RESEARCH PAPER

Lean Body Mass and Bone Health in Urban Adolescents From Northern India

*RAMAN K MARWAHA, #MK GARG, $KUNTAL BHADRA, ‡NAMITA MAHALLE, **AMBRISH MITHAL AND ##NIKHIL TANDON

*From #Army Hospital (Research & Referral) Delhi Cantt, New Delhi; India, $Department of Endocrinology and Thyroid Research Centre, Institute of Nuclear Medicine & Allied Sciences, Delhi; ‡Biochemistry Division Department of Pathology, Deenanath Mangeshkar Hospital and Research Center, Pune; ** Division of Endocrinology and Diabetes, Medanta, The Medicity, Gurgaon; and ##Department of Endocrinology and Metabolism, AIIMS, New Delhi, India.*

Correspondence to: Maj Gen (retd) Dr RK Marwaha, Flat No 17, Gautam Apartments, Gautam Nagar, New Delhi 110 049, marwaha_ramank@hotmail.com

Received: August 04, 2015; Initial review: October 20, 2015; Accepted: December 27, 2016.

Objective: To prepare percentile charts of lean body mass (LBM) among Indian urban children and adolescents; and to evaluate gender differences in LBM, and its relation with pubertal status.

Design: Secondary data analysis.

Setting: School in city of Delhi, India.

Participants: 1403 apparently healthy children and adolescents (826 boys) with mean (SD) age 13.2 (2.7) years.

Outcome measures: Lean body mass assessed by dual energy absorptiometry.

Results: Total and regional lean mass were greater in older age groups in both sexes. LBM showed rising trends up to the age of 18 years in boys, whereas it plateaued after the age of 15 years in girls. The age-associated increase in LBM was significantly higher in boys (130%) compared to girls (83%) (*P*<0.001). Total and regional lean mass increased with progression of pubertal staging in both genders. During pubertal development, LBM almost doubled (100% increase) from stage-2 to stage-5 in boys, as opposed to a 73% rise in girls (*P*<0.001). Total and regional lean mass and Appendicular skeletal muscle mass index (ASMI) was positively correlated with age, body mass index (BMI), serum 25(OH)D, total fat mass, and bone mineral content (BMC). Relation between LBM and BMC remained significant even after adjusting for age, fat mass and various biochemical parameters.

Conclusions: Total and regional LBM rise with age and pubertal maturation in both genders, but more so in boys when compared to girls. LBM has direct bearing on BMC even after adjusting for age, fat mass and biochemical parameters.

Keywords: *Bone mineral content, Bone health, Children, Muscle mass*

Published online: February 02, 2017. PII:S097475591600039

Lean body mass (LBM) at older age depends on the peak LBM which is acquired during adolescent and puberty [1]. LBM during childhood and adolescence depends on genetic factors, hormonal status, growth, sexual maturation, nutritional status and ethnicity [1-4]. Ethnic differences occur due to variation in adiposity, fat-free mass (surrogate for lean mass) and effect of environment [3]. There are gender differences in body composition during puberty [3,4]. During puberty, males gain greater amounts of LBM, whereas females acquire significantly more fat mass [5]. There are few population-based cross-sectional [6,7] and longitudinal studies [8-10], which have assessed LBM in children and adolescents. However, there are no normative data available for Indian population. This study aimed to describe percentile charts of LBM among children and adolescents, evaluate gender differences and its relation with pubertal status, and assess its effect on bone mineral contents.

METHODS

This study was a secondary analysis of data from our earlier study [11,12]. Adolescents were recruited from different schools in the city of Delhi as a part of a project to generate normative data for bone mineral density (BMD). There were 1829 apparently healthy children and adolescents who underwent health examination (clinical, biochemical and densitometric) on voluntary basis. For present study, the data on lean mass and its distribution was available from 1403 children and adolescents (age 5-18 years). Children and adolescents with clinically overt hepatic, renal, neoplastic, gastrointestinal, dermatological and endocrine and systemic infective disorders, steroid intake or alcoholism were excluded. Demographic, anthropometric and clinical data were ascertained and a detailed physical examination conducted. The study was approved by the ethics committee of the Institute of Nuclear Medicine and Allied Sciences and all children gave written informed consent.

Pubertal staging were assessed in females by breast development according to diagrams and descriptions based upon the Tanner criteria [13]. Testicular volume was determined by Prader orchidometer (Pharmacia and Upjohn, Uppsala, Sweden). Average of left and right testicular volume was used to determine pubertal stage in males, and staged as: stage 1 = ≤3mL, stage 2 4-8 mL, stage 3 10-15 mL, stage 4 = 20mL, and stage 5 25 mL [14].

Fasting blood samples were drawn for the estimation of serum 25-hydroxy vitamin D (25(OH)D), intact parathyroid hormone (iPTH), total and ionized calcium, inorganic phosphorus, and serum alkaline phosphatase (SAP). The normal range for different biochemical parameters were as used before [12].

Lean mass and regional distribution, total fat mass, and BMD at anteroposterior (AP) lumbar spine (L1–L4), femur (total hip, femoral neck), forearm (33% radius) and total body was measured using the Prodigy Oracle (GE Lunar Corp., Madison, WI) according to standard protocol. Quality control procedures were carried out in accordance with the manufacturer's recommendations. Instrument variation was determined regularly using a phantom supplied by the manufacturer and mean coefficient of variation was <0.5%. For *in vivo* measurements, mean coefficients of variation for all sites were <1%.

Appendicular skeletal muscle mass index (ASMI) was calculated by lean mass at arms and leg (kg) divided by square of height (m^2). Percentile charts were generated for boys and girls separately. Lean mass index (LMI) and fat mass index (FMI) were calculated by dividing total LBM and total fat mass with square of height in meters [15]. Other variables calculated were LBM (kg)/height (m) ratio, total bone mineral content (BMC) and LBM ratio [10,16].

Statistical analysis was carried out using SPSS version 20.0 (Chicago, IL, USA). Percentile charts were generated through the software used in the predefined age group according to gender. Independent two variables (gender) were tested by Student's t-test. One way analysis of variance (ANOVA) was used test differences between pubertal staging and age groups. Post-hoc analysis was used to compare the significance level between two groups within each parameter. Pearson's correlation coefficient was calculated to assess the strength of relationship between total lean mass and its distribution and BMC at various sites. Multiple regression analysis was done to find association between lean mass and its distribution with BMC at various sites after adjustment with variables like age, total fat, serum calcium, phosphates, SAP, 25(OH)D and iPTH levels. The trend line in the graph between total lean mass and age was plotted using Loess fit method with Epanechnikov variation.

RESULTS

We included 1403 (826 boys) children and adolescents with mean (SD) age of 13.2 (2.7) years. Basic characteristics are shown in ***Web Table* I**. Boys were younger, taller and heavier than girls, but their BMI was lower than that of girls. Boys had higher serum 25(OH)D, calcium, phosphates and SAP levels. BMC at all sites except trunk was higher in boys when compared to girls (***Web Table* I**).

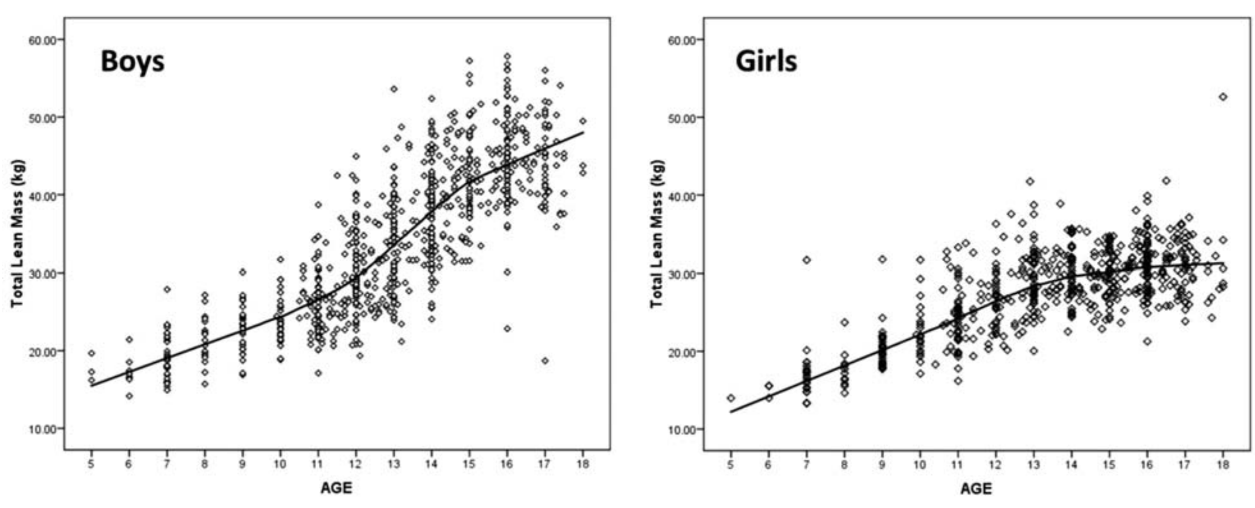

FIG.1 *Total lean mass according to age in boys and girls*.

TABLE I PERCENTILE DISTRIBUTION OF LEAN MASS AS ASSESSED BY DUAL-ENERGY ABSOPTIOMETRY IN BOYS (*N*=826)

Percentile	*5th*	*10th*	*15th*	*25th*	*50th*	*75th*	*85th*	*90th*	*95th*
Age (n)					*Total lean mass (kg)*				
Total lean mass									
5-8 (62)	15.72	15.93	16.22	17.04	18.98	21.56	22.55	23.34	24.37
>8-11 (138)	19.55	20.65	21.37	22.32	24.24	27.19	28.23	29.36	30.95
>11-15 (447)	23.95	25.55	26.65	29.02	34.50	39.96	42.89	45.28	47.73
>15-18 (179)	37.63	38.57	39.21	40.78	44.48	48.47	50.23	51.33	53.64
Appendicular skeletal muscle mass index (kg/m^2)									
5-8 (62)	4.52	4.74	4.86	4.96	5.41	6.09	6.40	6.51	6.74
>8-11 (138)	5.36	5.62	5.79	6.09	6.64	7.08	7.42	7.66	8.11
>11-15 (447)	6.14	6.56	6.79	7.33	8.47	9.60	10.34	10.69	11.19
>15-18 (179)	8.77	9.03	9.30	9.67	10.37	11.44	12.02	12.29	12.67
Arm lean mass (kg)									
5-8 (62)	1.35	1.39	1.48	1.59	1.80	2.10	2.20	2.32	2.50
>8-11 (138)	1.78	1.91	2.06	2.20	2.41	2.75	2.92	3.09	3.22
>11-15 (447)	2.27	2.46	2.62	3.00	3.70	4.51	4.95	5.21	5.61
>15-18 (179)	3.97	4.23	4.39	4.60	5.16	5.69	6.16	6.30	6.59
Leg lean mass (kg)									
5-8 (62)	4.44	4.62	4.78	5.12	5.74	6.75	7.29	7.61	8.11
>8-11 (138)	6.25	6.59	6.90	7.37	8.24	9.39	9.80	10.33	10.95
>11-15 (447)	8.02	8.69	9.19	10.14	12.11	14.30	15.18	15.84	17.11
>15-18 (179)	12.66	13.11	13.35	13.94	15.45	17.01	18.05	19.59	19.20
Trunk lean mass (kg)									
5-8 (62)	7.13	7.27	7.36	7.67	8.65	9.75	10.27	10.85	12.28
>8-11 (138)	8.57	9.22	9.31	9.75	10.76	12.08	12.83	13.41	14.26
>11-15 (447)	10.56	11.42	11.97	12.98	15.74	18.06	19.60	20.49	21.43
>15-18 (179)	16.15	17.93	17.93	18.60	20.13	21.85	22.82	23.52	24.66

Total, trunk, arm, and leg lean mass as well as ASMI increased with increasing age in both sexes (***Tables* I** and **II**). The increase persisted till the age of 18 years in boys but plateaued at 15 years in girls (***Fig.* 1**). LBM increased significantly more in boys (130%) compared to girls (83%) (*P*<0.0001).

Boys had significantly more total and regional lean mass when compared to girls, whereas girls had higher total fat mass than boys. When LBM was adjusted for height (LBM/Ht ratio), and total BMC (LBM/BMC ratio), boys still had significantly higher ratio than girls. A similar pattern was observed at other sites (***Web Table* I**). Boys had higher arm to leg lean mass ratio when compared to girls (0.31(0.03) *vs* 0.29 (0.03), *P* <0.0001). Boys had highest percent increase in lean mass at all sites in the age group of >11-15 years, whereas girls had in the age group of >8-11 years. A similar pattern was also observed in ASMI. In all age groups, boys had significantly higher total and regional lean mass when compared to girls (***Tables* I** and **II**). Girls had significantly higher total BMC per gram of LBM when compared with boys (61 *vs* 53 g/kg LBM, *P*<0.0001).

Total and regional lean mass were more at higher stages of puberty. Total lean mass in individuals in stage 5 of puberty was 100% and 73% higher than those in stage 2 for boys and girls, respectively. A similar pattern was observed at other regional sites (***Table* III**). Total and trunk lean mass showed highest percent increase in the pubertal stage 3 in both sexes. However, there were regional differences between sexes, with the largest percentage increase in arm and leg lean mass, and ASMI being seen in pubertal stage-2 in girls as compared with stage 3 in boys (***Table* III**).

Total and regional lean mass and ASMI was positively correlated with age, BMI, serum 25(OH)D, total fat mass, BMC in total study population and both sexes independently. These parameters were negatively correlated with iPTH, phosphorus and SAP. Total, trunk and leg lean mass showed strongest correlation with leg

TABLE II PERCENTILE DISTRIBUTION OF LEAN MASS AS ASSESSED BY DUAL-ENERGY ABSORPTIOMETRY IN GIRLS (*N*=577)

Age (N)	*Percentile total lean mass (kg)*								
	5th	*10th*	*15th*	*25th*	*50th*	*75th*	*85th*	*90th*	*95th*
Total lean mass (kg)									
5-8 (34)	13.76	14.19	14.75	15.40	16.52	18.01	18.59	19.24	21.37
>8-11 (97)	17.87	18.35	18.85	19.90	22.00	24.84	26.34	29.31	30.94
>11-15 (260)	22.48	23.80	24.53	26.31	28.81	31.60	32.73	33.69	35.18
>15-18 (186)	25.87	26.59	27.44	28.21	30.99	33.16	34.39	35.04	36.13
Appendicular Skeletal Muscle mass index (kg/m^2)									
5-8 (34)	3.92	4.07	4.12	4.23	4.74	5.11	5.36	5.62	5.77
>8-11 (97)	4.69	4.94	5.08	5.37	5.92	6.47	6.94	7.39	7.90
>11-15 (260)	5.46	5.78	6.11	6.31	6.83	7.52	7.90	8.17	8.49
>15-18 (186)	5.98	6.29	6.42	6.67	7.29	7.90	8.19	8.43	8.85
Arm lean mass (kg)									
5-8 (34)	1.10	1.18	1.25	1.30	1.45	1.68	1.82	1.86	2.11
>8-11 (97)	1.49	1.63	1.71	1.84	2.06	2.44	2.63	2.96	3.17
>11-15 (260)	1.95	2.19	2.32	2.50	2.85	3.13	3.31	3.44	3.63
>15-18 (186)	2.37	2.48	2.59	2.72	3.04	3.40	3.59	3.69	3.83
Leg lean mass (kg)									
5-8 (34)	3.48	3.70	4.02	4.35	4.83	5.71	5.87	6.21	6.88
>8-11 (97)	5.38	5.74	6.02	6.62	7.39	8.29	9.23	10.12	10.88
>11-15 (260)	7.41	7.82	8.11	9.74	9.69	10.76	11.38	11.64	12.50
>15-18 (186)	8.22	8.81	9.04	9.45	10.46	11.54	12.01	12.37	12.72
Trunk lean mass (kg)									
5-8 (34)	6.61	6.71	6.86	7.11	7.79	8.44	8.82	9.41	11.14
>8-11 (97)	8.16	8.42	8.62	9.09	9.90	11.47	12.27	13.25	14.02
>11-15 (260)	10.04	10.64	11.36	12.12	13.42	14.86	15.38	15.70	16.46
>15-18 (186)	11.95	12.31	12.91	13.37	14.53	15.57	16.11	16.31	16.94

BMC, followed by arm, total and trunk BMC, whereas arm lean mass and ASMI showed strongest correlation with arm BMC compared to other sites. In multiple regression analysis, after adjusting for age, total fat mass, serum calcium, phosphates, alkaline phosphatase, 25OHD and PTH, total and regional lean mass at all sites showed positive correlation with BMC at all sites among study population and gender separately. The total lean mass showed strongest relation with leg BMC followed by arm, total and trunk BMC. Trunk BMC had the lowest correlation with total and regional lean mass in total population and both sexes. Leg and arm lean mass had highest correlation with their respective regional BMC (data not shown).

DISCUSSION

In this study, we generated the percentile charts for total and regional lean mass and ASMI in Indian urban children and adolescents according to gender. While the total and regional lean mass increased with age in both sexes, boys continued to acquire lean mass beyond the age of 18 years, whereas the increase plateaued after the age of 15 years in girls. Boys had significantly more lean mass when compared to girls across all ages (5-18 years), but girls had significantly higher BMC per unit LBM in comparison to boys. In the present study, lean mass was higher at higher stages of puberty, with the difference being more marked in boys than girls. There was strong correlation between lean mass and BMC in both sexes, with the weakest relationship being observed between total lean mass and spinal BMC.

Since this was a cross-sectional study, we could not assess the change in lean mass over time in individual subjects during pubertal development as described by others [9,11]. The study was able to capture the end of the growth period in females. However, since growth in males, continues beyond the studied age, there can be further increase in LBM in males, which the present study was unable to capture [16]. Growth of lean mass and BMC also depends on genetic factors, in addition to local and systemic factors such as exercise and diet, which were not assessed in this study. In this large cross-sectional study, percentile charts were generated according to age groups

TABLE III LEAN MASS ACCORDING TO PUBERTAL STAGING

	*Pubertal Staging**				
	1 (B=103; G=39)	*2 (B=194; G=49)*	*3 (B=183; G=80)*	*4 (B=148; G=117)*	*5 (B=198; G=292)*
Total Lean Mass (kg)					
Boys	22.16 (4.21)	27.04 (4.72)	34.71 (6.39)	39.71 (6.49)	44.24 (5.59)
% Increase#		22.0	28.4	14.4	11.4
Girls	17.61 (3.34)	20.96 (3.02)	25.51 (3.85)	28.58 (4.12)	30.38 (3.65)
% Increase#		19.0	21.7	12.0	6.3
Arm Lean Mass (kg)					
Boys	2.15 (0.50)	2.73 (0.62)	3.74 (0.86)	4.47 (1.03)	5.13 (0.87)
% Increase#		26.9	37.0	19.5	14.8
Girls	1.57 (0.48)	2.00 (0.40)	2.44 (0.49)	2.78 (0.53)	3.00 (0.48)
% Increase#		27.4	22.0	13.9	7.9
Leg Lean Mass (kg)					
Boys	7.20 (1.76)	9.26 (1.84)	12.21 (2.46)	13.90 (2.39)	15.49 (2.25)
% Increase#		28.6	31.9	13.8	11.4
Girls	5.36 (1.46)	6.85 (1.21)	8.72 (1.59)	9.77 (1.61)	10.27 (1.49)
% Increase#		27.8	27.3	12.0	5.1
Trunk Lean Mass (kg)					
Boys	10.03 (1.98)	12.09 (2.40)	15.50 (3.23)	17.98 (3.19)	20.01 (2.68)
% Increase#		20.5	26.6	15.4	11.3
Girls	8.26 (1.59)	9.52 (1.40)	11.64 (1.88)	13.26 (2.01)	14.25 (1.96)
% Increase#		15.3	22.3	13.9	7.4
ASMI (kg/m^2)					
Boys	6.07 (0.93)	7.00 (1.04)	8.59 (1.34)	9.50 (1.47)	10.46 (1.39)
% Increase#		15.3	22.7	10.6	10.1
Girls	4.95 (0.80)	5.66 (0.76)	6.46 (0.91)	6.91 (0.99)	7.19 (0.89)
% Increase#		14.3	14.1	7.0	4.1

*B=boys, G=girls; *P value trends <0.001 for all; #percentage increase of mean lean mass between successive pubertal stage.*

and gender. While the sample size for each category is small, it may form basis for comparison with larger studies in future.

Though, similar reference data are available for US population studied in the National Health and Nutrition Examination Survey (NHANES) [17] and Polish children and adolescents [7]. There are differences in height and BMI of children and adolescents of Indian, US and Polish origin; hence, comparison betw een these data sets is not feasible due to lack of data for adjustment for height and BMI. Increase in total and regional lean mass with age has been observed in children and adolescents in several other studies [4,5,10,18]. Maximum increase in lean mass occurred earlier in girls (8-11 years) than boys (11-15 years) in this study. A longitudinal study has also shown that girls accrue lean mass predominantly in the age group 10-12 years when compared to boys (12-14 years) [10]. Gender difference in LBM, similar to our study, have also been seen in studies from UK and New Zealand [7,10]. However, in a study by Boots, *et al.* [3], the difference between sexes emerged only after the age of 14 years. Ferretti, *et al*. [16] reported a constant relationship between BMC and LBM across all ages, with a value of 50-54 g per unit of LBM, which is similar to that reported in the present study. This ratio reverses in adults [19], thereby suggesting that girls accumulate more BMC during puberty as compared to boys. However, boys continue to accumulate bone mineral content with age and surpass girls with reversal of ratio in adulthood. Increase in LBM occurs significantly more with pubertal maturation in boys compared with girls. However, the increase in lean mass with puberty was significantly higher in Dutch boys and girls compared to their Indian counterparts in the present study (146% *vs* 100% and 100% *vs* 73%, respectively). In contrast, girls from New Zealand showed similar increase with puberty compared to the girls in the present study (86% *vs* 83%). The variation in lean mass during pubertal maturation could be explained based on genetic, nutritional and lifestyle factors.

Muscles are integral part of lean mass. Low LBM may be forerunner of sarcopenia in future, which has bearing on

WHAT THIS STUDY ADDS?

- Reference percentile charts of total and regional lean body mass among Indian urban adolescents are generated.
- There is increase in total and regional lean body mass with age and pubertal progression in Indian adolescents in both genders.

morbidity and mortality in elderly age group [1,2]. This study provides reference data for LBM in Indian children and adolescents. Total and regional LBM increases with age and pubertal progression. Boys have more LBM than girls, but girls have more BMC per unit of LBM. LBM is strongly correlated with BMC in both sexes. Further longitudinal studies are required to assess the LBM as well as other body composition in Indian children and adolescents.

Contributors: RKM, AM, NT: conceptualized the study; KB: supervised and collected the data; MKG, NM: prepared the manuscript.

Funding: Institute of Nuclear Medicine and Allied Sciences, DRDO. *Competing interest*: None stated.

REFERENCES

1. Von Haehling S, Morley JE, Anker SD. An overview of sarcopenia: facts and numbers on prevalence and clinical impact. J Cachexia Sarcopenia Muscle. 2010;1:129-33.
2. Mithal A, Bonjour JP, Boonen S for IOF CSA Nutrition Working Group. Impact of nutrition on muscle mass, strength, and performance in older adults. Osteoporos Int. 2013;24:1555-66.
3. Boot AM, Bouquet J, de Ridder MA, Krenning EP, de Muinck Keizer-Schrama SM. Determinants of body composition measured by dual-energy *X*-ray absorptiometry in Dutch children and adolescents. Am J Clin Nutr. 1997;66:232-8.
4. Wells JC. Sexual dimorphism of body composition. Best Pract Res Clin Endocrinol Metab. 2007;21:415-30.
5. Courteix D, Lespessailles E, Loiseau-Peres S, Obert P, Ferry B, Benhamou CL. Lean tissue mass is a better predictor of bone mineral content and density than body weight in prepubertal girls. Rev Rhum Engl Ed. 1998;65:328-36.
6. Weber DR, Moore RH, Leonard MB, Zemel BS. Fat and lean BMI reference curves in children and adolescents and their utility in identifying excess adiposity compared with BMI and percentage body fat. Am J Clin Nutr. 2013;98: 49-56.
7. P³udowski P, Matusik H, Olszaniecka M, Lebiedowski M, Lorenc RS. Reference values for the indicators of skeletal and muscular status of healthy Polish children. J Clin Densitom. 2005;8:164-77.
8. Zhu K, Greenfield H, Zhang Q, Du X, Ma G, Foo LH, *et al.* Growth and bone mineral accretion during puberty in Chinese girls: a five-year longitudinal study. J Bone Miner Res. 2008;23:167-72.
9. Xu L, Nicholson P, Wang Q, Alén M, Cheng S. Bone and muscle development during puberty in girls: a seven-year longitudinal study. J Bone Miner Res. 2009;24:1693-8.
10. Wey HE, Binkley TL, Beare TM, Wey CL, Specker BL. Cross-sectional versus longitudinal associations of lean and fat mass with pQCT bone outcomes in children. J Clin Endocrinol Metab. 2011;96:106-14.
11. Shivaprasad C, Marwaha RK, Tandon N, Kanwar R, Mani K, Narang A, *et al.* Correlation between bone mineral density measured by peripheral and central dual energy *X*-ray absorptiometry in healthy Indian children and adolescents aged 10-18 years. J Pediatr Endocrinol Metab. 2013;26:695-702.
12. Marwaha RK, Tandon N, Reddy DR, Aggarwal R, Singh R, Sawhney RC, *et al.* Vitamin D and bone mineral density status of healthy schoolchildren in northern India. Am J Clin Nutr. 2005;82:477-82.
13. Tanner JM. Growth at Adolescence: With a General Consideration of the Effects of Hereditary and Environmental Factors Upon Growth and Maturation From Birth to Maturity. Blackwell Scientific Publications, Oxford, 1969.
14. Wardhaugh B. Pubertal Staging. Available From: *http://www.patient.co.uk/doctor/Puberty-Normal-and-Abnormal.htm*. Accessed December 01, 2015.
15. Marwaha RK, Garg MK, Tandon N, Mehan N, Sastry A, Bhadra K. Relationship of body fat and its distribution with bone mineral density in Indian population. J Clin Densitom. 2013;16:353-9.
16. Ferretti JL, Capozza RF, Cointry GR, García SL, Plotkin H, Alvarez Filgueira ML, *et al.* Gender-related differences in the relationship between densitometric values of whole-body bone mineral content and lean body mass in humans between 2 and 87 years of age. Bone. 1998;22:683-90.
17. Borrud LG, Flegal KM, Looker AC, Everhart JE, Harris TB, Shepherd JA. Body composition data for individuals 8 years of age and older: U.S. population, 1999-2004. Vital Health Stat. 2010;250:1-87
18. Mølgaard C, Michaelsen KF. Changes in body composition during growth in healthy school-age children. Appl Radiat Isot. 1998;49:577-9.
19. Wang Z, Heo M, Lee RC, Kotler DP, Withers RT, Heymsfield SB. Muscularity in adult humans: proportion of adipose tissue free body mass and skeletal muscle. Am J Hum Biol. 2001;13:612-19.