Bone 127 (2019) 44–48

Contents lists available at ScienceDirect

Bone

journal homepage: www.elsevier.com/locate/bone

Full Length Article

Bone mineral density in an urban and a rural children population—A comparative, population-based study in Enugu State, Nigeria

Uloma B. Nwogu*, Kenneth K. Agwu, Angel-Mary C. Anakwue, Felicitas U. Idigo, Mark C. Okeji, Everistus O. Abonyi, Julius A. Agbo

Department of Medical Radiography and Radiological Sciences, Faculty of Health Sciences and Technology, University of Nigeria, Enugu Campus, Nigeria

ARTICLE INFO

Keywords:
Bone mineral density
Rural
Urban
Nigeria
Children
Quantitative ultrasound

ABSTRACT

Introduction: Osteoporosis is one of the non-communicable diseases linked to urbanisation. The foundation of osteoporotic fractures stems from childhood. Therefore, studies that promote maximising peak bone mass are strongly advocated. Studies have shown that there are differences in the incidence of osteoporotic fractures in rural and urban communities. No study has investigated urban-rural differences in BMD of Nigerian children. This study, therefore, aimed to investigate urban-rural differences in BMD of Nigerian children and the association with physical activity, demographic and anthropometric variables.

Methods: In a cross-sectional, study in Enugu, Nigeria, estimated bone mineral density (eBMD) was measured at the calcaneum using the QUS densitometer, Hologic Sahara, in 457 urban (Enugu metropolis) and 559 rural (Nsukka community) children aged 6–14 years. Height, weight and physical activity were measured. Independent sample *t-test* was used for comparative analysis while Pearson correlation coefficients and multiple regression models were used to examine the relationship between the eBMD and the other parameters.

Results: The mean (S.D) eBMD of the urban children [0.52(0.09) g/cm^2] were significantly higher ($p < 0.05$) than their age- and gender-matched counterparts in the rural areas [0.51(0.08) g/cm^2]. Age and weight predicted ($p < 0.05$) the eBMD in the urban subjects while only age was the predictor ($p < 0.05$) in the rural subjects. The physical activity pattern had no relationship with eBMD in both urban and rural children in Enugu, Nigeria.

Conclusions: The eBMD of rural children is lower than that of their age- and gender-matched urban counterparts.

1. Introduction

Osteoporosis is one of the numerous non-communicable diseases (NCDs) that has become a major health challenge and is associated with significant morbidity globally from the increased prevalence of pathological fractures in the population [1–3]. A lot of attention had been given to individuals at high risk of this condition among the elderly and post-menopausal women. However, the recent understanding that the foundation of osteoporotic fractures stems from childhood and adolescence years [4–6], has necessitated studies that promote raising peak bone mass to optimal levels among the younger population.

Although osteoporosis is linked to urbanisation [7,8], there are conflicting reports about the effects of urbanisation on bone mineral density (BMD) as one of the indices of bone mass. While previous studies reported that rural subjects had higher BMD than the urban subjects [9,10], another study found no such difference [11].

Nigeria, being a developing country with fast urbanisation patterns [12], presents a classical scenery for studying the urban-rural difference in BMD, particularly as no such records exists to the best of the researchers' knowledge. A look, therefore, at the urban-rural difference in the BMD of Nigerian children may indicate what awaits the Nigerian population in adulthood. This study, therefore, aimed to explore urban-rural differences in BMD of Nigerian children and also investigated their association with some risk factors like demographics, anthropometric variables and physical activity.

2. Methods

2.1. Participants

Four hundred and fifty-seven children (457) from 6 urban schools and 559 children from 6 rural schools whose ages ranged from 6 to

* Corresponding author at: Department of Medical Radiography and Radiological Sciences, Faculty of Health Sciences and Technology, College of Medicine, University of Nigeria, P.O. Box 15519, Enugu 401103, Nigeria.
E-mail address: uloma.nwogu@unn.edu.ng (U.B. Nwogu).

https://doi.org/10.1016/j.bone.2019.05.028
Received 26 March 2019; Received in revised form 21 May 2019; Accepted 21 May 2019
Available online 31 May 2019

Table 1
The characteristics of the study population.

Parameters	Boys			Girls			Both genders		
	Urban: mean (S.D.)	Rural: mean (S.D.)	*P*-value	Urban: mean (S.D.)	Rural: mean (S.D.)	P-value	Urban: mean (S.D.)	Rural: mean (S.D.)	P-value
Number of subjects	229	265		228	294		457	559	
Age	11.34 (2.261)	11.41 (2.371)	0.749	11.39 (2.138)	11.53 (2.407)	0.475	11.36 (2.198)	11.47 (2.388)	0.453
Height (m)	1.463 (0.120)	1.423 (0.122)	< 0.001	1.483 (0.109)	1.458 (0.142)	0.029	1.473 (0.115)	1.441 (0.134)	< 0.001
Weight (kg)	37.119 (8.734)	33.974 (8.140)	< 0.001	40.352 (9.882)	38.089 (11.080)	0.016	38.732 (9.454)	36.138 (10.010)	< 0.001
BMI (kg/m^2)	17.098 (2.217)	16.519 (1.677)	0.001	18.089 (2.834)	17.471 (2.564)	0.009	17.593 (2.588)	17.020 (2.238)	< 0.001
Mean physical activity	2.498 (0.629)	2.653 (0.561)	0.004	2.199 (0.608)	2.384 (0.619)	0.001	2.349 (0.636)	2.511 (0.607)	< 0.001

14 years were enlisted into the comparative, cross-sectional, community-based study after protocol approval was granted by the Enugu State Ministry of Health Ethical Committee. This age range represents that of Nigerian children in primary and junior secondary schools [13]. The urban population included subjects who reside in the main city of Enugu State, Nigeria, while the rural population included children from the traditional farming communities of Nsukka, 65 km away from Enugu, Nigeria. The subjects were included if they were born and are being raised in their present locality, had no disease known to affect bone metabolism, had been fully mobile for at least 6 months before the evaluation and their parents gave consent.

2.2. Procedures

The participants' demographic information such as age and sex were collected via a questionnaire and confirmed from the class register.

2.2.1. Assessment of anthropometric variables

The subjects' height and weight were measured using a standard clinical portable stadiometer (Seca 224; Seca, Hamburg, Germany) and an electronic weighing scale (Seca 861) respectively. Further details of these procedures have been described elsewhere [14].

2.2.2. Assessment of physical activity patterns

The physical activity pattern of the participants was measured with 'The Physical Activity Questionnaire for Older Children (PAQ−C) as described by Kowalski et al. [15]. The PAQ-C was adopted, slightly modified and re-validated by a human kinetics and health education professional to suit our environment and also to accommodate the subjects within the 6- and 7-year age group. The PAQ-C offers a summary physical activity score resulting from 9 items; each scored on a 5-point scale. The item-scale correlations were all > 0.30, and the scale reliability (internal consistency) was satisfactory for both females ($\alpha = 0.83$) and males ($\alpha = 0.80$). Most PAQ-C items had means near the centre of the range, and the variability was tolerable. The enlisted children's parents/guardians assisted in the completion of the physical activity Questionnaires.

2.2.3. Assessment of the estimated bone mineral density (eBMD)

A clinical bone sonometer, Sahara 06569 manufactured July 2015 by Hologic, Inc., Waltham, Massachusetts, U.S.A, was the quantitative ultrasound (QUS) densitometer used to measure the broadband ultrasound attenuation (BUA in dB/MHz) and speed of sound (SOS in m/s) on the right heel in all the subjects according to the standard protocol described by Nwogu et al. and Zaini [14,16]. To calibrate the sonometer, the measurement procedure began with a daily quality assurance test using the manufacturer's phantom. The operator applied the gel on the transducers, and with the phantom placed in the densitometer footwell, measurements were taken according to the standard procedure provided by the manufacturer. The sonometer uses the measured values of the BUA and SOS to automatically generate the calcaneal (heel) BMD using the following equation: Estimated heel BMD (g/cm^2) = 0.002592 × (BUA + SOS) − 3.687. Trained researchers were used to perform the QUS and anthropometric measurements to ensure quality.

2.3. Statistical analysis

Data were categorised according to the age, sex, and location (urban/rural) of the participants. An independent-sample *t*-test made comparisons between gender and locations. Pearson correlation coefficients were calculated to determine the association between the eBMD, age, height, weight, BMI and physical activity. Multiple linear regression model was used to determine which independent variables best predicted the eBMD. All of the independent variables were entered irrespective of their strength in the bivariate correlations. We did not enter BMI into the regression model due to its multicollinearity with height and weight. Results were reported as mean ± standard deviation (SD); as well as adjusted unstandardized regression coefficient (B), with its associated standard error (SE) and the model's coefficient of multiple determination (R^2) for the multiple linear regression analyses. The statistical analysis was performed with SPSS version 23.0 software for Windows (IBM Corporation, Armonk, NY). $P < 0.05$ was considered statistically significant.

3. Results

3.1. The characteristics of the study population

A total of 1016 children aged 6–14 years (mean age ± S.D., urban 11.36 (± 2.198) years, rural 11.47 (± 2.388) years), were investigated. Table 1 showed the characteristics of urban and rural study subjects. The differences in mean age were not significant between urban and rural subjects. Altogether, urban children were both taller and weighed more than their rural counterparts ($p < 0.05$). However, rural children were more physically active ($p < 0.05$) than their urban counterparts.

When compared based on gender as seen in Table 2, the result showed no significant difference in the mean age and sex distribution of the children living in both urban and rural areas. The urban girls were however found to weigh more than their male counterparts ($p < 0.05$). The rural girls, however, are significantly taller and weighed more than the boys ($p < 0.05$).

3.2. Physical activity mean scores comparison by location and gender

The rural subjects were significantly more physically active than their urban counterparts when compared based on location whereas when compared based on gender, the boys in both locations were more physically active than the girls ($p < 0.05$) as can be seen in Table 3.

3.3. eBMD comparison by location and gender

Table 4 shows the eBMD comparison by location and gender. eBMD

Table 2
The characteristics of the study population by gender.

Parameters	Urban			Rural		
	Boys: Mean (S.D.)	Girls: Mean (S.D.)	P-value	Boys: Mean (S.D.)	Girls: Mean (S.D.)	P-value
Number of subjects	229	228		265	294	
Age (yrs.)	11.34 (2.261)	11.39 (2.138)	0.826	11.41 (2.371)	11.53 (2.407)	0.543
Height (m)	1.463 (0.120)	1.483 (0.109)	0.067	1.423 (0.122)	1.458 (0.142)	0.002
Body weight (kg)	37.118 (8.734)	40.352 (9.882)	< 0.001	33.974 (8.140)	38.089 (11.080)	< 0.001
BMI (kg/m^2)	17.098 (2.217)	18.089 (2.834)	< 0.001	16.519 (1.677)	17.471 (2.564)	< 0.001
Mean physical activity	2.497 (0.629)	2.199 (0.608)	< 0.001	2.653 (0.560)	2.384 (0.619)	< 0.001

Table 3
Physical activity mean scores comparison by location and gender.

	N	Mean (S.D)	t-Values	*p*-Values
PA[a] Mean (Male)				
Urban	229	2.498 (0.629)	−2.899	0.04
Rural	265	2.653 (0.561)		
PA Mean (Female)				
Urban	228	2.199 (0.608)	−3.407	0.001
Rural	294	2.384 (0.619)		
PA Mean (Urban)				
Male	229	2.498 (0.629)	5.161	< 0.001
Female	228	2.199 (0.608)		
PA Mean (Rural)				
Male	265	2.653 (0.561)	5.369	< 0.001
Female	294	2.384 (0.619)		
PA Mean (Overall)				
Urban	457	2.349 (0.636)	−4.160	< 0.001
Rural	559	2.511 (0.607)		

[a] PA = Physical Activity.

Table 4
eBMD comparison by location and gender.

Variable	N	Mean (S.D)	t-Values	p-Values
eBMD (Overall)				
Urban	457	0.52(0.09)	2.472	0.01
Rural	559	0.51(0.08)		
eBMD (Male)				
Urban	229	0.525(0.09)	0.27	0.79
Rural	265	0.523(0.08)		
BMD (female)				
Urban	228	0.52(0.10)	3.09	< 0.01
Rural	294	0.50(0.08)		
BMD (Urban)				
Male	229	0.525(0.09)	0.27	0.79
Female	228	0.523(0.10)		
BMD (Rural)				
Male	265	0.523(0.08)	3.61	< 0.01
Female	294	0.500(0.08)		

Note: eBMD is in g/cm^2 and means estimated bone mineral density.

of the urban children (0.524 g/cm^2) were significantly higher ($p < 0.05$) than their age- and sex-matched counterparts in the rural areas (0.510 g/cm^2). The eBMD of the urban males were not significantly different from their rural counterparts ($p > 0.05$) whereas the urban females had higher eBMD than their rural counterparts. When compared based on gender, there was no significant difference ($p > 0.05$) between the eBMD of boys and girls in the urban areas whereas that of the rural boys were significantly higher ($p < 0.05$) than the girls.

3.4. Pearson partial correlations between the eBMD, age, anthropometric variables and physical activity

The Pearson correlation analysis showed that in both the urban and rural subjects, age, height and weight were all positively associated with BMD as can be seen in Table 5.

Table 5
Pearson partial correlations between the eBMD, age, anthropometric variables and physical activity.

Variable	eBMD (g/cm^2)	
	Urban	Rural
Age (years)	0.168*	0.221*
Height (m)	0.149*	0.180*
Weight (kg)	0.189	0.177*
BMI (kg/m^2)	0.173*	0.148*
Physical activity level	0.010	−0.018

* $p < 0.05$.

Table 6
Multiple regression analysis of eBMD, age, anthropometrics and physical activity scores by location.

Variables	Urban[a]			Rural[b]		
	B	SE	p	B	SE	P
Age (years)	0.007	0.003	< 0.05	0.011	0.003	< 0.05
Height (m)	−0.104	0.080	> 0.05	−0.066	0.068	> 0.05
Weight (kg)	−0.002	0.001	< 0.05	-4.483×10^{-5}	0.001	> 0.05
Physical activity	0.007	0.007	> 0.05	0.006	0.005	> 0.05

eBMD was the dependent variable while age, height, weight and physical activity were the independent variables.
B = Unstandardized regression coefficient.
SE = Standard Error.
[a] Urban adjusted $R^2 = 0.037$.
[b] Rural adjusted $R^2 = 0.045$.

3.5. Multiple regression analysis of eBMD, age, anthropometrics and physical activity scores by location

After linear regression analysis (Table 6), age and body weight were shown to be predictors of the eBMD in the urban subjects ($R^2 = 0.037$; $p < 0.05$) while only age was a significant predictor of the eBMD in the rural subjects ($R^2 = 0.045$; $p < 0.05$). The physical activity pattern of the subjects had no significant relationship with the eBMD in both the urban and rural subjects.

4. Discussion

Nigeria is a developing country in Africa with a challenging divide between its rural and urban areas. For instance, in Nigeria, concerns like the recent battle against insurgencies and poverty are usually less adequately addressed in rural areas than in the urban [17,18]. To the best of our knowledge, this is the first research on the investigation of urban-rural difference in the BMD among Nigerian urban and rural children and adolescent students aged 6–14 years and their association with some risk factors. As the popular phrase goes, “catch them young”, this study majorly hoped to establish the urban-rural difference in BMD

of Nigerian children bearing in mind that the result of the study would help identify children with low bone mineral density early enough, to prevent or reduce the scourge of osteoporosis in adulthood.

Our findings did not reveal any significant difference between urban and rural subjects concerning age or sex distribution. There was also no significant difference in the mean age and heights of both genders of the children living in urban areas. However, urban girls were found to weigh more than their male counterparts. While there was also no significant difference in the ages of both gender of children in the rural areas, the girls, however, are significantly taller and weighed more than the boys. The difference in anthropometric values between urban and rural children could be due to the difference in lifestyle and dietary patterns in the two communities [19]. The rural subjects were significantly more physically active than their urban counterparts when compared based on location whereas when compared based on gender, the boys in both locations were more physically active than the girls ($p < 0.05$). Rural populations are thought to be more physically active than urban populations. The rural population in this study was mainly school children whose parents are predominantly farmers. They have to trek to and fro- school and most times after school are also required to join their parents in the farming activities. In contrast, the urban population was drawn mainly from children who mostly are driven to school and who come back to do work that was not as physically demanding.

This study showed the eBMD of urban children to be significantly higher than their age- and sex-matched counterparts in rural areas. Our study is in agreement with the findings of the study by Yang et al. [19], which also showed the urban children to have higher bone quality than their rural counterparts. In contrast, a study of 246 Swedish adolescents by Sundberg et al. [9], reported that the BMD was lower in urban adolescents compared with their rural counterparts. The inconsistency between our results and that of the Swedish adolescents may be because most rural communities in Nigeria are majorly characterised by peasant farming which is the impoverished people's source of revenue [20], unlike in Sweden where rural areas have all kind of facilities with good infrastructure and an enviable standard of living [21]. Another reason may be the differences in research designs. Also, even though the dietary patterns of the children were not investigated in this study, Yang et al. [19] noted that the higher BMD among the urban children could be a result of their higher calcium diet pattern. Further studies which will include the dietary patterns are suggested to verify this for Nigerian children population.

Age and body weight were found to be the predictors of the eBMD in the urban subjects while only age was the predictor of the eBMD in the rural subjects. This implies that the urban subjects will most likely attain peak bone mass earlier than their rural counterparts. The influence of age on BMD in children was in agreement with the results obtained by previous studies which showed an increase of BMD and QUS parameters with age in both genders [22–24]. Body weight is one of the most constant and robust determinants of bone mass especially in children, such that subjects with higher body weight have higher BMD [22,24,25] than their counterparts with lower weight.

Several studies [26–30] showed physical activity as positively influencing BMD. Their results revealed that increased physical activity levels result in higher levels of peak bone mass which in turn would lead to a decline in the osteoporotic fracture risk later in life. In our study, however, the physical activity patterns of the children did not explain the urban-rural difference in BMD, even though a significant difference existed between the physical activity patterns between the urban and rural dwellers. A similar observation was also found, showing no correlation between physical activity and bone variables [31]. This disparity in results may be attributed to the different methods of estimation or measurement of physical activity. Our study used self-reported questionnaire while Tobias et al. [26], used an accelerometer to measure the physical activity of the children.

The strength of this study was that a large population of children from both urban and rural areas was used. However, the study had some limitations. First is the fact that it was a cross-sectional design. A longitudinal design may better delineate the relationships between the variables measured. These findings can be verified in future research. Secondly, due to the retrospective evaluation of physical activity, recall bias may have been difficult to be excluded. Finally, although calcaneal quantitative ultrasound has been known to have the advantage of reflecting the bone microarchitecture and strength [32], there may still exist some inaccuracies associated with calcaneal bone parameter measurements in some children due to their small foot size.

The authors of this study recommend more studies with robust designs and analytical techniques so as to conceptualize the effects of urbanisation on BMD adequately. In addition, we advocate for a study on the urban-rural difference in Nigerian children which will include the influence of dietary patterns on their BMD. Furthermore, a regional BMD reference data for Nigerian children is required in other to effectively compute definitive risk factors.

In conclusion, the BMD of the rural children is lower than that of their age- and sex-matched urban counterparts. If the standard reference values are established for Nigerian children population, definitive risk factors can be effectively computed and analyzed for both localities. The differences in the BMD in the rural and urban communities are estimated to be due to body weight and not physical activity. This study is fundamental for the correct and early introduction of effective, preventive and therapeutic strategies in managing children with low bone mineral density.

References

[1] M. Fatima, H. Nawaz, M. Kassi, R. Rehman, P.M. Kasi, M. Kassi, et al., Determining the risk factors and prevalence of osteoporosis using quantitative ultrasonography in Pakistani adult women, Singap. Med. J. 50 (1) (2009) 20–28.

[2] A.A. Aliyu, L. Amadu, Urbanization, cities, and health: the challenges to Nigeria–a review, Ann. Afr. Med. 16 (4) (2017) 149.

[3] D.J. Vanderjagt, B. Bond, R. Dulai, A. Pickel, I.O. Ujah, W.W. Wadinga, J.K. Scariano, R.H. Glew, Assessment of the bone status of Nigerian women by ultrasound and biochemical markers, Calcif. Tissue Int. 68 (5) (2001) 277–284.

[4] S. Bass, P.D. Delmas, G. Pearce, E. Hendrich, A. Tabensky, E. Seeman, The differing tempo of growth in bone size, mass, and density in girls is region-specific, J. Clin. Invest. 104 (1999) 795–804.

[5] L.K. Bachrach, I.N. Sills, Bone densitometry in children and adolescents, Pediatr 127 (1) (2011) 189–194.

[6] C.M. Weaver, C.M. Gordon, K.F. Janz, H.J. Kalkwarf, J.M. Lappe, R. Lewis, M. O'Karma, T.C. Wallace, B.S. Zemel, The National Osteoporosis Foundation's position statement on peak bone mass and lifestyle factors: a systematic review and implementation recommendations, Osteoporos. Int. 27 (4) (2016) 1281–1386. Apr.

[7] C. Pongchaiyakul, T.V. Nguyen, V. Kosulwat, N. Rojroongwasinkul, S. Charoenkiatkul, R. Rajatanavin, Effect of urbanization on bone mineral density: a Thai epidemiological study, BMC Musculoskelet. Disord. 6 (2005) 5.

[8] W. Gu, K.L. Rennie, X. Lin, Y. Wang, Z. Yu, Differences in bone mineral status between urban and rural Chinese men and women, Bone 41 (2007) 393–399.

[9] M. Sundberg, H. Duppe, P. Gardsell, O. Johnell, E. Ornstein, I. Sernbo, Bone mineral density in adolescents. Higher values in a rural area – a population-based study of 246 subjects in southern Sweden, Acta Orthop. Scand. 68 (1997) 456–460.

[10] P. Gärdsell, O. Johnell, B.E. Nilsson, I. Sernbo, Bone mass in an urban and a rural population: a comparative, population-based study in Southern Sweden, J. Bone Miner. Res. 6 (1991) 67–75.

[11] R.S. Filip, J. Zagorski, Bone mineral density and osteoporosis in rural and urban women. Epidemiological study of the Lublin region (Eastern Poland), Ann. Agric. Environ. Med. 8 (2001) 221–226.

[12] S. Fox, R. Bloch, J. Monroy, Understanding the dynamics of Nigeria's urban transition: a refutation of the 'stalled urbanisation' hypothesis, Urban Stud. 55 (5) (2018) 947–964.

[13] F. Huebler, Age and level of education in Nigeria, Huebler Blogspot website https://huebler.blogspot.com/2005/12/age-and-level-of-education-in-nigeria.html , Accessed date: May 2018.

[14] U.B. Nwogu, K.K. Agwu, A.M. Anakwue, M.C. Okeji, F.U. Idigo, S.O. Ogbu, Calcaneal broadband ultrasound attenuation and speed of sound measurements in a population of Nigerian children: reference data and the influence of socio-demographic variables, J. Ultrasound Med. 38 (5) (2018) 1349–1360.

[15] K.C. Kowalski, P.R. Crocker, R.M. Donen, The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual, vol. 87(1), College of Kinesiology, University of Saskatchewan, 2004, pp. 1–38.

[16] W.M. Zaini, M. Ariff, Bone mineral density assessment in pre- and postmenopausal women: comparison between T scores by heel QUS and DXA in HRPZII, Med J Malaysia 67 (2012) 487–490.

[17] E. Akinwotu, On the rural-urban divide in Nigeria, https://guardian.ng/opinion/

on-the-rural-urban-divide-in-nigeria/, (2017) , Accessed date: 18 March 2019.
[18] A. Khan, L. Cheri, An examination of poverty as the foundation of crisis in Northern Nigeria, Insight Afr. 8 (1) (2016) 59–71.
[19] Y. Yang, X.M. Hu, T.J. Chen, M.J. Bai, Rural-urban differences of dietary patterns, overweight, and bone mineral status in Chinese students, Nutrients 8 (9) (2016) 537.
[20] N.A. Etim, E.J. Udoh, The determinants of rural poverty in Nigeria, Int. J. Agric. Manag. Dev. 3 (1047-2016-85508) (2013) 141.
[21] World factbook, https://www.cia.gov/library/publications/the-world-factbook/geos/sw.html , Accessed date: 8 March 2019.
[22] J.M. Lavado-Garcia, J.F. Calderon-Garcia, J.M. Moran, M.L. Canal-Macias, T. Rodriguez-Dominguez, J.D. Pedrera-Zamorano, Bone mass of Spanish school children: impact of anthropometric, dietary and body composition factors, J. Bone Miner. Metab. 30 (2012) 193–201.
[23] G.I. Baroncelli, G. Federico, S. Bertelloni, F. De Terlizzi, R. Cadossi, G. Saggese, Bone quality assessment by quantitative ultrasound of proximal phalanxes of the hand in healthy subject aged 3–21 years, Pediatr. Res. 49 (2001) 713–718.
[24] R. Ramírez-Vélez, M.L. Ojeda-Pardo, J.E. Correa-Bautista, et al., Normative data for calcaneal broadband ultrasound attenuation among children and adolescents from Colombia: the FUPRECOL study, Arch. Osteoporos. 11 (2) (2016).
[25] K. Wünsche, B. Wünsche, H. Fähnrich, et al., Ultrasound bone densitometry of the os calcis in children and adolescents, Calcif. Tissue Int. 67 (2000) 349–355.
[26] J.H. Tobias, C.D. Steer, C.G. Mattocks, C. Riddoch, A.R. Ness, Habitual levels of physical activity influence bone mass in 11-year-old children from the United Kingdom: findings from a large population-based cohort, J. Bone Miner. Res. 22 (1) (2007) 101–109.
[27] K.J. MacKelvie, H.A. McKay, M.A. Petit, O. Moran, K.M. Khan, Bone mineral response to a 7-month randomized controlled, school-based jumping intervention in 121 prepubertal boys: associations with ethnicity and body mass index, J. Bone Miner. Res. 17 (5) (2002) 834–844.
[28] K.J. MacKelvie, K.M. Khan, M.A. Petit, P.A. Janssen, H.A. McKay, A school-based exercise intervention elicits substantial bone health benefits: a 2-year randomized controlled trial in girls, Pediatrics 112 (6) (2003) 447–452 1.
[29] R.K. Fuchs, J.J. Bauer, C.M. Snow, Jumping improves hip and lumbar spine bone mass in prepubescent children: a randomized controlled trial, J. Bone Miner. Res. 16 (1) (2001) 148–156.
[30] M.A. Petit, H.A. McKay, K.J. MacKelvie, A. Heinonen, K. Khan, T.J. Beck, A randomized school-based jumping intervention confers site and maturity-specific benefits on bone structural properties in girls: a hip structural analysis study, J. Bone Miner. Res. 17 (3) (2002) 363–372.
[31] S. Cvijetić, I.C. Barić, S. Bolanča, V. Jureša, D.D. Ožegović, Ultrasound bone measurement in children and adolescents: correlation with nutrition, puberty, anthropometry, and physical activity, J. Clin. Epidemiol. 56 (6) (2003) 591–597.
[32] K.Y. Chin, S. Ima-Nirwana, Calcaneal quantitative ultrasound as a determinant of bone health status: what properties of bone does it reflect? Int. J. Med. Sci. 10 (12) (2013) 1778.