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Growth charts of Brazilian youngs: 20-years data of 95,000 children and adolescents from "*Projeto Esporte Brasil*"

Curvas de crescimento de jovens brasileiros: dados de 20 anos com 95.000 crianças e adolescentes do "Projeto Esporte Brasil"

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Abstract *This article aims to present growth curves for height, weight, and BMI of 95,000 Brazilian youths aged 6 to 17 years, including the five regions of the country, the Amazon region, and indigenous populations, and compare them with the World Health Organization (WHO) growth references. The final sample consisted of 52,729 boys and 42,731 girls from the "Projeto Esporte Brasil" database. Body mass and height information were used to derive the curves. The generalized additive model for location, scale, and shape was employed. In this study, we present smoothed weight-for-age, height-for-age, and BMI-for-age curves for boys and girls. Differences were observed between the results of the Brazilian curves and the WHO growth references. The developed curves will be valuable for professionals in medicine, public health, nutrition, physical education, and other related fields, regarding the assessment of physical growth in Brazilian children and adolescents and monitoring the nutritional status of this population. Additionally, these curves will facilitate the identification of individuals or subgroups at risk of diseases and delayed growth, with a greater focus on specific country-related factors.*

Key words *Growth charts, Anthropometry, Body weights and measures, Growth and development, Public health*

Resumo *O objetivo do artigo é apresentar curvas de crescimento de altura, peso e IMC de 95.000 jovens brasileiros com idades entre 6 e 17 anos, incluindo as cinco regiões do país, a região da Amazônia e os povos indígenas, e comparar com as referências de crescimento da Organização Mundial da Saúde (OMS). A amostra final foi composta por 52.729 meninos e 42.731 meninas provenientes do banco de dados do "Projeto Esporte Brasil". As informações de massa corporal e estatura foram utilizadas para derivar as curvas. O modelo aditivo generalizado para localização, escala e forma foi usado. neste estudo, apresentamos as curvas suavizadas de peso-idade, altura-idade e IMC-idade para meninos e meninas. Foram observadas diferenças entre os resultados das curvas brasileiras e as referências de crescimento da OMS. As curvas desenvolvidas serão úteis para profissionais da medicina, saúde pública, nutrição, educação física, entre outros, no que diz respeito a avaliação do crescimento físico de crianças e adolescentes brasileiros e para monitorar o estado nutricional desta população. Além disso, essas curvas permitirão a detecção de indivíduos ou subgrupos em risco de doenças e crescimento retardado, com um foco maior em fatores específicos do país.*

Palavras-chave *Curvas de crescimento, Antropometria, Medidas corporais, Crescimento e desenvolvimento, Saúde pública*

Introduction

Physical growth is related to cultural differences in nutritional behaviour, physical activity across lifespan, educational and instruction levels, and socioeconomic differences[1,2]. Recognising that there are different patterns of physical growth in variables such as height, body mass (including fat mass), time and tempo of the growth spurt, in addition to naturally implying final height in adulthood[3] there is a need to consider different strategies for physical growth monitoring at the population level.

The need for physical growth monitoring is in line with a growing concern with the body development of children and adolescents, mainly related to obesity and underweight[4,5]. According to NCD-Risc Fator Collaboration[5], in a study conducted with 128 million participants, globally between 1975 and 2016 the number of obese children and adolescents increased tenfold. Underweight and obesity can also lead to adverse health outcomes during childhood and adolescence[6], affecting decisions around public health policies to prevention and treatment. It is therefore important to understand current trends in growth and to be able to monitor growth at a population level.

Traditionally, physical growth has been globally monitored through standardized anthropometric measures (e.g., height, body mass and BMI), through joint efforts by researchers and research centres and government agencies[7]. Based on these anthropometric measures, the World Health Organization (WHO)[8], as well as the Center for Disease Control and Prevention (CDC)[9] developed a set of charts with growth curves designed from studies carried out on four continents. The purpose of these charts is to assist in the process of monitoring the growth of children and adolescents. However, the growth curves often do not meet the specificities of some countries and in this sense, different nations have proposed their own growth curves (e.g., India[10], United Kingdom[1], among others).

In Brazil, some initiatives aimed at developing growth curves have already occurred[11,12] although comprehensive growth curves for children and adolescents in Brazil remain lacking. However, like the curves developed by the WHO or CDC, the growth curves for Brazil require a comprehensive study, with children and adolescents from all regions. Previously published studies have reported growth curves of Brazilian children[13-17]. Conde and Monteiro[14] proposed a BMI reference curve for children and adolescents, from 2 to 19 years-old, with data extracted from the National Nutrition and Health Survey dataset. Research conducted by Silva *et al.*[17] proposed growth reference values for height, body mass and BMI for children and adolescents aged 7-17 years from Cariri, in the northeast region of Brazil. Barbosa Filho *et al.*[13] described the percentile curves for BMI, waist circumference and waist-to-height of children from Colombo, state of Parana, southern Brazil. Further, Ferreira *et al.*[15] proposed weight and height growth curves for indigenous Xavante children aged from 3-10 years from Central Brazil. Recently, Freitas *et al.*[16] proposed BMI reference values to classify the nutritional status of children 6-10 years-old from Montes Claros city, Southeast Brazil. Although these studies have provided important physical growth indicators for Brazilian children and adolescents, they are limited due to the use of relatively small samples collected in short periods, from specific Brazilian region. Such endeavours, although useful do not provide growth curves that are representative of children and adolescents in Brazil.

Thus, the collaborative use of growth curve charts (height and body mass, and BMI) with updated values can be considered a monitoring strategy with a low risk of misinterpretation. Such a suggestion is justified because puberty is a time of drastic changes in body size and composition, caused by a complex hormonal production, influencing rapid gain in body mass and height[18]. In this way, a cross-sectional assessment (usually carried out by paediatricians, strength, and conditioning professionals, etc.) of only one variable can induce an interpretation error in relation to the growth and nutritional status.

Taking account the importance to consider populational specificities for proposing growth curve charts, especially in a continental-size countries such as Brazil, (e.g., 5th largest territorial extension and 6th largest global population), our study presents height, weight, BMI growth curves from representative Brazilian children and adolescents sample aged 6-17 years using a cross-sectional design study, enrolling a population sample assessed over the last 20 years. To our knowledge, there are no national growth indicators considering in their sample the five regions of the country, including the Amazon region and native peoples (indigenous). Therefore, it is necessary to propose height, weight, BMI growth charts for Brazilian children and adolescent population.

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Methods

Study design

This is a cross-sectional surveillance study, with a national sample of 95,470 children and adolescents. The data are from "*Projeto Esporte Brasil* (PROESP-Br)". The PROESP-Br is a repeated cross-sectional surveillance study that was carried out since 1999. During 2003 and 2009, the Brazilian Ministry of Sports through National Secretariat of High-Performance Sports funded the PROESP-Br. It was designed to evaluate the anthropometry, and physical fitness levels of Brazilian children and adolescents using a standardized data collection protocol. The data collection throughout the project (1999-2019) occurred over the years by previously trained volunteers. For all evaluation is written informed consent was obtained from parents or legal guardians. Ethics approval for this project was originally obtained from the Universidade Federal do Rio Grande do Sul, Brazil, under register number: 2008010.

Volunteers register protocol

The volunteers for executing the data collection in all Brazilian states were physical education teachers, sports coaches and strength and conditioning professionals. These volunteers access the PROESP-Br's guidelines[19] on a website (https://www.ufrgs.br/proesp/) for video training and orientation about the formulary, measurements, and fitness test. The PROESP-Br research team has been available by email or telephone for an additional necessary explanation.

After this step, the volunteers made a register using them personal Brazilian ID and complete a formulary with the institution (e.g., school, sports club), city, state, phone number, and e-mail address. After data collection, the volunteers send the data using them individual register and receive a general and individual report about growth, skills- and health-related fitness of them students/athletes. For this study, 563 volunteers participate in data collection in 313 institutions (schools, sport clubs, scholar sport teams and educational sport teams).

Recruitment protocol

Using recruitment with intentional and non-random sampling methods, all regions of Brazil were recruited in at least five cities, considering the wide geographic distribution of Brazil. Among recruitment sites, primary and secondary schools account for more than 50%, the rest of the sites are made up of public and private sports clubs, sports schools, social projects, and local cross-sectional research projects (linked to PROESP-Br). In all stages of the research, participants were invited to participate in the study, aware that they could give up for any reason, without consequences.

Information on the sample size and sample distribution is shown in Table 1. Participants were considered eligible for this study if they were between 6 and 18 years old, able to perform physical tests at maximum effort and moderate to vigorous physical activities were not contraindicated by a pre-existing medical condition. Young people with disabilities had a protocol adapted to participate in all assessments. Anthropometric results of young people with physical disabilities, in which anthropometry must be analysed separately, were not eligible for the present study. During the repeated cross-sectional surveillance data collections, some young people participated more than once in different years (minimum interval of one year), their results were eligible for the study because their absence was previously tested and did not change the mean and dispersion values, even though these cases represent less than 3% of the sample size.

Data collect and procedures

For data collection, volunteers were trained to instruct children and adolescents about the project objectives and protocols. In this study, the procedures suggested by Lohman *et al.*[20] for anthropometric assessment were adopted. The children undertook the measurements wearing light clothes (e.g., physical education class clothes) and without shoes.

For the measurement of body mass, volunteers were instructed to use of a portable scale with an accuracy of up to 500 grams. During the assessment, the children and adolescents remained standing (except children with disabilities that prevented this) with their elbows extended and close to the body. The measurement was recorded in kilograms to two decimal places after the comma.

For the measurement of height, they were instructed to use of a portable stadiometer or measuring tape with a precision of up to 2 mm. When the measuring tape was used (considering that it normally measures 150 centimetres in length) it

Table 1. Characteristic of cross-sectional surveillance study sample (*Projeto Esporte Brasil*).

	1999-2001	2002-2004	2005-2007	2008-2010	2011-2013	2014-2016	2017-2019	Total
Sample Size	**704**	**31,178**	**31,105**	**10,198**	**10,147**	**2,019**	**10,119**	**95,470**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Sex								
Boys	370 (52.6)	16,659 (53.4)	16,724 (53.8)	5,818 (57.1)	6,025 (59.4)	1,143 (56.6)	5,990 (59.3)	52,729 (55.2)
Girls	334 (47.4)	14,519 (46.6)	14,381 (46.2)	4,380 (42.9)	4,122 (40.6)	876 (43.4)	4,119 (40.7)	42,731 (44.8)
Brazilian Region								
North	4 (0.6)	3,213 (10.3)	908 (2.9)	2 (0.1)	8 (0.1)	0 (0)	953 (9.5)	5,088 (5.3)
Northeast	9 (1.3)	4,823 (15.5)	608 (2.0)	484 (4.7)	612 (6.0)	84 (4.2)	2,877 (28.6)	8,326 (8.7)
Centre-West	8 (1.3)	4,932 (15.8)	3,005 (9.7)	1,593 (15.6)	1,353 (13.3)	505 (25)	1,375 (13.7)	12,771 (13.4)
Southeast	10 (1.4)	8,386 (26.9)	10,871 (34.9)	3,003 (29.4)	3,089 (30.4)	326 (16.1)	2,877 (28.6)	28,562 (29.9)
South	673 (95.6)	9,824 (31·5)	15,713 (50.5)	5,116 (50.2)	5,085 (50.1)	1,104 (54.7)	3,151 (31.3)	40,666 (42.6)
Zone								
Urban	704 (100)	30,147 (97)	29,350 (94.8)	9,827 (96.8)	9,925 (98.8)	2,001 (99.1)	9,545 (94.4)	91,500 (96.2)
Rural	0 (0)	926 (3)	1,615 (5.2)	330 (3.2)	122 (1.2)	18 (0.9)	568 (5.6)	3,579 (3.8)

Note: n = frequency; % = percentage.

Source: Authors.

was advisable to attach it to the wall 100 centimetres from the ground, extending it from bottom to top (in this case, the evaluator added 100 centimetres to the result measured by the measuring tape). To read the height, a square device should be used (this procedure eliminates errors resulting from possible material inclinations such as rulers or clipboards when freely supported only on the children's head). Height measurement was recorded in centimetres with two spaces after the comma.

For the calculation of the body mass index, after sending the data to the PROESP-Br website, the system itself performs the equation (kg/m^2) and add in the value. The measure was recorded to two decimal places.

Data cleaning

The data received underwent an initial screening to check the data of the volunteer responsible for data collection (to avoid false data). The second screening assessed whether there were any typing errors, and, in this stage the data of the child/adolescent are correlated (measurements and physical fitness tests), when observing the lack of agreement between the values and the marked data. The third step is the deletion of data entered incorrectly, after confirmation by the research team. Finally, to meet an essential precaution in proposition analysis and curve smoothing, we removed the outliers from the database (values below and above the 4-standard deviation (SD)).

Data analysis

The presentation of the results was realized through mean (M), SD and z-scores (-3, -2, -1, 0, 1, 2, 3). The generalized additive model for location, scale, and shape (GAMLSS) was used to derive the percentiles curves for weight, height, and BMI according to sexes. GAMLSS, is an extension of the LMS method, in which can model the kurtosis using different distributions. The LMS method uses the Box-Cox transformation, specific for each age[21]. This method consists of three smoothing age-specific curves, which are referred to as L curve (Box-Cox transformation), M curve (median) and S curve (coefficient of variation).

The model class was defined by the Box-Cox Cole Green (BCCG) distribution and penalized splines as smoothing for the distribution parameters L, M and S[21]. The smoothing complexity of each curve was measured through the degrees of freedom equivalent for L(t), M(t) and S(t). The Bayesian information criterion (BIC) was used as method of goodness of fit to select the best model, comparing models with different degrees of freedom. It is typically used to choose among a model with a different setting of hyper-parameters. The hyper-parameters were analysed for each growth curve and, the selected models were choose considering the lowest BIC. Estimation diagnostics were performed using worm plots and quantile plots (QQ plots) to verify the fit of the models regarding to the data. The analyses were conducted using the package "gamlss" available from the free software R studio.

Results

The final reference curve charts for height-for-age, weight-for-age, and BMI-for-age and the respective values for general using are presented in the supplementary images and tables. The sample consisted of children and adolescents evaluated from 1999 to December 2019 (when the project was interrupted due to the COVID-19 pandemic). Table 1 shows that more than 10.000 participants data were collected every year, except between 2014 and 2016 when the server that stores the data experienced instability resulting in a loss of data. The years between 2003 and 2007 had a much higher volume of participants than other years because it was the time when the project received the most funding (see section on methods; study design).

The southern region of Brazil was the most evaluated in all stages of the research, followed by the southeast region. There was an equivalence between boys and girls at all stages of the research (boys 55.2%; girls 44.8%). Table 2 shows the distribution of the sample by age. It is notable and expected that the extreme ages of the group (6 and 17 years old) have fewer participants than the others. Visually, a consistent increase in height and body mass is observed with age in both sexes.

Figure 1 presents the smoothed z-scores curves of the weight-for-age (Figure 1a), height-for-age (Figure 1b) and BMI-for-age (Figure 1c) for boys and comparison with WHO growth standards. Intervals of three months of age were presented. The weight-for-age analyses showed a slightly linear increase up to 10 years-old in the majority of the curves. Regarding to comparison with WHO growth standards, the Brazilian curves present higher values of z-scores in median, 1 SD, 2 SD and, especially in 3 SD scores. The other curves presented similar z-scores.

Regarding to height-for-age, analysis showed a marked linear increase in most of the z-score curves up to 13-years-old approximately, a marked increase until the 16.6 approximately and posteriorly a smooth increase on the height until the 17.9-years-old. Concerning to comparison with WHO standards, similar z scores were observed in median and -1 SD curves, in most ages. Further, Brazilian curves present higher values of z scores in 1 SD, 2SD, and 3 SD scores up to 15-years-old, approximately. After this age, the WHO curves presented higher z score values.

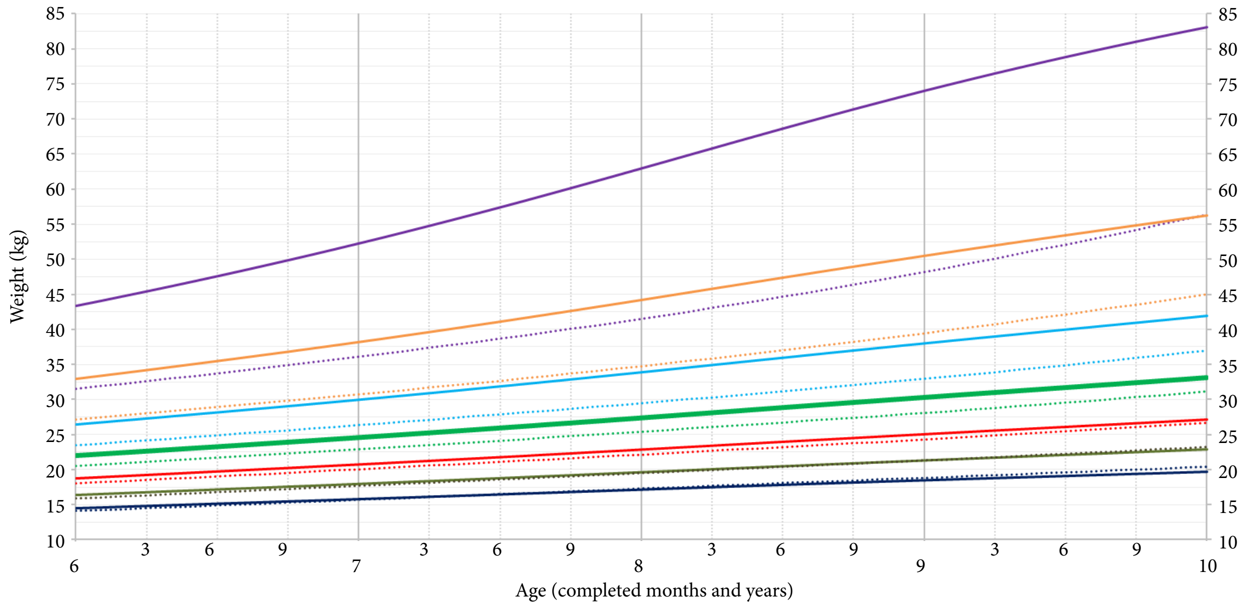
BMI showed values of median from 15.8, at 6-years-old, to 22 kg/m² at 17.9-years-old. In comparison with WHO standards, Brazil-

Table 2. Sample distribution and means values (with standard deviation) according to gender and age (*Projeto Esporte Brasil*).

Age	Boys					Girls				
	N	Height		Weight		N	Height		Weight	
		M	SD	M	SD		M	SD	SD	M
6	908	122.49	7.58	24.85	5.82	815	121.16	6.84	24.28	5.11
7	2,379	126.85	6.93	27.05	6.07	1,998	125.22	6.60	26.16	5.75
8	3,042	132.10	6.97	30.45	7.42	2,618	130.81	7.06	29.44	6.91
9	4,200	137.04	7.34	33.36	8.18	3,426	136.83	7.30	32.98	8.00
10	7,178	141.75	7.44	36.35	9.06	5,999	142.88	7.86	36.57	8.99
11	9,633	146.87	7.87	40.13	10.21	8,222	149.04	7.96	41.19	9.81
12	10,286	152.69	8.97	44.37	11.50	8,322	154.31	7.38	45.87	10.23
13	6,093	159.77	9.56	50.52	12.28	4,638	158.27	7.12	50.66	10.45
14	4,255	166.76	9.03	57.27	13.05	3,187	160.41	6.99	54.18	10.34
15	2,267	170.82	8.13	61.76	12.94	1,710	160.89	7.01	55.83	11.02
16	1,715	172.84	8.01	65.77	13.89	1,194	161.37	6.97	56.81	11.08
17	773	174.05	7.54	67.84	14.05	602	162.37	7.00	57.46	10.81
Total	52,729	149.65	14.91	43.15	14.69	42,731	148.28	12.97	42.23	12.88

M = mean; SD = standard deviation.

Source: Authors.



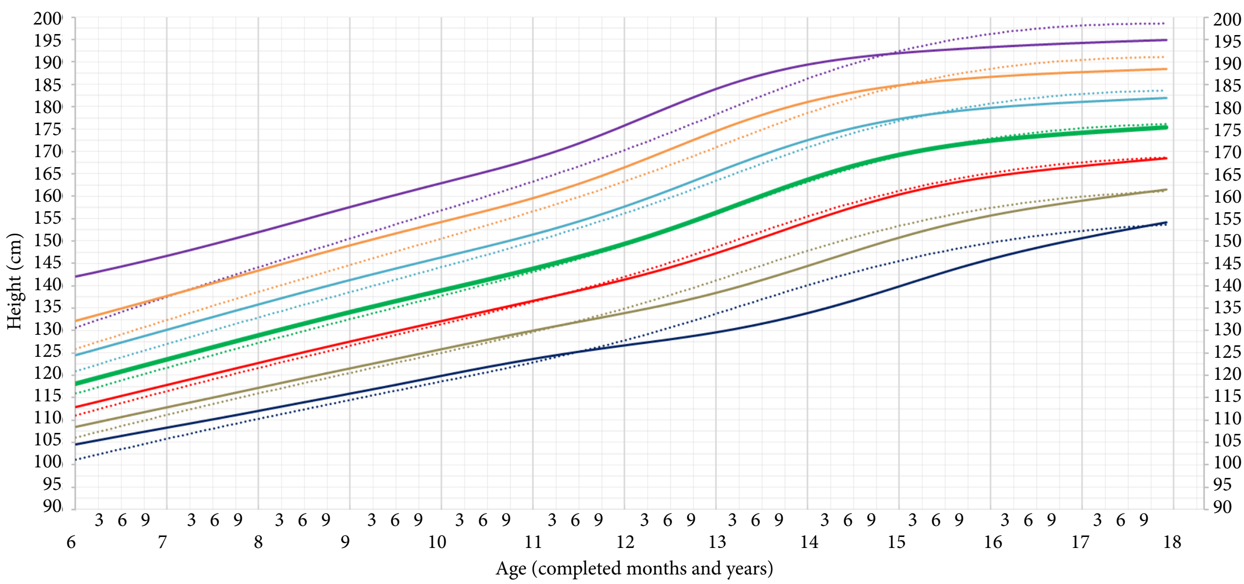


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Figure 1. Weight-for-age (Figure 1a), height-for-age (Figure 1b) and BMI-for-age (Figure 1c) for boys and comparison with WHO growth standards (2007).

ian curves showed values slightly higher in median, especially from 11.6-years-old, and considerably higher values in the 1 SD, 2 SD and 3 SD z-scores. On the other hand, Brazilian curves were slightly lower in -2 SD, especially from 6 to 10-years-old and from 15 to 17.11 years-old. Brazilian BMI -3 SD z-scores were somewhat lower than WHO. Z values according to each month are presented in SciELO Data: https://doi.org/10.48331/scielodata.XA4CFF.

Figure 2 presents the smoothed z-scores curves of the weight-for-age (Figure 2a), height-for-age (Figure 2b) and BMI-for-age (Figure

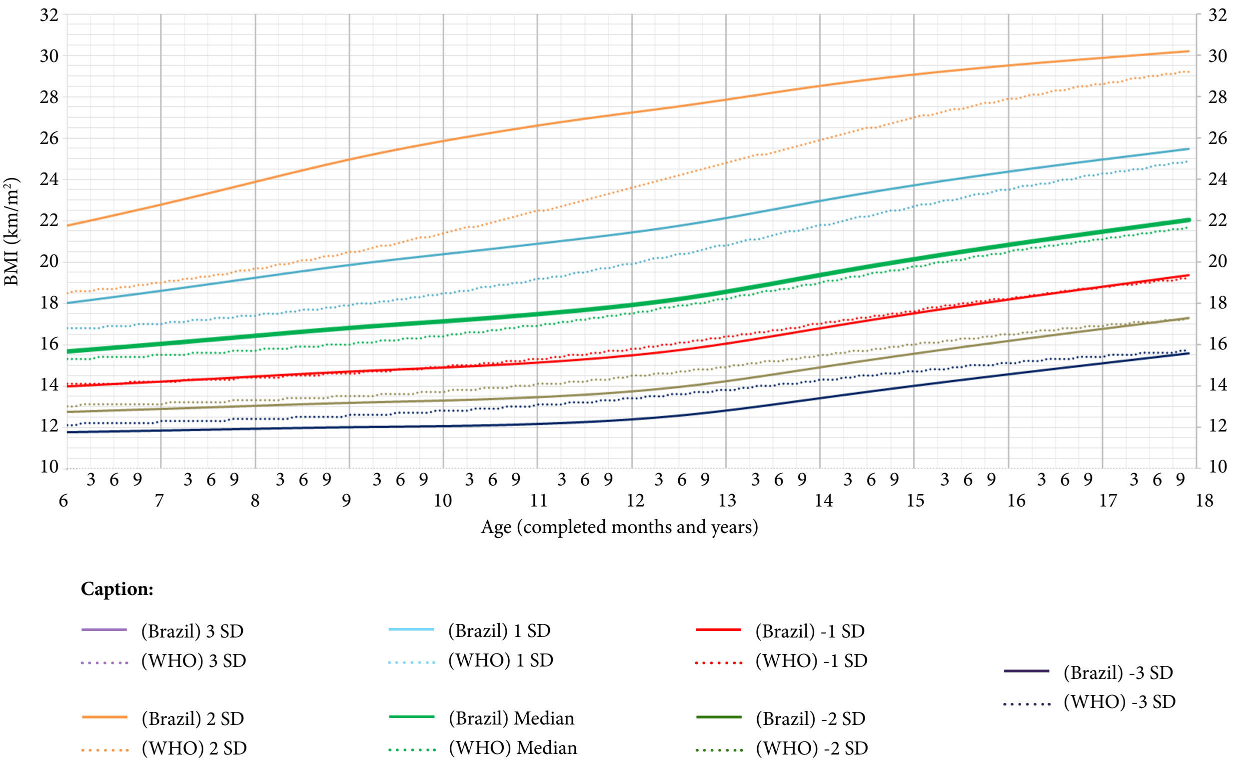

Figure 1. Weight-for-age (Figure 1a), height-for-age (Figure 1b) and BMI-for-age (Figure 1c) for boys and comparison with WHO growth standards (2007).

Source: Authors.

2c) for girls and, also, comparison with WHO standards. Intervals of three month of age were presented. The weight-for-age analyses showed a slightly linear increase up to 10 years-old in many of the curves. Regarding to comparison with WHO growth standards, the Brazilian curves present higher values of z scores in median, 1 SD, 2 SD and, especially in 3 SD scores. The other curves presented similar z- scores.

Regarding to height-for-age, a marked linear increase in z-scores was observed up to 14-9 years-old approximately. Curves remains practically constant up to 17.9-years-old. Concerning to comparison with WHO growth standards, were observed similar z-scores in median, -1 SD and -2 SD curves, in most ages. Brazilian girls present higher values of z-scores in 1 SD, 2SD and, especially in 3 SD scores up to 12.9-years-old, approximately. After this age, the WHO curves presented slightly higher z score values.

Brazilian curves present BMI values of median from 15.8, at 6-years-old, to 21 kg/m² at 17.9-years-old. In comparison with WHO standards, Brazilian curves showed values marginally higher in median. Very close values between WHO and Brazilian z-scores were observed in -1 SD, specifically from 6 to 14-years-old approximately. Higher Brazilian 1 SD, 2 SD and 3 SD z-scores were observed from 6 to 14.6-years-old and from 6 to 15.6-years-old respectively. However, from these ages, WHO curves were higher. Brazilian BMI -2SD z-scores were similar to WHO standards up to 9-years-old. From this age, WHO z-scores were higher up to 13.3-years-old. After this age, Brazilian BMI scores were higher than WHO. Further, Brazilian BMI -3SD z-scores were similar from 6 to 6.9 years-old and from 13.3 to 13.7-years-old. WHO z-scores were higher from 6.9 to 13-years-old. From 13.9 to 17.11-years-old, Brazilian BMI -3SD z-scores were higher than WHO.

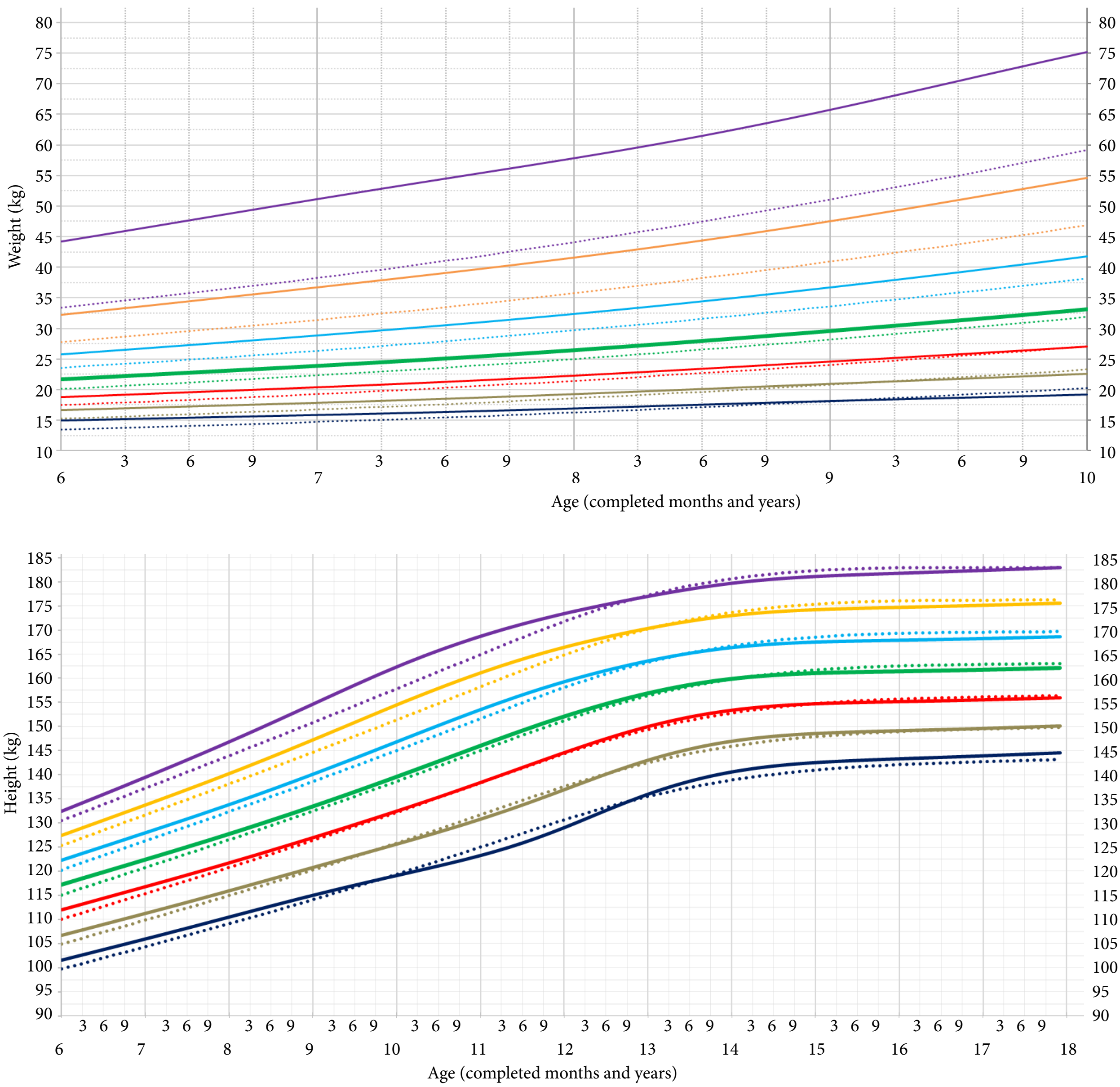

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Figure 2. Weight-for-age (Figure 2a), height-for-age (Figure 2b) and BMI-for-age (Figure 2c) for girls and comparison with WHO growth standards (2007).

Discussion

This study presents growth curves for height, weight, BMI from representative Brazilian children and adolescents sample aged 6-17 years. Previously published studies have reported growth curves of Brazilian children[13-17] but are not comparable to the data presented in the current study in terms of sample size and representativeness of the whole country. Although these studies have provided important physical growth indicators for Brazilian young people, all of them enrolled non-large samples collected over relatively short periods, from specific Brazilian regions. In this sense, the present study aggregates evidence on the growth status of children and adolescents from a national sample, contains subjects from all regions of Brazil, including the Amazon and native people (indigenous), and consequently this work represents an original contribution to the literature.

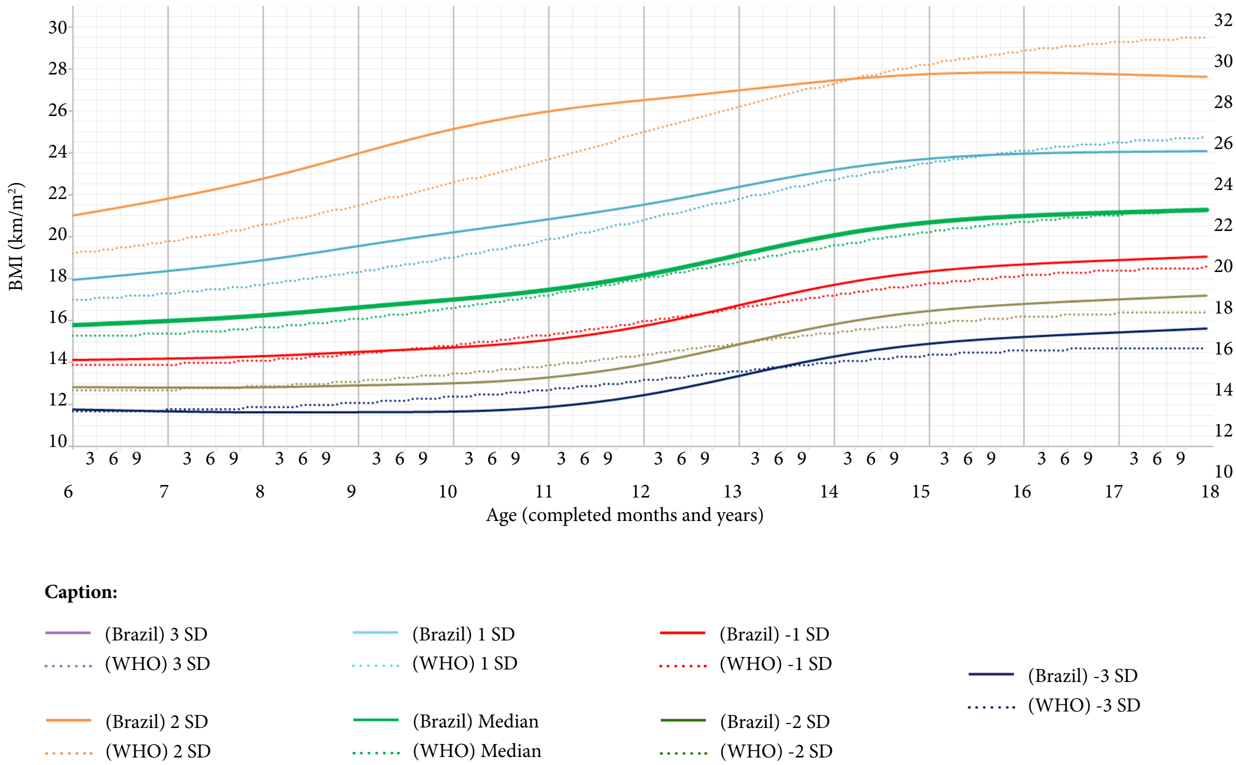

Figure 2. Weight-for-age (Figure 2a), height-for-age (Figure 2b) and BMI-for-age (Figure 2c) for girls and comparison with WHO growth standards (2007).

Source: Authors.

Our results naturally demonstrate that boys are taller than girls at all curves (SD) are. However, the accentuation of the height curve for boys seems to occur between 12 and 14 years of age in boys (median; from 143.7 to 163.4), while among girls it occurred between 11 and 13 years of age (median; from 145.8 to 156.8). These values are consistent with the trajectory of the bone acquisition described by Heaney *et al.*[22], also indicating that this phase (growth spurt) contributes 15% to adult height. Our results do not agree with the study by Malina *et al.*[23] which indicated that peak growth velocity usually occurs around 12 years of age in girls and 14 years of age in boys, although this study uses a sample of young soccer players. However, our results indicate not all height percentiles in the sample had the same period of greater height acquisition.

The results found in the present study suggested that sexual maturation seems to develop at different times for boys with a tendency to be taller (2 SD) or shorter (-2 SD). Our results for boys seem to follow the theoretical curve adapted by Lloyd *et al.*[24], indicating that early entry into puberty may indicate a peak of growth velocity that is also early. Our data go further than prior research and demonstrates that this phenomenon seems to occur with taller boys (2 SD and 3 SD).

Regarding girls, our results indicate, as expected, that the trend of the growth curve is different from that of boys. While boys at all height tend to have a later peak growth velocity but with a strong magnitude, girls tend to have an earlier peak growth velocity at all percentiles. However, the most important result for girls was the time at a high growth rate, which was approximately 3 years earlier. That is, while boys have a growth peak with a later time and greater magnitude, girls have a growth peak with an early time and a long tempo.

The Brazilian growth curves showed a highest weight, height, and BMI values, especially in the highest z-scores (3 SD, 2 SD and 1 SD) when compared to WHO. These results show an underestimation trend of WHO standards in Brazilian children, especially those taller and that have greater weight. In addition, similar curves (e.g., median, 1 SD) was observed in height-for-age in boys and girls. These results reinforce a misfit of the WHO standard curves for Brazilian children with higher z-scores.

World Health Organisation (WHO) had provided growth references curves based on multinational samples, but they also consider the importance for providing and utilizing growth charts adapted from a target population[25]. For example, a collaborative work enrolling different Canadian health entities, such as, the Dietitians of Canada, the Canadian Paediatric Society, the College of Family Physicians of Canada, Community Health Nurses of Canada, and the Canadian Paediatric Endocrine Group provide a WHO Growth Charts Adapted for Canada. They provided two versions of the WHO Growth Charts for Canada, with alternative percentile choices[25].

Like the present study, other researchers have been proposed growth reference curves based on their population (e.g., China[26], Iran[27], Zimbabwe[28], Korea[29] and Saudi Arabia[30]) and compared with WHO growth standards. Ma *et al.*[26] provided a BMI percentile curves for Chinese children aged 7-18 years. They observed that BMI distributions and growth patterns in Chinese children were dramatically different from those in the WHO reference population. Compared with WHO standard, younger Chinese boys (7-12 years-old) showed higher values of the percentiles above the median and lower values of the percentiles below the median, suggesting that they had larger proportions of extreme BMI values in both directions. Chinese girls and older Chinese boys (15-18 years of age) had significantly lower BMI percentiles than WHO reference, especially those high percentiles among older age groups.

Recently, Mohammadi *et al.*[27] provided national growth charts for BMI among Iranian children and adolescents. Iranian curve for girls showed higher BMI scores in 50 and 80 percentiles, and boy's curve showed higher BMI scores in 50th compared do WHO standards. In addition, Iranian curve showed significant lower values in 5th compared to WHO reference in both sexes.

Further, Marume *et al.*[28] developed a Zimbabwean child growth curve for Height-for-age, weight-for-age, and BMI-for age. They observed that Zimbabwean children were shorter and weighed less in comparison with the WHO growth standards. The -2 SD z-score for height-for-age in both boys and girls were below the -1 SD z-score curves of the WHO growth standards. Zimbabwean Z-scores (BMI-for-age) values above -1 SD were significantly higher in comparison with the corresponding WHO growth standards. In addition, Korea[29] and Saudi Arabia[30] growth curves studies also reported differences in some percentiles compared with WHO and CDC growth references.

Similar to observed in the present study, growth charts research results showed noticeable differences between their target population[26-30] and WHO reference; it revealed a trend to under or overestimation of the curves and reinforce the importance for proposing growth curves based in a national population.

Strengths and limitations

Our study has strengths that deserve to be highlighted: 1) for data analysis, we used a known and qualified method for curve smoothing, allowing us to present more accurate curves; 2) the representativeness of the sample, which, although not random, has subjects from all 5 regions of Brazil, and therefore includes minority ethnic groups such as native (indigenous) people; and 3) we present the growth rate curves together with the growth curves. These results have practical applicability in several areas, such as healthcare, sports development, and population monitoring.

Nevertheless, our results must also be observed from the perspective of their limitations: 1) although the sample is large, data were collected over 20 years. Thus, the effect of time on growth variables may have an influence mainly on extreme percentiles because of obesity and malnutrition; 2) the Southeast and South regions of Brazil represent the largest number of subjects in the sample, which may represent a tendency to characterize these regions more at the expense of others.

Conclusion

The current study presents the growth charts of a large and representative sample Brazilian children and adolescents aged 6-17 years. These data are useful for those working in medicine, public health, nutrition, and human biology in assessing growth in this population. The reference growth charts, available through this study, provide paediatricians, nutritionists, and educators essential information to monitor growth status of Brazilian children and adolescents using specific charts. Furthermore, these charts allow the detection of individuals or sub-groups at risk of disease and delayed growth (more related to country specificity). Finally, these Brazilian growth references provide important information that can support to public policy to combat and prevent malnutrition as thinness and obesity among Brazilian children and adolescents.

Collaborations

JB Mello contributed to conceptualization, methodology, data collection, data analysis, data curation, writing the original draft preparation. GC Nobre contributed to methodology, data analysis, data curation and writing the original draft preparation. AR Gaya contributed to methodology, results' discussion and reviewed it critically for important intellectual content. M Duncan contributed results' discussion and reviewed it critically for important intellectual content. A Nevill contributed to data curation, results' discussion and reviewed it critically for important intellectual content. A Gaya had guided the development of the research question and data analysis, to drafting the manuscript, reviewed it critically for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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