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RESEARCH PAPER

Growth references for Brazilian children and adolescents: Healthy growth in Cariri study

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***Aim*: To construct reference values for height, body mass and BMI of children and adolescents from the Cariri region, Brazil; to compare the growth of Cariri children with those from CDC (Centers for Disease Control and Prevention) and with references from other Brazilian regions; to verify the associations between socioeconomic status and height, body mass and BMI in children and youth from both sexes.**
***Subjects and methods*: The sample comprised 3311 girls and 3280 boys aged 7–17 years, participating in the study 'Healthy Growth in Cariri'. Socioeconomic status was defined according to school attendance: private and public. Centile curves for height, body mass and BMI were constructed using the LMS method.**
***Results*: Significant differences between children and adolescents from Cariri and those from other Brazilian regions and the CDC references were found for height and body mass. In girls from private schools, average differences in height compared to the CDC references ranged from 0.79–5.9 cm and in boys from 2.9–8.6 cm.**
***Conclusion*: Children from Cariri show a growth pattern in height, body mass and BMI that closely resembles the patterns observed in developed countries, but the absolute values in height and body mass are markedly lower than CDC references and growth references for other regions in Brazil.**

Keywords: Growth, populations, socioeconomic status, cultural

INTRODUCTION

Human growth and development are characterized by their extraordinary capacity for plasticity and population heterogeneity (Bogin 2001; Ulijaszek 2006). Both processes are end-points of exposures to different environmental agents, such as geoclimatic, socioeconomic and cultural, that shape the expression of individual genetic potential (Ulijaszek 2006; Alfaro et al. 2008). Growth patterns in different populations are the net results of interactions of genetic and environmental conditions. Eveleth and Tanner (1990) suggested that associations between socioeconomic status and ethnic background can thus distort the picture of social differences in growth in various ways. Higher socioeconomic status allows for better nutrition, healthcare, reduced physical labour for children and greater growth-promoting psychological stimulation from the parents (Bielicki 1986). Growth patterns can be used as proxies of health and well-being and reflect nutrition and living conditions (Molinari et al. 2004).

Growth references for children are among the most widely used instruments in public health and clinical medicine (Garza and De Onis 1999) as well as in physical education and paediatric sport science (Malina et al. 2004; Beunen and Malina 2008). Their value resides in helping to determine the degree to which physiological needs for growth and motor development process are being met during important periods of the growing years (De Onis 2009). The dynamics of growth require that suitable growth charts describing its pattern are made available at the population level. Many countries have developed their own growth standards, but this requires extensive and expensive studies. The World Health Organization has recommended the adoption of the US growth charts where no local standards exists, although it is evident that they do not mirror the growth patterns of distinct cultural and ethnic different populations.

Cariri is a developing region located in the northeast part of Brazil, having a low socioeconomic status when compared to the south, southeast and midwest regions. Furthermore, geoclimatic, socioeconomic wealth and cultural characteristics are very different. This region has a semi-arid climate with annual temperatures ranging between 19–35°C. The Cariri population was estimated at

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528 398 inhabitants and is divided into eight districts (IBGE 2009). Juazeiro do Norte is the most important city in the Cariri region. Its population has become quite heterogeneous due to the high rate of migration from other northeast states, motivated by religious reasons. This region has an economy mainly based in industries (small and medium size), commercial activity and especially religious tourism. Growth references will provide local authorities with information about the growth status of their children and adolescents, identify groups of children that have special needs and, furthermore, provide medical staff, other health workers, physical educators, sport scientists and trainers with tools to monitor the growth and motor development associations of their children and adolescents.

The Brazilian territory is large and has many socio-economic disparities clearly seen in different regions and states and reflected in diversified population characteristics. Although it has a population of ~ 193 million inhabitants (Brazilian Institute of Geography and Statistics (IBGE) 2009) the country has no national reference charts for somatic growth during the first 20 years of life.

Very few Brazilian studies have produced state or regional centile curves for growth. In the Northeast region, namely in Cariri, no reference values are available for height, body weight and body mass index. This paucity of studies poses difficulties when comparing results from different regions of the country. Despite this fact, in the present study the representative Brazilian cross-sectional studies were selected for comparisons according to their sample size and local relevance. In the study of Marcondes (1989) originated in St. André, São Paulo's Southeast region, 15 643 subjects of both sexes aged 0–20 years were sampled and local reference values for height and weight were produced. One of the main findings was that children from foreign immigrants were taller than those without a foreign origin in the family. Guedes and Guedes (1997) developed reference values for growth and motor performance in children and adolescents from Londrina, South region. The sample comprised 4289 subjects from both sexes, aged 7–17 years. When compared to studies from the South and Southeast, similar results were found for height, weight and BMI. On the other hand, children and youth from Londrina showed lower values for height, weight and estimated subcutaneous fat than North American children and youth. Amorim et al. (2009) conducted a study in the state of Paraná, southern region, using a sample of 13 216 children and youths of both sexes aged 10–18 years. The results showed a very similar pattern in height compared to the CDC reference (2000).

This study has three purposes: (1) to present reference values for height, body mass and body mass index (BMI) of children and adolescents from the Cariri region, Brazil; (2) to compare Cariri data with CDC 2000 reference (Kuczmarski et al. 2002) as well as the other growth values from different regions of Brazil; and (3) to identify the influence of socioeconomic differences of the Cariri sample on height, body mass and body mass index in children and youth of both sexes.

SUBJECTS AND METHODS

Sample

Data were collected from three main cities of the Cariri region: Juazeiro do Norte, Crato and Barbalha. The representative sample consisted of randomly selected students and comprises 6591 individuals, 3311 girls and 3280 boys, aged 7–17 years. Two distinct samples were simultaneously studied during the period of 2006–2009. The first sample came from a longitudinal study of four birth cohorts: 8 ($n = 146$), 10 ($n = 103$), 12 ($n = 133$) and 14 years ($n = 54$), who were followed for 3 consecutive years over 6-month intervals, resulting in 2616 observations in total. The second sample originated from a cross-sectional study for 3975 subjects. Both samples comprised healthy youths participating in the Healthy Growth in Cariri study (Table I). Socioeconomic status was defined according to the average family income collected from a questionnaire as well as from school attendance: private (high level) and public (low level). School attendance was used as an indicator of socio-economic status (SES).

All measurements were made by highly trained staff following the same procedures given by Claessens et al. (2008). Height was measured with a portable stadiometer (CARDIOMED® Welmy Model 220) and body mass was measured with a digital scale (TANITA® Model 683W). Body mass index was derived according to the formula: weight(kg)/height(m)^2. The 'Healthy Growth in Cariri' project was approved by the Ethics Research Committee of the Medical School of Juazeiro (FMJ – ERC n° 01/07).

Pilot study

A pilot study involving all variables of somatic growth of 'Healthy Growth in Cariri' was conducted in order to detect possible problems in the field data collection ($n = 26$). Data quality control was done using a reliability study where five children were randomly re-assessed each day of data collection, with a total of 377 children being re-assessed. The intra-class correlation coefficients were 0.95 for height and 0.99 for body mass. The technical error of measurement for height was 0.5 cm and 0.2 kg for body mass.

Table I. Sample size by age and sex.

Age (years)	Girls	Boys	Total
7	117	127	244
8	244	296	540
9	306	300	606
10	394	377	771
11	403	376	779
12	560	520	1080
13	454	414	868
14	411	426	837
15	230	223	453
16	132	148	280
17	60	73	133
Total	3311	3280	6591

Age classification in each group was as follows: for 7 + ages are between 7.00–7.99 and the same applies for all ages between 7–17 years.

Statistical analyses

Centile curves for height, body mass and body mass index were constructed separately for each sex using the LMS method (Cole et al. 1998; 2000). A Box-Cox power transformation was used to normalize the data at each age. Natural cubic splines with knots at each distinct age t were fitted by maximum penalized likelihood to create three smooth curves: $L(t)$ the Box-Cox power, $M(t)$ the median and $S(t)$ the coefficient of variation. Centile curves at age t were then obtained as:

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

where Z_α is the normal equivalent deviate for tail area α, and $C_{100\alpha}(t)$ is the centile corresponding to Z_α. Equivalent degrees of freedom (edf) for $L(t)$, $M(t)$ and $S(t)$ measure the complexity of each fitted curve. Q tests (Royston and Wright 2000; Pan and Cole 2004) were used to check the goodness of fit with the aid of deviance measure of penalized likelihood (Cole et al. 1998; Pan and Cole 2004; Pan et al. 2009). The LMS method was applied to generate growth references with the software LMSchartmaker Pro version 2.3 (Pan and Cole 2006). A Z-score for a given measurement and age in the reference range can be obtained by inverting the above equation.

In general, if the age interval between two measurements is less than 3 months we need to consider the correlation effects of the longitudinal data. Since the longitudinal measurements were collected in an age interval of ~6 months at a period of 8–16 years, the correlations between two measurements would have little effect on the construction of growth references with the LMS method. A similar procedure was used by WHO in which longitudinal data from 0–2 years was merged with cross-sectional data from 2–6 and then fitted from 0–5 years (Garza and De Onis 1999).

Comparisons between CDC (considered here as a reference in terms of population means) and the Cariri sample was made by using one sample t-test for each age and sex for height, body mass and BMI.

RESULTS

Table II shows the proportions of the data in the channels round the nine fitted centiles of 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 97th of height, weight and BMI. The proportions were compared to the expected values of the normal distribution in each centile, showing their closeness to the expected distribution for each of the three somatic characteristics, indicating a good fit. Similar proportions were found in the results for both public and private schools.

Figure 1 shows reference curves for height, body mass and body mass index for children of 7–17 years of age of both sexes. The 3rd, 10th, 25th, 50th, 75th, 90th and 97th centiles are provided and numerical values for the 3rd, 50th and 97th centiles are available in the Appendix (online version only). These growth curves show similar shapes to those observed in other populations. Until 10 years boys are slightly taller than girls, however, from 11–13 years of age, girls' stature is slightly taller than boys; from 14 years onward boys' height exceeds that of girls. Median values (50th centile) for height in males increase almost linearly from 7–11 years, at which time the curve shows a linear increases up to 14 years, followed by lower rates until 17 years, the rate being ~5 cm/year. In girls, there is a linear increase, the rate being ~6 cm/year until age 12, followed by smaller rates until age 16, when the 50th centile stabilizes. At 17 years of age the 50th centile for height is 156.4 cm for girls and 167.4 cm for boys, a difference of 11 cm.

Table II. Distribution of Z-scores of height, body mass and BMI for the Cariri sample compared to expectation assuming normality—area between adjacent centiles (%).

Centile	Expected (%)	Height		Body mass		BMI	
		Girls	Boys	Girls	Boys	Girls	Boys
3	3	2.6	2.9	2.8	3.0	2.5	3.0
5	2	2.5	2.2	2.2	1.8	1.8	1.9
10	5	4.9	4.3	4.5	5.1	5.0	3.7
25	15	15.4	14.6	14.8	14.1	15.9	15.7
50	25	25.2	26.3	26.6	26.6	25.6	28.1
75	25	23.8	25.3	24.4	24.8	24.8	23.0
90	15	15.1	14.7	14.9	13.8	13.8	12.5
95	5	5.6	4.1	4.3	4.7	4.7	5.5
97	2	1.9	2.4	2.0	2.0	2.4	2.1

In boys, the 50th centile for body mass shows a curvilinear increase. From 12–16 years a more pronounced increase is observed of ~4.5–5.0 kg/year, thereafter growth rates slow down and a maximum is reached at ~17 years (58.0 kg). In girls, the body mass growth curve presents a similar increase and shape. From 11–15 years gains approximate 4.0–4.5 kg/year and the maximum weight is reached at 17 years (51.0 kg). At all ages boys are heavier than girls, with the exception of 11, 12 and 13 years, when girls are slightly heavier.

The curves for body mass index increase slightly with age in both sexes. Girls from private school have higher values (50th) at 14 years and from the age of 15 years onwards girls from public schools show slightly higher values up to 17 years. Similar results are seen in boys from private school at all ages.

DISCUSSION

This manuscript provides growth references for height, body mass and body mass index for children and youth from the Cariri region, Brazil and compares them with international references (CDC 2000) as a function of socioeconomic status. Differences between regional studies should be interpreted with caution given that Brazilian regions have distinct historical and cultural characteristics, demographics and socioeconomic disparities. The regions used for comparisons (St. André, Paraná and Londrina) have high human developmental indexes (HDI): 0.835, 0.820 and 0.824, respectively (UNDP 2009). The Cariri region has a low level of development. Inequality in pay, very low level of industry and technological concentration and climatic conditions related to lack of rain are the main problems.

The studied cities (Juazeiro do Norte, Crato and Barbalha) are classified in HDI as low-to-medium (0.697, 0.716 and 0.687, respectively) (UNDP 2009). Furthermore, it is important to realize that socioeconomic status (private and public school) was determined according to the socioeconomic disparity between these groups that favours the private school children. Children from the Cariri region do not have equal access to healthcare and do not live in an optimal environment.

Cariri children are markedly smaller than the CDC references and are also smaller than children from other regions of Brazil. Providing growth references for the Cariri represents an important step in describing and adequately monitoring growth, especially its dynamics. It is important to note, however, that this study is an observational one, as are all studies concerning the monitoring of human growth across the globe. Analysis of growth patterns in function of socioeconomic status has a relatively long tradition in public health and auxology (Bielicki 1986; Eveleth and Tanner 1990; Tanner 1990). Causal interpretations of differences in growth of children from the Cariri and the CDC references or even other regions of Brazil cannot be made. On the other hand, it will be argued that these differences most likely reflect differences in social gradients within the sample, emigration, population admixture and economic factors.

For height, in all comparisons, the Cariri children consistently showed the lowest values in both sexes at all ages. There is a significant difference in average height, between the CDC references and the Cariri reference at all ages in both sexes (Table III). At 17 years, girls and boys from Cariri are 'shorter' than Americans by ~7.0 and 7.6 cm, respectively. Similar significant average differences are found between SES-categories. Boys and girls from private school are significantly taller at almost all ages, At 17 years, this difference is ~7.8 and 5.8 cm, respectively. Compared to St. André the differences in girls vary between 3.1–5.3 cm and in boys between 2.7–5.6 cm. Compared to Paraná, differences were found at almost all ages, the differences varying between 4.6–6.7 cm in girls and 5.5–6.9 cm in boys. And, finally, compared to Londrina, girls are between 2.2–4.2 cm shorter and boys are between 2.2–4.0 cm shorter. According to Stinson (1985), boys show

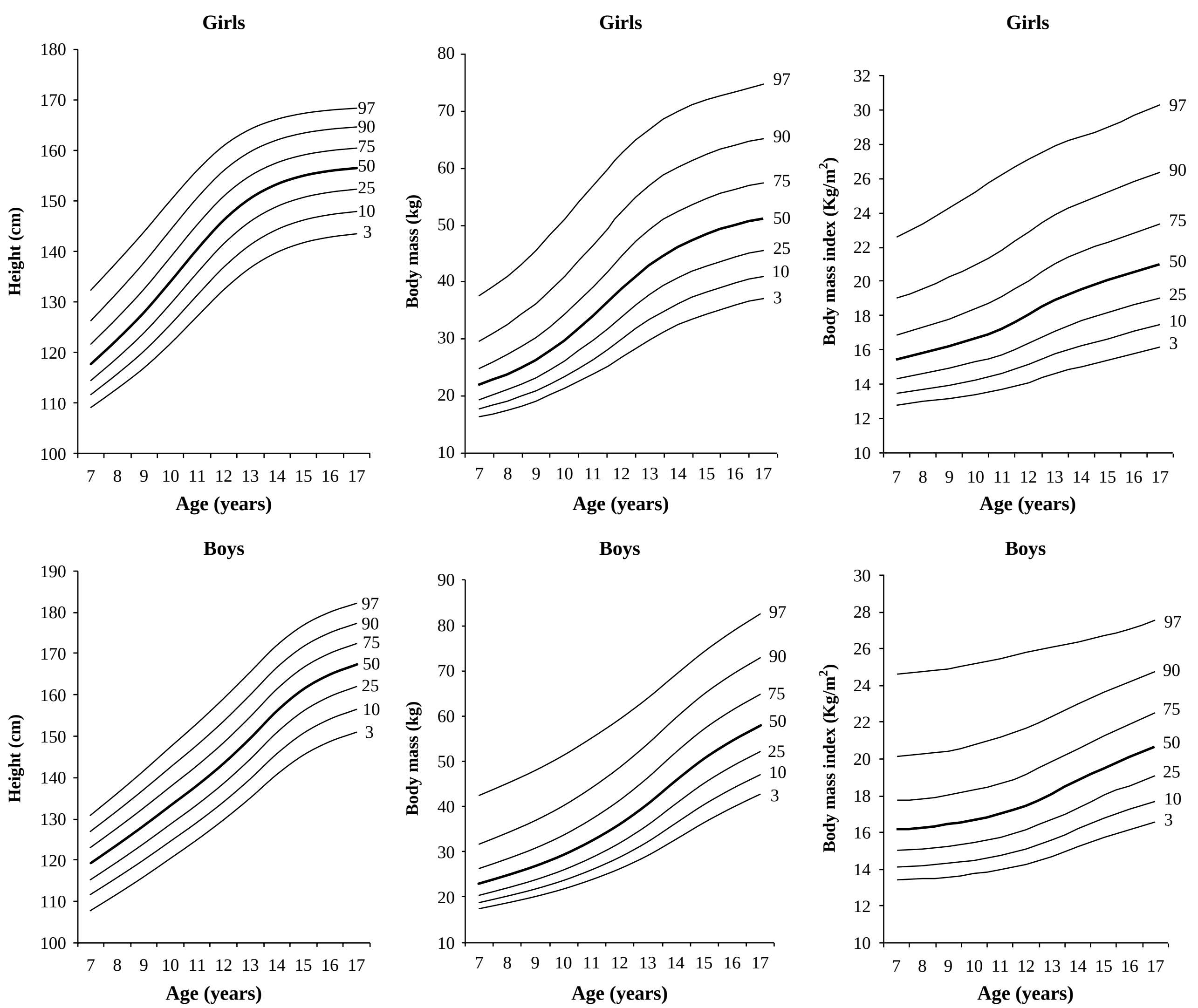

Figure 1. Cariri charts for height, body mass and body mass index for girls and boys.

Table III. Mean values and differences for age groups, sex and SES by height, body mass and BMI.

	Girls								Boys							
Age	Cariri *M* ± SD	CDC *M*	Mean difference	*p*	Public *M* ± SD	Private M ± SD	Mean difference	*p*	Cariri M ± SD	CDC *M*	Mean difference	*p*	Public M ± SD	Private M ± SD	Mean difference	*p*
Height (cm)																
7	121.0 ± 6.1	123.6	−2.6	<0.001	119.4 ± 4.9	125.6 ± 6.4	−6.2	<0.001	121.3 ± 5.9	125.0	−3.7	<0.001	120.5 ± 5.5	123.0 ± 6.6	−2.4	0.035
8	125.5 ± 6.8	130.3	−4.8	<0.001	125.0 ± 7.1	126.7 ± 6.0	−1.7	0.068	126.5 ± 6.5	130.2	−3.7	<0.001	125.5 ± 6.8	128.7 ± 4.8	−3.2	<0.001
9	131.1 ± 7.5	135.5	−4.3	<0.001	130.3 ± 7.6	133.4 ± 6.8	−3.1	0.001	130.7 ± 7.2	135.9	−5.2	<0.001	129.4 ± 7.2	133.9 ± 6.1	−4.5	<0.001
10	138.0 ± 7.3	141.2	−3.1	<0.001	137.2 ± 6.9	140.5 ± 7.9	−3.3	<0.001	135.8 ± 7.0	141.2	−5.4	<0.001	134.5 ± 6.8	139.6 ± 6.2	−5.1	<0.001
11	143.4 ± 7.7	148.4	−4.9	<0.001	143.0 ± 7.3	145.7 ± 9.6	−2.7	0.059	141.3 ± 6.7	145.9	−4.6	<0.001	140.8 ± 6.6	144.9 ± 6.9	−4.1	0.001
12	148.9 ± 7.4	154.9	−6.0	<0.001	148.4 ± 7.3	152.2 ± 6.7	−3.8	<0.001	146.7 ± 7.8	152.6	−5.9	<0.001	146.2 ± 7.6	149.2 ± 8.4	−3.0	0.004
13	151.6 ± 7.1	159.1	−7.5	<0.001	151.5 ± 6.7	152.8 ± 6.8	−1.3	0.239	152.9 ± 8.7	159.9	−7.0	<0.001	152.5 ± 8.9	154.8 ± 7.1	−2.3	0.028
14	154.4 ± 6.2	161.3	−7.0	<0.001	153.8 ± 6.1	156.8 ± 6.4	−2.9	0.001	158.2 ± 8.1	167.3	−9.1	<0.001	157.4 ± 8.1	162.0 ± 7.2	−4.6	<0.001
15	155.3 ± 6.3	163.1	−7.8	<0.001	154.8 ± 6.2	158.5 ± 6.6	−3.6	0.013	163.9 ± 8.0	172.0	−8.0	<0.001	163.5 ± 7.7	166.0 ± 9.2	−2.5	0.015
16	155.2 ± 6.4	162.7	−7.5	<0.001	154.7 ± 6.1	160.2 ± 7.1	−5.5	0.029	165.5 ± 6.7	174.5	−9.0	<0.001	165.1 ± 6.7	169.5 ± 5.6	−4.4	0.019
17	156.3 ± 6.1	163.3	−7.0	<0.001	155.9 ± 6.0	163.8 ± 1.7	−7.8	0.002	168.3 ± 7.5	175.9	−7.6	<0.001	162.7 ± 2.5	168.5 ± 7.5	−5.8	<0.001
Body mass (kg)																
7	23.9 ± 5.2	23.6	0.34	0.479	22.7 ± 4.3	27.18 ± 6.2	−4.45	0.001	24.9 ± 5.6	24.5	0.30	0.511	23.9 ± 5.1	27.0 ± 6.2	−3.13	0.004
8	25.9 ± 6.3	23.8	−0.78	0.053	25.9 ± 6.7	26.1 ± 5.1	−0.19	0.812	27.1 ± 6.6	26.7	0.41	0.286	25.6 ± 5.8	30.5 ± 7.1	−4.94	<0.001
9	29.5 ± 7.3	30.1	−0.57	0.170	28.5 ± 6.3	31.9 ± 8.8	−3.38	0.001	29.8 ± 7.8	30.1	−0.20	0.643	27.9 ± 6.7	34.9 ± 8.2	−7.08	<0.001
10	33.8 ± 8.4	33.6	0.23	0.594	32.6 ± 7.3	37.3 ± 10.4	−4.72	<0.001	32.5 ± 7.7	33.5	−1.04	0.009	30.9 ± 6.7	37.5 ± 8.6	−6.63	<0.001
11	37.8 ± 9.1	39.0	−1.22	0.007	37.1 ± 8.6	42.1 ± 10.9	−4.96	0.003	36.4 ± 8.1	37.0	−0.61	0.193	35.8 ± 7.7	41.1 ± 9.7	−5.36	0.002
12	42.6 ± 9.6	45.0	−2.41	<0.001	41.8 ± 9.1	47.8 ± 10.8	−5.98	<0.001	39.4 ± 8.4	41.7	−2.33	<0.001	38.5 ± 7.8	44.5 ± 10.1	−5.96	<0.001
13	45.7 ± 9.3	49.3	−3.64	<0.001	45.5 ± 9.1	47.5 ± 10.7	−2.05	0.218	45.1 ± 10.1	48.1	−3.02	<0.001	44.7 ± 10.3	47.8 ± 8.2	−3.19	0.009
14	48.4 ± 9.1	52.5	−4.08	<0.001	48.0 ± 9.0	49.9 ± 9.8	−1.84	0.146	49.1 ± 9.0	55.2	−6.93	<0.001	48.2 ± 9.0	53.3 ± 7.9	−5.09	<0.001
15	50.1 ± 8.7	54.5	−4.44	<0.001	50.1 ± 8.6	50.1 ± 9.5	0.01	0.992	54.1 ± 9.4	59.5	−5.41	<0.001	53.6 ± 9.2	57.4 ± 10.0	−3.79	0.052
16	51.4 ± 9.4	55.2	−3.77	<0.001	51.3 ± 9.6	52.2 ± 7.0	−0.82	0.724	55.8 ± 8.2	64.4	−8.56	<0.001	55.2 ± 8.1	62.3 ± 7.1	−7.09	0.004
17	51.8 ± 10.1	56.8	−4.96	0.002	51.9 ± 10.4	50.6 ± 5.3	1.37	0.780	62.4 ± 12.8	65.9	−3.57	0.020	62.7 ± 12.8	51.2 ± 1.6	11.53	<0.001
Body Mass Index (kg/m^2)																
7	16.2 ± 2.5	15.4	0.84	<0.001	15.9 ± 2.2	17.1 ± 3.1	−1.26	0.039	16.8 ± 2.6	15.6	1.15	<0.001	16.4 ± 2.4	17.7 ± 2.8	−1.35	0.007
8	16.3 ± 2.4	15.8	0.55	<0.001	16.4 ± 2.5	16.2 ± 2.3	0.21	0.523	16.7 ± 2.6	15.9	0.87	<0.001	16.1 ± 2.1	18.3 ± 3.2	−2.18	<0.001
9	16.9 ± 2.9	16.4	0.51	0.002	16.6 ± 2.5	17.7 ± 3.5	0.41	0.011	17.3 ± 3.1	16.2	1.05	<0.001	16.5 ± 2.5	19.3 ± 3.5	−2.83	<0.001
10	17.6 ± 3.3	16.9	0.75	<0.001	17.2 ± 2.9	18.7 ± 4.0	−1.46	0.001	17.4 ± 2.9	16.9	0.50	0.001	16.9 ± 2.6	19.1 ± 3.4	−2.14	<0.001
11	18.3 ± 3.4	18.1	0.15	0.371	18.1 ± 3.3	19.7 ± 3.9	−1.59	0.008	18.1 ± 3.0	17.3	0.79	<0.001	17.9 ± 2.9	19.4 ± 3.3	−1.46	0.011
12	19.1 ± 3.4	18.6	0.47	0.001	18.8 ± 3.1	20.5 ± 4.1	−1.68	0.001	18.2 ± 2.7	17.9	0.32	0.007	17.9 ± 2.6	19.8 ± 3.0	−1.87	<0.001
13	19.8 ± 3.3	19.3	0.48	0.002	19.7 ± 3.3	20.2 ± 3.5	−0.45	0.404	19.1 ± 3.1	18.7	0.49	0.001	19.0 ± 3.1	19.7 ± 2.6	−0.85	0.024
14	20.3 ± 3.3	20.1	0.12	0.434	20.2 ± 3.3	20.3 ± 3.5	−0.01	0.990	19.5 ± 2.6	19.5	−0.02	0.861	19.3 ± 2.7	20.3 ± 2.3	−0.91	0.002
15	20.8 ± 3.4	20.2	0.54	0.016	20.9 ± 3.4	20.0 ± 3.6	0.90	0.235	20.1 ± 2.6	20.1	−0.05	0.739	20.0 ± 2.7	20.7 ± 2.5	−0.75	0.119
16	21.3 ± 3.6	20.8	0.47	0.131	21.4 ± 3.7	20.2 ± 1.8	1.17	0.008	20.3 ± 2.5	21.3	−0.92	<0.001	20.2 ± 2.4	21.7 ± 2.7	−1.51	0.070
17	21.2 ± 3.7	21.4	−0.21	0.698	21.3 ± 3.7	18.9 ± 2.3	2.44	0.359	21.9 ± 3.6	21.2	0.77	0.007	22.0 ± 3.6	19.4 ± 0.07	2.64	<0.001

more sensitivity to adverse environmental conditions. The lower values of attained height in children caused by poor socioeconomic conditions may induce an unhealthy adulthood (Bogin 2001).

Body mass results from the Cariri region showed average differences similar to those observed for height. Girls differ significantly only until 12 years, while boys from private school are heavier until 16 years old. Until 11 years the differences in body mass between youngsters from Cariri and CDC reference values are limited. From 12 years onwards, Americans are significantly heavier. At 17 years, the average difference between the CDC reference and Cariri girls is − 5.0 kg and in boys − 3.6 kg (Table III). When compared to St. André, the differences vary between 1.8–3.5 kg for girls and between 1.5–4.7 kg for boys. Similar differences were found when comparing Cariri youngsters with those from Londrina; for girls differences vary between 0.2–2.0 kg and for boys between 0.1–2.3 kg.

BMI results showed smaller diferences among samples. Differences were minimized as a function of the short stature of the Cariri sample. Higher values are found in boys and girls from private schools until 13 and 14 years. When compared to CDC references the BMI at 17 years is higher for the CDC reference. Schoolchildren of lower socioeconomic status (public school) show low values of BMI at almost all ages and for both sexes compared to those from higher SES-levels (private schools). In boys, significant differences between public and private schools are seen at all ages with the exception of 15 and 16 years (Table III). Girls from Cariri show higher values (between 0.1–1.46 kg/m^2) than those from Londrina at almost all ages. Boys from Cariri, at 11 years of age, show a slightly higher BMI (0.2–0.99 kg/m^2). At 17 years, however, boys from Londrina have a higher BMI (0.6 kg/m^2). Nevertheless, Londrina and the CDC reference show slightly higher values in both sexes at 17 years of age.

The Cariri region, specifically the city of Juazeiro do Norte, has a very heterogeneous population composed of a mixture of indigenous communities called *Kariris* (Brigido 2007) and immigrants of poor socioeconomic status from other northeastern states. People immigrated because of a religious phenomena that attracts thousands of people every year to visit the city and often stay to live there (Figueiredo 2002). Furthermore, it has been shown that Indian children from northern Brazil were smaller compared to the reference populations (Niswander et al. 1967; Eveleth et al. 1974; Santos 1993). The present sample of Cariri children is composed of descendents from indigenous ancestors, northeastern immigrants from poor regions and their admixture. Consequently, the composition of the Cariri population does not permit us to make generalizations about the impact of Indian descent. It would have been of interest to study the growth and maturity over time of children from this region and at the same time to monitor the genetic diversity and socioeconomic conditions. Such data are lacking. However, it is clear that Cariri children are very small.

A social gradient affects growth and maturational status and rates within and between societies which differ in multiple facets of their socioeconomic situation (Bielicki 1986). In Cariri, a social gradient was also operating in body size between children and youth from public and private school, favouring the latter better-off group. Significant differences in height and BMI between regions of the same country are well documented (Bielicki 1986; Eveleth and Tanner 1990; Beunen et al. 2006). Even in a developed country such as Italy, marked differences exist between regions that are more or less economically privileged (Cacciari et al. 2002).

Comparison of the height and weight of children from different regions of Brazil showed small height and body mass in Cariri children. Because of the time lag between Brazilian studies conducted earlier (13 years for Londrina and almost 30 years for Santo André) it is not easy to interpret these differences. In the past, these discrepancies were probably greater, because socio-economic and developmental history promoted different rates of economic growth between regions of the country. The Cariri region is still, at present, the least favoured (see HDI-indexes of the different regions, UNDP 2009), which is most likely one of the major reasons for the differences identified in this study.

Large disparities in height and body weight were found in schoolchildren from the Cariri region when compared to samples from different regions from Brazil as well as the CDC references. Socioeconomic status may explain, in part, these discrepancies because of systematic pronounced differences in public school children of both sexes at all ages. However, the growth patterns of the Cariri sample seem to be the result of a combination of several factors including genetic, socioeconomic, geographic and cultural factors and most likely the interaction between these indicators.

Taken together, the results of this study have clear implications in human biology terms. First, even after several centuries of immigration, there is still a major difference between the growth of the ancestors of immigrants; the population in this area is very diverse, which is a good natural environment to document variability. Centile charts will provide paediatricians, nutritionists and educationists with important information to monitor growth status and changes in children and adolescents using cultural and regional specific charts. Such charts were not available before now. Furthermore, these are the most recent growth charts for the north–northeast regions of Brazil. Secondly, the charts describe children as they are and their growth status reflects the complexities of genetic and environmental influences (Eveleth and Tanner 1990). As such, they show the influence of an adverse socioeconomic gradient seen in heights and weights of children from private and public schools, as well as their difference from more healthy Brazilian regions and CDC references. In addition, the charts will permit identification of individuals or sub-groups at risk of disease and delayed growth.

The effort made to provide accurate and relevant information in the health area and motor development associations is important to be mentioned. On the other hand, some limitations of the present study need to be acknowledged: (1) since no previous information about schoolchildren from the Cariri is available, we had great difficulty in assessing local growth trends in paediatric terms, which may reflect changes in health and developmental conditions; (2) socioeconomic discrepancies, geographic and cultural differences, as well as the time lags between studies used in the comparisons limit interpretation of the observed differences. Despite these limitations, the present study has some strengths: (1) the sample size and its representativeness in terms of age groups, sex and SES; (2) the use of adequate statistical analysis and graphical representations given the complexity of the data structure; (3) the relevance of reference height, weight and BMI values for children and adolescents of a region where no such information is available; and (4) the research design and the presentation of the information. This last issue has to be regarded as an important tool for paediatricians, physical educators and other Brazilian researchers.

In conclusion, children from Cariri show a growth pattern in height, body mass and BMI that resembles closely the patterns observed in developed countries, but the absolute values in height and body mass are markedly lower than CDC references and growth references for other regions in Brazil. The observed differences between socioeconomic levels provide evidence that part of these differences are due to the lower socioeconomic conditions that children in Cariri experience during their growing years.

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