included 15 athletes who are members of the national junior track and field team of Serbia and 15 non-athlete boys, aged 17 to 19 years. Sahara (Hologic, Inc., MA 02154, USA) clinical sonometer was used for assessing bone density. The parameters of bone mineral density were measured, Speed of sound (SOS), Broadband ultrasound attenuation (BUA), Bone mineral density (BMD) and Width of the heel bone, as well. T-test for two independent groups confirmed that there is statistically significant difference between elite track and field athletes and non-athletes in all measured parameters ($p < 0.05$). The results of this study confirm the significant effects of practicing track and field events on increasing bone mineral density and preventing osteoporosis.

Keywords: Bone density, calcaneus, male, track and field, sedentary controls

Introduction

The World Health Organization (WHO) defines osteoporosis as a condition in which the bone mass decreases by 2.5 standard deviations from those in young and healthy people of the same sex (WHO, 1994). Disorder of bone remodeling, in which newly formed bone is being formed then it breaks down old bone previously, is the main cause of osteoporosis. Osteoporosis is characterized by low bone mass and bone loss leads to fragility and increased risk of fracture (Drinkwater, 1994). The result of decreased bone strength is increasing the

risk of fracture, even due to slight injuries. Osteoporosis occurs in both sexes and can occur at any age. For both sexes, the risk of osteoporosis increases with age, while the risk of osteoporotic fractures is the highest in people over 80 years (Delmas & Fraser, 1999).

Although aging is inevitable, mechanical stresses that occur during exercise, are proven to alter or delay the reduction of bone mass associated with the aging process (Smith & Gilligan, 1991). The first study that addressed this hypothesis showed that athletes subjected to high load activities had 10–20% higher bone mineral density (BMD) compared to the controls (Nilsson & Westlin, 1971). Today, there is compelling evidence indicating that physical activity affects the skeleton and the BMC and BMD in an anabolic way (Hind & Burrows, 2007).

Maximum of bone mass is acquired during the second and the third decade of life. Active practice of sport in the years in which the peak of bone mass is obtained, can lead to adaptive changes that improve the architecture of the bones through increased density and improved geometric properties of bone (Tenforde & Fredericson, 2011).

Research done on athletes shows that they have higher bone mass than non-athletes and that the bone density increases during the periods of intensive training (Baji Z, Ponorac, Rašeta, & Baji, 2010). Exercise studies have also shown which type of exercise confers maximal anabolic effects on the skeleton. Skeletal load that includes a dynamic load, a load with a high magnitude, a high frequency load, a fast load and a load with unusually distributed strains provide the most pronounced osteogenic stimuli (Lanyon, 1992; Rubin & Lanyon, 1984; Turner, Woltman & Belongia, 1992). Researches has shown that BMD is the highest in athletes who participate in high- impact exercise, defined as activities involving running, jumping and weight lifting (Bennell, Malcolm, Khan, Thomas, Reid, Brukner et al., 1997; Pettersson, Nordström, Alfredson, Henriksson-Larsén & Lorentzon, 2000; Yung, Lai, Tung, Tsui, Wong, Hung & Qin, 2005; Andreoli, Monteleone, Van Loan, Promenzio, Tarantino & De Lorenzo, 2001). These results suggest that the type of sport activity may be an important factor in achieving a high peak bone mass and reducing osteoporosis risk (Andreoli et al., 2001).

Furthermore, it is very important for elite athletes to have healthy bones, because low BMD significantly increases the risk of fractures at minimal traumas (stress fracture) (Kohrt, Bloomfield, Little, Nelson & Yingling, 2004). These types of injuries are common in certain populations of athletes and represent between 0.7% and 20% of all sports medicine injuries seen in medical clinics (Matheson, Clement, McKenzie, Taunton, Lloyd-Smith & MacIntyre, 1987; Chen, Tenforde & Fredericson, 2013; Harrast & Colonn, 2010; McCormick, Nwachukwu & Provencher, 2012). The current understanding is that maximizing peak bone mass is key to preventing osteoporosis and osteoporotic fractures (Heinonen, Sievanen, Kannus et al., 2000; Courteix, Lespessailles, Peres et al., 1998).

The present study is aimed at assessing the characteristics of the bones of high-performance, top level competitive athletes, using calcaneal ultrasound. This study investigates the differences in parameters of bone mineral density in highly trained athletes, in elite track and field athletes and sedentary male controls.

Method

The survey was conducted on a sample of 30 boys, aged 17 to 19 years. Of that number, 15 boys are members of the national junior track and field team of Serbia, and another 15 are high school students who are not engaged in sports. The first part of the survey was conducted in April 2015, at the official training camp for a national track and field selection in Bar (Montenegro). The second part of research is also conducted in April 2015, at the Central School of Economics in Niš.

The sample of variables in this study reflected the four variables for assessment of skeletal status, ie. Bone density:

- 1) The width of the take-off leg calcaneus (Width, in mm),
- 2) Sos - Speed of sound: take-off leg calcaneus (SOS, in m/s),
- 3) Bua - Broadband ultrasound attenuation: take-off leg calcaneus (BUA, in dB/MHz),
- 4) Bmd - Bone mineral density: take-off leg calcaneus (BMD, in g/cm).

Ultrasound bone densitometry was performed in each subject. The device used was Sahara (Hologic, Inc., MA 02154, USA) clinical sonometer that uses 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 (Faulkner, McClung, Coleman, Kingston-Sandahle, 1994). This device was used because it is easily portable, so each subject could be scanned quickly, without disturbing their daily routine training/competition. Measurements were taken while the subjects were seated with the dominant foot resting in the heel bath of the instrument. Patient examination time was 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 are measured. The device is calibrated daily using a model (phantom). All scans were performed by the same technician. Following parameters were measured: SOS, BUA, BMD as well as Width of calcaneal bone of take-off leg of respondents.

The obtained data were processed in the statistical package SPSS (20.0). The Kolmogorov-Smirnov test was used to assess normal distribution of the variables. The standard tests for normality and homogeneity of variance found that these assumptions were valid. Differences between two groups were analyzed with T-test for two independent groups, track and field athletes and non-athletes. Statistical significance was set at $p < 0.05$.

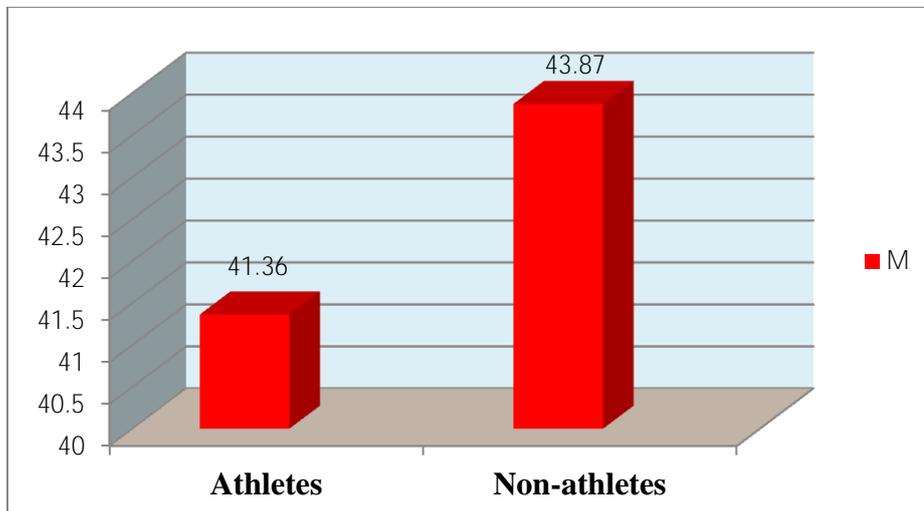
The principal inclusion criteria to this study were age, sex, sport history (minimum five years of active sports occupation in track and field) and absence of diseases. The survey did not include the hormonal status of respondents nor trial of the use of supplements in the diet, rather than that it focused on the differences in the above mentioned parameters of bone mineral density between the top athletes, ie. track and field athletes and non-athlete male controls.

Results

On the base of the values of the statistical parameters of normality of the curve distribution of data, it was observed that the distribution of the data of all the variables applied in this study does not deviate significantly from the normal distribution.

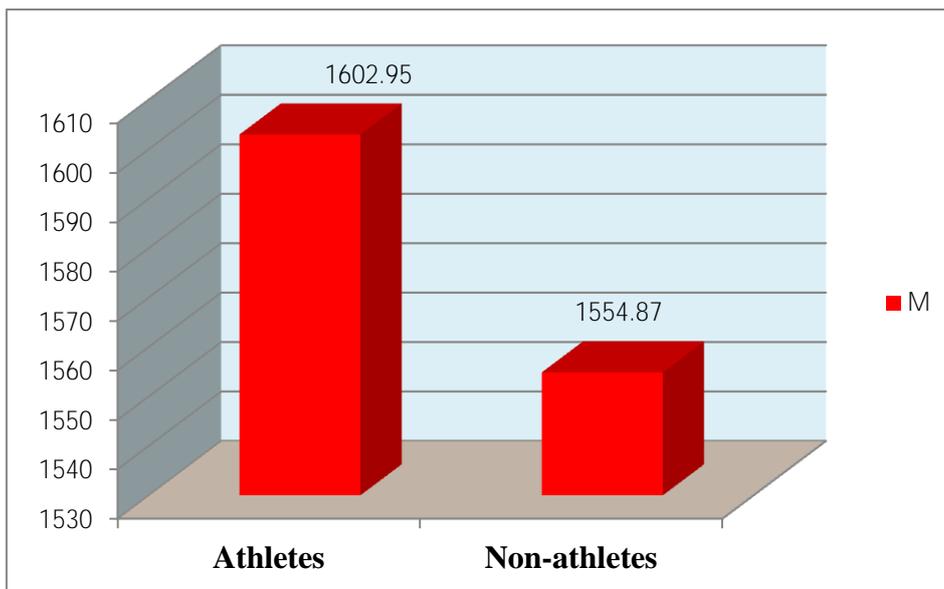
For the variable Width of heel bone, value of t-test was 2.32 at a significance level of 0.03, which indicates that there is a statistically significant difference between athletes and non-athletes. The sign of t-test indicates a direction of determined difference. A negative value means the difference in favor of another group, ie. non-athletes, who obtained better result, respectively they had a greater width of the heel bone (calcaneus) in relation to the track and field athletes. This confirms the value of arithmetic means of groups that is higher in non-athletes (M=43.87 mm) with a standard deviation of 2.83 mm compared to track and field athletes (M=41.36; SD=3.11) (Graph 1).

Graph 1. The value of the arithmetic mean width of the heel bone athletes and non-athletes.



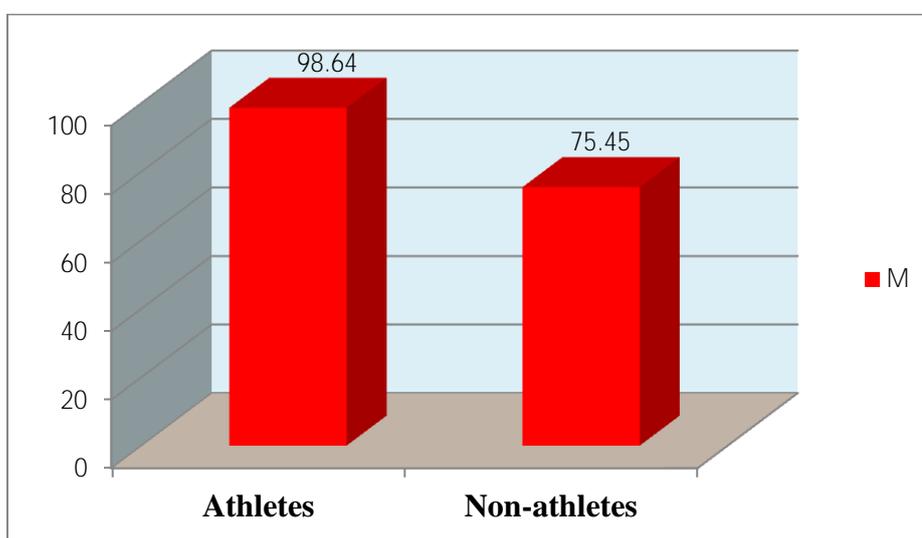
The value of the t-test for a variable SOS was 5.46 at significance level of 0.000 which is less than the selected limit value of 0.05. Based on the values of the results, it can be concluded that there is a statistically significant difference in the rate of penetration of the ultrasonic waves (SOS) through the heel bone. As the results are expressed in seconds, the ultrasonic wave penetrated faster into the heel bone of non-athletes (M=1554.87; SD=19.49) at a statistically significant level, in comparison to the track and field athletes (M=1602.95; SD=27.95) (Graph 2).

Graph 2. The value of the arithmetic mean of penetration rate of ultrasonic waves through the heel bone (SOS) in athletes and non-athletes.



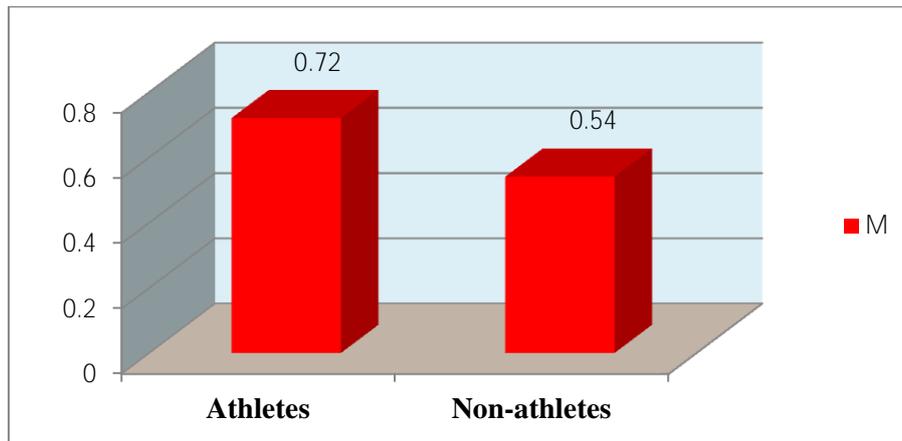
For the variable BUA, the values of significance of t-test ($t = 3.87$) showed that there is a statistically significant difference ($p = 0.001$) in the speed of the ultrasonic wave attenuation through the heel bone. In the group of track and field athletes, weakening of the wave through the calcaneus was greater than in the group of sedentary controls, which can be recognized on the base of the arithmetic mean value of this parameter ($M=98.64$; $SD=20.12$) compared to the sedentary group ($M=75.45$; $SD=11.58$) (Graph 3).

Graph 3. The value of the arithmetic mean in weakening of the ultrasonic wave when passing through the heel bone (BUA) in athletes and non-athletes.



According to the results obtained for BDM parameter, it can be concluded that the group of athletes has increased estimated mineral density of the calcaneus ($M=0.72$, $SD=0.12$) compared to the control group ($M = 0.54$; $SD=0.08$) (Graph 4). The differences between these two groups was at significant level ($p=0.000$).

Graph 4. The value of the arithmetic mean of the estimated mineral (eBDM) density of the calcaneus in athletes and non-athletes.



Discussion

The main goal of this study is to examine and compare the bone mineral density parameters of elite track and field athletes and inactive controls. The results of our study are consistent with the results of numerous studies between athletes and non-athletes (Arasheben, Barzee & Morley, 2011; Kaštelan, Kraljevi, Kardum, Kasovi, Dušek, Protulipac et al., 2007; Suominen, 1993; Karlsson, Johnell & Obrant, 1993a; Karlsson, Johnell & Obrant, 1993b; Nikander, Sievanen, Heinonen & Kannus, 2005; Karlsson, Hasserijs & Obrant, 1996) and support the fact that athletes have greater bone mineral density than sedentary controls. In our study elite athletes had higher values of all measured parameters of BMD at statistically significant level ($p < 0.03$) compared with sedentary male controls, except width of the heel bone. In the existing literature, the authors found neither research that explicitly compares data width of the calcaneus between athletes and non-athletes, nor research that compares width of calcaneus with correlation of bone mineral density.

The second measured parameter in our study was the Speed of sound, 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 SOS parameter revealed statistically significant difference between the group of track and field athletes and sedentary male controls (Graph 2).

The third 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). Weakening of the ultrasonic signal as it passes through the heel bone is bigger in athletes than non-athletes, in this study (Graph 3).

The level of significance showed that elite track and field athletes had greater BMD at statistically significant level comparing to inactive controls (Graph 4). Generally, athletes

have higher BMD than age-matched sedentary controls (Suominen, 1993; Karlsson, Johnell & Obrant, 1993a; Karlsson, Johnell & Obrant, 1993b; Nikander, Sievanen, Heinonen & Kannus, 2005; Karlsson, Hasserijs & Obrant, 1996). Several cross-sectional studies have demonstrated higher BMD among athletes who engage in weight bearing and impact sports when compared to non-athletes (Davee et al., 1990; Stewart & Hannan, 2000). It is more effective to provide a higher intensity stimulus than simply to extend the duration of lower intensity loading activities (Bennell et al., 1997; Marcus, 2001), as it is in practicing track and field events.

In the 12 month longitudinal cohort study, Benell et al. (1997) came up with results that track and field athletes also had higher mineral bone density than non-athletes. They were comparing bone mass and bone turnover in elite and subelite track and field athletes and less active controls, aged 17-26 years. Baseline results showed that power athletes had higher regional BMD at lower limb, lumbar spine, and upper limb sites compared with controls ($p < 0.05$). Endurance athletes had higher BMD than controls in lower limb sites only ($p < 0.05$). Besides that, Whittington et al. (2009) concluded that throwers had greater BMD than non-athletes and most other athletes. Furthermore, the cross-sectional study of Andreoli et al. (2001) showed that athletes, especially those engaged in high-impact sports, had significantly higher total BMD than controls. These results suggest that the type of sport activity may be an important factor in achieving a high peak bone mass and reducing osteoporosis risk (Andreoli et al., 2001).

Low BMD significantly increases the risk of fractures at minimal traumas (stress fracture) (Kohrt et al., 2004). In a meta-analysis, Moayyeri et al. (2012) confirmed that SOS, BUA, SI (stiffness index) and QUI (quantitative ultrasound index) significantly predicted fractures after reviewing 21 independent studies. Bone stress injuries result from chronic repetitive training and can range from a stress reaction to a cortical fracture (Matheson et al., 1987). Stress fractures occur in several different bones. The distribution of stress fractures differs according to activity. The tibia is reported to be the most frequently injured bone in runners (Hulkko & Orava, 1987; Ha, Hahn, Chung, Yang & Yi, 1991), followed by the fibula, metatarsal and pelvis (Matheson et al., 1987). Fifteen percent of all stress fractures occur in runners (Matheson et al., 1987) accounting for 70% of all of their injuries (Orava, 1980). This study results can be helpful in the prediction of fractures for both coaches and athletes because this type of injuries are common in athletes (Knobloch, Schreibmueller, Jagodzinski, Zeichen, Krettek, 2007; Brukner, Bradshaw, Kahn, White, Crossley, 1996; Øyen, Klungland, Torstveit, Sundgot-Borgen, 2009).

This study supports previous researches, indicating a positive effect of high-impact sports, as well as track and field, as one of that type of sport, on BMD in elite athletes.

References

Andreoli, A., Monteleone, M., Van Loan, M., Promenzio, L., Tarantino, U. & De Lorenzo, A. (2001). Effects of different sports on bone density and muscle mass in highly trained athletes. *Medicine and Science in Sports and Exercise*, 33(4):507-11.

- Arasheben, A., Barzee, K. A. & Morley, C. P. (2011). A meta-analysis of bone mineral density in collegiate female athletes. *Journal of American Board of Family Medicine*, 24(6):728-34.
- Baji , Z., Ponorac, N., Rašeta, N. & Baji , . (2010). Uticaj fizi ke aktivnosti na kvalitet kosti. *Sportlogia*, 6 (1):7-13.
- Bennell, K. L., Malcolm, S. A., Khan, K. M., Thomas, S. A., Reid, S. J., Brukner, P. D., Ebeling, P. R., & Wark, J. D. (1997). Bone mass and bone turnover in power athletes, endurance athletes, and controls: a 12-month longitudinal study. *Bone*, 20(5), 477-484.
- Brukner P, Bradshaw C, Kahn KM, White S, Crossley K. Stress fractures: a review of 180 cases. *Clin J Sport Med*. 1996;6(2):85–89.
- Chen, Y. T., Tenforde, A. S., Fredericson, M. (2013). Update on stress fractures in female athletes: epidemiology, treatment, and prevention. *Current Reviews in Musculoskeletal Medicine*, 6(2):173–181.
- Courteix, D., Lespessailles, E., Peres, S. L., et al. (1998). Effect of physical training on bone mineral density in prepubertal girls: a comparative study between impactloading and non-impact-loading sports. *Osteoporosis International*, 8:152–8.
- Davee, M. A., Rosen, J. C., & Alder, A. R. (1990). Exercise patterns and trabecular bone density in college woman. *Journal of Bone and Mineral Research*, 5(3), 245-250.
- Delmas, P. D. & Fraser, M. (1999). Strong bones in later life: luxury or necessity? *Bulletin of the World Health Organization The International Journal of Public Health*, 77(5):416-422.
- Drinkwater, B. L. (1994). CH McCloy research lecture: does physical activity play a role in preventing osteoporosis? *Research Quarterly Exercise in Sport*, 65:197–206.
- Faulkner, K. G., McClung, M. R., Coleman, LJ. & Kingston-Sandahle, E. (1994). Quantitative ultrasound of the heels: correlation with densitometric measurements at different skeletal sites. *Osteoporosis International*, 4: 42–7.
- Ha, K. I., Hahn, S. H., Chung, M. Y., Yang, B. K. & Yi, S. R. (1991). A clinical study of stress fractures in sports activities. *Orthopedics*, 14:1089–1095.
- Harrast, M. A. & Colonno, D. (2010). Stress fracture in runners. *Clinics in Sports Medicine*, 29(3):399–4.
- Heinonen, A., Sievanen, H., Kannus, P., Oja, P., Pasanen, M. & Vuori, I. (2000). High-impact exercise and bones of growing girls: a 9-month controlled trial. *Osteoporosis International*, 11:1010–7.
- Hind, K. & Burrows, M. (2007). Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials. *Bone*, 40:14–27.

- Hulkko, A. & Orava, S. (1987). Stress fractures in athletes. *International Journal of Sports Medicine*, 8:221–226.
- Karlsson, M. K., Hasserijs, R. & Obrant, K. J. (1996). Bone mineral density in athletes during and after career: a comparison between loaded and unloaded skeletal regions. *Calcified Tissue International*, 59 (4): 245-248.
- Karlsson, M. K., Johnell, O. & Obrant, K. J. (1993). Bone mineral density in professional ballet dancers. *Bone and Mineral*, 21 (3): 163-169.
- Karlsson, M. K., Johnell, O. & Obrant, K. J. (1993). Bone mineral density in weight lifters. *Calcified Tissue International*, 52 (3): 212-215.
- Kaštelan, D., Kraljević, I., Kardum, I., Kasović, M., Dušek, T., Protulipac, J. M., et al. (2007). The effects of the level of physical activity on calcaneal ultrasound measurements: bone properties of medical and physical education students. *Collegium Antropologicum*, 31:701-4.
- Knobloch, K., Schreibmueller, L., Jagodzinski, M., Zeichen, J. & Krettek, C. (2007). Rapid rehabilitation programme following sacral stress fracture in longdistance running female athlete. *Archives of Orthopaedic and Trauma Surgery*, 127, pp.809-813.
- Kohrt, W. M., Bloomfield, S. A., Little, K. D., Nelson, M. E., Yingling, V. R. (2004). American College of Sports Medicine. American College of Sports Medicine Position Stand: Physical activity and bone health. *Medicine and Science in Sports and Exercise*, 36(11), 1985-1996.
- Kok-Yong, C. & Ima-Nirwana, S. (2013). Calcaneal Quantitative Ultrasound as a Determinant of Bone Health Status: What Properties of Bone Does It Reflect? *International Journal of Medical Sciences*, 10(12): 1778–1783.
- Lanyon, L.E.(1992). Control of bone architecture by functional load bearing. *Journal of Bone and Mineral Research*,7(Suppl 2):S369–75.
- Marcus, R., Feldman, D., & Kelsey, J. (2001). *Osteoporosis*. San Diego, CA: Academic Press.
- Matheson, G. O., Clement, D. B., McKenzie, D. C., Taunton, J. E., Lloyd-Smith, D. R., MacIntyre, J. G. (1987). Stress fractures in athletes. A study of 320 cases. *American Journal of Sports Medicine*, 15(1):46-58.
- McCormick, F., Nwachukwu, B. U. & Provencher, M. T. (2012). Stress fractures in runners. *Clinics in Sports Medicine*, 31(2):291-306.
- Moayyeri, A., Adams, J., Adler, R., Krieg, M. A., Hans, D., Compston, J. et al. (2012). Quantitative ultrasound of the heel and fracture risk assessment: an updated meta-analysis. *Osteoporosis International*, 23:143–53.
- Nikander, R., Sievanen, H., Heinonen, A. & Kannus, P. (2005). Femoral neck structure in adult female athletes subjected to different loading modalities. *Journal of Bone and Mineral Research*, 20 (3): 520-528.

- Nilsson, B.E. & Westlin, N.E. (1971). Bone density in athletes. *Clinics in Orthopedics Surgery*, 77:179–82.
- Orava, S. (1980). Stress fractures. *British Journal of Sports Medicine*, 14:40–44.
- Øyen, J., Torstveit, M. K. & Sundgot-Borgen, J. (2009). Self-Reported Versus Diagnosed Stress Fractures in Norwegian Female Elite Athletes. *Journal of Sport Science and Medicine*, 8(1): 130–135.
- Pettersson, U., Nordström, P., Alfredson, H., Henriksson-Larsén, K., Lorentzon, R. (2000). Effect of high impact activity on bone mass and size in adolescent females: A comparative study between two different types of sports. *Calcified Tissue International*, 67(3):207-14.
- Rubin, C. T., Lanyon, L. E. (1984). Regulation of bone formation by applied dynamic loads. *Journal of Bone Joint Surgery*, 66:397–402.
- Smith, E. L. & Gilligan, C. (1991). Physical activity effects on bone metabolism. *Calcified Tissue International*, 49 Suppl:S50-4.
- Stewart, A. D., & Hannan, J. (2000). Total and regional bone density in male runners, cyclists, and controls. *Medicine and Science in Sports and Exercise*, 32(8), 1373-1377.
- Suominen, H. (1993). Bone mineral density and long term exercise. An overview of cross-sectional athlete studies. *Sports Medicine*, 16 (5): 316-330.
- Tenforde, A. S. & Fredericson, M. (2011). The Influence of Sports Participation on Bone Health in the Young Athlete: A Review of the Literature. *PM&R Journal* 3(9): 861-867.
- Turner, C. H., Woltman, T. A., Belongia, D. A. (1992). Structural changes in rat bone subjected to long-term, in vivo mechanical loading. *Bone*, 13:417–22.
- Whittington, J., Schoen, E., Labounty, L. L., Hamdy, R., Ramsey, M. W., Stone, M. et al. (2009). Bone mineral density and content of collegiate throwers: influence of maximum strength. *Journal of Sports Medicine and Physical Fitness*, 49(4):464-73.
- World Health Organization: Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: Report of a World Health Organization Study Group (1994). World Health Organization Technical Report Series, 843, 1-129.
- Yung, P., Lai, Y., Tung, P., Tsui, H., Wong, C., Hung, V., Qin, L. (2005). Effects of weight bearing and non-weight bearing exercises on bone properties using calcaneal quantitative ultrasound. *British Journal of Sports Medicine*, 39(8): 547–551.