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ORIGINAL ARTICLE

Physical growth of schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil: Comparison with the CDC-2000 reference using the *LMS* method

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Abstract
Objective: To analyse the physical growth of a representative school population sample from the Jequitinhonha Valley, Minas Gerais, Brazil, in comparison with the reference proposed by the Centre for Disease Control and Prevention (CDC-2000).
Methods: The sample was composed of 5100 individuals (2730 girls and 2370 boys), aged 6–18 years. Body weight-for-age and height-for-age percentiles were obtained using the *LMS* method. Statistical and graphical comparisons were made with the corresponding percentiles of the CDC-2000 reference, estimated using the same method.
Results: Overall, the calculated values of the *L* (asymmetry) and the *S* (variability) parameters were quite similar to the CDC-2000 reference values. However, *M* (median) was substantially different from the reference used in the study, mainly in schoolchildren over 12–13 years of age of both genders. The magnitude of the deficits of height-for-age and body weight-for-age observed in the schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil, varied from 4 to 6 cm and from 3 to 6 kg, respectively.
Conclusion: The body weight-for-age and height-for-age percentiles of schoolchildren population in the Jequitinhonha Valley, Minas Gerais, Brazil differed substantially from those referenced.

Keywords: *Anthropometry, body mass, stature, child, adolescent*

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Introduction

Although growth is genetically determined, it is sensitive to environmental contingencies, such as economic, geo-climatic, social and cultural factors, which may alter the expression of genetic potential with higher or lesser intensity (Palmert and Hirschhorn 2003; Silventoinen 2003). This complex biological and environmental interaction leads to an extraordinary plasticity of human physical growth and to intra- and inter-population heterogeneity. In fact, human physical growth is an important attribute to use in analyses of the health condition and quality of life in a population (WHO 1995). Systematic monitoring programmes of physical growth are commonly accepted as an important indicator of the quality of life in a specific young population, or of the extent of the existing distortions in different subgroups from the same population (Onis et al. 2007).

Previous studies involving young populations from different regions of Brazil (Guedes and Guedes 2002), and other countries (Onis et al. 2004), have highlighted the physical growth variability within and between populations. Interpretation of the physical growth of individuals or a population requires the use of a reference system. Literature has systematically suggested the use of a single reference, seen as universal, based on gathered information of young populations from developed countries where, supposedly, the best environmental conditions for ideal physical growth exist (WHO 1995).

This suggestion is based on the assumption that physical growth follows a unique pattern highly resistant to external influences, but which could be changed if negative conditions persist for long periods (Gafni and Baron 2000). Therefore, differences observed in the physical growth indicators of young people from different regions of the world could be explained by differences in life conditions (nutrition, primary health care, etc.).

In this context, the reference system originally proposed in the 1970s by the National Centre for Health Statistics (NCHS), involving a representative sample of the young North American population (Hamill et al. 1979), and recently adjusted and updated by the Centre for Disease Control and Prevention (CDC) (Kuczmarski et al. 2000), is the suggested instrument for monitoring physical growth throughout the world and is also widely accepted by human growth researchers (Hasan et al. 2001; Ogden et al. 2002; Alfaro et al. 2004; Hakeem et al. 2004; Marwaha et al. 2006; Ayatollahi and Pourahmad 2006; Neyzi et al. 2006; Davies 2007).

The purpose of this study was to describe the parameters associated with physical growth according to age and gender in a representative sample of schoolchildren, from the Jequitinhonha Valley in Minas Gerais, Brazil, comparing them with the parameters published by the Centre for Disease Control and Prevention – CDC-2000.

Methodology

This study is part of a cross-sectional survey, involving anthropometric and socio-demographic indicators of the schoolchildren population from the Jequitinhonha Valley, Minas Gerais, Brazil. The data were gathered between August and November 2007. The research was approved by the Committee of Ethics in Research of the State University of Montes Claros – UNIMONTES (Protocol no. 529/2006).

The Jequitinhonha Valley is known as one of the poorest regions in Brazil. It is located in the northeast of Minas Gerais state, where cities have the worst socio-economic index in Brazil. Concerning the Human Development Index (HDI), 58.8% of the State's cities show values between 0.57 and 0.65, which represent a variation from 74% to 85% from the national average (UNDP 2007). The infant mortality rate of 51% of these cities is

40 deaths/1.000 live births. Figure 1 indicates the geographical location of the Jequitinhonha Valley, Minas Gerais, Brazil.

Sample

The reference population includes schoolchildren of both genders aged between 6 and 18 years, who were enrolled in the 2007 school year. According to information given by the Sector of Statistics of the State of Minas Gerais' Secretariat of Education, at the beginning of the 2007 school year there were 175 826 schoolchildren enrolled in 5022 primary classes and 32 245 in secondary classes, which made up a total of 208 071 schoolchildren.

The selection of the sample followed a certain sequence of steps, in an attempt to obtain a stratified probabilistic sample which would actually represent the considered schoolchildren population. Firstly, all of the Jequitinhonha Valley's schoolchildren were classified separately by gender and chronological age, according to the school they were enrolled in. Secondly, the population of schoolchildren was stratified by the five administrative districts of the Jequitinhonha Valley.

It was decided to include 60 schools that were randomly selected from groups of schools gathered in the same section of an administrative micro region, each section having 16 schools.

The sample size was established assuming a 95% confidence interval, a 3% sampling error and an increment of 10% in order to cover possible losses when gathering the data. Since a cluster sampling selection was used, 1.5 of design effect was obtained. The sample size calculated was 4800 subjects. However, the sample used was 5100 subjects (2730 girls and 2370 boys).

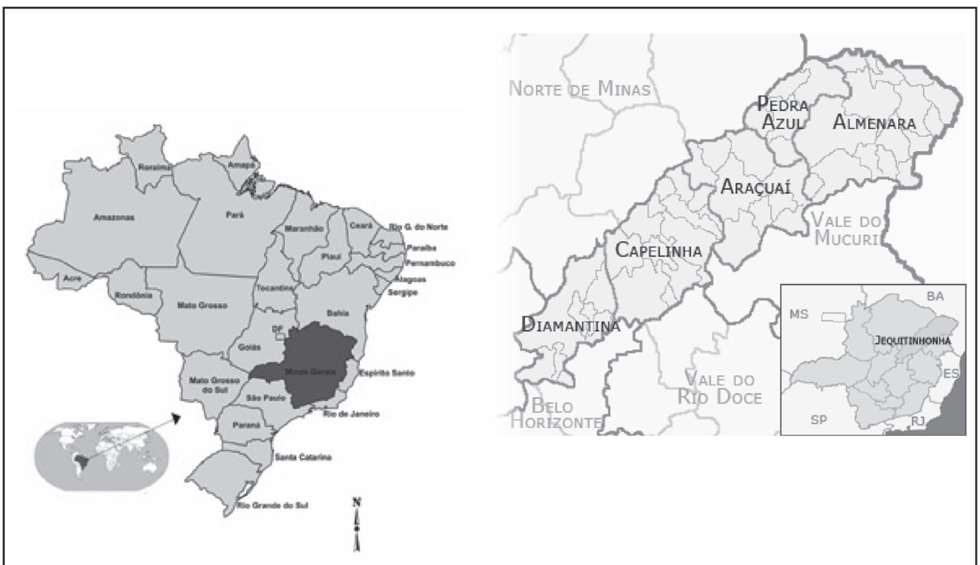

Figure 1. Geographical location of the Valley of Jequitinhonha, Minas Gerais, Brazil.

The criteria for excluding subjects were: (a) refusal to participate in the study; (b) not being authorized by the parents or tutors; (c) not going to class on the day scheduled for collecting the data; and (d) any physical incapacity.

Collecting data

Age was established in years and months. Height and body weight were measured according to standardized procedures (WHO 1995). Measurements were taken by three anthropometries. Technical error varied between 20 and 50 g for body weight and between 2 and 5 mm for height.

Statistical analyses

The *LMS* parameters (Lambda for the skew, Mu for the median, and Sigma for the generalized coefficient of variation) were obtained using the method proposed by Cole et al. (1998). This method takes note of any departures from normality of the growth reference by inclusion of the *L* parameter. The *LMS* parameters were calculated for each gender for each age segment of 3 months.

From the *L*, *M* and *S* values for body weight and height the percentiles of weight-for-age and of height-for-age were calculated according to the mathematical model (Cole 1990):

$$C = M\,(1 + LSZ)^{1/L}$$

where *L*, *M* and *S* are values of asymmetry, median and variability calculated for each age segment and gender, and *Z* represents the value of score *z* corresponding to the selected percentile. In this case, we chose to consider the percentiles traditionally used in studies of physical growth and considered in international references (P3, P10, P25, P50, P75, P90 and P97).

For each age segment and gender, the calculated percentiles equivalent to weight-for-age and height-for-age were compared with the corresponding values of the CDC-2000 reference (Kuczmarski et al. 2000), also established according to the *LMS* method, according to the fraction: 100 log(percentile of reference/calculated percentile). However, the results were gathered in three age groups: (1) from 6 to 9.5 years old; (2) from 10 to 14.5 years old; and (3) from 15 to 18 years old. The average in each age group and gender was used. All data analysis was carried in Stata 9.2 (Stata Corp. College Station, TX, USA).

Results

Tables I and II present the parameters *L*, *M* and *S* for body weight-for-age and for height-for-age at/with 6 months intervals for girls and boys, respectively.

In Figures 2 and 3 the *L*, *M* and *S* curves of body weight-for-age and height-for-age are compared with the CDC-2000 reference. Overall, noticeable similarities between the curves can be observed. However, in the *M* curve, the observed differences in both genders are quite evident.

The comparison results of the percentiles body weight-for-age and height-for-age with the CDC-2000 reference can be observed in Table III. The discrepancy results between the percentiles of the present study, and the percentiles of CDC-2000 were positive when the reference values were superior to the calculated ones and otherwise negative. In the first segment of age the differences fluctuated between 0.02 and 3.43. Highest positive values

Table I. Values of the *L*, *M* and *S* parameters, for body weight-for-age and height-for-age of the schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil 2007 – Girls.

Age	Body weight-for-age			Height-for-age		
(years. months)	*L*	*M*	*S*	*L*	*M*	*S*
6.0	−1.345	21.15	0.158	−0.241	117.84	0.047
6.6	−1.312	21.98	0.163	−0.235	119.41	0.048
7.0	−1.282	22.87	0.168	−0.222	121.37	0.047
7.6	−1.240	23.31	0.172	−0.177	123.91	0.047
8.0	−1.160	24.51	0.176	−0.113	126.81	0.047
8.6	−1.104	25.99	0.187	−0.008	128.93	0.048
9.0	−1.052	27.34	0.190	0.065	131.25	0.049
9.6	−0.998	29.57	0.198	0.185	134.25	0.049
10.0	−0.947	30.96	0.205	0.274	137.70	0.050
10.6	−0.881	33.97	0.210	0.435	141.41	0.051
11.0	−0.847	35.97	0.213	0.650	146.78	0.049
11.6	−0.840	39.08	0.214	0.847	150.45	0.048
12.0	−0.836	41.11	0.212	1.097	151.13	0.047
12.6	−0.847	43.01	0.206	1.197	152.63	0.046
13.0	−0.881	45.26	0.201	1.212	154.87	0.045
13.6	−0.942	46.94	0.191	1.173	156.26	0.044
14.0	−1.026	48.23	0.187	1.06	157.12	0.043
14.6	−1.143	48.59	0.181	0.975	157.19	0.042
15.0	−1.266	49.16	0.180	0.955	157.23	0.042
15.6	−1.379	50.24	0.173	0.953	157.27	0.041
16.0	−1.480	51.72	0.171	0.957	157.29	0.040
16.6	−1.620	51.96	0.164	0.947	157.34	0.040
17.0	−1.706	52.28	0.163	0.957	158.45	0.041
17.6	−1.788	52.98	0.162	0.984	158.57	0.041
18.0	−1.806	53.84	0.161	1.005	158.65	0.041

were observed in the percentiles of body weight-for-age, in boys between 15 and 18 years of age. In percentiles for height-for-age, the difference increased proportionally with age, in both girls and boys, reaching the highest discrepancies at 15–18 years old.

Discussion

When growth curves are generated from *LMS* parameters the distribution is mathematically captured (Cole 1989). The *LMS* parameters can then be used to generate a growth chart. This process of generating a growth reference decreases the influence of minor errors originated during the sampling and measurement of the subjects and the abnormality of the distribution (Mei et al. 1998).

Comparison of the *L* curves between this study and the CDC-2000 references, showed large similarities. The body weight-for-age *L* curves always had negative values for both genders, suggesting an increase of positive skew distribution which slowly decreased with age, reaching an inflexion point which tended to show once again more accentuated asymmetries, mainly in girls. In schoolchildren from Jequitinhonha, Minas Gerais, Brazil, the mean *L* values was close to −1.10 for both genders; however in girls the highest asymmetry occurred at the age of 16 years, with a mean *L* value of −1.68; whilst in boys this phenomenon was observed before the expected age of peak of biological maturation, between the 6 and 11 years of age, with a medium value of *L* equal to −1.28.

Table II. Values of the *L*, *M* and *S* parameters, for body weight-for-age and height-for-age of the schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil 2007 – Boys.

Age (years. months)	Body weight-for-age			Height-for-age		
	L	*M*	*S*	*L*	*M*	*S*
6.0	–1.421	21.64	0.157	0.914	117.08	0.045
6.6	–1.404	22.31	0.161	0.876	119.30	0.045
7.0	–1.394	22.95	0.163	0.802	122.11	0.046
7.6	–1.391	23.97	0.164	0.679	124.92	0.047
8.0	–1.389	24.82	0.166	0.557	126.34	0.047
8.6	–1.366	26.87	0.167	0.519	129.75	0.048
9.0	–1.351	28.04	0.170	0.501	132.09	0.048
9.6	–1.292	29.03	0.173	0.496	134.20	0.049
10.0	–1.220	29.75	0.194	0.489	136.36	0.049
10.6	–1.150	32.17	0.197	0.481	137.86	0.049
11.0	–1.113	34.09	0.205	0.478	143.58	0.049
11.6	–1.016	36.68	0.208	0.421	146.31	0.049
12.0	–0.882	38.22	0.215	0.448	147.94	0.050
12.6	–0.831	42.23	0.217	0.595	151.12	0.050
13.0	–0.775	43.97	0.217	0.887	154.35	0.052
13.6	–0.673	46.83	0.214	1.283	157.44	0.053
14.0	–0.616	48.15	0.206	1.642	161.10	0.051
14.6	–0.611	53.18	0.205	2.117	164.55	0.050
15.0	–0.676	56.07	0.197	2.243	167.83	0.049
15.6	–0.736	57.13	0.188	2.302	169.52	0.048
16.0	–0.824	57.82	0.183	2.116	170.38	0.047
16.6	–0.902	58.14	0.180	1.900	170.51	0.046
17.0	–0.978	58.34	0.177	1.673	170.92	0.046
17.6	–1.081	59.58	0.168	1.463	170.98	0.045
18.0	–1.100	61.86	0.167	1.333	171.03	0.044

The *L* parameter for height-for-age in girls had a progressive increase of asymmetry up to the age of 13, when a slight decline was detected and then a stable value until the age of 18 years. In boys, between the ages of 6–13 years there was a tendency for the *L* parameter value to remain stable, then an abrupt rise up until they were 16 years of age, and later a decrease of similar intensity.

The *L* curves drawn from the data of this study were very similar to curves presented by the CDC-2000 reference. According to Cole (1989), occurrence of the same *L* curve pattern in different populations is a proof that the variations in asymmetry are genuine and not a consequence of technical artifice (sample or procedure).

The *S* curves of body weight-for-age and height-for-age drawn from the data taken from the schoolchildren from Jequitinhonha, Minas Gerais, Brazil, were similar to the curves that represent the CDC-2000. Besides, the dimensions of the *S* values can be considered of low magnitude and considerably higher for the measurements associated with body weight-for-age than for the measurements related to height-for-age. The *S* curves for body weight-for-age showed a peak value close to 22% for each gender, which coincides with the expected beginning of puberty, earlier in girls than in boys, but longer in boys.

The *M* curves for body weight-for-age and height-for-age drawn from the data of the present study and the data from CDC-2000 reference are quite similar up to 12–13 years of age, earlier in girls. In older ages, the curves depart from each other, with greater values for the curve drawn of the CDC-2000, reaching the highest discrepancies at the age of 18 years.

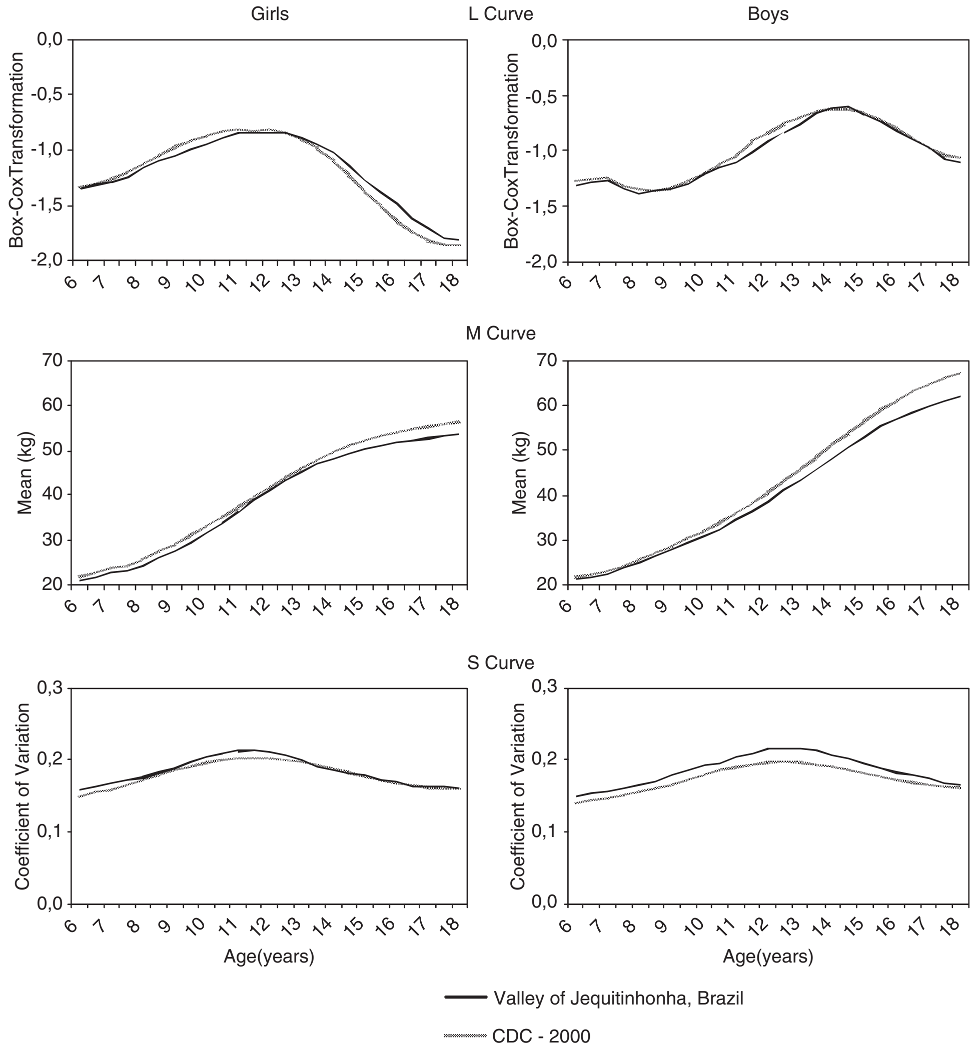

Figure 2. *L*, *M* and *S* curves of body weight-for-age for the subjects of the present study and for the CDC-2000 reference values.

The differences between the mean values presented by this study up to 12–13 years of age and the CDC-2000 references were 4–6 cm lower. These values represent a deficit of height-for-age of about 3%, at an age close to reaching adult stature.

The *M* values, for body weight-for-age had a similar tendency to the measurements of height-for-age. However, the differences between the measurements presented by the CDC-2000 reference and those presented in schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil were more accentuated, clearly in older ages, which confirm a higher sensitivity of this growth parameter to environmental factors. At the ages preceding the expected biological maturation peak, the mean body weight of the girls of the present study presented values from 0.5 to 1.0 kg lower than the CDC-2000 references. In boys, the differences started at 0.6 kg at the age of 6 years and reached values of about 3 kg when close

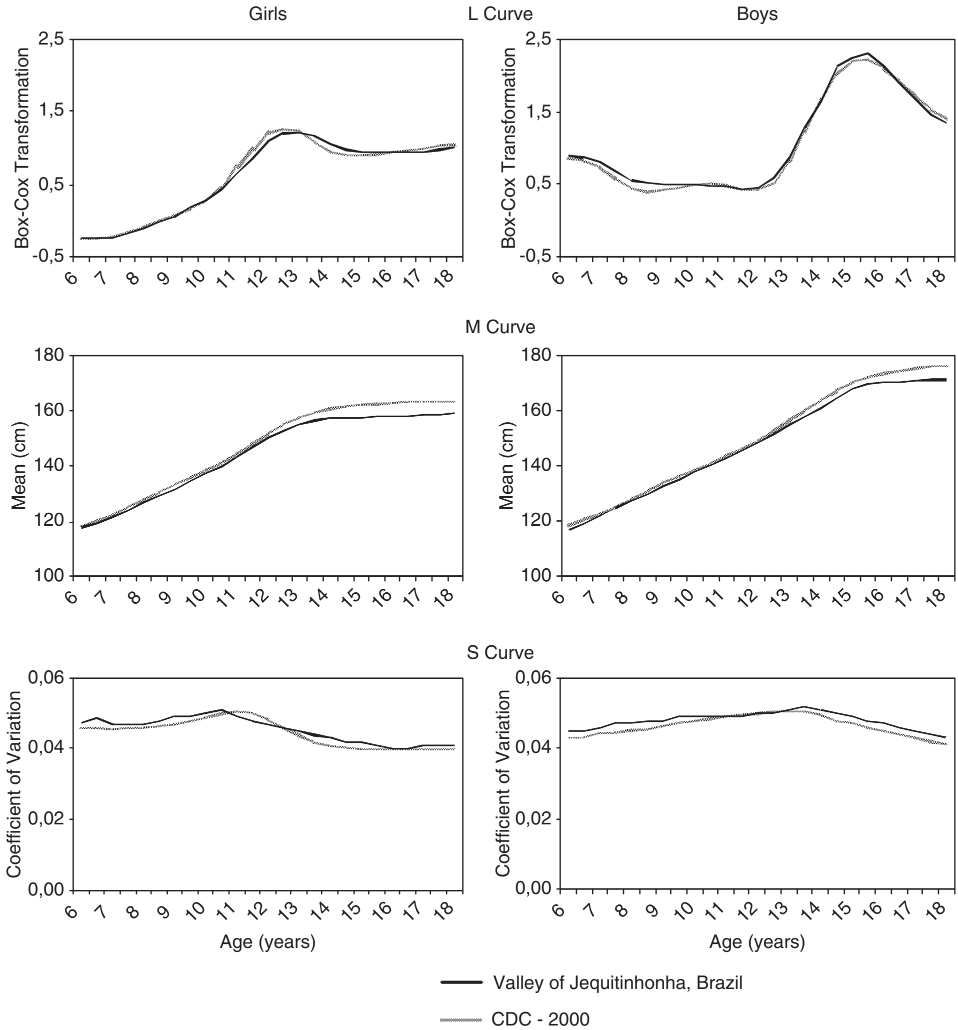

Figure 3. *L*, *M* and *S* curves of height-for-age for the subjects of the present study and for the CDC-2000 reference values.

to 14 years of age. Then, with the advancing of age, the differences became progressively more accentuated in both genders, so that at 18 years of age the weight deficit reached values of about 3 kg in girls and of 6 kg in boys.

Comparisons of percentiles for height-for-age and for body weight-for-age in this study and the CDC-2000 reference confirmed the differences associated with gender and age related to the magnitude of physical growth deficits identified in the schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil. Higher deficits were observed in the measurements of body weight-for-age in boys in the age segment from 15 to 18 years old.

When consulting the literature available in this area, it can be observed that differences with similar magnitudes to those found in the present study have also been identified in studies comparing distinct ethnic populations (Hasan et al. 2001; Hakeem et al. 2004; Marwaha et al. 2006; Neyzi et al. 2006; Davies 2007). It is possible and reasonable to speculate that these differences could be due to the genetic factors. However, it seems that

Table III. Differences between the percentiles presented by the CDC-2000 reference and by the schoolchildren of the Jequitinhonha Valley, Minas Gerais, Brazil 2007.

Age group	P3	P10	P25	P50	P75	P90	P97
Body weight/age – girls							
6–9 years old	1.07	1.07	1.04	1.06	1.08	1.04	1.01
10–14 years old	1.26	1.26	1.25	1.30	1.36	1.36	1.38
15–18 years old	2.14	2.15	2.15	2.19	2.27	2.29	2.35
Height/age – girls							
6–9 years old	0.13	0.10	0.13	0.10	0.02	0.09	0.20
10–14 years old	0.45	0.34	0.23	0.13	0.16	0.16	0.16
15–18 years old	1.32	1.32	1.31	1.31	1.31	1.30	1.30
Body weight/age – boys							
6–9 years old	0.47	0.46	0.45	0.46	0.48	0.45	0.43
10–14 years old	2.01	2.01	1.99	2.03	2.07	2.03	2.07
15–18 years old	3.40	3.11	2.92	2.88	2.99	3.15	3.43
Height/age – boys							
6–9 years old	0.18	0.19	0.19	0.20	0.21	0.21	0.20
10–14 years old	0.64	0.62	0.58	0.57	0.55	0.52	0.50
15–18 years old	0.84	0.88	0.91	0.96	1.00	1.02	1.05

*100 log(percentile of CDC-2000 reference/calculated percentile).

the hypothesis of genetic differences cannot be applied in this case, since in the early ages which precede the expected moment of peak biological maturation, there were similarities in the comparisons.

It is important to note that results obtained in a study with a sample from an industrialized region of Brazil (Guedes et al. 2009) showed no noticeable differences in weight and height from the CDC-2000 reference data, being, therefore, superior to the growth indicators of the sample in the present study.

In this context, there may be indications that the deficits observed in height and body weight measures per age presented for both genders, from the beginning of the process peak of biological maturation, could be associated with environmental conditions, which can restrict adequate physical growth. In fact, at this period there are extremely significant nutritional needs associated with physical growth, which demand a balanced contribution of the metabolic energy offer, amino acids, mineral salts and vitamins, essential to a large spectrum of physiological functions (Spear 2002). The contrast observed between girls and boys may be explained by gender differences in sensitivity to adverse environmental conditions. Although the mechanisms of these phenomena are still unknown, Stinson (1985) summarized several studies that show how boys are more sensitive to changes in the environment than girls. According to this author, boys under environmental stress conditions showed higher percentages of prenatal mortality, delays in physical growth, and higher incidence of contagious diseases.

On the other hand, the most important factor associated with physical growth identified in older ages may be related to the selected schoolchildren's nutritional history. Recent social advances and aid programmes available specifically for sections of the population from less developed regions in Brazil may have contributed to a greater physical growth profile for younger schoolchildren when comparing to older ones, considering that, a decade ago, when the adolescent schoolchildren were infants, there were almost no such programmes. This phenomenon has occurred in a similar way in other undeveloped and developing countries' young populations, changing, in a positive way, the trend of physical growth in children and teenagers (Prista et al. 2003).

Conclusions

Using the information related to physical growth observed in this study we can conclude that, at younger ages, there were strong similarities between the data collected from the schoolchildren from the Jequitinhonha Valley, Minas Gerais, Brazil, and the data presented by the CDC-2000 references. However, deficits of height-for-age and body weight-for-age that increased with age were identified, despite the similarity of the increase presented by the curves of the *L*, *M* and *S* parameters of the present study and the CDC-2000 references after the moment the process of biological maturation is expected to start reaching its peak. At the age of 18 years the analysed schoolchildren were 4–6 cm shorter and 3–6 kg lighter when compared with CDC-2000 references.

Based on the results found in this study and considering that information associated with physical growth has been found to be one of the most important indicators concerning the condition of global health and the quality of life of young populations throughout the world, the lower values of height-for-age and body weight-for-age observed in schoolchildren from the of Jequitinhonha Valley, Minas Gerais, Brazil, when compared to the CDC-2000 reference, suggest the need for adequate interventions as a way of correcting the existing distortions.

Declaration of interests: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

Alfaro E, Bejarano I, Dipierri J, Quispe Y, Cabrera G. 2004. Percentilos de peso, talla e índice de masa corporal de escolares jujeños calculados por el método LMS. Arch Argent Pediatr 102:431–439.

Ayatollahi SMT, Pourahmad S. 2006. Height and weight of school children of Shiraz in relation to the CDC growth charts and the previous study in Shiraz (15 years ago). JRMS 11:375–381.

Cole TJ. 1989. The British, American NCHS, and Dutch weight standard compared using the LMS method. Am J Hum Biol 1:397–408.

Cole TJ. 1990. The LMS method for constructing normalized growth standards. Eur J Clin Nutr 44:45–60.

Cole TJ, Freeman JV, Preece MA. 1998. British 1990 growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. Stat Med 17:407–429.

Davies PS. 2007. Growth charts for use in Australia. J Paediatr Child Health 43:4–5.

Gafni RI, Baron J. 2000. Catch-up growth: Possible mechanisms. Pediatr Nephrol 14:616–619.

Guedes DP, Guedes JERP. 2002. Crescimento, Composição Corporal e Desempenho Motor de Crianças e Adolescentes. São Paulo: CLR Balieiro.

Guedes DP, Martini FAN, Borges MB, Bernardelli R. Jr. 2009. Physical growth of schoolchildren: A comparison with the Centers for Disease Control and Prevention reference using the LMS method. Rev Bras Saúde Matern Infant 9:39–48.

Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM. 1979. Physical growth: National Center of Health Statistics Percentiles. Am J Clin Nutr 32:607–629.

Hakeem R, Shaikh AH, Asar F. 2004. Assessment of linear growth of affluent urban Pakistani adolescents according to CDC 2000 references. Ann Hum Biol 31:282–291.

Hasan MA, Batieha A, Jadou H, Khawaldeh AK, Ajlouni K. 2001. Growth status of Jordanian schoolchildren in military-funded schools. Eur J Clin Nutr 55:380–386.

Kuczmarski RJ, Ogden CL, Grummer-Strawn LM. 2000. CDC Growth Charts United States. Adv Data 314:1–27.

Marwaha AY, Tandon N, Singh Y, Aggarwal R, Grewal K, Mani K. 2006. A study of growth parameters and prevalence of overweight and obesity in school children from Delhi. Indian Pediatr 43:943–952.

Mei Z, Yip R, Grummer-Strawn LM, Trowbridge FL. 1998. Development of a research child growth reference and its comparison with the current international growth reference. Arch Pediatr Adolesc Med 152:471–479.

Neyzi O, Furman A, Bundak R, Gunoz H, Darendeliler F, Bas F. 2006. Growth references for Turkish children aged 6 to 18 years. Acta Paediatr 95:1635–1641.

Ogden CL, Kuczmarski RJ, Flegal KM, Mei Z, Guo S, Wei R, et al 2002. Centers for Disease Control and Prevention 2000 Growth Charts for the United States: Improvements to the 1977 National Center for Health Statistics version. Pediatrics 109:45–60.

Onis M, Wijnhoven TMA, Onyango AW. 2004. Worldwide practices in child growth monitoring. J Pediatr 144:461–465.

Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 85:660–667.

Palmert MR, Hirschhorn JN. 2003. Genetic approaches to stature, pubertal timing, and other complex traits. Mol Genet Metab 80:1–10.

Prista A, Maia JAR, Damasceno A, Beunen G. 2003. Anthropometric indicators of nutritional status: Implications for fitness, activity, and health in school-age children and adolescents from Maputo, Mozambique. Am J Clin Nutr 77:952–959.

Silventoinen K. 2003. Determinants of variation in adult body weight. J Biosoc Sci 35:263–285.

Spear BA. 2002. Adolescent growth and development. J Am Diet Assoc 102(3 Suppl):S23–S29.

Stinson S. 1985. Sex differences in environmental sensitivity during growth and development. Am J Phys Anthrop 28:123–147.

UNDP (United Nations Development Programme). 2007. Human development report 2007/2008. UNPD: New York.

WHO. 1995. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series, v.854. Geneva: World Health Organization.