0021-7557/06/82-04/266
Jornal de Pediatria

doi:10.2223/JPED.1502

ORIGINAL ARTICLE

Body mass index cutoff points for evaluation of nutritional status in Brazilian children and adolescents

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Abstract

Objective: To delineate a classification system, comprising reference curves and cutoff points, based on the distribution of body mass index (BMI) across a national reference population and designed for the assessment of the nutritional status of Brazilian children and adolescents.

Methods: Data from 13,279 males and 12,823 females aged from 2 to 19 years, extracted from the National Nutrition and Health Survey dataset (1989), were used to construct a reference curve. The LMS method was employed to calculate the BMI curve parameters and polynomial functions were used to model these parameters against age. The cutoff values for classifying nutritional status as underweight, overweight and obese were expressed as centiles and BMI values equivalent to 17.5, 25 and 30 kg/m^2 at 20 years, respectively.

Results: Values for the L, M and S parameters were tabulated at 6-month intervals for each sex. Using these values, a graph was plotted with nine BMI distribution reference centiles. Cutoff values were presented that are equivalent to BMIs of 17.5, 25 and 30 kg/m^2 at the start of adulthood.

Conclusions: The classification system presented here can be used for clinical and epidemiological assessments, it is methodologically similar to the majority of national curves that have been presented to date and, furthermore, it offers a definition of underweight.

J Pediatr (Rio J). 2006;82(4):266-72: Reference standard, nutritional status, children, adolescents, BMI.

Introduction

The use of anthropometric measurements for the evaluation of nutritional status has become, albeit with limitations, the most practical and lowest cost means of analyzing individuals and populations, whether for clinical reasons, for screening projects or for monitoring tendencies.

An anthropometric reference standard or curve is a summarized representation of the distribution of a given anthropometric measurement according to a co-variable (usually age) and for each sex.[1] Reference curves represent a "healthy empirical model" and serve both for classification (comparing against the reference group) and for diagnosis (to separate healthy form unhealthy individuals) of the nutritional status of an individual or population.

Historically, the basis of anthropometric diagnosis of childhood nutritional status has oscillated between epidemiological and statistical foundations. Included in the initial classification systems are those proposed by Gomez, McLaren and Waterlow. These proposals were debated on the basis of indicators and outcomes selected to describe and classify childhood nutritional status.[2] Waterlow was the first of these to propose a classification system that was effectively probabilistic, i.e. statistical – to deal with the classification of nutritional status in children. This proposal was adopted by the WHO in 1975[3] and, since then, has predominated in the diagnosis of childhood nutritional status. Nevertheless, the choice of probabilistic classification for nutritional status in children contrasts with the classification of nutritional status in adults based on body mass index (BMI). In the latter case, classification is based on the no risk of mortality or disease associated with different BMI ranges, an epidemiological criterion.

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Manuscript received Sep 27 2005, accepted for publication Apr 29 2006.

Suggested citation: Conde WL, Monteiro CA. Body mass index cutoff points for evaluation of nutritional status in Brazilian children and adolescents. J Pediatr (Rio J). 2006;82:266-72.

The nutritional status of people less than 20 years old has traditionally been classified on the basis of probabilistic criteria. In 1997, the International Obesity Task Force (IOTF) proposed that nutritional status of people under 20 be defined on the basis of outcomes which, in adulthood would define diagnoses of malnutrition, overweight and obesity and/or on the basis of alterations to a variety of biochemical indicators that are associated with chronic diseases in the adult phase.[4] In 2000, a suite of cutoff values was published to define overweight and obesity in the 2 to 18 year age group.[5]

The use of curves based on BMI for age to define the nutritional status of children and adolescents offered practical solutions, but, on the other hand, it has also opened a debate on the use of such curves to assess the nutritional status of populations made up of growing individuals. The main points of this debate center on: 1) the universal or specific nature of body composition, a feature that is reflected in the debate on the adoption of local or international reference curves;[6,7] 2) the underlying principals and properties of a classification system based on BMI for age, which is reflected in the debate on the use of statistical or epidemiological criteria[8] and; 3) the influence of sexual maturation on body composition and the need to take account or not the stage of sexual maturity of those assessed.[9,10]

The objective of this paper is to present a reference system based on BMI, for the assessment of the nutritional status of Brazilian children and adolescents including the delineation of a reference curve and the definition of "statistical" and "functional" cutoff points for the diagnosis of malnutrition, overweight and obesity.

Material and methods

The dataset employed for delineation of the national BMI reference curve comes from the National Nutrition and Health Survey (*Pesquisa Nacional de Saúde e Nutrição*, PNSN) carried out by the Brazilian Institute of National Statistics and Geography in 1989.[11] The rigorous preparation and quality control observed during collection of anthropometric measurements, in addition to its national representativity (with the exception of the rural area of the North region), were decisive in the choice of this database.

In order to determine the adequacy of the PNSN dataset to the study objectives, the following analysis was performed: the PNSN data and data from the National Survey on Household Expenses (*Estudo Nacional de Despesa Familiar*, ENDEF), performed 14.5 years earlier, were standardized for age and sex according to CDC 2000 reference values for height and weight and then compared. Secular tendencies of figures for height for age below -2 z-scores and weight for age above 2 z-scores were observed. Over the period a reduction had occurred in height deficits (-59.5%) and there had been an increase in overweight (106.5%). However, the frequency of individuals whose weights for age were above 2 z-scores on the PNSN did not pass the classification's probability value.

The individuals selected for this study were 2 to 19 years old, with complete data available for sex, age (expressed in months), height (in cm, to one decimal place) and weight (in kg, to one decimal place). The final sample comprised 13,279 males and 12,823 females, representing 99% of available individuals of each sex.

Values for BMI more than 4 standard deviations from the mean from age and sex were excluded. The unconventional cutoff of ± 4 deviations was chosen to preserve, as far as possible, the heterogeneous nature of the sample.

The method used to compile the Brazilian curves was basically the same as that used to produce the BMI international standards.[5] In essence the LMS method assumes that, for independent data with positive values, the age-specific Box-Cox transformation can be used to make data normally distributed; the L values, M and S are *natural cubic splines* with *knots* at each age interval.[12] Each sample, male and female, was split into 3-month age groups. This 3-month subdivision was intended to represent the diversity of growth velocity and to ensure at least 100 individuals in each stratum, which is considered the minimum required for the LMS method. The L, M and S parameters were calculated for each stratum. The M parameter expresses the median value of the observed index within each stratum; the S parameter represents the coefficient of variation of each stratum and the L parameter the coefficient (Box-Cox) employed for the mathematical transformation of the BMI figures with the objective of obtaining normal distribution within each stratum. The value chosen for the L coefficient is that value whose transformation produces the lowest sum of the squares of the deviations of the variable. Next the curves for each parameter were smoothed using polynomials for each sex. Finally, by means of interpolation based on arithmetic means, monthly distribution values were obtained.

Using these three parameters it is possible to construct a curve for any centile that is required, using the formula:

$$\mathbf{C_{100\alpha(t)} = M_{(t)}\,[1 + L_{(t)}S_{(t)}Z_{\alpha}]^{1/L_{(t)}}}, \quad (1)$$

where Z_α is the equivalent normal deviation for the area α; $C_{100\alpha(t)}$ is the centile corresponding to $Z\alpha$; t is age in months and $L_{(t)}$, $M_{(t)}$, $S_{(t)}$ and $C_{100\alpha(t)}$ indicate the corresponding values for each curve at age t.

In order to establish cutoff points for the classification of nutritional status according to statistical criteria, the formula[1] used z values equivalent to centiles 85 and 95, recommended to diagnose overweight and obesity, respectively.[13,14]

In order to establish cutoff values according to epidemiological criteria, the final values desired at 20 years were set at a BMI of 25 kg/m^2 for overweight and a BMI of 30 kg/m^2 for obesity. Applied to the formula (2), these values allow their equivalent values over previous years to be estimated retrospectively.

$$\mathbf{Z = [(BMI/M)^{L} - 1]/(LS)} \qquad (2)$$

Additional analyses were carried out in the case of underweight, bearing in mind that the cutoff point traditionally recommended (18.5 kg/m^2) has not proven adequate for this classification on the international standard.[5] The selection of a cutoff point (at 20 years) to define underweight took account of statistical and epidemiological features. In the case of statistical criteria, the aim was to maintain compatibility with those statistical criteria usually employed, i.e. the value of -2 z-scores for defining nutritional deficits. In the case of epidemiological criteria, the plausibility of diagnosis was foremost, observed according to the following two features: 1) the expected prevalence – estimated on the basis of frequency of the z value – cannot be greater than or equal to the observed prevalence in the populations under study, in order to reduce the number of false-positive cases and to improve detection of true-negatives; 2) the BMI distribution at the start of adulthood selected was from a population in the top quartile of *per capita* income, a social stratum in which it is improbable that nutritional deficits of a socioeconomic nature will occur. In this group, the third centile of BMI between 19.5 and 20.4 years is 17.57 kg/m^2 for males and 17.48 kg/m^2 for females.

At 20 years, the z = -2 (p = 0.0228) point for the PNSN population sample was equivalent to BMI values of 17.78 kg/m^2 for males and 17.14 kg/m^2 for females.

On the basis of the assumptions and evidence described, the curve corresponding to a BMI of 17.5 kg/m^2 (at 20 years) was selected as the cutoff point to define underweight in the Brazilian population. In this manner, the use of a single figure for the classification of nutritional status of adults of both sexes was maintained for the classification of underweight.

All analyses were performed using the Stata statistical package (version 8).

Results

The low percentage of exclusions (1%), whether because of incomplete data or because of biological implausibility (BMI 4 standard deviations above or below average), is indicative of the consistency of data across the age spectrum, and evidence of the quality of the anthropometric measurements in the database that was employed, in addition to preserving the sample's national representativity.

Subdivision of the sample into three-month age groups resulted in a mean of 190 cases (n, minimum of 129 and maximum of 235) for the male sex, and 183 (minimum of 132 and maximum of 229) for the female sex.

Values for the parameters L, M and S for the Brazilian population are presented in six-month intervals by sex in Table 1.

Smoothing the curves for each sex produced the following results: the L curve was analyzed with a 4th degree polynomial for both sexes, the M curves, with a 4th degree polynomial for males an 8th degree polynomial for females, the S curve was adjusted with a 4th degree polynomial for both sexes.

Table 1 contains descriptive parameters of the reference BMI distribution for the Brazilian population aged 2 to 20 years, obtained at the end of the modeling process. Figure 1 presents, for each sex, seven centiles from the reference distribution.

The L values permit the inference of the magnitude and type of adjust needed to normalize BMI within each stratum. The preponderance of negative values indicates that the data employed in the preparation of the standard proposed exhibited asymmetry (skewness) to the right; the relatively small amplitude of the L parameter, in both sexes, is indicative of the low magnitude of the asymmetry that had to be removed. The mean for the L values for both sexes approaches -1. For the age range where one would expect to find peaks in the sexual maturation process (11

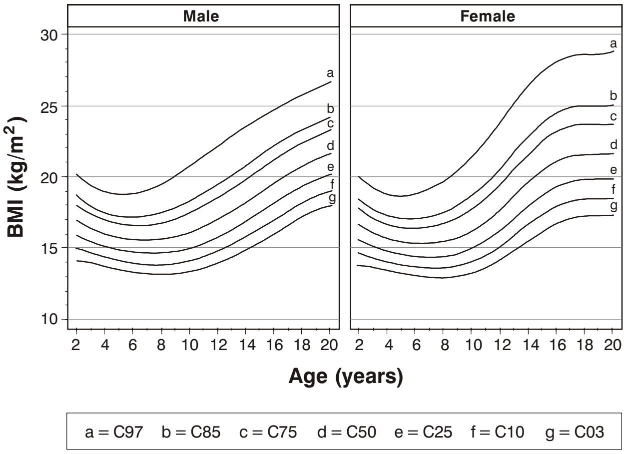

Figure 1 - Centiles for distribution of Brazilian BMI curves, by sex BMI = body mass index.

to 13 years), the L parameter had a mean of -1.20. The most intense asymmetrical point was in the age range from 6 to 11 years, a period before the start of the collection of phenomena that make up sexual maturation, with L values of -1.36 for males and -1.38 for females.

The mean variance of BMI across the different strata, expressed by the S parameter, was around 10% for each sex, with a small amplitude (from 8 to 14%). In the age range within which one would expect to observe peak sexual maturation (11 to 13 years), the mean for the S parameter was 13.2%.

The path traced by the S curve against age declines from the start point up to 52 months (4.3 years), at which point it begins to follow an ascending trajectory until the point at which sexual maturation would be expected (11 to 13 years). The S values for both sexes reach their highest values at this stage. Next there is a short stabilization period around the highest values. After the phase of sexual maturation, the S curve takes on different characteristics depending on sex. For males, the S curve exhibits a clear reduction in variance, while for females the reduction is not so accentuated and

Table 1 - Values for L, M and S parameters of the body mass index distribution for a Brazilian reference population aged 2 to 19 years, by age and sex

Age	Male			Female		
(months)	L	M	S	L	M	S
24.0	0.1791	16.9476	0.0939	0.1228	16.7003	0.0990
24.5	0.1551	16.9242	0.0935	0.0970	16.6730	0.0985
30.5	-0.1155	16.6587	0.0892	-0.1906	16.3666	0.0936
36.5	-0.3564	16.4192	0.0864	-0.4427	16.1042	0.0903
42.5	-0.5691	16.2071	0.0848	-0.6613	15.8899	0.0884
48.5	-0.7549	16.0233	0.0843	-0.8487	15.7212	0.0878
54.5	-0.9153	15.8687	0.0847	-1.0069	15.5927	0.0882
60.5	-1.0519	15.7438	0.0859	-1.1381	15.4984	0.0895
66.5	-1.1659	15.6492	0.0877	-1.2442	15.4331	0.0915
72.5	-1.2588	15.5852	0.0899	-1.3273	15.3937	0.0941
78.5	-1.3321	15.5519	0.0926	-1.3893	15.3791	0.0972
84.5	-1.3870	15.5491	0.0955	-1.4321	15.3907	0.1006
90.5	-1.4250	15.5767	0.0985	-1.4575	15.4316	0.1043
96.5	-1.4475	15.6341	0.1016	-1.4675	15.5062	0.1080
102.5	-1.4557	15.7209	0.1046	-1.4637	15.6196	0.1118
108.5	-1.4510	15.8361	0.1075	-1.4479	15.7766	0.1154
114.5	-1.4348	15.9787	0.1101	-1.4219	15.9811	0.1190
120.5	-1.4082	16.1477	0.1126	-1.3872	16.2358	0.1223
126.5	-1.3727	16.3417	0.1147	-1.3454	16.5409	0.1254
132.5	-1.3296	16.5590	0.1165	-1.2983	16.8943	0.1282
138.5	-1.2800	16.7981	0.1180	-1.2472	17.2914	0.1306
144.5	-1.2252	17.0571	0.1190	-1.1937	17.7248	0.1326
150.5	-1.1665	17.3337	0.1197	-1.1392	18.1845	0.1343
156.5	-1.1051	17.6259	0.1199	-1.0852	18.6589	0.1355
162.5	-1.0423	17.9312	0.1198	-1.0330	19.1345	0.1364
168.5	-0.9792	18.2468	0.1193	-0.9838	19.5971	0.1369
174.5	-0.9170	18.5701	0.1185	-0.9392	20.0331	0.1370
180.5	-0.8569	18.8981	0.1173	-0.9001	20.4294	0.1368
186.5	-0.8001	19.2275	0.1159	-0.8679	20.7755	0.1364
192.5	-0.7476	19.5551	0.1143	-0.8438	21.0626	0.1357
198.5	-0.7008	19.8773	0.1126	-0.8287	21.2880	0.1348
204.5	-0.6606	20.1904	0.1108	-0.8239	21.4503	0.1339
210.5	-0.6282	20.4905	0.1090	-0.8303	21.5551	0.1329
216.5	-0.6048	20.7735	0.1074	-0.8490	21.6111	0.1321
222.5	-0.5913	21.0352	0.1060	-0.8809	21.6310	0.1314
228.5	-0.5889	21.2712	0.1050	-0.9268	21.6297	0.1310
234.5	-0.5986	21.4768	0.1044	-0.9877	21.6220	0.1311
240.0	-0.6191	21.6343	0.1044	-1.0575	21.6195	0.1316

variance remains concentrated around values close to those at the end of the sexual maturation stage.

Table 2 presents the cutoff points for the Brazilian population aged 2 to 20 years, obtained by applying formula (1), for the classification of underweight (curve equivalent to BMI of 17.5 kg/m^2 at 20 years), overweight (curve equivalent to BMI of 25 kg/m^2 at 20 years) and obesity (curve equivalent to BMI of 30 kg/m^2 at 20 years).

The curves for the centiles traditionally used as cutoff points for overweight (centile 85) and obesity (centile 95) together with those for the values based on outcomes at the start of adulthood (25 kg/m^2 and 30 kg/m^2, respectively) are shown in Figure 2. For the male sex, the prevalence rates of underweight, overweight and obesity would be higher than those obtained if, instead of employing cutoffs based on adult values, the

Table 2 - Proposed BMI cutoff points for the definition of underweight, overweight and obesity in the Brazilian 2 to 19 year-old reference population, by sex and age

Age	**Male**			**Female**		
(months)	**UW (17.5 kg/m^2)**	**OW (25 kg/m^2)**	**OB (30 kg/m^2)**	**UW (17.5 kg/m^2)**	**OW (25 kg/m^2)**	**OB (30 kg/m^2)**
24.0	13.77	19.17	21.98	13.95	18.47	20.51
24.5	13.77	19.13	21.94	13.94	18.43	20.47
30.5	13.76	18.76	21.53	13.87	18.03	20.00
36.5	13.70	18.45	21.21	13.76	17.70	19.64
42.5	13.61	18.20	20.98	13.66	17.44	19.38
48.5	13.50	18.00	20.85	13.55	17.26	19.22
54.5	13.39	17.86	20.81	13.46	17.14	19.15
60.5	13.28	17.77	20.85	13.37	17.07	19.16
66.5	13.18	17.73	20.98	13.28	17.05	19.23
72.5	13.09	17.73	21.19	13.21	17.07	19.37
78.5	13.02	17.78	21.48	13.15	17.12	19.56
84.5	12.96	17.87	21.83	13.10	17.20	19.81
90.5	12.93	17.99	22.23	13.07	17.33	20.10
96.5	12.91	18.16	22.69	13.07	17.49	20.44
102.5	12.92	18.35	23.17	13.09	17.70	20.84
108.5	12.95	18.57	23.67	13.16	17.96	21.28
114.5	13.01	18.82	24.17	13.26	18.27	21.78
120.5	13.09	19.09	24.67	13.40	18.63	22.32
126.5	13.19	19.38	25.14	13.58	19.04	22.91
132.5	13.32	19.68	25.58	13.81	19.51	23.54
138.5	13.46	20.00	25.99	14.07	20.01	24.21
144.5	13.63	20.32	26.36	14.37	20.55	24.89
150.5	13.82	20.65	26.69	14.69	21.12	25.57
156.5	14.02	20.99	26.99	15.03	21.69	26.25
162.5	14.25	21.33	27.26	15.37	22.25	26.89
168.5	14.49	21.66	27.51	15.72	22.79	27.50
174.5	14.74	22.00	27.74	16.05	23.28	28.04
180.5	15.01	22.33	27.95	16.35	23.73	28.51
186.5	15.29	22.65	28.15	16.63	24.11	28.90
192.5	15.58	22.96	28.34	16.87	24.41	29.20
198.5	15.86	23.27	28.52	17.06	24.65	29.42
204.5	16.15	23.56	28.71	17.22	24.81	29.56
210.5	16.43	23.84	28.89	17.33	24.90	29.63
216.5	16.70	24.11	29.08	17.40	24.95	29.67
222.5	16.95	24.36	29.28	17.45	24.96	29.70
228.5	17.18	24.59	29.50	17.47	24.96	29.74
234.5	17.37	24.81	29.75	17.49	24.97	29.83
240.0	17.50	25.00	30.00	17.50	25.00	30.00
Z	- 2.17	1.32	2.83	- 1.80	1.02	2.10
p	0.015	0.907	0.998	0.036	0.847	0.982

BMI = body mass index; OB = obesity; OW = overweight; UW = underweight.

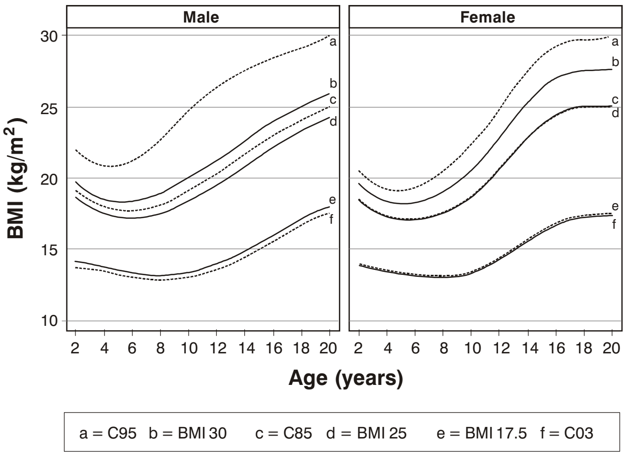

Figure 2 - Cut off points (traditional centiles and adult outcomes) based on the Brazilian body mass index distribution for the classification of the nutritional status of children and adolescents
BMI = body mass index.

traditional centiles were used to define these diagnoses. For females, the same "overestimation" would only occur for diagnoses of obesity; overweight and underweight would be comparably classified whether using the 85th and 3rd centiles or the curves equivalent to 25 kg/m^2 and 17.5 kg/m^2, respectively.

Discussion

The debate on the properties of a national, BMI-based system for the classification of nutritional status in children and adolescents can be broken down into 1) appreciation of the adequacy of the sample used to compile the reference curves and 2) appreciation of the criteria selected to identify the nutritional problems that need to be diagnosed.

An analysis of the period 1974/1975 to 1989 and an analysis of the richest quartile of the PNSN sample shows that the database selected was not negatively impacted by secular height and weight tendencies within the selected group.

Two other published studies have used the PNSN and described the distribution of BMI by age and sex in Brazilian children and adolescents. The first of these worked with the 10 to 17 year age group, at annual intervals. The 10th and 90th percentiles were proposed as cutoffs for diagnosing nutritional deficit and overweight, respectively. The 99th centile was chosen because, at 18 years, it coincided with 25 kg/m^2. The values were smoothed using movable means.[15] The second of these papers used the 0 to 25 year age range, for both sexes. The resulting values were not subjected to any kind of modeling.[16]

While there were differences in terms of statistical procedure, the two studies exhibited similar values for the distribution of BMI from 10 and 17 years, the age range that is common to both. The essential difference between the two studies is that, while Sichieri & Allam[15] generated their distribution as a national reference for nutritional classification by BMI, Anjos et al.[16] explicitly recommend that their distribution should not be used for nutritional diagnosis.

Modeling of data that change with age and are, originally, asymmetrical, can be performed using a variety of methods.[17] Using the LMS method allows Box-Cox transformation to be performed (which is efficient at removing asymmetry), and also to independently model the coefficient of variation, better than standard deviation. Furthermore, the fact that LMS is the most widely used method for the delineation of BMI reference curves allows for greater international compatibility between the parameters compiled here and those of curves from other countries or from international ones. Some exercises already carried out along these lines have demonstrated that using the international curve can alter the prevalence of overweight as measured during childhood and adolescence. The direction of the effect depends on age group and national characteristics.[18,19]

The decision on which criteria to adopt for the classification of nutritional status in children and adolescents based on their BMI is a subject that is still open, although recently opinion has been coalescing around the option tom use the set of curves obtained by retrogression from the values used to classify the nutritional status of young adults. In the Brazilian context, using the 85th and 95th centiles, rather than adult BMI-based cutoffs, would result in higher numbers of women diagnosed as obese and for men, higher prevalence rates of malnutrition, overweight and obesity. The observation that height continues to increase until close to 20 years in the population used to construct the curve, motivated the choice of this age for BMI outcomes. Any possible option for a classification system based on adult outcomes, however, should only be chosen after wider discussion, which should take account of the aspect of classifying nutritional deficits.

The proposal made here of using a BMI of 17.5 kg/m^2 as a cutoff point for nutritional deficit among children and adolescents, however, requires further analysis and wider discussion before possibly being adopted.

The process of sexual maturation, whose progress includes modifications to body composition, can be a complicating factor when performing nutritional assessment on the basis of BMI for age. Therefore, analysis of variance within and across generations is the key issue for answering the question of whether or not it is necessary to control for phase of sexual maturity.

Evidence obtained from population studies suggests that intergenerational variation is smaller than intragenerational. This includes: 1) the small differences observed between countries in terms of median age of menarche and the reduction in the rhythm of secular tendencies, in particular when analyzed according to Tanner stages;[20] 2) indications that, for the population as a whole, countries such as the USA and Holland do not currently exhibit the tendency towards reducing age at menarche;[21,22] 3) in Brazil, the reduction in age at menarche is estimated at 2.4 to 2.7 months per decade.[23,24]

Taken together this evidence allows for the assumption that, in the case of Brazil, the impact of intergenerational variation (including variations within and between individuals) should not distort the curves presented here.

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