Published in final edited form as:

J Pediatr. 2008 January ; 152(1): 45–49.e2. doi:10.1016/j.jpeds.2007.05.046.

HUMAN BODY SHAPE INDEX BASED ON AN EXPERIMENTALLY DERIVED MODEL OF HUMAN GROWTH

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Abstract

Objectives—To test the assumption of geometrically similar growth by developing experimentally derived models of human body growth during the age interval of 5–18 years; to use the derived growth models to establish a new Human Body Shape Index (HBSI) based on natural age related changes in HBS; and to compare various metrics of relative body weight (body mass index, ponderal index, HBSI) in a sample of 5–18 year old children.

Study design—Non-disabled Polish children (N=847) participated in this descriptive study. To model growth, the best fit between body height (H) and body mass (M) was calculated for each sex with the allometric equation $M = m_1 H^{\chi}$. HBSI and HBSI were calculated separately for girls and boys, using sex-specific values for χ and a general HBSI from combined data. The customary body mass and ponderal indices were calculated and compared to HBSI values.

Results—The models of growth were $M = 13.11 H^{2.84}$ ($R^2 = .90$) and $M = 13.64 H^{2.68}$ ($R^2 = .91$) for girls and boys respectively. HBSI values contained less inherent variability and were influenced least by growth (age and height) than customary indices.

Conclusion—Age-related growth during childhood is sex-specific and not geometrically similar. Therefore, indices of human body shape formulated from experimentally derived models of human growth are superior to customary geometric similarity-based indices for the characterization of human body shape in children during the formative growth years.

Keywords

children; pediatrics; growth; obesity; ponderal

Human body shape (HBS), body mass relative to standing height, is of interest in various scientific disciplines such as anthropometry, biomechanics, nutrition, and ergonomics. Behavioral, environmental, and genetic factors influence the establishment and subsequent alterations in HBS. Changes in HBS may also indicate the onset or acceleration of disease. Thus, monitoring and prediction of the physiological and pathological processes that affect HBS are important.

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edited by SRD and WFB

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Prenatal development is characterized by dramatic and qualitative changes in HBS. During the first year of life, rapid growth (age-related increase in body height and mass) and change in HBS take place. Body proportions change until a more robust adult-like body structure emerges by the age of 5–7 years, at which time growth is characterized by mainly quantitative changes, and a geometrically proportional increase in body size and mass in three dimensions (except during puberty). Once adult body height is achieved, any changes in HBS may occur only in two dimensions (anterior/posterior and medial/lateral).

HBS can be quantified using several metrics (17,28). Customarily used methods are based on geometric similarity models that employ readily obtainable data: body mass (M) and body height (H). The body mass index (BMI) is defined as $BMI = M/H^2$. (1,2) In children, the BMI increases during development (3,4,5,6,7). Growth charts, percentile and z-score analyses are used to classify an individual in relation to a non-disabled population, but comparison between different populations is complex (8,9,10,11). Further, the discretization of the two-dimensional geometric similarity model via grouping eliminates the advantage provided by a continuous function and leads to increased variance. Thus, the ability of BMI growth charts to detect obesity in children is limited and a more precise classification of obesity is warranted (14, 15).

Another method is the Ponderal Index (PI), defined as $PI = M/H^3$. The PI, or its inverse, is often used to quantify obesity in young children 0–3 years of age (12), but it is seldom used in older children (13,6,7).

It is unclear how closely human growth during 5–18 years of age follows either of these geometric similarity models (17). Agarwal et al. (6) reported a decrease in PI related to body height during the age period of 5–18 years. Yet, respective values of BMI increase during development. These findings suggest that an experimentally derived model of growth may better capture the influence of growth on HBS.

Therefore, the aims of this study were to: (a) test the assumption of geometrically similar growth by developing experimentally derived models of human body growth during the age interval of 5–18 years; (b) use the derived growth models to establish a new Human Body Shape Index (HBSI) based on natural age related changes in HBS; and (c) compare various metrics of relative body weight (BMI, PI, HBSI).

Methods

The present study used data first presented by Lebiedowska et al. (16) which were collected from Warsaw, Poland area school children from 1985–1990. Body mass and body height were obtained from a convenient sample of 847 non-disabled children (444 girls and 403 boys, aged 5–18 years) (Table I; available at www.jpeds.com). The group contained a homogeneous sample of children with generally ideal body fat composition levels, as indicated by 95 percent of the girls and boys having BMI values less than 24.4 and 23.5 respectively. All subjects and their parents gave consent to be included in the study, according to institutional requirements. The original study protocol conformed to the declaration of Helsinki.

To mathematically model growth, the best fit between body height (H) and body mass (M) was calculated for each sex using the allometric equation $M = m_i H^\chi$ (where m_i = a constant and χ = power). BMI and PI were calculated as is customary ($BMI = M/H^2$, $PI = M/H^3$). $HBSI_G$ and $HBSI_B$ were calculated for the girls and boys respectively using sex-specific values for χ . A general HBSI was calculated by averaging the two sex-specific values for χ , thus $HBSI = M/H^\chi$.

Means, standard deviations and variability of all indices were calculated, as well as the Pearson correlations and slopes of regression lines between each index and body height. Variability for each index was evaluated with a coefficient of variation (CV), which was defined as the ratio of the standard deviation to the mean value of a given index, expressed as a percentage.

The indices were compared using the CV and the slope of the regression line for the index relative to height measures. It was assumed that the slope of the regression line indicated the degree of the index's dependence upon H. Thus, the closer to zero the slope of the regression line was, the greater the extent the index was assumed to capture normal age related changes in HBS. To further determine the degree to which the indices were affected by age, each index was calculated for 4 age categories (5–9, 9–12, 12–15 and 15–18 years old) and compared with an ANOVA test, with Bonferroni adjustment. The mean of each index was compared separately in boys and in girls with two-tailed t-tests in order to test for sex specificity. In order to account for age-dependency of HBSI_G in girls, correction factors were derived, based upon the ratio of the mean overall HBSI_G to the HBSI_G in each of the four age groups studied. Statistica software (StatWorks, USA) was used to obtain the best mathematical fits and regression lines and to compare indices at a $P \leq .05$ level of significance.

Results

The best fit (mathematical model of human body growth) between body mass (M) and body height (H) obtained for girls was described by the function $M = 13.1H^{2.84}$ ($R^2 = .90$) and for boys by the function $M = 13.64H^{2.68}$ ($R^2 = .91$) (Figure). The HBSIs based on the mathematical models were thus $HBSI_G = M/H^{2.84}$ for girls, $HBSI_B = M/H^{2.68}$ for boys and $HBSI = M/H^{2.76}$ for the general model which combined both sexes. The regression equations for each index vs. body height, mean values, standard deviations, CVs, and the probability of the differences between the means in boys and girls obtained via t-test are displayed in Table II.

The slopes of each linear regression equation indicate BMI increased substantially with body height in girls ($BMI = 2.23 + 10.9H$, $r = .65$, $P < .001$) as well as in boys ($BMI = 5.2 + 8.57H$, $r = .62$, $P < .001$). PI decreased with body height in girls ($PI = 15.81 - 2.28H$, $r = -.15$, $P = .002$) and in boys ($PI = 17.32 - 3.46H$, $r = -.34$, $P < .001$). The general HBSI increased slightly with body height in girls ($HBSI = 12.18 + .98H$, $r = .1$, $P = .03$). There were no statistically significant correlations between body height and the general HBSI for boys, HBSI_G or HBSI_B.

CVs for BMI (17.8 % in girls and 16.4 % in boys) were larger than CVs for the other indices (range 12.5% – 13.3%) (Table II). Mean values for PI and HBSI were larger in girls than in boys.

Mean HBSI_B values did not significantly differ across the four age groups (Table III). The largest difference observed (.52 or .28 standard deviations) occurred between age groups 9–12 and 15–18 years. The relative magnitude of this difference was only 3.8 percent of the overall mean HBSI_B value. Statistical significance between age groups was established for mean HBSI_G values (Table IV). The largest difference occurred between age groups 9–12 and 15–18 years (1.28 or 0.75 standard deviations, $P = .003$). This represented 9.7 percent of the overall HBSI_G value. Smaller differences were found between age groups 5–9 and 12–15 years (–0.72 or 0.45 standard deviations, $P = .006$) and between age groups 12–15 and 15–18 years (1.24 or 0.7 standard deviations).

Discussion

Knowledge of body shape changes that occur as a result of the age related human growth process is crucial for the accurate detection and classification of abnormal trends in body shape

and body mass composition during the formative growth years. One goal of this study was to develop sex-specific models of natural human body growth in children 5–18 years of age. For this purpose, a data set was obtained from a homogeneous sample of able-bodied children with normal body fat using BMI as a guide. Knowledge of the extent to which this sample contained changes in HBS due to growth was limited by the lack of in depth behavioral, health, and body composition screening. Although BMI may not be based on an ideal model of human growth, the central tendency and variability of BMI values in the sample group indicate its membership clustered near the confluence of underweight and normal classifications (Table II). Therefore, changes in body shape due to increases in relative body fatness that were not growth related were assumed minimal.

Until human growth is completed and adult height is reached, a monotonic increase in body height corresponds with a two dimensional change in body dimensions and mass distribution. The process of age related human growth is geometrically similar if the proportions of each body part dimension over time are invariant (17). If growth were to conform to customary geometric models, body mass would increase proportionally to the third power of body height for a three-dimensional model and to the second power of body height for the two-dimensional model. The discrepancies between the experimentally obtained power of 2.76 and the customarily used values of 2 or 3 indicate the importance of utilizing an empirical approach to obtain an optimal allometric equation. This observation is further substantiated by the HBSI's lower sensitivity to age and height.

Using experimentally derived models of human body growth, we introduced sex-specific ($HBSI_G$ in girls and $HBSI_B$ in boys) and combined ($HBSI$) metrics of relative weight or "human body shape." Indices based on powers other than 2 or 3 (of body height as a function of body mass) have been applied in adults (19) and in children (20, 21, 22, and 23). All previous studies, with the exception of Rosenthal et al. (18) were restricted to the analysis of HBS during a single year, thus they described distributions rather than modeled changes in HBS due to age related growth during the formative growth years. The larger powers for girls obtained in this study may in part reflect the fact that the final average body height relative to weight reached by females is smaller than in males (1). However, concurrent sex-specific changes in body proportions likely play a role and thus consideration for using the sex-specific models ($HBSI_G$ and $HBSI_B$) is warranted. Similar powers for a combined growth model reported by Rosenthal et al in 1994 (18), obtained from a similar sample of English children, suggest a degree of concurrent validity may hold across cultures. However, the applicability of these derived growth models and related indices to growth in more disparate cultures has yet to be determined.

A slight decrease of PI with body height, which was not statistically significant, has been reported previously (13,7). The results of this study indicate that PI decreases as a function of height at approximately twice the rate of HBSI values. The finding that the HBSIs were relatively insensitive to body height sanctions the future HBS characterization of 5–8 year old children using sex-specific allometric equations. This approach is somewhat limited in that $HBSI_G$ was found to be slightly age dependent (Table IV). However, although statistically significant, the differences between age groups was on average only 3.9 percent of the mean $HBSI_G$ value of 13.17 (Table IV). This observation is further realized by the magnitude of the age related $HBSI_G$ correction factors being within two to five percent of unity. One reason that differences in HBSI between age groups reached statistical significance in girls (Table IV) could be related to the fact that puberty tends to affect body shape more considerably in girls than in boys. In addition, increases in body height with age was more linear in boys ($H = 0.85 + 0.05 \text{ Age}$; $r = 0.88$) than in girls ($H = 0.91 + 0.05 \text{ Age}$; $r = 0.84$), probably because, unlike boys, girls tend to reach their adult body height by age 18.

Quételet introduced body mass index in adults as $BMI = M/H^2$ (7). Use of BMI is justified in adults because an increase in body dimensions can occur only in two dimensions, whereas in children, growth occurs in three dimensions. Our data strongly suggest that, at least in some applications, BMI as a measure of HBS in children 5–18 years old should be replaced with an index that better represents human growth. PI, HBSI, HBSI_B, and HBSI_G appear superior for some applications. Using CV as a guide, HBSI_B, HBSI_G, HBSI, and PI are superior to BMI. Using sensitivity to height and age as a guide, HBSI appears to be superior to PI in reflecting body shape changes in children 5–18 years old. Our data support the opinion that PI may be useful, particularly in the analysis of different populations irrespective of sex, location and time (24,25,26,3,7,23). In the case of a population of children of both sexes, the combined HBSI could be beneficial to healthcare professionals. In the case of single sex analyses, the application of sex-specific HBSI_G or HBSI_B may be more appropriate. To facilitate further comparison and utilization, ranges of the customary classification categories for each index are presented in Table V (available at www.jpeds.com).

Loss of any allometric equation's continuous nature is not ideal. Historically, the dependency of BMI on age in children has been addressed through the discretization of the two-dimensional growth model by using age grouping. The approach also involves the application of percentile and/or z-score analysis; however, neither z scores nor percentiles allow for a direct comparison of means from different populations. Alternatively, the HBS indices proposed herein are relatively insensitive to age; thus the continuous nature of their inherent allometric equation can be fully leveraged.

Obesity has been identified recently as a major health risk factor of developed societies, not only in adults but also in children (10). Piers et al (27) and de Onis (14) indicate that growth charts based on BMI have limited ability to detect obesity in children. This study suggests that one important factor which limits their use may be the confounding influence of growth on HBS. Development of sex-specific HBS indices, based on experimentally derived models of human growth, have resulted in substantial reductions in index variability and sensitivity to age-related factors. However, future studies are necessary to determine if growth-based indices, such as those developed in this study, are superior to customary methods (28) for the classification of obesity and malnutrition in children during their formative years of growth.

References

1. Department of Health and Human Services. Centers for Disease Control and Prevention. <http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-adult.htm>
2. Dahlstrom S, Viikari J, Akerblom HK, et al. Atherosclerosis precursors in Finnish children and adolescents. II. Height, weight, body mass index, and skinfolds, and their correlation to metabolic variables. *Acta Paediatr Scand Suppl* 1985;318:65–78. [PubMed: 3879093]
3. Rolland-Cachera MF, Sempé M, Guillaud-Bataille M, Patois E, Pequignot-Guggenbuhl F, Fautrad V. Adiposity indices in children. *Am J Clin Nutr* 1982;36(1):178–184. [PubMed: 7091028]
4. Garn SM, Leonard WR, Hathorne VM. Three limitations of the body mass index [letter]. *Am J Clin Nutr* 1986;44(6):996–7. [PubMed: 3788846]
5. Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. *Arch Dis Child* 1995;73(1):25–29. [PubMed: 7639544]
6. Agarwal KN, Saxena A, Bansai AK, Agarwal DK. Physical growth assessment in adolescence. *Indian Pediatr* 2001;38(11):1217–1235. [PubMed: 11721062]
7. Ricardo DR, Araujo CG. Body mass index: a scientific evidence-based inquiry. *Arq Bras Cardiol* 2002;79(1):61–78. [PubMed: 12163946]
8. Hammer LD, Kraemer HC, Wilson DM, Ritter PL, Dornbusch SM. Standardized percentile curves of body-mass index for children and adolescents. *Am J Dis Child* 1991;145(3):259–263. [PubMed: 1750869]

9. Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: a validation study. *J Pediatr* 1998;132(2):204–210. [PubMed: 9506629]
10. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;320(7244):1240–1243. [PubMed: 10797032]
11. Turconi G, Guarcello M, Bazzano R, Maccarini L, Cena H, Roggi C. Adolescent Body Mass Index data: what differences result using different reference standard curves? . *Ann Ig* 2003 Sept-Oct;15 (5):601–10. [PubMed: 14969314]
12. Davies DP, Beverley D. Changes in body proportions over the first year of life: comparisons between ‘light-for-dates’ and ‘appropriate-for-dates’ term infants. *Early Hum Dev* 1979;3(3):263–265. [PubMed: 527529]
13. Alley RA, Narduzzi JV, Robbins TJ, Weir TF, Sabeh G, Danowski TS. Measuring success in the reduction of obesity in childhood. Limited weight reduction success among 50 outpatients. *Clin Pediatr* 1968;7(2):112–118.
14. de Onis M. The use of anthropometry in the prevention of childhood overweight and obesity. *Int J Obes Relat Metab Disord* 2004 Nov;28(Suppl 3):S81–5. [PubMed: 15543225]Review
15. Wang Y. Epidemiology of childhood obesity-methodological aspects and guidelines: what is new? . *Int J Obes Relat Metab Disord* 2004 Nov;28(Suppl 3):S21–8. [PubMed: 15543215]
16. Lebiedowska MK, Syczewska M, Graff K, Kalinowska M. Application of biomechanical growth models of the quantitative evaluation of the motor system in children. *Disabil & Rehab* 1996;18(3): 137–142.
17. Günther B. Dimensional analysis and theory of biological similarity. *Physiol Rev* 1975;55(4):659–699. [PubMed: 1103169]
18. Rosenthal M, Bain SH, Bush A, Warner JO. Weight/height (2.88) as a screening test for obesity or thinness in school age children. *Eur J Pediatr* 1994;153(12):876–83. [PubMed: 7859789]
19. Benn RT. Some mathematical properties of weight-for-height indices used as measures of adiposity. *Br J Prev Soc Med* 1971;25(1):42–50. [PubMed: 5551233]
20. Cole TJ. Weight/height^P compared to weight/height² for assessing adiposity in childhood; influence of age and bone age on p during puberty. *Ann Hum Biol* 1986;13(5):433–451. [PubMed: 3800308]
21. Thomas PW, Peters TJ, Golding J, Haslum M. Weight-for-height in two national cohorts with particular reference to 10-years-old children. *Ann Hum Biol* 1989;16 (2):109–119. [PubMed: 2729888]
22. Newens EM, Goldstein H. Height, weight, and the assessment of obesity in children. *Br J Prev Soc Med* 1972 Feb;26(1):33–9. [PubMed: 5016134]
23. Hattori K, Hirohara T. Age change of power in weight/height(p) indices used as indicators of adiposity in Japanese. *Am J Hum Biol* 2002;14(2):275–279. [PubMed: 11891939]
24. Seltzer CC. Some re-evaluations of the build and blood pressure study, 1959, as related to ponderal index, somatotype and mortality. *New Eng J Med* 1966;274(5):259–9. [PubMed: 5322870]
25. Nahum LH. The ponderal index. *Conn Med* 1966;30(4):241–242. [PubMed: 5910408]
26. Huber NM. Ponderal Index and Height. *Am J Phys Anthropol* 1969;31(2):171–176. [PubMed: 5348793]
27. Piers LS, Soares MJ, Frandsen SL, O’Drea K. Indirect estimates of body composition are useful for groups but unreliable in individuals. *Int J Obes Relat Metab Disord* 2000;24(9):1145–52. [PubMed: 11033983]
28. Field AE, Laird N, Steinberg E, Fallon E, Semega-Janneh M, Yanovski JA. Which metric of relative weight best captures body fatness in children? *Obesity Research* 2003;11(11):1345–1352. [PubMed: 14627755]

Figure.

Body mass (M) as a function of body height (H) in 847 (444 girls: gray open circles; 403 boys: black closed circles) Polish children 5–18 years of age.

Table 1

The demographics of the children.

Age (years)	Girls (N=444)				Boys (N=403)			
	M (kg)		H (m)		M (kg)		H (m)	
	N	mean ± S.D.	mean ± S.D.	N	mean ± S.D.	mean ± S.D.	mean ± S.D.	N
5	26	18.88±2.19	1.12±0.04	29	20.81±2.75	1.14±0.05	1.14±0.05	29
6	43	22.57±4.64	1.19±0.06	30	22.37±3.48	1.20±0.06	1.20±0.06	30
7	37	24.78±3.55	1.25±0.05	33	25.15±3.60	1.26±0.06	1.26±0.06	33
8	23	26.79±5.13	1.28±0.06	34	29.96±6.83	1.33±0.07	1.33±0.07	34
9	42	28.68±4.97	1.34±0.06	35	30.23±4.73	1.35±0.05	1.35±0.05	35
10	33	34.59±8.30	1.39±0.08	37	34.72±6.83	1.42±0.07	1.42±0.07	37
11	30	39.18±8.30	1.49±0.08	31	37.67±6.17	1.46±0.08	1.46±0.08	31
12	36	42.25±7.71	1.55±0.08	34	42.71±10.90	1.52±0.10	1.52±0.10	34
13	31	48.84±9.14	1.58±0.07	36	48.48±11.30	1.60±0.09	1.60±0.09	36
14	38	52.73±6.25	1.63±0.06	38	56.74±9.50	1.68±0.07	1.68±0.07	38
15	21	52.97±6.10	1.63±0.04	10	51.61±9.70	1.66±0.07	1.66±0.07	10
16	36	56.88±7.26	1.64±0.06	20	65.30±8.47	1.76±0.06	1.76±0.06	20
17	37	58.16±8.27	1.63±0.06	29	65.72±7.99	1.78±0.07	1.78±0.07	29
18	11	61.35±10.05	1.67±0.08	7	67.97±10.69	1.79±0.08	1.79±0.08	7

N = number of subjects

M = body mass

H = body height

S.D. = standard deviation

Table 2
mental axis) and the differences between girls and boys.

Girls, N=444		Boys, N=403		p
Regression equation	mean ± S.D. (CV %)	Regression equation	mean ± S.D. (CV %)	
2.23 + 10.90H r=0.65, p<0.001	18.00 ± 3.20 (17.8)	5.20 + 8.57H r= 0.62, p<0.001	17.70 ± 2.90 (16.4)	0.29

15.81 – 2.28H r= –0.15, p=0.002	12.47 ± 1.64 (13.2)	17.32 – 3.46H r= –0.34, p<0.001	12.21 ± 1.62 (13.3)	0.03

p	
Girls, N=444	Boys, N=403
<div>Regression equation</div> <div> </div>	<div>Regression equation</div> <div> </div>
mean ± S.D. (CV %)	mean ± S.D. (CV %)

Table 3HBSI_B by age group of boys.

Age group(years)	N	Mean ± STD
5–9	124	13.80 ± 1.55
9–12	103	13.51 ± 1.65
12–15	107	13.69 ± 1.93
15–18	66	14.03 ± 1.75

The differences were not statistically significant ($P = .253$)

Table 4HBSI_G by age group of girls.

Age group(years)	N	Mean $\pm$ STD	HBSI _G age correction
5–9	129	13.42 $\pm$ 1.37 ^{a,b}	0.98
9–12	105	12.65 $\pm$ 1.76 ^c	0.96
12–15	105	12.69 $\pm$ 1.83 ^d	0.96
15–18	105	13.93 $\pm$ 1.67	1.05

Statistically significant differences between the age groups:

^a 5–9 and 9–12 years old, $P = .003$ ^b 5–9 and 15–18 years old, $P = .006$ ^c 9–12 and 15–18 years old, $P = .001$ ^d 12–15 and 15–18 years old, $P = .001$

Table 5

The estimates* of ranges of indices for underweight (<5th percentile), normal (5th percentiles to 85th percentiles), at risk of overweight (between 85th and 95th percentiles), and overweight (≥95th percentiles) in Polish children 5–18 years old.

Index	Ranges of indices in Polish children population	
	Girls, n=444	Boys, n=403
PI (kg/m ³)	Underweight	< 10.11
	Normal	10.11 – 14.08
	At risk of overweight	14.08 – 15.19
	Overweight	≥ 15.19
HBSI _G (kg/m ^{2.84})	Underweight	< 10.67
	Normal	10.67 – 14.97
	At risk of overweight	14.97 – 16.40
	Overweight	≥ 16.40
HBSI _B (kg/m ^{2.68})	Underweight	< 11.27
	Normal	11.27 – 15.36
	At risk of overweight	15.36 – 17.90
	Overweight	≥ 17.19
HBSI (kg/m ^{2.76})	Underweight	< 10.96
	Normal	10.96 – 15.39
	At risk of overweight	15.39 – 16.85
	Overweight	≥ 16.85

N = number of children

PI = Ponderal index

HBSI= modified body mass index

HBSI_B= sex specific modified body mass index for boys

HBSI_G= sex specific modified body mass index for girls

* The accuracy of estimation is 0.75 and 0.28 of one standard deviation for girls and boys respectively; this is related to the effect of calendar age on HBSI (which is statistically significant for girls).