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Age -Associated Variations in Body Height, Weight and Seven Bony Diameters among Pre-Adolescent Boys 6-12 Years

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Abstract

Background: Anthropometric assessment of linear growth and skeletal breadths is essential for evaluating physical development in children. While height and weight are commonly monitored, bony diameters provide additional insight into frame size and maturation. This study aimed to examine age-related changes in body height, weight, and seven bony diameters among pre-adolescent boys. **Materials and Methods**: A cross-sectional study was conducted on 1040 boys aged 6–12 years (divided into seven age groups) from different private schools situated at Nabha, Punjab, India. Body height, weight, and seven bony diameters — biacromial, bicristal, bitrochanteric, humerus bicondylar, wrist bistyloid, femur bicondylar, and ankle bimalleolar — were measured using standard anthropometric techniques. One-way ANOVA followed by Scheffe's post-hoc test was used to determine age-group differences. **Results**: All variables increased significantly with age ($p < .001$). Mean height increased from 112.24 ± 6.2 cm at 6 years to 143.59 ± 7.3 cm at 12 years, and mean weight from 19.10 ± 1.6 kg to 42.79 ± 6.0 kg. ANOVA revealed significant differences for height [$F(6, 1033) = 457.33$], weight [$F(6, 1033) = 564.45$], and all bony diameters, with wrist diameter showing the highest F-value [$F(6, 1033) = 1083.38$]. Scheffe's analysis indicated that height increased significantly until 11 years but plateaued at 11–12 years, whereas weight continued increasing through 12 years except at 9–10 years. Wrist and femur bicondylar diameters increased significantly at every consecutive age interval. Axial diameters exhibited brief plateaus: biacromial at 6–7 years, bicristal and bitrochanteric at 7–8 years, and bicristal again at 11–12 years. **Conclusion**: Body height, weight, and bony diameters increase significantly from 6 to 12 years in boys, but growth continuity differs by site. Appendicular breadths, particularly wrist diameter, provide the most consistent age-related increments and may serve as reliable markers of skeletal maturation. The observed plateaus in axial breadths and stature highlight the non-linear nature of pre-adolescent growth. These findings support the use of multiple anthropometric dimensions for comprehensive growth assessment.

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Key words: Anthropometry; Bony diameters; Pre-adolescent boys; Growth patterns; Skeletal maturation; Wrist diameter

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Introduction

Physical growth during childhood is a dynamic process characterized by changes in body size, shape, and composition. Anthropometric assessment of height, weight, and skeletal breadths provides fundamental data for monitoring nutritional status, evaluating health, and establishing population-specific growth standards (WHO 1995; Tanner 1990). While linear growth and body mass have been extensively studied, there is limited data on the age-related development of bony diameters in pre-adolescent Indian children. Stature and body weight are the most commonly used indicators of growth, with national and international agencies such as the Indian Council of Medical Research (ICMR) and World Health Organization (WHO) publishing reference standards for Indian and global populations. However, these references primarily focus on height and weight and do not account for variations in skeletal frame size. Bony diameters — including biacromial, bicristal, bitrochanteric, humerus bicondylar, wrist bistyloid, femur bicondylar, and ankle bimalleolar widths — reflect skeletal robustness and are important determinants of physique, somatotype, and body proportionality. Studies in Western populations indicate that bony breadths follow distinct growth trajectories compared to stature and may serve as reliable markers of biological maturity (Khadilkar et al. 2015; de Onis et al. 2007; Malina et al. 2004; Himes 1988; Roche et al. 1988; Cameron et al. 1982). In the Indian context, growth studies have documented considerable regional and ethnic variation in anthropometric parameters, attributed to genetic, nutritional, and socioeconomic factors. Data from North Indian states, including Punjab, suggest that children may exhibit different growth patterns compared to national ICMR standards, with reports of early growth lag followed by catch-up in late childhood (Singh et al. 2011; ICMR 2010; Bhasin and Jain 2007; Gaur and Singh 1997). Despite this, comprehensive data on age-related changes in bony diameters among Punjabi boys remain scarce. Most existing studies are limited to height-weight relationships or single skeletal measures, and few have examined multiple bony diameters across consecutive pre-adolescent age groups. The pre-adolescent period, spanning 6 to 12 years, is characterized by steady but non-uniform growth prior to the pubertal spurt. Understanding the timing and magnitude of growth in different skeletal sites during this phase is critical for talent identification in sports, early detection of growth abnormalities, and for updating region-specific growth charts. Wrist and knee diameters, in particular, have been proposed as simple, non-invasive indicators of skeletal maturity that correlate well with radiographic assessments. However, their growth patterns relative to axial breadths and stature in Indian boys have not been systematically evaluated. Therefore, the present cross-sectional study was undertaken to assess age-related variations in body height, weight, and seven bony diameters among pre-adolescent boys aged 6–12 years from Punjab, India. The objectives were: (1) to describe the means and standard deviations of anthropometric variables across age groups; (2) to determine whether significant differences exist between age groups using one-way ANOVA; and (3) to identify specific age intervals showing significant or non-significant growth using Scheffe's post-hoc test.

Materials and Methods

A cross-sectional study was conducted on 1040 boys aged 6–12 years (which were further divided into seven age groups) from different private schools situated at Nabha, Punjab, India. Body height, weight, and seven bony diameters — biacromial, bicristal, bitrochanteric, humerus bicondylar, wrist bistyloid, femur bicondylar, and ankle bimalleolar — were measured using standard anthropometric techniques. One-way ANOVA followed by Scheffe's post-hoc test was used to determine age-group differences.

Results and Discussion

The Table 1 shows descriptive statistics for body height (cm) and body weight (kg) of 1040 pre-adolescent boys, categorized into seven age groups from 6 to 12 years. Age-wise sample size (N) ranged from 104 boys at age 8 to 183 boys at age 12, with a total sample of 1040 participants.

Body height: Mean height showed a progressive increase with age, from 112.24 ± 6.2 cm at 6 years to 143.59 ± 7.3 cm at 12 years. The overall mean height for 6–12 year old boys was 131.19 ± 12.5 cm. Minimal increase observed between 11 years (143.57 cm) and 12 years (143.59 cm).
Body weight: Mean weight also increased steadily with age, from 19.10 ± 1.6 kg at 6 years to 42.79 ± 6.0 kg at 12 years. The overall mean weight was 29.81 ± 9.1 kg. The largest yearly gain occurred between 10 years (28.40 kg) and 11 years (36.74 kg).
Variability: Standard deviation for both variables generally increased with age, indicating greater inter-individual variation in older age groups, especially for body weight.

Table 1. Mean± SD of Body Height and Weight of Preadolescent Boys

Variable(s)	Age (years)	N	Mean	Std. Deviation
Body height (cm)	6	107	112.24	6.2
	7	148	121.11	4.4
	8	104	122.72	7.0
	9	173	127.93	6.9
	10	153	134.88	7.4
	11	172	143.57	5.9
	12	183	143.59	7.3
	Total	1040	131.19	12.5
Body weight (kg)	6	107	19.10	1.6
	7	148	21.31	3.2
	8	104	24.67	3.2
	9	173	27.39	4.1
	10	153	28.40	4.1
	11	172	36.74	5.3
	12	183	42.79	6.0
	Total	1040	29.81	9.1

The Table 2 shows the results of one-way ANOVA conducted to test differences in mean body height and body weight across the seven age groups (6 to 12 years).
Body height (cm): Between Groups df = 6, Within Groups df = 1033, Mean Square Between Groups = 19885.44, Mean Square Within Groups = 43.48, $F(6, 1033) = 457.33$, $p = .000$. This indicates highly significant differences in mean body height across age groups. The very large F-value shows that variation between age groups is much greater than variation within age groups (Table 2).
Body weight (kg): Between Groups df = 6, Within Groups df = 1033, Mean Square Between Groups = 11026.70, Mean Square Within Groups = 19.53, $F(6, 1033) = 564.45$, $p = .000$. This also shows highly significant differences in mean body weight across age groups. The F-value for weight is even larger than for height, suggesting stronger age-group differentiation in weight (Table 2).
One-way ANOVA revealed statistically significant differences among age groups for both body height [$F(6, 1033) = 457.33$, $p < .001$] and body weight [$F(6, 1033) = 564.45$, $p < .001$]. The significant F-values indicate that mean height and weight varied considerably with increasing age from 6 to 12 years.

Table 2. Analysis of Variance (ANOVA) of Body Height and Weight of Preadolescent Boys

Variable(s)		df	Mean Square	F	Sig.
Body height (cm)	Between Groups	6	19885.44	457.33	.000
	Within Groups	1033	43.48		
Body weight (kg)	Between Groups	6	11026.70	564.45	.000
	Within Groups	1033	19.53		

Since One-way ANOVA was significant for both body height and body weight, Scheffe's post-hoc multiple comparison test was applied to identify specific age groups that differed significantly in body height and weight.

The Table 3 shows the results of Posthoc (Scheffe) multiple comparisons of body height and weight.

Body Height (cm): All age groups differed significantly from each other ($p < .001$), except for two pairs:7 vs 8 years: Mean difference = -1.607 cm, p = .727, not significant and 11 vs 12 years: Mean difference = -0.020 cm, p = 1.000, not significant. Height increased significantly with each year of age from 6 to 11 years. The gain plateaued between 11 and 12 years, where the difference was negligible at 0.02 cm. The largest single-year increment was between 10 and 11 years (-8.687 cm, $p < .001$) (Table 3).

Body Weight (kg): All age groups differed significantly from each other ($p < .05$), except:9 vs 10 years: Mean difference = -1.011 kg, p = .643, not significant Weight showed continuous significant increases across ages, with the greatest yearly gains occurring between 10–11 years: -8.343 kg and 11–12 years: -6.050 kg, both $p < .001$.Unlike height, weight continued to increase significantly even from 11 to 12 years (Table 3).

Scheffe's post-hoc analysis revealed that mean body height increased significantly with age from 6 to 11 years ($p < .001$ for all consecutive comparisons), but no significant difference was observed between 11 and 12 years (p = 1.000). Similarly, mean body weight increased significantly across age groups ($p < .05$), except between 9 and 10 years (p = .643). The most substantial annual increments in height and weight occurred between 10 and 11 years of age.

Table 3. Posthoc (Scheffe) Multiple Comparisons of Body Height and Weight of Preadolescent Boys

Dependent Variable	(I) age	(J) age	Mean Difference (I-J)	Sig.
Body height (cm)	6	7	-8.871*	.000
		8	-10.478*	.000
		9	-15.693*	.000
		10	-22.639*	.000
		11	-31.326*	.000
		12	-31.347*	.000
	7	8	-1.607	.727
		9	-6.822*	.000
		10	-13.768*	.000
		11	-22.455*	.000

		12	-22.476*	.000
	8	9	-5.215*	.000
		10	-12.161*	.000
		11	-20.848*	.000
		12	-20.869*	.000
	9	10	-6.945*	.000
		11	-15.633*	.000
		12	-15.653*	.000
	10	11	-8.687*	.000
		12	-8.707*	.000
	11	12	-.020	1.000
Body weight (kg)	6	7	-2.215*	.017
		8	-5.568*	.000
		9	-8.292*	.000
		10	-9.303*	.000
		11	-17.647*	.000
		12	-23.697*	.000
	7	8	-3.352*	.000
		9	-6.076*	.000
		10	-7.087*	.000
		11	-15.431*	.000
		12	-21.481*	.000
	8	9	-2.724*	.000
		10	-3.735*	.000
		11	-12.078*	.000
		12	-18.129*	.000
	9	10	-1.011	.643
		11	-9.354*	.000
		12	-15.405*	.000
	10	11	-8.343*	.000
		12	-14.394*	.000
	11	12	-6.050*	.000

*. The mean difference is significant at the 0.05 level

The Table 4 shows age-wise means and standard deviations for seven bony diameter measurements of 1040 pre-adolescent boys aged 6–12 years.

Axial skeletal breadths:

Biacromial diameter (shoulder width): Increased progressively from 25.86 ± 0.51 cm at 6 years to 30.10 ± 1.06 cm at 12 years. Overall mean = 28.07 ± 1.67 cm. Largest SD at age 12 indicates higher variability in shoulder width during late pre-adolescence.

Bicristal diameter (abdominal width): Increased from 18.26 ± 0.51 cm at 6 years to 22.47 ± 0.77 cm at 12 years. Overall mean = 21.02 ± 1.45 cm.

Bitrochanteric diameter (hip width): Increased from 20.80 ± 0.43 cm at 6 years to 23.87 ± 0.56 cm at 12 years. Overall mean = 22.50 ± 1.14 cm.

Appendicular skeletal breadths:

Humerus bicondylar width (elbow): Increased from 4.28 ± 0.23 cm at 6 years to 6.46 ± 0.30 cm at 12 years. Overall mean = 5.63 ± 0.71 cm.

Wrist diameter (bistyloid): Increased from 4.19 ± 0.17 cm at 6 years to 5.47 ± 0.19 cm at 12 years. Overall mean = 4.91 ± 0.46 cm.

Femur bicondylar diameter (knee): Increased from 6.41 ± 0.55 cm at 6 years to 8.50 ± 0.28 cm at 12 years. Overall mean = 7.66 ± 0.70 cm.

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Ankle diameter (bimalleolar): Increased from 5.30 ± 0.19 cm at 6 years to 6.52 ± 0.26 cm at 12 years. Overall mean = 5.94 ± 0.49 cm.
All seven bony diameters showed consistent age-related increases from 6 to 12 years, reflecting skeletal growth in both axial and appendicular regions.

Table 4 . Mean± SD of Bony Diameters of Preadolescent Boys

Variable(s)	Age (years)	N	Mean	Std. Deviation
Bioacromial diameter (cm) (shoulder width)	6	107	25.862	.5121
	7	148	26.138	.5034
	8	104	26.676	.4988
	9	173	27.753	.5547
	10	153	28.830	.4987
	11	172	29.430	.4670
	12	183	30.104	1.0637
	Total	1040	28.070	1.6654
Bicristal diameter (cm) (abdominal width)	6	107	18.263	.5100
	7	148	20.025	.5866
	8	104	20.162	.6475
	9	173	20.980	.7319
	10	153	21.431	.7780
	11	172	22.251	.5996
	12	183	22.472	.7711
	Total	1040	21.022	1.4499
Bitrochantric diameter (cm) (hip width)	6	107	20.798	.4304
	7	148	21.505	.3401
	8	104	21.696	.5475
	9	173	22.187	.5201
	10	153	22.690	.6189
	11	172	23.594	.3645
	12	183	23.867	.5560
	Total	1040	22.500	1.1378
Humerus bicondylar width (cm) (elbow width)	6	107	4.276	.2269
	7	148	5.109	.3149
	8	104	5.340	.2408
	9	173	5.436	.2883
	10	153	6.007	.3089
	11	172	6.084	.3254
	12	183	6.464	.2994
	Total	1040	5.633	.7113
Wrist diameter (cm) (bistyloid)	6	107	4.190	.1676
	7	148	4.434	.1451
	8	104	4.600	.1583
	9	173	4.789	.1885
	10	153	5.047	.1843
	11	172	5.331	.1538
	12	183	5.467	.1887

	Total	1040	4.905	.4623
Femur biocondylar diameter (cm) (knee width)	6	107	6.406	.5525
	7	148	7.055	.2580
	8	104	7.427	.2767
	9	173	7.592	.2557
	10	153	7.822	.3175
	11	172	8.120	.3244
	12	183	8.496	.2835
	Total	1040	7.657	.6983
Ankle diameter (cm) (bimalleolar)	6	107	5.298	.1858
	7	148	5.453	.1875
	8	104	5.482	.0973
	9	173	5.836	.2418
	10	153	6.098	.2226
	11	172	6.410	.1705
	12	183	6.516	.2570
	Total	1040	5.944	.4903

One-way ANOVA was conducted to examine age-group differences in seven bony diameter measurements among boys aged 6–12 years. Results are shown in Table 5. All seven variables showed highly significant differences across age groups ($p < .001$).
Biacromial diameter (shoulder width): $F(6, 1033) = 996.29$, $p < .001$. Mean Square Between Groups = 409.52, Within Groups = 0.41. This very large F-value indicates substantial age-related variation in shoulder breadth. Bicristal diameter (abdominal width): $F(6, 1033) = 619.29$, $p < .001$. MSB = 284.86, MSW = 0.46. Significant age differences in pelvic breadth were observed.
Bitrochanteric diameter (hip width): $F(6, 1033) = 749.42$, $p < .001$. MSB = 182.28, MSW = 0.24. Hip width varied significantly with age.
Humerus bicondylar width (elbow width): $F(6, 1033) = 841.99$, $p < .001$. MSB = 72.73, MSW = 0.08. Elbow breadth showed strong age-group differentiation.
Wrist diameter (bistyloid): $F(6, 1033) = 1083.38$, $p < .001$. MSB = 31.93, MSW = 0.02. This yielded the highest F-value among all variables, indicating wrist breadth is extremely age-sensitive in this period.
Femur bicondylar diameter (knee width): $F(6, 1033) = 626.37$, $p < .001$. MSB = 66.22, MSW = 0.10. Knee width differed significantly across ages.
Ankle diameter (bimalleolar): $F(6, 1033) = 796.71$, $p < .001$. MSB = 34.23, MSW = 0.04. Ankle breadth also showed significant age variations.

Table 5. Analysis of Variance (ANOVA) of Bony Diameters of Preadolescent Boys

Variable(s)		df	Mean Square	F	Sig.
Bioacromial diameter (cm) (shoulder width)	Between Groups	6	409.52	996.29	.000
	Within Groups	1033	.41		
Bicristal diameter (cm) (abdominal width)	Between Groups	6	284.86	619.29	.000
	Within Groups	1033	.46		
Bitrochantric diameter (cm) (hip width)	Between Groups	6	182.28	749.42	.000
	Within Groups	1033	.24		
Humerus bicondylar width (cm) (elbow width)	Between Groups	6	72.73	841.99	.000
	Within Groups	1033	.08		

Wrist diameter (cm) (bistyloid)	Between Groups	6	31.93	1083.38	.000
	Within Groups	1033	.02		
Femur biocondylar diameter (cm) (knee width)	Between Groups	6	66.22	626.37	.000
	Within Groups	1033	.10		
Ankle diameter (cm) (bimalleolar)	Between Groups	6	34.23	796.71	.000
	Within Groups	1033	.04		

One-way ANOVA revealed statistically significant differences among the seven age groups for all bony diameter measurements ($p < .001$). The F-values ranged from 619.29 for bicristal diameter to 1083.38 for wrist diameter, indicating that age accounted for substantial variance in both axial and appendicular skeletal breadths. The significant results confirm that biacromial [$F(6, 1033) = 996.29$], bicristal [$F(6, 1033) = 619.29$], bitrochanteric [$F(6, 1033) = 749.42$], humerus bicondylar [$F(6, 1033) = 841.99$], wrist [$F(6, 1033) = 1083.38$], femur bicondylar [$F(6, 1033) = 626.37$], and ankle diameters [$F(6, 1033) = 796.71$] all increased significantly with age from 6 to 12 years (Table 5).

Wrist diameter had the highest F-value (1083.38), suggesting it's the most discriminative bony marker for age in pre-adolescent boys (Table 5).

Following significant ANOVA results, Scheffe's post-hoc tests (Table 6) were used to identify specific age-group differences for each bony diameter.

1. Biacromial diameter (shoulder width): Mean shoulder width increased significantly with age across all comparisons ($p < .001$), except between 6 and 7 years ($p = .075$). All other consecutive and non-consecutive age pairs differed significantly. The largest annual increment occurred between 10–11 years (-0.599 cm) and 11–12 years (-0.674 cm).
2. Bicristal diameter (abdominal width): Significant increases were observed for all age comparisons ($p < .001$) except 7 vs 8 years ($p = .871$) and 11 vs 12 years ($p = .155$). This indicates growth plateaus in abdominal width at ages 7–8 and 11–12 years.
3. Bitrochanteric diameter (hip width): All age groups differed significantly ($p < .001$) except 7 vs 8 years ($p = .164$). Hip width showed consistent annual increases, with the greatest gain between 10–11 years (-0.904 cm).
4. Humerus bicondylar width (elbow width): Significant differences were found for most comparisons ($p < .001$), except 8 vs 9 years ($p = .336$) and 10 vs 11 years ($p = .473$). This suggests periods of slowed elbow breadth growth at ages 8–9 and 10–11 years.
5. Wrist diameter (bistyloid): All age groups differed significantly from each other ($p < .001$). Wrist breadth showed the most consistent year-on-year increase among all bony diameters, with no growth plateaus observed between 6–12 years.
6. Femur bicondylar diameter (knee width): All age groups differed significantly ($p \leq .011$). Knee width increased steadily each year, with significant gains even between adjacent ages.
7. Ankle diameter (bimalleolar): Significant differences were found for all comparisons ($p \leq .001$) except 7 vs 8 years ($p = .977$). Ankle breadth growth slowed temporarily between 7–8 years but resumed significantly thereafter.

Table 6. Posthoc (Scheffe) Multiple Comparisons of Bony Diameters of Preadolescent Boys

Dependent Variable	(I) age	(J) age	Mean Difference (I-J)	Sig.
Bioacromial diameter (cm) (shoulder width)	6	7	-.276	.075
		8	-.814*	.000
		9	-1.891*	.000

		10	-2.968*	.000
		11	-3.568*	.000
		12	-4.242*	.000
	7	8	-.538*	.000
		9	-1.615*	.000
		10	-2.692*	.000
		11	-3.291*	.000
		12	-3.966*	.000
	8	9	-1.077*	.000
		10	-2.154*	.000
		11	-2.753*	.000
		12	-3.427*	.000
	9	10	-1.076*	.000
		11	-1.676*	.000
		12	-2.350*	.000
	10	11	-.599*	.000
		12	-1.273*	.000
	11	12	-.674*	.000
Bicristal diameter (cm) (abdominal width)	6	7	-1.762*	.000
		8	-1.898*	.000
		9	-2.717*	.000
		10	-3.168*	.000
		11	-3.988*	.000
		12	-4.209*	.000
	7	8	-.136	.871
		9	-.955*	.000
		10	-1.406*	.000
		11	-2.226*	.000
		12	-2.446*	.000
	8	9	-.818*	.000
		10	-1.269*	.000
		11	-2.089*	.000
		12	-2.310*	.000
	9	10	-.451*	.000
		11	-1.270*	.000
		12	-1.491*	.000
	10	11	-.819*	.000
		12	-1.040*	.000
	11	12	-.220	.155
Bitrochantric diameter (cm) (hip width)	6	7	-.706*	.000
		8	-.898*	.000
		9	-1.388*	.000
		10	-1.891*	.000
		11	-2.795*	.000
		12	-3.068*	.000
	7	8	-.191	.164
		9	-.682*	.000
		10	-1.184*	.000
		11	-2.088*	.000
		12	-2.361*	.000
	8	9	-.490*	.000
		10	-.993*	.000
		11	-1.897*	.000
		12	-2.170*	.000
	9	10	-.502*	.000
		11	-1.406*	.000
		12	-1.680*	.000

	10	11	-.904*	.000
		12	-1.177*	.000
	11	12	-.273*	.000
Humerus bicondylar width (cm) (elbow width)	6	7	-.833*	.000
		8	-1.064*	.000
		9	-1.160*	.000
		10	-1.731*	.000
		11	-1.808*	.000
		12	-2.188*	.000
	7	8	-.231*	.000
		9	-.327*	.000
		10	-.898*	.000
		11	-.975*	.000
		12	-1.355*	.000
	8	9	-.095	.336
		10	-.666*	.000
		11	-.743*	.000
		12	-1.124*	.000
	9	10	-.571*	.000
		11	-.648*	.000
		12	-1.028*	.000
	10	11	-.077	.473
		12	-.457*	.000
	11	12	-.380*	.000
Wrist diameter (cm) (bistyloid)	6	7	-.244*	.000
		8	-.410*	.000
		9	-.599*	.000
		10	-.857*	.000
		11	-1.141*	.000
		12	-1.277*	.000
	7	8	-.165*	.000
		9	-.354*	.000
		10	-.612*	.000
		11	-.896*	.000
		12	-1.032*	.000
	8	9	-.189*	.000
		10	-.447*	.000
		11	-.730*	.000
		12	-.867*	.000
	9	10	-.258*	.000
		11	-.541*	.000
		12	-.678*	.000
	10	11	-.283*	.000
		12	-.420*	.000
	11	12	-.136*	.000
Femur biocondylar diameter (cm) (knee width)	6	7	-.649*	.000
		8	-1.021*	.000
		9	-1.186*	.000
		10	-1.416*	.000
		11	-1.714*	.000
		12	-2.090*	.000
	7	8	-.372*	.000
		9	-.537*	.000
		10	-.767*	.000
		11	-1.065*	.000
		12	-1.441*	.000
	8	9	-.165*	.011

		10	-.395*	.000
		11	-.692*	.000
		12	-1.069*	.000
	9	10	-.230*	.000
		11	-.527*	.000
		12	-.904*	.000
	10	11	-.297*	.000
		12	-.674*	.000
	11	12	-.376*	.000
Ankle diameter (cm) (bimalleolar)	6	7	-.154*	.000
		8	-.183*	.000
		9	-.537*	.000
		10	-.799*	.000
		11	-1.111*	.000
		12	-1.217*	.000
	7	8	-.029	.977
		9	-.383*	.000
		10	-.645*	.000
		11	-.957*	.000
		12	-1.063*	.000
	8	9	-.354*	.000
		10	-.616*	.000
		11	-.928*	.000
		12	-1.034*	.000
	9	10	-.262*	.000
		11	-.574*	.000
		12	-.680*	.000
	10	11	-.311*	.000
		12	-.417*	.000
	11	12	-.106*	.001

*. The mean difference is significant at the 0.05 level

Scheffe's post-hoc analysis (Table 6) shows that all seven bony diameters increased significantly with age ($p < .001$), though specific growth patterns varied. Wrist diameter, femur bicondylar diameter, and ankle diameter showed significant increases at every consecutive age interval, except for ankle diameter at 7 vs 8 years. In contrast, biacromial, bicristal, bitrochanteric, and humerus bicondylar widths exhibited one or two non-significant intervals, indicating brief plateaus in growth. Notably, biacromial diameter showed no significant change between 6–7 years, bicristal and bitrochanteric diameters plateaued at 7–8 years, and humerus bicondylar width plateaued at 8–9 and 10–11 years. The 11–12 year interval showed non-significant change only for bicristal diameter, while all other diameters continued to increase significantly.

Overall, while all variables demonstrated significant age-related growth, wrist diameter, femur bicondylar diameter, and body weight showed the most continuous year-on-year increases. Axial diameters exhibited brief periods of growth stabilization, particularly between 6–8 years and 11–12 years.

Discussion

Overview of Growth Patterns

The present study examined age-related changes in body height, weight, and seven bony diameters in pre-adolescent boys aged 6–12 years. All variables demonstrated significant age effects, confirming that linear growth and skeletal breadths increase progressively during pre-adolescence. However, Scheffe post-hoc analysis revealed that the tempo and continuity of growth differed markedly between variables, with appendicular diameters showing more consistent year-on-year increases than axial diameters or stature.

Height and Weight Growth Dynamics

Mean body height increased significantly each year from 6 to 11 years but plateaued between 11 and 12 years. This cessation of significant height gain at 11–12 years suggests that, for this cohort, the pre-adolescent growth spurt in stature may peak before age 12. In contrast, body weight continued to increase significantly through 12 years, except for a brief stabilization at 9–10 years. The continued weight gain despite a height plateau implies disproportionate increases in body mass, likely due to gains in muscle mass, skeletal mass, or adipose tissue as boys approach adolescence. The largest annual increments in both height and weight occurred between 10–11 years, indicating this interval may represent peak growth velocity for overall body size in the present sample.

Axial vs. Appendicular Skeletal Growth

Bony diameter analysis revealed two distinct patterns. Axial breadths — biacromial, bicristal, and bitrochanteric diameters — exhibited brief, intermittent growth plateaus. Shoulder width did not increase significantly between 6–7 years, while pelvic and hip widths stabilized at 7–8 years. Bicristal diameter also plateaued again at 11–12 years, the only diameter to do so. These transient stagnations suggest that trunk and pelvic breadth growth is non-linear and may be influenced by differential maturation rates of the shoulder and pelvic girdles.

Conversely, appendicular breadths — wrist, femur bicondylar, and ankle diameters — showed near-continuous growth. Wrist and knee widths increased significantly at every consecutive age interval with no plateaus, and ankle width plateaued only briefly at 7–8 years. The wrist diameter yielded the highest F-value (1083.38) of all variables, identifying it as the most age-sensitive skeletal marker in boys aged 6–12 years. This finding aligns with auxological evidence that distal limb segments are among the earliest and most consistent indicators of skeletal maturity during childhood.

Specific Growth Plateaus and Their Implications

The observed plateaus have functional and methodological implications. The 6–8 year period showed stabilization in shoulder, hip, and ankle breadths, potentially reflecting a mid-childhood lull in transverse skeletal growth before the late pre-adolescent acceleration. Similarly, the humerus bicondylar width plateau at 8–9 and 10–11 years indicates that elbow breadth growth is episodic rather than linear. For researchers, these results caution against assuming uniform annual increments when constructing growth standards; certain diameters may require wider age bands for normative data.

Clinical and Sports Science Relevance

The differential growth of bony breadths versus stature is relevant to talent identification and pediatric assessment. Since height gains ceased at 11–12 years but all appendicular breadths except humerus continued to increase, frame size and limb robustness may continue developing after statural growth slows. Wrist and knee diameters, with their uninterrupted growth, may serve as reliable, easy-to-measure proxies for biological age and skeletal maturation in field settings where radiographs are impractical. The continued increase in biacromial and bitrochanteric diameters through age 12 also suggests that shoulder-to-hip ratio, an important anthropometric index, remains dynamic in late pre-adolescence.

Limitations and Future Directions: This cross-sectional design precludes analysis of individual growth velocity curves, and the sample was limited to boys from a single region. Longitudinal studies are needed to confirm whether the identified plateaus represent true growth slowdowns or cohort effects. Additionally, socioeconomic status, nutritional factors, and physical activity levels were not controlled and may influence bony diameter development. Future research should examine these diameters in relation to maturity indicators such as peak height velocity and skeletal age to determine predictive utility.

Conclusion

The present cross-sectional study of 1040 pre-adolescent boys aged 6–12 years demonstrated significant age-related increases in body height, weight, and seven bony diameters. While overall growth was progressive, the tempo varied by anatomical site. Body height increased significantly until 11 years and then plateaued, whereas body weight continued to rise through 12 years, indicating differential changes in body composition during late pre-adolescence.

Among skeletal breadths, appendicular diameters exhibited the most consistent growth. Wrist diameter and femur bicondylar diameter increased significantly at every consecutive age interval, with wrist diameter emerging as the most age-sensitive bony marker (F = 1083.38). In contrast, axial diameters showed intermittent growth plateaus: biacromial diameter at 6–7 years, bicristal and bitrochanteric diameters at 7–8 years, and bicristal diameter again at 11–12 years. Humerus bicondylar width also showed episodic growth with plateaus at 8–9 and 10–11 years.

These findings indicate that skeletal breadth growth in pre-adolescent boys is non-uniform, with distal limb segments providing more continuous indices of maturation than trunk breadths or stature. Wrist and knee diameters may serve as practical, non-invasive indicators for assessing biological age and growth status in pediatric, clinical, and sports talent identification settings. These findings highlight the importance of using multiple anthropometric dimensions, rather than height alone, to characterize pre-adolescent growth and maturation. Future longitudinal studies are recommended to validate these growth patterns and examine their relationship with maturity indicators such as skeletal age and peak height velocity.

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