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Argentine references for the assessment of body proportions from birth to 17 years of age

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ABSTRACT

Introduction.Abnormal body proportions may indicate skeletal disorders; therefore, their detection has great clinical significance.

Objectives.To estimate centiles for head circumference/height (HC/H) and sitting height/height (SH/H) ratios, and assess their diagnostic usefulness among a group of children with skeletal dysplasia.

Methods.Centiles 3, 10, 25, 50, 75, 90 and 97 for HC/H and SH/H ratios were estimated with the LMS method using Box-Cox transformation to normalize data distribution for each age. *Q-Q plot* tests were applied to evaluate normality of residuals and the *Q test* to calculate goodness-of-fit.

Results.The sample included 4818 girls and 4803 boys, all healthy, between 0-17 years old. The median of the SH/H ratio for each age decreased from 0.67 at birth to 0.57 at age 4. At 12 years of age, values reached 0.52 and 0.53 for males and females, respectively, remaining unchanged until age 17. The median of the HC/H ratio decreased from 0.45 at 6 years old to 0.34 at 17 years old for both sexes. Z-scores for SH/H among 20 children diagnosed with hypochondroplasia were better at showing abnormal proportions than the SH/H ratio not adjusted by age.

Conclusions.Estimated centiles for HC/H and SH/H ratios show that the most dramatic changes in body proportions occur in the prepubertal period. These references allow an earlier detection of abnormal body proportions in children with skeletal dysplasia.

Key words: *sitting height/height ratio, body proportions, head circumference/height ratio, hypochondroplasia, growth curves.*

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INTRODUCTION

The evaluation of body proportions, such as the relationship between the length of limbs, the trunk and the head circumference (HC) and height, are significant both for the clinical as well as the epidemiological assessment, because they reflect the nutritional and health status during early life.[1]

Abnormal findings in body proportions during the physical examination of a child may suggest the presence of an underlying skeletal disorder. Skeletal dysplasia (SD) is relatively rare, with an incidence of 3.2 out of 10,000 newborn infants in South America.[2] This condition affects both bones and cartilage.[3] Clinical signs are variable, but the most characteristic indication is short stature with abnormal body proportion, caused by a large head circumference, or short limbs or trunk in relation to height. In this kind of diseases, the clinical radiological diagnosis can be established in the neonatal period. In other cases, however, long term follow-up sometimes even up to the later stages of growth is required. By this time, clinical and/or radiological signs are evident.[3-10]

Many patients with SD have a HC that is normal for their age (between ± 2 Z-scores), but clinically "large" for their height. The term *relative macrocephaly* is used for cases in whom head circumference is normal for a given age and sex, but "high" for their height. Thus, and assuming there is a relationship between these two measurements in the healthy population, references were developed for the head circumference/height (HC/H) ratio for healthy males and females from birth to 6 years old.[11] These references are very useful for pediatricians and were collected in the *Physical Growth Assessment Guidelines* of the Argentine Society of Pediatrics.[12]

The availability of references for the assessment of body proportions is very useful for auxological evaluations.

Several authors have published sitting height/height (SH/H) references, but these correspond to populations with average heights that differ greatly from those in Argentina, due to genetic and/or environmental reasons.[13-15] Therefore, these references are inadequate for the clinical evaluation of body proportions in the Argentinean population.

The objectives of this study were to estimate centiles of HC/H and SH/H ratios for Argentinean children, and evaluate their diagnostic usefulness to detect abnormal body proportions in children with SD.

POPULATION AND METHODS

Population

HC/H and SH/H centiles were estimated based on data obtained from the following samples: **(a)** Longitudinal sample of 250 healthy children, 0-18 years old, measured at Hospital San Roque de La Plata (Buenos Aires) in 1965.[16-18] From this sample, growth references were estimated for Argentinean boys and girls. These references were used from 1987 until WHO standards were implemented in Argentina.[19] **(b)** Cross-sectional sample of 1790 healthy children (878 boys and 912 girls) from La Plata, Buenos Aires, measured in 1970. This population was part of the sample used to establish Argentine references for weight and height in healthy children 4-12 years old.[12,18,20] **(c)** Cross-sectional sample of 1411 girls and 1442 boys, 2-16 years old, attending state-fund and private schools in La Plata and Gran La Plata, Buenos Aires, from 2007 to 2009. **(d)** Cross-sectional sample of 4556 students of both sexes (2232 girls and 2324 boys), 5-15 years old, attending state-fund and private schools in Santa Rosa-Toay, province of La Pampa, from 2004 to 2007. Based on these data, weight and height centiles were calculated for children and adolescents living in urban areas in the central region of Argentina.[21]

Height, SH and HC measurements were standardized in each sample.[16-21]

Data processing and statistical methods

Dispersion and box plots were developed to remove extreme values. The study included HC, height and SH data within the range between the mean ± 5 points from the standard deviation (SD).

Given the time differences among the samples used to estimate centiles, medians of samples between 4-12 years old taken in 1970 and 2007/2009 were graphically compared. The T test was applied to compare the different age groups in both samples.

SH/H and HC/H centiles for each age were estimated by the LMS method. With this method, it is possible to adjust by asymmetry using the Box-Cox (L) transformation, thus normalizing data distribution for each age,[22,23] considering the median (M) and the distribution variation coefficient (S). Data adjustment allows L, M and S values to change smoothly with the abscissa X (in this case, age). Thus, data can be representative of the population with smooth curves plotted based on the Y ordinate (SH/H and HC/H ratios).

For each age, the distribution of SH/H and HC/H ratios is summarized in three coefficients: L, M and S, where L indicates symmetry, M is the median, and S is the variation coefficient for each age and sex. These parameters were calculated following the maximum penalized likelihood procedure.[23,24] Centiles were calculated using the formula below:[22,24]

$$C_{100\alpha}(t) = M(t)\,(1 + L(t)\,S(t)\,Z_\alpha)^{1/L(t)}$$

Z_α is the equivalent normal deviation for the area of tail α; $C_{100\alpha}$ is the SH/H or HC/H centile corresponding to Z_α; t is the age in years. L(t): asymmetry; M(t): median; S(t): variation coefficient and $C_{100\alpha}(t)$ indicate the corresponding values of each curve at age t.

Q-Q plot testswere applied to evaluate normality of residuals and the Q test to calculate goodness-of-fit.[24-26]

The Pearson correlation coefficient was calculated to determine the correlation among HC, height, SH and length of lower limbs (LL= H – SH), transformed into a Z-score (ZS) for 4 age groups (≤ 2.99 years, 3-5.99 years, 6-11.99 years and ≥ 12 years). ZS was calculated using the formula below:

$$ZS = [(y/M(t))^{L(t)} - 1]/S(t) * L(t)$$

Where y is either a measurement (HC, height, etc.) or a ratio (SH/H) at a certain age, and L(t), M(t) and S(t) are the smoothed values for that measurement or ratio at the same age. Statistic processing was performed using LMS ChartMaker Pro software.

In a cross-sectional sample of 20 children (10 boys and 10 girls) < 12 months old, diagnosed with hypochondroplasia based on radiological and clinical criteria[13], and confirmed by molecular tests, height and SH values were obtained from their medical records. Anthropometric measurements were taken using standardized methods[16] by the same observer at the Anthropometrics Laboratory of the Service of Growth and Development of Hospital Garrahan. The technical error of measurement was 0.10 cm in all cases.[27,28]

Height, SH/H ratio adjusted by age (current references) and unadjusted SH/H ratio data were transformed to ZS. The LMSGrowth[29] software was used for height and SH/H ratio adjusted by age. Unadjusted SH/H values were processed manually from median and standard deviation data.[12,30]

RESULTS

The overall amount of children included, by age group, was ≤ 2.99 years old: 287 and 282; 3-5.99 years old: 689 and 725; 6-11.99 years old: 2624 and 2585; ≥ 12 years old: 1203 and 1226, with a total of 4803 boys and 4818 girls.

The graphic comparison and the statistical data obtained in the comparison of samples from 1970 and 2007/2009 indicated that changes in body proportions were not significant (*Figures 1. A and B*); therefore, both were included in the study.

Table 1 shows the Pearson correlation coefficients for ZS among height, SH, LL and HC in both sexes and in the 4 age groups. High correlations were obtained between SH and LL with height, showing values between 0.79 and 0.90 for children > 3 years old and for both sexes. In children < 3 years, the correlation coefficients were larger for boys. The correlations between HC and height fluctuated between 0.30 and 0.50.

Figures 2. A and B show the SH/H ratio references from birth to 17 years of age in the 7 centile format: 3, 10, 25, 50, 75, 90 and 97. Changes in the median for SH/H and HC/H ratios by age were similar in both sexes. The median of the SH/H ratio for each age fell rapidly from about 0.67 at birth to 0.57 at age 3-4. Then it decreased at a slower pace and, at age 12, the values were at 0.52 for boys and 0.53 for girls. These values remained the same until age 17.

Figures 3. A and B show the HC/H ratio references from 6 to 17 years for girls and boys, respectively, in the 7 centile format: 3, 10, 25, 50, 75, 90 and 97. The median decreased from values around 0.45 at age 6 to 0.34-0.33 in both sexes at age 17.

Figure 1 (A and B). *Comparison of the sitting height/height ratio median between the 1970 and 2007/2009 samples*

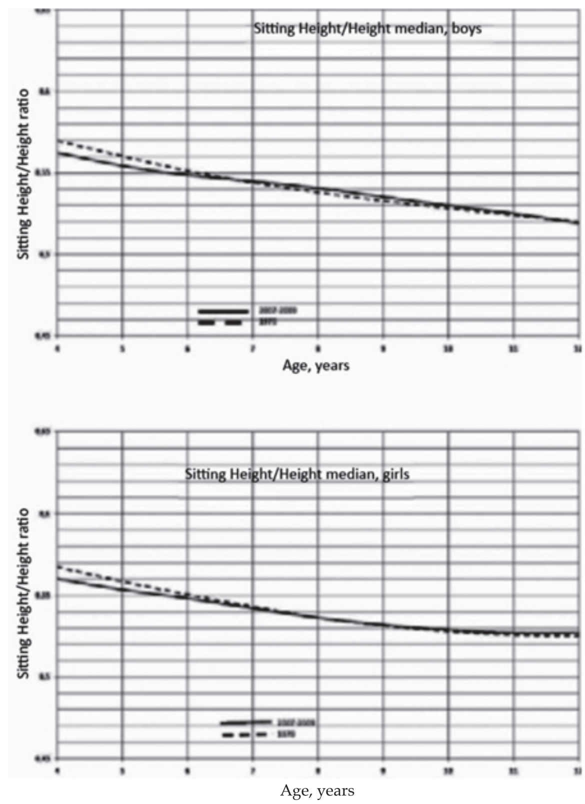


Table 1. *Correlation coefficients between the Z-score for head circumference, sitting height and lower limb length and height, by age group in both sexes*

Age group	Sex	SH vs. H	LL vs. H	HC vs. H
0 to 2.99 years old	Boys	0.62 (N= 284)	0.52 (N= 284)	0.30 (N= 280)
	Girls	0.49 (N= 272)	0.36 (N= 265)	0.31 (N= 272)
3 to 5.99 years old	Boys	0.80 (N= 620)	0.79 (N= 620)	0.44 (N= 417)
	Girls	0.83 (N= 661)	0.85 (N= 661)	0.44 (N= 436)
6 to 11.99 years old	Boys	0.82 (N= 2451)	0.87 (N= 2450)	0.45 (N= 1761)
	Girls	0.85 (N= 2387)	0.90 (N= 2384)	0.44 (N= 1708)
≥ 12 years old	Boys	0.83 (N= 1148)	0.89 (N= 1144)	0.50 (N= 853)
	Girls	0.82 (N= 1143)	0.87 (N= 1143)	0.40 (N= 865)

H: height; SH: sitting height; LL: lower limbs length; HC: head circumference.

Table 2 shows the ZS for height, SH/H by age and unadjusted SH/H for 10 boys and 10 girls < 12 months old diagnosed with hypochondroplasia. Among these patients, 9/10 girls and 7/10 boys had SH/H Z-scores > 2 for their age, which evidenced an alteration of normal body proportions. In contrast, the ZS for unadjusted SH/H ratios did not indicate abnormal values (> 2) in any of the children. For example, it should be noted that patient no. 7 showed a high SH/H ratio adjusted by age (ZS +2.82), with no height deficit (ZS -1.56) and with a normal unadjusted SH/H ratio (ZS +0.87).

DISCUSSION

This study provides growth references related to the SH/H and HC/H ratios, by age, for Argentinean boys and girls 0 to 17 years old.

As expected, correlations between the SH and LL were high for all ages and larger than those published for Dutch children, [13] between 3 and 12 years old, but similar in both sexes after age 12.

The SH/H ratio decreased from 0.67 at birth to 0.57 at age 4, and reached values around 0.53-0.52 in adolescents. This shows that the most significant change in body proportions occurs in the first 3 years of life, with more significant growth in the legs than in the trunk, and a mean reduction of 10% in the HS/H ratio. As from age 3 and up to age 12, the decrease in SH/H ratio means is lower (5%). Beyond that age, there is little change between height and body segments. On the one hand, this reveals the importance of early childhood as a critical period for the detection of postnatal SD. On the other hand, it evidences that adult proportions are established before final adult height is achieved.

FIGURE 2.A. *Sitting height/height ratio by age in boys*

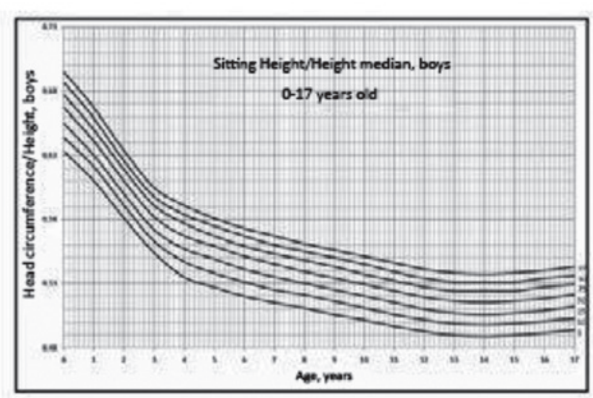


FIGURE 3.A. *Head circumference/height ratio by age in boys*

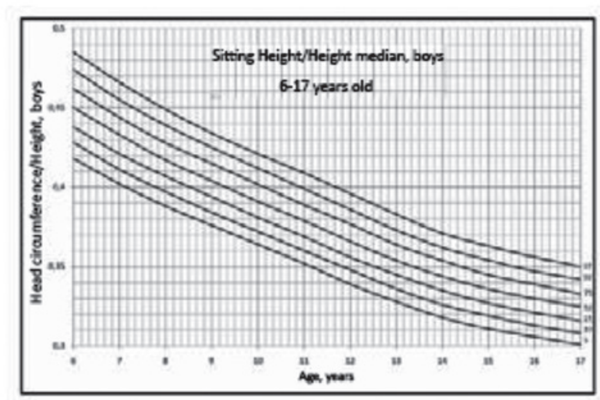


FIGURE 2.B. *Sitting height/height ratio by age in girls*

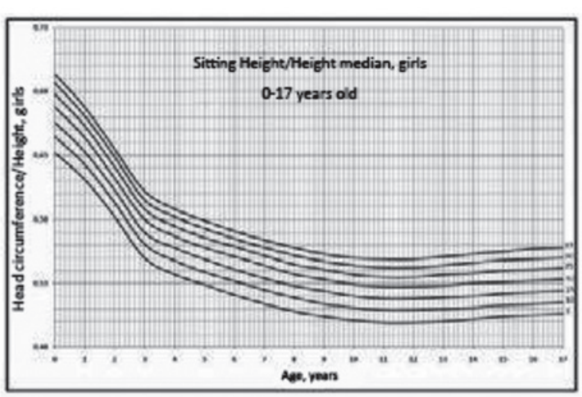
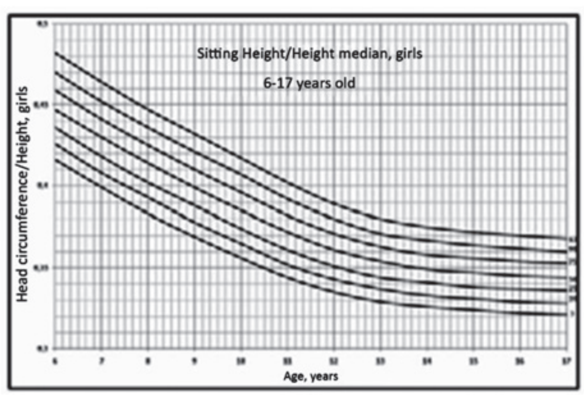


FIGURE 3.B. *Head circumference/height ratio by age in girls*



The correlations between the HC and height have been previously reported for both sexes between the ages of 0 and 6.[11,31]Such studies show coefficients between 0.30 and 0.79, similar to those found in this research. Moreover, the existence of correlations between 0.30 and 0.50 between these variables shows the usefulness of relating HC with height in the clinical practice. The HC/H ratio decreases by 9%-10% between the ages of 6 and 17, which shows that the change in body proportions between the HC and total height occurs, mostly, during childhood, together with a greater development of the brain.[1,30]

These references were drawn up based on the need to adjust SH and HC with the height for each age, so as to make anthropometric diagnosis more accurate when evaluating undiagnosed children with short stature. This is particularly useful in the first years, when there are few radiological and clinical signs, and when other causes of retarded growth have been ruled out. In these cases, the presence SDs, such as hypochondroplasia, should be considered.[9] When no other family members are affected, this disorder is generally diagnosed after the first years of life, when the clinical abnormality in proportions is more evident.

Table 2. *Z-scores for height, sitting height/height adjusted by age and unadjusted sitting height/height in 20 children diagnosed with hypochondroplasia*

Patient	Age	Sex	Height	SH/H/age	SH/H
1	0.26	M	-2.87	1.38	0.32
2	0.27	M	-2.39	2.05	0.71
3	0.36	M	-3.06	3.63	1.34
4	0.36	M	-2.39	3.78	1.36
5	0.37	M	-0.66	1.85	0.72
6	0.39	M	-2.82	2.42	0.71
7	0.62	M	-1.56	2.82	0.87
8	0.67	M	-3.52	4.03	1.40
9	0.67	M	-2.34	1.65	0.72
10	0.64	M	-4.48	4.28	0.87
11	0.22	F	-0.66	1.96	0.33
12	0.44	F	-3.94	6.03	1.40
13	0.46	F	-2.06	4.20	1.36
14	0.61	F	-2.95	4.06	0.87
15	0.62	F	-2.12	2.88	0.71
16	0.65	F	-2.75	2.21	0.68
17	0.76	F	-3.35	2.39	0.67
18	0.78	F	-2.52	3.36	0.88
19	0.86	F	-2.34	3.25	0.89
20	0.92	F	-3.30	2.79	0.70

SH/H/age: sitting height/height ratio adjusted by age;
SH/H: unadjusted sitting height/height ratio;
M: male; F: female.
Age: expressed in decimal fractions for the year of age.

Table 2 shows an example of the usefulness of these references: an alteration of body proportions can be observed, even when the height is normal or only slightly low in 12-months-old children.

Saunders[11] showed greater sensitivity to detect macrocephaly with HC/H references, in comparison with only HC references by age in children diagnosed with hypochondroplasia.

Thus, these references allow the early detection of skeletal disorders. This would reduce the number of unnecessary screenings and tests that many children have to undergo when trying to find the cause of growth retardation, or for confirmation of a clinical impression or abnormal body proportions with no auxological evidence.

These references are also useful to restrict the number of possible diagnoses during late childhood in patients with short stature without a certain etiology. In this study, abnormal body proportions are a sign used to evaluate children with short stature without a clear cause.[10]

It is necessary to note certain limitations of this study, such as the lower number of data between birth and age 3, which did not allow the proper adjustment of data. Another limitation is that the sample is not representative of all regions in Argentina. The different genetic composition of each region may influence body proportions.

However, the anthropometric data used to establish the references were taken from healthy populations, by trained personnel and following the standards of the Argentine Society of Pediatrics.[12] In addition, more than 200 values were available for each age group and sex, between the ages of 4 and 15, which makes the sample adequate to establish growth references to assess body proportions between birth and 17 years of age.

To conclude, estimated HC/H and SH/H centiles show that the more dramatic changes in body proportions occur in the prepubertal period. These references allow the earlier detection of abnormal body proportions, which in turn improves SD diagnosis in children. ■

Note:

Values obtained for L, M and S, by age, are available at *garrahan@gov.ar/ tdecrecimiento* for incorporation to the program LMSGrowth (*www.healthforallchildren.co.uk*).

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