J Bone Miner Metab (2012) 30:232–237
DOI 10.1007/s00774-011-0310-8

ORIGINAL ARTICLE

Bone mineral density and body composition of South African cricketers

Lisa K. Micklesfield · Janine Gray · Mogammad S. Taliep

Received: 17 May 2011 / Accepted: 11 August 2011 / Published online: 21 September 2011

Abstract Mechanical loading associated with weight-bearing physical activity has been positively associated with bone mineral density in athletes participating in various sports. The aim of this study was to compare the body composition and bone mineral density of South African male cricketers to controls. Whole body (WB), femoral neck (FN), proximal femur (PF) and lumbar spine (LS) BMD, as well as whole body fat mass (WBFM) and lean mass (WBLM) were measured, using dual-energy X-ray absorptiometry (DXA), on 34 high-performance (senior provincial and national level) cricketers and 23 physically active controls between the ages of 16 and 34 years. Cricketers were significantly younger, taller, and had greater WBLM and WBBMC compared to the controls. LS, PF and FN BMD were higher in the cricketers and controls before and after adjusting for age and height. WBBMD was significantly lower in the spin bowlers compared to the batsmen and fast bowlers, after adjusting for age and height; however, there were no differences at the BMD sites between the groups. Bone mineral density at the lumbar spine and hip sites was significantly greater in the cricketers compared to the controls, suggesting that the mechanical loading associated with cricket is beneficial for bone mineral density.

Keywords Cricket · Bone · Impact · Sport · Loading

Introduction

It is widely accepted that bone responds positively to the mechanical loading and muscle forces associated with physical activity [1]. Athletes have higher bone mineral density than sedentary controls, depending on the loading associated with their particular sport [2, 3], and the influence of site-specific loading on bone mineral density, bone mass and bone size has been further demonstrated in the dominant arm of athletes participating in racquet sports such as tennis [4, 5].

The other components of body composition, namely, fat and lean mass, have been measured in athletes using techniques such as skinfold thickness, near infrared reactance and bioelectrical impedance [6, 7], with very little published body composition data using dual energy X-ray absorptiometry (DXA) [7]. DXA has become more widely accepted as a means of measuring body composition in adults [8], with reference values from NHANES being reported in 2009 [9]. In addition to providing whole body measurements of bone, fat mass and lean mass, DXA can also provide information on the regional distribution of these components of body composition. Regional tissue differences between athletes and controls, as well as between athletes with different playing functions within a team, have been reported by Bell et al. [10] in rugby

L. K. Micklesfield (✉) · J. Gray
UCT/MRC Research Unit for Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Private Bag, Rondebosch 7700, South Africa
e-mail: lisa.micklesfield@uct.ac.za

L. K. Micklesfield
MRC/WITS Developmental Pathways for Health Research Unit, Department of Paediatrics, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

M. S. Taliep
Department of Sports Management, Cape Peninsula University of Technology, Cape Town, South Africa

players, with the aim of contributing to a better understanding of athletic performance and its requirements.

The science and medicine of cricket have been studied and reviewed [11, 12], with a particular focus on the injuries and biomechanics of fast bowlers [13, 14]. However, this does not include any studies on the bone health of these athletes even though stress injuries have commonly been reported in cricketers, most particularly at the lumbar spine [14–16]. Cross-sectional studies have identified that stress fractures of the lumbar spine consistently occur more often in the fast bowling population than in the general population [14–16, 19]. The prevalence for stress fractures is reported to be between 23.5 and 66.7% in fast bowling populations.

Therefore the aim of this study was to compare the bone mineral density and body composition of competitive cricketers to controls.

Materials and methods

Participants

All participants were male, and included 34 high-performance (senior provincial and national level) cricketers and a convenience sample of 23 physically active controls between the ages of 16 and 34 years.

The cross-sectional study was conducted according to the guidelines in the Declaration of Helsinki, and all procedures were approved by the Research Ethics Committee of the Faculty of Health Sciences at the University of Cape Town. Written informed consent was obtained from all the subjects.

Measurements

Whole body (WB), femoral neck (FN), proximal femur (PF) and lumbar spine (LS) BMD, as well as whole body fat mass (WBFM) and lean mass (WBLM) were measured using dual-energy X-ray absorptiometry (DXA) (Hologic Discovery-W, software version 12.1, Hologic Bedford Inc., Bedford, MA, USA). The regional placement of markers to delineate the arms, legs and trunk was determined by the manufacturer algorithm. In vivo precision (%CV) for this machine has been determined for fat-free tissue mass (0.7%), fat mass (1.67%) and whole body bone mineral content (0.9%) by measuring 30 individuals twice on the same day with re-positioning. Low bone mass was defined as a z score below -2.0 (2 SD below the expected value for a healthy young adult) [17]. Appendicular skeletal muscle mass index (ASMI) was calculated as the sum of the lean soft tissue masses for the arms and legs (kg) divided by the squared height (m^2).

Statistical analyses

One-way ANCOVA was used to compare BMD between cricketers and controls, after covarying for age and height. The association between lean mass and bone mass was calculated using Pearson's correlation coefficient. The alpha level was set at $p < 0.05$. One-way ANCOVA, covarying for age and height, was also used to compare BMD among the different playing positions within the cricketers (i.e. batsmen, spin bowlers and fast bowlers). When a significant p level was achieved, a post hoc Bonferroni test was used to explore these differences further.

Results

Cricketers compared to controls

The descriptive characteristics of the cricketers and controls are presented in Table 1. Although there were no significant differences in weight between the cricketers and controls, the cricketers were significantly younger and taller than the controls. WBFM, in kg and as a % of weight, was not different between the groups; however, the cricketers had significantly greater WBLM and WBBMC compared to the controls, although the correlation between WBLM and WBBMC was significant in both groups (cricketers $r = 0.64, p < 0.001$; controls $r = 0.84, p < 0.001$). ASMI was also significantly higher in the cricketers compared to the controls.

Fat, lean and bone mass of the arms and legs are presented in Table 2. Arm and leg absolute lean mass and bone mineral content were higher in the cricketers compared to the controls. There was no difference in absolute or relative fat mass of the arm or legs between the groups,

Table 1 Descriptive characteristics for cricketers and controls

	Cricketers ($n = 34$)	Controls ($n = 23$)	p value
Age (years)	22.0 ± 3.3	29.0 ± 4.1	0.000
Weight (kg)	77.8 ± 9.6	74.8 ± 10.6	0.262
Height (cm)	180.3 ± 7.2	176.1 ± 8.1	0.047
BMI (kg/m^2)	23.9 ± 2.5	24.1 ± 3.1	0.805
WBFM (kg)	12.4 ± 4.9	13.8 ± 5.7	0.318
WBLM (kg)	61.4 ± 6.0	56.8 ± 7.1	0.010
WBBMC (kg)	3.1 ± 4.1	2.7 ± 3.5	0.004
WBFM (%)	15.7 ± 4.9	18.4 ± 6.0	0.068
ASMI (kg/m^2)	8.9 ± 0.8	8.4 ± 0.9	0.046

Data presented as mean ± SD

WBFM whole body fat mass, *WBLM* whole body lean mass, *WBBMC* whole body bone mineral content, *ASMI* appendicular skeletal muscle mass index and relative lean mass and bone mineral content, as a % of weight, were not different. Absolute and relative bone mineral content of the trunk was higher in the cricketers compared to the controls (Table 3).

Table 2 Absolute (kg) and relative (%) amounts of fat, lean and bone mass in the arms and legs in cricketers and controls

	Cricketers ($n = 34$)	Controls ($n = 23$)	p value
AFM (kg)	1.3 ± 6.4	1.3 ± 5.9	0.913
ALM (kg)	7.4 ± 0.9	6.7 ± 0.9	0.012
ABMC (kg)	0.44 ± 0.07	0.40 ± 0.05	0.034
AFM (%)	13.6 ± 5.4	15.1 ± 5.7	0.341
ALM (%)	81.6 ± 5.4	80.2 ± 5.5	0.341
ABMC (%)	4.8 ± 0.5	4.8 ± 0.4	0.207
LFM (kg)	4.7 ± 2.0	5.3 ± 2.6	0.332
LLM (kg)	21.1 ± 2.2	19.1 ± 2.8	0.003
LBMC (kg)	1.2 ± 0.2	1.1 ± 0.2	0.003
LFM (%)	17.0 ± 5.5	20.3 ± 7.6	0.065
LLM (%)	78.5 ± 5.4	75.5 ± 7.2	0.779
LBMC (%)	4.5 ± 0.5	4.3 ± 0.5	0.053

Data presented as mean ± SD

AFM arm fat mass, *ALM* arm lean mass, *ABMC* arm bone mineral content, *LFM* leg fat mass, *LLM* leg lean mass, *LBMC* leg bone mineral content

Table 3 Absolute (kg) and relative (%) amounts of fat, lean and bone mass in the trunk in cricketers and controls

	Cricketers ($n = 34$)	Controls ($n = 23$)	p value
TFM (kg)	5.4 ± 2.5	6.2 ± 2.6	0.252
TLM (kg)	29.4 ± 3.4	27.4 ± 3.8	0.046
TBMC (kg)	0.9 ± 0.1	0.7 ± 0.1	<0.000
TFM (%)	14.7 ± 5.3	17.8 ± 6.1	0.053
TLM (%)	82.8 ± 5.0	80.1 ± 6.0	0.081
TBMC (%)	2.5 ± 0.3	2.1 ± 0.3	<0.000

Data presented as mean ± SD

TFM trunk fat mass, *TLM* trunk lean mass, *TBMC* trunk bone mineral content

LS, PF and FN BMD were higher in the cricketers and controls before and after adjusting for age and height (Table 4). One cricketer (batsman) had a z score below −2 at the lumbar spine, while one control had a z score below −2 at the femoral neck.

Comparison among cricketers

The cricketers were divided into three groups according to their predominant skill: batsmen (B $n = 8$), spin bowlers (SB $n = 17$) and fast bowlers (FB $n = 9$). The fast bowlers were significantly older than the spin bowlers (FB 24.1 ± 2.3 years vs. SB 20.6 ± 3.4 years, $p = 0.021$), and taller than the other groups (FB 186.3 ± 3.4 cm vs. B 176.3 ± 5.5 cm, SB 178.9 ± 70.7 cm, $p = 0.005$). There were no differences in weight (FB 81.7 ± 10.1 kg, B 79.1 ± 4.1 kg, SB 75.1 ± 10.7 kg), WBFM (FB 13.3 ± 6.1 kg, B 13.2 ± 3.2 kg, SB 11.5 ± 4.9 kg) or WBLM (FB 64.1 ± 5.2 kg, B 61.7 ± 3.3 kg, SB 59.8 ± 7.0 kg) among the groups.

WBBMD was significantly lower in the spin bowlers compared to the batsmen and fast bowlers, after adjusting for age and height (Fig. 1). There were no differences in LS (FB 1.280 ± 0.181 g/cm^2, B 1.225 ± 0.107 g/cm^2, SB 1.125 ± 0.133 g/cm^2), PF (FB 1.232 ± 0.141 g/cm^2, B 1.290 ± 0.129 g/cm^2, SB 1.143 ± 0.113 g/cm^2) or FN BMD (FB 1.091 ± 0.142 g/cm^2, B 1.100 ± 0.129 g/cm^2, SB 1.020 ± 0.127 g/cm^2) among the groups.

Discussion

To our knowledge, this is the first study to examine the bone mineral density of high-performance cricketers, a group of athletes who have been identified to be at high risk of stress fractures [15, 18, 19]. Our results have shown that when compared to males of a relatively similar age and weight, the cricketers had greater bone mineral density at all sites including the lumbar spine, proximal femur and

Table 4 BMD measurements in cricketers and controls

	Cricketers ($n = 34$)	Controls ($n = 23$)	p value
Unadjusted (g/cm^2)			
WBBMD	1.245 ± 0.111	1.196 ± 0.106	0.102
LSBMD	1.189 ± 0.153	1.037 ± 0.114	<0.000
PFBMD	1.201 ± 0.136	1.076 ± 0.138	0.001
FNBMD	1.057 ± 0.133	0.924 ± 0.138	<0.000
Adjusted for age and height (g/cm^2)			
WBBMD	1.267 (1.223–1.311)	1.163 (1.106–1.221)	0.016
LSBMD	1.217 (1.162–1.272)	0.996 (0.924–1.067)	<0.000
PFBMD	1.201 (1.145–1.258)	1.077 (1.003–1.151)	0.024
FNBMD	1.054 (0.997–1.110)	0.927 (0.854–1.001)	0.021

Unadjusted data presented as mean ± SD; adjusted data presented as mean (95% CI)

WBBMD whole body bone mineral density, *LSBMD* lumbar spine bone mineral density, *PFBMD* proximal femur bone mineral density, *FNBMD* femoral neck bone mineral density

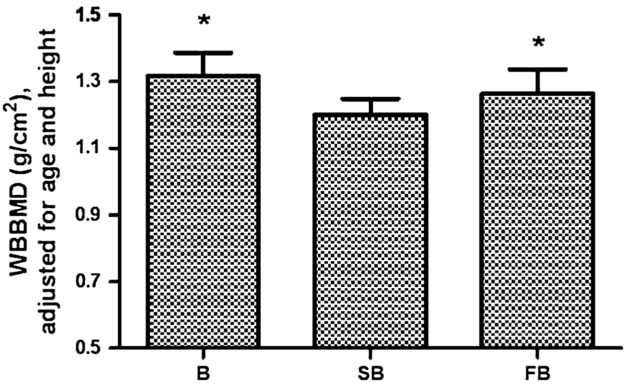

Fig. 1 Whole body bone mineral density (WBBMD), adjusted for age and height, in batsmen (B $n = 8$), spin bowlers (SB $n = 17$) and fast bowlers (FB $n = 9$). *$p < 0.05$, compared to spin bowlers. Adjusted data presented as mean (95% CI)

femoral neck. It therefore appears that bone mineral density may not be the only determinant of stress fractures in cricketers and that there may be other factors responsible for the increased incidence of stress fractures reported in these athletes.

Although low bone mineral density has been proposed as a risk factor for stress fractures in athletes [20], other factors unique to the sport itself may also play a role in their aetiology. The biomechanics and excessive loading associated with bowling has been well explored in fast bowlers. Fast bowlers using a 'mixed' action technique that involves a counter-rotation of the shoulders during the delivery stride have been found to have an increased risk of developing a stress fracture [14, 18, 21]. A high workload with infrequent rest days is associated with increased risk of injury in both junior and senior bowlers [22, 23]. In addition, adolescent cricketers have been shown to be at a particularly high risk of lower back injury [14, 18, 21, 24], which rather than being a result of low BMD, may actually be due to the incomplete closure of ossification centres in these young athletes.

It is well known, from cross-sectional and longitudinal studies, that athletes have a higher bone mineral density compared to non-athletes [25–27]. We showed a 12.8, 10.4 and 12.5% higher BMD at the lumbar spine, proximal femur and femoral neck, respectively, in the cricketers compared to the controls. When compared to controls, soccer players show similar differences at the lumbar spine (10%) but greater differences at the femoral neck (21%) [28]. The loading characteristics associated with different sports contribute to differences in bone strength, with athletes participating in higher impact sports having a greater bone mineral density compared to athletes participating in lower impact sports or those with no impact at all [29, 30]. It has also been shown that not just high-impact sports, but also sports that involve unusual loading as well as acceleration and deceleration are associated with stronger weight-bearing structures [31]. The characteristics of the game of cricket may fit into the latter category as it is associated with high ground reaction forces of 4.8–6.4 times body weight occurring during the bowling action [18, 32, 33]. In addition, cricketers are required to change direction rapidly, accelerate and decelerate quickly, and fast bowlers in particular place a significant amount of weight on the leading leg when bowling.

The mechanostat theory hypothesizes that the increasing muscle forces that occur during growth influence the size and strength of the bone [1, 34], and that the largest forces on the skeleton are from muscles [35]. The cricketers in our study had higher whole body and appendicular muscle and bone mass compared to the controls. Although we do not know whether this is due to selection bias, the findings of some longitudinal studies show that the bone mass of well-trained athletes still responds to mechanical loading [36]. Therefore, it is likely that the higher bone mass in our cricketers is a consequence of their high lean mass, the result of a regular strength-training regimen. Although the cricketers had higher muscle and bone mass compared to the controls, there was no difference in whole body or appendicular fat mass between the groups. Although we did not collect exercise diaries on the control group, a convenience sample of males who had had DXA measurements on the same machine, most of them were physically active, which may explain a lower fat mass than would be found in a sedentary control group.

The difference in body composition and bone mineral density among athletes playing in different positions within the same sport has been shown in sports such as rugby [10, 37]. In our study the spin bowlers had lower whole body BMD compared to the fast bowlers and batsmen. Although we did adjust for age, which may help to account for the influence of age itself on bone mineral density, it does not take into account the fact that, being younger, the spinners had had fewer hours of competitive cricket, equating to less playing time, less impact on weight-bearing structures and therefore lower bone mineral density. When dividing the spin bowlers into wrist spinners and finger spinners (data not shown due to small sample size), the mean age of the wrist spinners was 18.3 years, approximately 5 years less than the finger spinners who had a mean age of 23.1 years. This age difference, which is a proxy for years of competitive cricket, is reflected in the difference in whole body BMD, which was 8% higher in the finger spinners compared to the wrist spinners. As it is now proposed that peak bone mass is attained by approximately 18 years of age [38, 39], this difference may be due to the hours of competitive cricket, and therefore mechanical loading and impact on the bone.

There were no differences in site-specific BMD between the different playing positions, which may be due to the fact that although cricketers do specialise in a particular playing position, they are required to spend time in all positions during training and competition. This may explain why the differences are not as large as in other sports such as rugby, in which players train very specifically for their playing position.

The small sample size of the cricket and control groups can be considered to be a limitation of this study. The cricketers were recruited from a very select group of provincial and national cricketers, which naturally decreases the sample available for recruitment, and the control group were a convenience sample recruited for another study. In addition, the significant age difference between the cricketers and controls, as well as the spin bowlers compared to the batsmen and fast bowlers, is unfortunate and cannot be adequately adjusted for statistically. The mean age of all the groups was however greater than 20 years, which is above that suggested for the attainment of peak bone mass [39].

In this study, cricketers had a 10–13% greater BMD at all sites compared to controls, suggesting that the mechanical loading associated with cricket is beneficial for bone mineral density. The implications of this in terms of future bone health and fracture risk remain to be determined.

Conflict of interest All authors have no conflicts of interest.

References

1. Frost HM (2001) From Wolff's law to the Utah paradigm: insights about bone physiology and its clinical applications. Anat Rec 262:398–419
2. Heinonen A, Oja P, Kannus P, Sievanen H, Haapasalo H et al (1995) Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone 17:197–203
3. Andreoli A, Monteleone M, Van LM, Promenzio L, Tarantino U et al (2001) Effects of different sports on bone density and muscle mass in highly trained athletes. Med Sci Sports Exerc 33:507–511
4. Haapasalo H, Kannus P, Sievanen H, Pasanen M, Uusi-Rasi K et al (1998) Effect of long-term unilateral activity on bone mineral density of female junior tennis players. J Bone Miner Res 13:310–319
5. Kontulainen S, Sievanen H, Kannus P, Pasanen M, Vuori I (2003) Effect of long-term impact-loading on mass, size, and estimated strength of humerus and radius of female racquet-sports players: a peripheral quantitative computed tomography study between young and old starters and controls. J Bone Miner Res 18:352–359
6. Duthie GM, Pyne DB, Hopkins WG, Livingstone S, Hooper SL (2006) Anthropometry profiles of elite rugby players: quantifying changes in lean mass. Br J Sports Med 40:202–207
7. Fornetti WC, Pivarnik JM, Foley JM, Fiechtner JJ (1999) Reliability and validity of body composition measures in female athletes. J Appl Physiol 87:1114–1122
8. Li C, Ford ES, Zhao G, Balluz LS, Giles WH (2009) Estimates of body composition with dual-energy X-ray absorptiometry in adults. Am J Clin Nutr 90:1457–1465
9. Kelly TL, Wilson KE, Heymsfield SB (2009) Dual energy X-ray absorptiometry body composition reference values from NHANES. PLoS One 4:e7038
10. Bell W, Evans WD, Cobner DM, Eston RG (2005) Regional placement of bone mineral mass, fat mass, and lean soft tissue mass in young adult rugby union players. Ergonomics 48:1462–1472
11. Bartlett RM (2006) Medicine and science in cricket. J Sci Med Sport 9:470–471
12. Johnstone JA, Ford PA (2010) Physiologic profile of professional cricketers. J Strength Cond Res 24:2900–2907
13. Elliott BC (2000) Back injuries and the fast bowler in cricket. J Sports Sci 18:983–991
14. Portus MR, Mason BR, Elliott BC, Pfitzner MC, Done RP (2004) Technique factors related to ball release speed and trunk injuries in high performance cricket fast bowlers. Sports Biomech 3:263–284
15. Engstrom CM, Walker DG (2007) Pars interarticularis stress lesions in the lumbar spine of cricket fast bowlers. Med Sci Sports Exerc 39:28–33
16. Ranson CA, Kerslake RW, Burnett AF, Batt ME, Abdi S (2005) Magnetic resonance imaging of the lumbar spine in asymptomatic professional fast bowlers in cricket. J Bone Joint Surg Br 87:1111–1116
17. Khan AA, Bachrach L, Brown JP, Hanley DA, Josse RG et al (2004) Standards and guidelines for performing central dual-energy X-ray absorptiometry in premenopausal women, men, and children. J Clin Densitom 7:51–64
18. Elliott BC, Hardcastle P, Burnett A, Foster DH (1992) The influence of fast bowling and physical factors on the radiologic features in high performance young fast bowlers. Sports Med Train Rehabil 3:113–130
19. Gregory PL, Batt ME, Kerslake RW (2004) Comparing spondylolysis in cricketers and soccer players. Br J Sports Med 38:737–742
20. Myburgh KH, Hutchins J, Fataar AB, Hough SF, Noakes TD (1990) Low bone density is an etiologic factor for stress fractures in athletes. Ann Intern Med 113:754–759
21. Foster D, John D, Elliott B, Ackland T, Fitch K (1989) Back injuries to fast bowlers in cricket: a prospective study. Br J Sports Med 23:150–154
22. Dennis R, Farhart P, Goumas C, Orchard J (2003) Bowling workload and the risk of injury in elite cricket fast bowlers. J Sci Med Sport 6:359–367
23. Dennis RJ, Finch CF, Farhart PJ (2005) Is bowling workload a risk factor for injury to Australian junior cricket fast bowlers? Br J Sports Med 39:843–846
24. Elliott B, Khangure M (2002) Disk degeneration and fast bowling in cricket: an intervention study. Med Sci Sports Exerc 34:1714–1718
25. Fredericson M, Chew K, Ngo J, Cleek T, Kiratli J et al (2007) Regional bone mineral density in male athletes: a comparison of soccer players, runners and controls. Br J Sports Med 41:664–668
26. Wittich A, Mautalen CA, Oliveri MB, Bagur A, Somoza F et al (1998) Professional football (soccer) players have a markedly greater skeletal mineral content, density and size than age- and BMI-matched controls. Calcif Tissue Int 63:112–117
27. Bennell KL, Malcolm SA, Khan KM, Thomas SA, Reid SJ et al (1997) Bone mass and bone turnover in power athletes, endurance athletes, and controls: a 12-month longitudinal study. Bone 20:477–484
28. Calbet JA, Dorado C, Diaz-Herrera P, Rodriguez–Rodriguez LP (2001) High femoral bone mineral content and density in male football (soccer) players. Med Sci Sports Exerc 33:1682–1687

29. Dook JE, James C, Henderson NK, Price RI (1997) Exercise and bone mineral density in mature female athletes. Med Sci Sports Exerc 29:291–296
30. Stewart AD, Hannan J (2000) Total and regional bone density in male runners, cyclists, and controls. Med Sci Sports Exerc 32:1373–1377
31. Nikander R, Sievanen H, Heinonen A, Kannus P (2005) Femoral neck structure in adult female athletes subjected to different loading modalities. J Bone Miner Res 20:520–528
32. Hurrion PD, Dyson R, Hale T (2000) Simultaneous measurement of back and front foot ground reaction forces during the same delivery stride of the fast-medium bowler. J Sports Sci 18:993–997
33. Elliott BC, Davis JW, Khangure M, Hardcastle P, Foster D (1993) Disc degeneration and the young fast bowler in cricket. Clin Biomech 8:227–234
34. Frost HM (2000) Muscle, bone, and the Utah paradigm: a 1999 overview. Med Sci Sports Exerc 32:911–917
35. Frost HM, Ferretti JL, Jee WS (1998) Perspectives: some roles of mechanical usage, muscle strength, and the mechanostat in skeletal physiology, disease, and research. Calcif Tissue Int 62:1–7
36. Taaffe DR, Robinson TL, Snow CM, Marcus R (1997) High-impact exercise promotes bone gain in well-trained female athletes. J Bone Miner Res 12:255–260
37. Elloumi M, Ben OO, Courteix D, Makni E, Sellami S et al (2009) Long-term rugby practice enhances bone mass and metabolism in relation with physical fitness and playing position. J Bone Miner Metab 27:713–720
38. Bailey DA (1997) The Saskatchewan Pediatric Bone Mineral Accrual Study: bone mineral acquisition during the growing years. Int J Sports Med 18(Suppl 3):S191–S194
39. Lorentzon M, Mellstrom D, Ohlsson C (2005) Age of attainment of peak bone mass is site specific in Swedish men—The GOOD study. J Bone Miner Res 20:1223–1227