Glob. J. Med. Pharm. Sci.
ISSN PRINT: 2957-3610, **ISSN ONLINE**: 2957-3629
Website: https://globapc.com/
Open Access Journal

Global
Journal of Medical and
Pharmaceutical Sciences

ORIGINAL ARTICLE OPEN ACCESS

A Longitudinal Study of Brazilian Adolescents' Growth

Isa de Pádua Cintra[1], Gerson Luis de Moraes Ferrari[2]
[1,2] Adolescent Medicine Sector, Department of Pediatrics, Federal University of São Paulo (UNIFESP/EPM), São Paulo, Brazil.

OPEN ACCESS

Corresponding Author
Isa de Pádua Cintra
Adolescent Medicine Sector, Department of Pediatrics, Federal University of São Paulo (UNIFESP/EPM), São Paulo, Brazil.

Received:12-11-2023
Accepted:18-12-2023
Available online:27-12-2023

ABS TRAC T

***Objectives*:** The goal of this research was to document the changes in adolescents' heights over a three-year period and look into how these changes related to age, gender, sexual maturation, and nutritional markers. ***Methods*:** Age, gender, height, body weight, body mass index, sexual maturity as measured by the Tanner scale, menarche date, birth weight and height, childhood obesity, length of nursing, family income, and mother education level were all evaluated. Logistic regressions, percentile analyses, and two-way analyses of variance, often known as the Friedman test, were used for statistical analysis. ***Results*:** 557 teenagers between the ages of 10 and 15 made up the sample; 54% of them were female. At the first, second, and third year follow-up assessments, the average heights were 152.02 ± 9.26 cm, 156.75 ± 8.61 cm, and 160.13 ± 8.14 cm, respectively. For girls and boys, the average height growth from baseline to the conclusion of the research was 6.74 cm and 9.73 cm, respectively. Ten-year-old underweight prepubescent boys had a greater mean growth velocity (GV) (5.4 cm/year). Lower GVs were linked to body weight (OR 1.05; 1.03–1.07), age (older adolescents; OR 2.43; 1.84–3.21), and gender (girls: odds ratio [OR] = 5.97; 95% confidence intervals [CI] = 3.36–10.59). ***Conclusions*:** Adolescent diagnoses were more accurate when development was evaluated according to sexual maturation stage rather than age. Growth was restricted by being female, overweight, and older. Brazilian teenagers attending public schools showed progress that was equivalent to global standards.

Keywords: *Percentiles, Body Height, Adolescents, Sexual Maturation, Longitudinal Study.*

INTRODUCTION

All of the physical changes connected to the transition from childhood to adulthood take place during puberty, a comparatively brief stage of adolescence that lasts between two and four years. The most common feature of puberty is its variability. Growth and development are genetically planned from conception to complete maturity, but this process may be altered by variables that are specific to each person (constitutional or intrinsic) or determined by external conditions. Therefore, parameters based on physiological maturity are required to measure pubertal development, since age is not a reliable indication of teenage growth. Adolescence is a time of intense skeletal development, sometimes known as the "adolescent growth spurt." Overcoming this obstacle will result in a greater comprehension of the beneficial changes that occur during this phase of life, the identification of the so-called normative elements that are essential for development, and the potential to gather more accurate, continuous, and supported information, all of which will set the stage for a healthy adolescence4. Longitudinal studies are sometimes used to provide a more detailed explanation of development in order to better comprehend this phenomena. Few long-term studies have evaluated adolescents' growth velocity (GV) in Brazil. Therefore, throughout a three-year period, the current research aimed to examine the relationships between GV and age, sexual maturation, and nutritional markers among teenagers from São Paulo.

MATERIALS AND METHODS

Participants and sampling methods

The population-based research "The Progression of Adolescent Height and its Relationship with Nutritional Indicators: A Longitudinal Study" includes the evaluated teenagers. The State Education Secretary of So Paulo requested that the participants be situated close to an adolescent care center in order to reduce transportation issues when the professional team requested specific care, so the sample was non-probabilistic, deliberate, and chosen through convenience sampling. From 2010 to 2013, three public schools participated in the sample collection, with permission from their directors. The participants were between the ages of 10 and 15, did not participate in weight-loss programs, had no mental or chronic illnesses, did not take any medications that may affect body composition, and were neither pregnant nor nursing. For the current longitudinal research, 837 teenagers in grades 4 through 8 who had their parents or guardians sign an informed consent form were chosen. 280 participants' data were not examined as they were absent, often as a result of the pupils transferring to a different school. As a result, 557 teenagers (54% female) who supplied three years of full data made up the final sample.

Adolescent sample selection

As a comparison group, data from a sample of teenagers who had the same project coordinators6–8 and who satisfied the inclusion criteria of earlier research carried out in São Paulo were used. These teenagers' average height was 156.64 cm (standard deviation [SD] = 9.68). With a statistical error of around 2.0%, the sample size was determined to be n = 5419. The Federal University of São Paulo Review Board, procedure 0803/09, authorised the current research.

Data Collection

Anthropometric measurements were taken at 12-month intervals throughout the first and second semesters between 2010 and 2013. The evaluations were coordinated by a professor and two graduate students, who also trained and oversaw the personnel who gathered the data. Over the course of the investigation, three time points were used for the measurements. To prevent memory bias and guarantee that the examiners would be blind to previous assessments, the data were recorded on different forms.

A Seca portable digital scale with a 150 kg capacity was used to measure body mass (kg). According to Jelliffe 11, the measurement was recorded. According to Jelliffe11, height (m) was measured using a Seca wall-mounted stadiometer that was fastened to a wall without a baseboard and perpendicular to the ground. Body mass index (BMI; kg/m2) was calculated using the participants' weights and heights. The results were interpreted using the World Health Organization's (WHO) criteria, which state that a z-score < -2 = underweight; -2 ≤ z-score ≤ +1 = normal weight; +1 < z-score ≤ +2 = overweight; and +2 > z-score = obese [12].

Using the Tanner scale, the girls' (B1–B5) and boys' (G1–G5) self-evaluations of their genital and breast development were used to determine the sexual maturation stage [13]. Individuals who self-reported stages B1 and G1 were categorised as prepubescent, those who self-reported stages B2–B4 and G2–G4 as pubescent, and those who self-reported stages B5 and G5 as postpubescent [14].

In order to determine the amount of time that had passed since menarche, the girls reported whether or not they had experienced menarche. If they had, they also reported the relevant date (recall method) [15, 16]. Weight and length at birth, childhood obesity, length of nursing, full-term delivery (yes or no), family income, and mother education level were all taken into account.

Statistical analyses

The quantitative variables' absolute (n) and relative (%) frequencies, means, SDs, minimums, maximums, medians, and quartiles were all calculated using descriptive statistics. Fisher's exact test or chi-square were used to compare categorical variables across groups. The Mann-Whitney test was used for comparisons between groups, and the Kruskal-Wallis test was used for comparisons between three or more groups. The McNemar, Bowker, Friedman, and Wilcoxon tests were used to compare the outcomes of the three evaluations17. GV (cm/year) was calculated as follows: Prior to calculating the overall velocity, the GVs between the three assessment pairings (first to second and second to third) were determined. The height disparities between the assessments were computed and then divided by the number of years between the tests. A univariate logistic regression was used to conduct a basic study of the GV in relation to the independent variables (reference group: "lower GV"). The odds ratio (OR) and associated 95% confidence intervals (CIs) with greater and lower GVs as outcomes were estimated using a binary regression analysis. The variables linked to $p<0.20$ on the adjusted analysis were included in the final model. The final model [18] was constructed using the stepwise process. Higher GV was defined as > 2.18 cm/year, while lower GV was defined as < 2.18 cm/year (1st quartile or 25th percentile). A repeated-measures analysis of variance (ANOVA) and Tukey's test were used to compare the groups. The data distribution was not normal, thus the variables were converted into rankings for analysis. Percentiles (3rd to 97th) [6] were used to represent the distribution of changes per assessment time-point, gender, and Tanner's stage. SAS (version 9.3) was used to conduct the analysis. 5% was used as the significant threshold [17, 19].

RESULTS

At baseline, the participants were 10 to 15 years old, and their anthropometric data (i.e., height, weight, and BMI) were assessed based on gender, age, and sexual maturation.

The results shown in Table 1 demonstrate that most adolescents from both genders were 12 years old and at stages G2 and B2 at the first assessment, 13 years old and at G2 and B4 at the second assessment, and 14 years old and at G3 and B4 at the third assessment.

Table 1: The percentage of adolescents by age and sexual maturation stage throughout the study

Age (years)	1st assess-ment	2nd assess-ment	3rd assess-ment
10	9.87%	-	-
11	25.49%	7.72%	.72%
12	31.96%	27.65%	14.18%
13	23.70%	30.16%	25.31%
14	7.36%	24.78%	33.03%
15	1.62%	8.62%	20.11%
16	-	1.08%	5.39%
17	-	-	1.26%
Sexual maturation	**1st assess-ment**	**2nd assess-ment**	**3rd assess-ment**
G1	20.31%	5.47%	1.17%
G2	49.61%	37.11%	20.31%
G3	22.26%	32.03%	37.11%
G4	6.64%	23.05%	34.37%
G5	1.17%	2.34%	7.03%
B1	7.31%	1.66%	.33%
B2	31.23%	17.61%	8.64%
B3	30.90%	27.24%	23.25%
B4	20.60%	34.55%	40.53%
B5	9.97%	18.94%	27.24%

Table 2 describes the sample characterization with regard to height, birth weight, family income, the education level of the mother or guardian, breastfeeding duration, and childhood obesity.

Table 2: Characterization of adolescents from São Paulo, including maternal and socioeconomic variables

Variable	Mean (SD) or N (%)	*p-value
Birth weight (kg)	3.220 (574.0)	---
Birth length (cm)	47.15 (3.59)	---
Family income (BRL)	2,049 (1,860)	---
Maternal education (finished secondary school)	76 (35.2)	---
Gender		
Boys	95 (57.2)	.051
Girls	71 (42.8)	
Breastfeeding		
No	18 (10.9)	.408
Yes	147 (89.1)	
Breastfeeding duration		
< 6 months	51 (35.0)	.355
≥ 6 months	96 (65.0)	
Preterm		
No	139 (84.1)	.441
Yes	26 (15.9)	
Childhood obesity		
No	149 (90.0)	.307
Yes	17 (10.0)	
* chi-square or Fisher's exact test (p < 0.05).		

The mean height (cm), weight and BMI of the girls at the beginning and end of the study were 152.23 (7.94) vs. 158.97 (6.10) cm; 47.25 (11.85) vs. 54.58 (11.88) kg; and 20.28 (4.37) vs. 21.56 (4.39), respectively; the corresponding values for boys were 151.77 (10.6) vs. 161.5 (9.86) cm; 45.80 (13.47) vs. 54.35 (14.05) kg; and 19.53 (4.03) *vs.* 20.75 (4.20), respectively.

Table 3: Adolescent mean height by age, gender, and assessment time-point

Age (years)	Assessment 1	Assessment 2	Assessment 3

Boys			
10	141.90 (n = 56)	142.95 (n = 6)	----
11	142.50 (n = 52)	148.60* (n = 49)	147.10 (n = 14)
12	151.90 (n = 89)	153.55 (n = 54)	155.00 (n = 52)
13	161.95 (n = 46)	151.50* (n = 81)	160.00 (n = 66)
≥ 14	166.50 (n = 13)	167.50 (n = 23)	167.30 (n = 123)
Girls			
10	145.00 (n = 58)	146.90 (n = 3)	----
11	150.50 (n = 89)	152.60 (n = 54)	154.30 (n = 7)
12	154.50 (n = 99)	154.40 (n = 90)	156.50 (n = 69)
13	157.90 (n = 45)	156.70 (n = 90)	159.50 (n = 86)
≥ 14	161.85 (n = 10)	160.40 (n = 64)	160.00 (n = 139)
$p < 0.05$ * difference between 1st and 2nd assessment; # difference between 2nd and 3rd assessment.			

Table 4 describes the mean height percentiles obtained at the three assessments by gender, age, and sexual maturation.

Table 4: Mean height (cm) of adolescents from São Paulo for the three assessments by age, gender, and sexual maturation stage

Variables	M (SD)	3%	5%	10%	15%	25%	50%	75%	85%	90%	95%	97%
Gender												
Boys	156.9	139.4	141.1	143.3	145.0	149.3	156.2	164.7	168.2	170.6	174.1	176.4
Girls	151.0	141.5	143.7	147.0	149.1	151.7	156.1	159.9	162.6	164.0	166.7	167.9
Age Boys												
10 years old	142.3	132.6	133.2	134.0	134.8	136.0	142.4	146.8	148.6	155.6	164.6	168.0
11 years old	148.2	135.1	135.9	139.1	140.4	142.7	147-4	152.5	157.5	159.8	163.7	167.5
12 years old	153.5	139.8	140.8	143.7	145.3	147.2	153.5	158.8	161.8	164.8	177.5	170.1
13 years old	160.2	144.3	145.6	148.4	150.9	153.4	160.2	165.8	168.7	170.6	174.4	175.8
14 years old	165.4	148.4	149.9	152.6	157.0	161.0	165.6	169.9	173.5	177.3	181.1	182.7
≥15 years old	170.2	159.0	160.2	162.7	164.7	167.2	170.0	173.8	175.9	178.9	180.9	182.9
Age Girls												
10 years old	146.4	135.6	136.9	138	138.3	139.8	145.9	150.0	151.7	155.0	156-7	158.3
11 years old	151.5	138.0	139.9	142.2	143.8	145.8	152.5	157.0	158.8	159.5	161.3	162.4
12 years old	155.3	141.8	143.8	146.9	148.9	150.9	155.6	159.9	162.0	163.3	166.1	167.1
13 years old	158.2	149.1	153.2	151.5	153.0	154.8	158.0	161.1	164.0	165.4	168.2	169.4
14 years old	160.3	150.9	151.9	153.1	154.1	155.7	160.2	163.9	167.0	168.1	170.7	171.8
≥ 15 years old	162.5	155.0	155,5	156.0	156.6	159.9	163.3	165.3	168.5	167.9	173.5	175.0
Tanner Boys												
G1	147.1	136.1	136.4	136.8	140.6	140.9	146.2	152.7	154.5	158.7	160.1	160.1
G2–G4	157.6	140.4	141.8	144.0	145.9	149.9	157.2	165.4	168.6	171.2	174.3	176.4
G5	162.2	148.7	148.9	150.0	151.2	158.1	163.8	166.7	168.3	172.1	172.2	172.2
Tanner Girls												
B1	143.1	134.1	134.2	135.2	135.7	139.6	142.6	147.8	149.9	150.7	150.8	151.1
B2–B4	155.5	141.7	143.3	146.8	149.0	151.4	156.0	158.4	162.1	163.6	166.6	168.0
B5	158.8	145.8	149.7	151.6	152.9	154.9	158.6	163.3	165.0	166.1	167.2	167.8

Approximately 61.4% of the girls had undergone menarche by the beginning of the study, and 89.4% had done so by the end of the study.

No nutritional deviation with regard to participants' height was detected at any point throughout the study, and more than 98% of the participants exhibited a normal height. The mean GVs measured at the first, second, and third assessments were 4.71 (3.54) cm, 4.32 (3.86) cm, and 4.53 (2.87) cm, respectively. The mean growth figures corresponding to the 1st quartile at the first, second, and third year were 1.97, 1.36, and 2.18 cm, respectively, and those corresponding to the 3rd quartile were 6.74, 6.49, and 6.37 cm, respectively.

Table 5: A comparative analysis between GV and gender, age, nutritional status, sexual maturation, and menarche

Variables	n	Mean	SD	Mini-	1Q	Median	3Q	Maximum	p-value

				mum					
Gender									
Boys	256	5.47	2.84	0.11	3.43	5.48	7.51	21.24	< .0001[*]
Girls	301	3.72	2.65	0.00	1.62	3.27	5.39	15.24	
Age (years)									
10[1]	55	5.75	2.27	0.82	4.62	5.68	6.74	12.92	
11[2]	142	5.53	2.84	0.44	3.53	5.39	6.99	21.24	
12[3]	178	4.82	2.93	0.00	2.48	4.39	6.89	15.16	< .0001[$]
13[4]	132	3.32[dgi]	2.46	0.15	1.35	2.89	5.21	12.40	
≥14[5]	50	2.48[ehj]	2.11	0.00	1.04	1.85	3.29	8.80	
IMC									
Underweight[1]	15	5.74	2.66	1.82	4.15	5.84	6.89	11.17	
Normal weight[2]	346	4.72	2.86	0.00	2.58	4.51	6.66	21.24	
Overweight[3]	131	4.10[c]	3.01	0.11	1.42	3.66	6.16	14.08	.016[$]
Obese[4]	65	4.10[d]	2.55	0.00	2.18	3.82	5.79	15.16	
Sexual maturation (boys)									
G1[1]	52	5.87	2.38	0.98	4.30	5.69	7.74	11.41	
G2–G4[2]	201	5.42	2.93	0.11	3.46	5.45	7.50	21.24	.034[$]
G5[3]	3	1.99[c f]	1.24	1.00	1.00	1.60	3.38	3.38	
Sexual maturation (girls)									
B1[1]	22	6.08[bc]	2.78	2.00	4.38	6.07	7.14	15.24	
B2–B4[2]	249	3.64	2.47	0.00	1.62	3.27	5.19	12.92	< .0001[$]
B5[3]	30	2.67	3.06	0.00	1.04	1.74	3.28	15.16	
Menarche									
No	110	5.03	2.32	0.70	3.45	4.87	6.36	15.24	< .0001[*]
Yes	175	2.72	2.42	0.00	1.08	1.91	3.82	15.16	

Abbreviations: SD: Standard deviation; 1Q: 1st quartile; 3Q: 3rd quartile

[*] Mann-Whitney test (p < 0.05)

[$] Two-way ANOVA (p < 0.05)

[a] Multiple comparisons using Tukey test

[b] for comparison between 1 and 2

[c] for comparison between 1 and 3

[d] for comparison between 1 and 4

[e] for comparison between 1 and 5

[f] for comparison between 2 and 3

[g] for comparison between 2 and 4

[h] for comparison between 2 and 5

[i] for comparison between 3 and 4

[j] for comparison between 3 and 5

Tables 6 and 7 display the results of the univariate and multivariate logistic regressions investigating the relationship of the factors associated with a lower GV. All of the variables analyzed in the model were significantly associated with a lower GV.

The results of the multivariate analysis (Table 7) using the stepwise method for variable selection showed that age, gender, and body weight were significantly associated with a lower GV. The adolescents at the highest risk for lower GV were females (6 times higher) who were older (2.4 times higher for each additional year) and heavier.

Table 6: The results of the univariate regression analysis for lower GV: OR and 95% CIs

Variable	OR	95% CIs	p-value
Gender			< 0.0001

Boys	1	---	
Girls	3.50	2.27-2.98	
Age (continuous)	2.42	1.96-2.98	< 0.0001
Age (years)			< 0.0001
10	1	---	
11	1.75	0.48-6.38	
12	5.02	1.49-16.95	
13	12.38	3.68-41.69	
≥ 14	22.06	6.07-80.20	
Sexual maturity			< 0.0001
Prepubescent	1	---	
Pubescent	8.03	2.48-25.97	
Postpubescent	47.31	12.11-184.86	
BMI (WHO)			0.043
Underweight	1	---	
Normal weight	3.68	0.48-28.44	
Overweight	8.37	1.07-65.60	
Obesity	4.96	0.61-40.60	
Weight	1.07	1.05-1.09	< 0.0001

*OR: odds ratio for lowest growth rate: (n = 139 with lowest rate and n = 418 with highest rate; 95% CIs: 95% confidence intervals corresponding to the OR.

Table 7: The results of the multivariate logistic regression analysis for lowest growth rate

Variable	OR	95% CIs	p-value
Gender			< 0.0001
Boys	1	---	
Girls	5.97	3.36-10.59	
Age (continuous)	2.43	1.84-3.21	< 0.0001
Weight	1.05	1.03-1.07	< 0.0001

*OR: odds ratio for the lowest growth rate: (n = 139 with lowest rate and n = 418 with highest rate; 95% CIs: 95% confidence interval corresponding to the OR.

DISCUSSION

In emerging nations like Brazil 20, the stabilisation of height that started in the second part of the 20th century in industrialised nations happened later. Brazilian teenagers' heights roughly matched inter-national reference values between the 1970s and the start of the 21st century, although in recent decades, there have been lower gains in height at the conclusion of adolescence and the start of adulthood. As a result, although the Brazilian population's overall height grew between 1974 and 2002, the growth in height between the ages of 10 and 19 slowed down gradually. Less than 2% of teenagers have a height disadvantage. 84.24% of the adolescents were born full-term; 80.09% had been breastfed for more than six months; 45.78% of the mothers or guardians had attended secondary school without graduating; and their mean birth weight and length were 3.22 kg and 38.89 cm, respectively, according to a questionnaire given over the phone to the relatives of about 30% of the adolescents. These elements help to improve children's nutritional condition [22, 23].

Boys aged 11 and 13 showed a substantial variation in height between the first and second evaluations, as Table 3 illustrates. Before the second examination, several of the boys who were ten years old at the time of the first assessment had grown. However, compared to the first evaluation, the number of boys rose and the median height dropped at age 13. As seen by the decline in mean height at that age, these results most likely indicate that many of the boys who were 13 years old at the second evaluation were shorter because they were prepubescent. The third assessment's mean height was close to baseline. According to the 2008–2009 Household Budget Survey (HBS), males aged 10, 11, 12, 13, and ≥ 14 had heights of 139.9, 143.6, 151, 157.5, and 164.1 cm, while girls of the same age had heights of 140.4, 147.5, 153, 157, and 159.1 cm. A comparison of the two datasets revealed that the participants in this research were taller, particularly the girls aged 10 to 12 and the males aged 10 to 13. Crucially, the current research only evaluated students from urban regions, while the HBS evaluated students from both urban and rural areas [24].

When females were between the ages of 10 and 12, their median height was greater than that of boys; at age 13, it became comparable; and at age 14, it began to decline. Bergmann *et al*., [25] discovered somewhat different outcomes because At ages 10 and 11, females were taller than boys; at age 12, they were comparable; and at ages 13 and 14, they were shorter. However, between the ages of 13 and 14, a significant gender difference was discovered. According to Machado *et al*., [26], girls outgrew boys at ages 10, 12, and 13, while boys outgrew girls at ages 11 and 14. In contrast, Silva *et al*., [27] discovered that girls' growth peaked between the ages of 10 and 12, while boys' growth peaked between the ages of 13 and 16. The findings in relation to the mean height and height percentiles are shown in Table 4. The females were taller than the boys below the 50th percentile. The difference between the boys and girls in the 97th percentile was 8.5 cm, and this trend inverted at the 50th percentile. At age 13, there was a gender shift that favoured males in terms of both mean height and the 50th percentile for height. The adolescents aged 10 to 15 had mean heights of 155.7 cm for females and 156.63 cm for boys. According to Silva *et al*., [27], boys' mean height was 155.82 cm and girls' was 154.03 cm. For both genders, these values are around 1 cm lower than those found in the current research. Boys were taller than girls in prepubescent, pubescent, and postpubescent phases, according to the evaluation of mean height based on sexual maturation stage. With the exception of teenage females who fell below the 50th percentile, this pattern was also seen in the height percentiles. The mean height disparities between the prepubescent and pubescent males and the girls were 10.5 cm and 12.4 cm, respectively; the differences between the pubescent and postpubescent boys and the girls were 4.6 cm and 3.3 cm, respectively. However, Table 1 indicates that in the third evaluation, the majority of boys (58.59%) had a sexual maturation stage that ranged from G1 to G3. These results suggest that a large number of males may not have experienced their teenage growth spurt. On the other hand, during the third assessment, the majority of the females (67.77%) reported that their sexual maturation stage was either B4 or B5. A substantial difference was found when the height percentiles for each age group were compared to those for each stage of sexual maturity. However, since the pubescent stage comprises stages G2 to G4 and B2 to B4 (corresponding to the largest proportion of adolescents included in the current study), we think that the height percentiles per sexual maturation stage provide a more accurate picture of the actual status of adolescents because individuals of the same age may differ significantly in their physiological development. Age is thus a poor predictor of maturation stage28. Beunen *et al*., [29] state that as biological maturation is closely linked to growth, the application of oneor more maturation indicators is recommended when establishing growth standards for pre-adolescents and adolescents.

Although secondary sex characteristics are primarily evaluated using clinical observation, youth self-assessments have been widely employed in large studies or lo-cations where doctors are unavailable. The reliability of this method is generally satisfactory, with approximately 80% concordance with regard to stage assessment. Nevertheless, some studies have found poor concordance (as low as 40%) [30].

When an assessment is made using sexual maturation, similarity with regard to the adolescents' biological maturation is proposed. Therefore, we might consider that the median height for a given 12 year-old-boy is 153.5 cm based on the results of the present study. However, if that same boy is prepubescent, then the 50th percentile for height is 146.2 cm (i.e., a difference of 7.3 cm). Thus, a growth assessment based on sexual maturity creates better data for examiners to establish whether youths have already undergone the growth spurt and therefore make a more accurate diagnosis.

GV is an important parameter, and it should be assessed annually as a function of the growth spurt exhibited by older children and adolescents [31].

The mean GV of the boys in the present study was 5.7 cm/year and that of girls was 3.72 cm/year. Only at 10 years of age was the girls' GV higher than the boys' (5.79 cm/year vs. 5.71 cm/year). Moreover, approximately 20.7% of the 10-year-old girls reported already having their menarches by the first assessment. On average, girls entered and completed each puberty stage earlier than their male counterparts [31].

The adolescent growth spurt usually occurs during stage B3 among girls, and its magnitude is typically smaller than that of boys. Girls average a peak GV of 9 cm/year at 12 years of age and grow 25 cm in height during the pubertal growth period [32]. On average, boys attain a peak GV of 10.3 cm/year 2 years later than girls during Tanner stage G4, and they gain 28 cm in height during puberty [32].

The mean GVs at 10, 11, 12, 13 and $\geq$ 14 years old were 5.71, 5.66, 6.40, 4.9, and 3.19 cm, respectively, among the boys (Dunn's multiple comparison test: 10, 11, 12, 13 $\neq \geq$ 14) and 5.79, 5.46, 3.38, 1.88, and 1.72 cm, respectively, among the girls (Dunn's multiple comparison test: 10, 11 $\neq$ 12, 13, $\geq$ 14). These results indicate that the mean GV was higher among boys $\geq$ 12 years of age than their female counterparts, and the peak velocity occurred at 12 years among the boys and at 10 years among the girls.

In Europe, the age of the GV peak was found to vary from 13.8 to 14.2 years of age among boys and from 11.6 to 12.3 years of age among girls. In the United States, the age of the GV peak was found to vary from 13.3 to 14.1 years of age among boys and from 11.3 to 11.9 years of age among girls [30].

The adolescents classified as prepubescent exhibited higher GVs, and the girls grew (on average) 6.08 cm/ year, whereas boys grew 5.87 cm/year.

The GV exhibited by the girls in stage B2 was 5.24 cm/ year, and no significant difference was found with regard to the GV between stages B1 and B2. In stages B3, B4, and B5, however, the GVs were 2.94, 2.42, and 2.67 cm/ year, respectively (B1 and B2 $\neq$ B3, B4, B5). Importantly, these adolescents were 10 years old when the study started, and the possibility that some girls entered puberty earlier cannot be ruled out. This possibility is a limitation of the present study because the maturation process might be starting earlier, with a consequent earlier occurrence of peak GV.

The highest GV among the boys occurred between stages G1 and G2–G4, and only three participants reporting being in stage G5. Among boys, growth accelerates by age 11 (on average), and the peak high velocity (9.5 cm/ year) is attained by 13.5 years of age, which corresponds to sexual maturation stages 3 and 4. Thus, many of the adolescents who participated in the present study might not have reached those stages because 37.1% of the boys self-rated as G3 at the end of the study. Table 5 shows that the minimum GV during stages G2–G4 was 0.11 cm, and the maximum was 21.4 cm (i.e., some of the boys barely grew at all, whereas others grew a significant amount).

The longer duration of prepubescent growth among boys combined with their higher peak GV resulted in a mean difference in height of 13 cm between the genders. Fol-lowing a period of deceleration in GV, growth finally stops when epiphyseal fusion occurs, which usually occurs at a skeletal age of 15 years of age among girls and 17 years of age among boys.

No significant differences were detected at any point with regard to participants' nutritional statuses. Nevertheless, the GV of underweight participants was higher than that of overweight and obese participants. Before puberty the GV and bone age of obese children are higher than those of thin children. This advantage is lost by puberty because the adolescent growth spurt is smaller among obese youth than thin children.

According to Leonibus *et al*., the GV of obese children is accelerated before puberty most likely. Later, the height percentile tends to diminish in these children with pubertal maturation, which suggests that the growth spurt is less accentuated in these children than in thin children, resulting in a similar final height[38]. This supposition might account for the higher GV exhibited by the thin adolescents in the current study com-pared with those with excess weight.

To the best of our knowledge, the present longitudinal study was the first to assess the GV relative to the sexual maturation stage of 10 to 15 year-old adolescents among a population-based sample from São Paulo. These results allow us to infer that the growth of students enrolled in public schools in São Paulo was comparable with international standards and we believe that the distribution of heights as percentiles based on adolescent sexual maturation stage performed in the present study provides a more adequate method of monitoring growth and enables the detection of adolescents at actual risk with greater precision. Nevertheless, each country should formulate its own growth curves based on sexual maturation, considering local, social, and biological characteristics.

We also suggest that future studies broaden the age range assessed to include 8- and 9-year-old children as well as 18- to 20-year-old adults to increase the number of prepubescent and postpubescent volunteers.

CONCLUSION

The present study demonstrates the importance of as-sessing growth based on the stages of sexual maturation and indicates certain factors that might affect growth. Of these factors, only excess weight is likely to be affected by intervention. Adequate body weights and healthy life-styles might contribute to the linear growth of adoles-cents.

REFERENCES

1. World Health Organization. Young People´s Health - a Challenge for Society. Report of a WHO Study Group on Young People and Health for All. Technical Report Series 731. Geneva: WHO. 1986.
2. Saito MI. A avaliação nutricional na adolescência: a escol-ha do referencial. J Pediatr (Rio J) 1993;69(3):165-75.
3. Colli AS. Maturação sexual na população brasileira: limites de idade. J Pediatr (Rio J) 1986;60:173-5.
4. Theokas C, Almerigi J, Lerner R, Dowling E, Benson P, Scales PC, *et al.*, Conceptualizing and modeling individual and ecological asset components of thriving in early adoles-cence. J Early Adolesc 2005;25(1):113-43.
5. Moraes Ferrari GL, Bracco MM, Matsudo VK, Fisberg M. Car-diorespiratory fitness and nutritional status of schoolchil-dren: 30-year evolution. J Pediatr (Rio J) 2013;89(4):366-73.
6. de Padua Cintra I, de Moraes Ferrari GL, de Sousa Vieira Soares AC, Passos MA, Fisberg M, de Souza Vitalle MS. Body fat percentiles of Brazilian adolescents according to age and sexual maturation: a cross-sectional study. BMC Pediatrics. 2013;13(1):96.
7. Cintra Ide P, Passos MA, Fisberg M, Machado HC. Evolution of body mass index in two historical series of adolescents. J Pediatr (Rio J) 2007;83(2):157-62.
8. Marangoni AB, Machado HC, Passos MAZ, Fisberg M, Cin-tra IP. Validade de medidas antropométricas autorreferidas em adolescentes: sua relação com percepção e satisfação corporal. J Bras Psiquiatr. 2011;60(3):198-204.
9. Spiegel MR. Estatística coleção Schaum, 3ª ed. São Paulo: Editora Afiliada; 1993.
10. WHO. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Ex-pert Committee. World Heatlh Organ Tech Rep Ser. 1995.
11. Jelliffe D. Evoluccion Del estado de nutrition de La comu-nidad. Genebra: Organizacion Mundial de La Salid (OMS). 1968.
12. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007;85(9):660-7.
13. Tanner JM. Growth at adolescence. Publications OBS, edi-tor. 1962. 212 p.
14. Matsudo SMM, Matsudo VKR. Self-assessment and physi-cal assessment of sexual maturation in Brazilian boys and girls: concordance and reproducibility. Am J Hum Biol 1994;6:451-5.
15. Zarow R, Cichocka BA. A comparative analysis of estima-tion of age at menarche by various methods in women par-ticipating in the Krakow Longitudinal Growth Study, Po-land. Am J Hum Biol 2008;20(2):146-8.
16. Izaguirre Espinoza I, Macias Tomei C, Lopez Contreras Blanco M. Estimation of the menarcheal age in a longitu-dinal study:

comparison of methods. Acta Cientifica Venezolana. 1989;40(3):215-21.
17. Conover WJ. Practical Nonparametric Statistics. 3rd ed. New York: John Wiley & Sons. 1999.
18. Field A. Descobrindo a estatistica usando o SPSS. 2 ed. Art-med, editor. Porto Alegre 2009 688 p.
19. SAS. The SAS System for Windows (Statistical Analysis System), versão 9.2. SAS Institute Inc, Cary, NC, USA.2002-2008.
20. Kac G. Secular trends in the stature of Brazilian Navy recruits born from 1940 and 1965. Cad Saude Publica 1998;14(3):565-73.
21. Fisberg M, García AC, C. L. Tendencia secular del crec-imiento estatural de adolescentes brasileños em lãs tres úl-timas décadas. In: Virginia F, Del Pino M, Caino S (comps.). Ensayos sobre crecimiento y desarrollo. Buenos Aires: Paid-ós. 2011.
22. Batista Filho M, Rissin A. Nutritional transition in Bra-zil: geographic and temporal trends. Cad Saude Publica 2003;19 Suppl 1:S181-91.
23. Spyrides MHC, Struchiner CJ, Barbosa MTS, Kac G. Efeitos das práticas alimentares sobre o crescimento infantil. Rev Bras Saude Mater Infant 2005;5(2):145-53.
24. POF. Pesquisa de Orçamentos Familiares 2008-2009: An-tropometria e estado nutricional de crianças, adolescentes e adultos no Brasil. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística. 2010.
25. Bergmann MLA, Pinheiro ES, Moreira RB, Marques AC, Gaya ACA. Estudo longitudinal do crescimento corporal de escolares de 10 a 14 anos: dimorfismo sexual e pico de velocidade. Rev Bras Cineantropom Desempenho Hum 2008;10(3):249-54.
26. Machado Z, Krebs RJ, Prestes JD, Santos MB, Santos JOL, Nobre GC, *et al.*, Comparative study of schoolchildren (1997 and 2009). Rev Bras Cineantropom Desempenho Hum 2011;13(3):216-22.
27. Silva DA, Pelegrini A, Petroski EL, Gaya ACA. Comparação do crescimento de crianças e adolescentes brasileiros em curvas de referência para crescimento físico: dados do pro- jeto esporte Brasil. Arch Pediatr Urug 2012;83(3):220-5.
28. Spear BA. Nutrição na adolescência. IN: Krause Alimen-tos, nutrição e dietoterapia. Mahan LK, Escott-Stump, S. (orgs.), 10 ed. São Paulo: Roca. Cap.11. p.247-260.2002.
29. Beunen GP, Rogol AD, Malina RM. Indicators of bio-logical maturation and secular changes in biological maturation. Food Nutr Bull 2006;27(4 Suppl Growth Standard):S244-56.
30. Malina RM, Bouchard C, Bar-OrO. Growth, maturation, and physical activity, 2nd ed. Champaign, lll, USA: Human Kinetics. 2004.
31. Rogol AD, Clark PA, Roemmich JN. Growth and pubertal de-velopment in children and adolescents: effects of diet and physical activity. Am J Clin Nutr 2000;72(2 Suppl):521S-8S.
32. Kelch RP, IZ. B. Adolescent sexual development. In: Kappy MS, Blizzard RM, Migeon CJ, eds. The diagnosis and treat-ment of endocrine disorders in childhood and adolescence. 4th ed. Springfield, IL: Charles C Thomas. 1994.