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Original Article

Mild stunting is associated with higher body fat: study of a low-income population

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Abstract

Objective: To test if individuals having height-for-age z scores between -2 and -1 present higher body fat percentage and, therefore, should not be categorized as having normal nutritional status.

Methods: The study involved 96 individuals (52 boys and 44 girls); 57% of whom had already attained puberty. Body composition was analyzed by dual energy X-ray absorptiometry.

Results: The percentage of abdominal body fat in pre-pubertal stunted girls was higher (27.4%; p = 0.01) in comparison with their non-stunted counterparts (20.6%). Similar differences in abdominal fat content (%) were observed for pubertal stunted and non-stunted girls and boys (37.6 and 29.8%, respectively, p = 0.01; 24.6 and 15.7%, p = 0.01, respectively). The percentages of total body fat percent in pre-pubertal stunted girls and pubertal stunted boys (29.9 and 24.5%, p = 0.03; 26.3 and 18.1%, p = 0.01, respectively) were higher than those of their non-stunted counterparts. Non-stunted groups showed lower waist circumferences.

Conclusion: Adolescents with mild stunting exhibit alterations in body composition indicating increased risk of metabolic diseases.

J Pediatr (Rio J). 2011;87(2):138-144: Height, malnutrition, overweight, adolescent, poverty.

Introduction

In many developing regions, the prevalence of maternal and child undernutrition remains unacceptably high, and represents a primary cause of elevated levels of disease burden and mortality. According to an assessment of 388 national surveys from 139 countries, some 20.2% (112 million) of children under 5 years of age and living in developing countries were classified in 2005 (according to World Health Organization [WHO] child growth standards) as underweight (weight-for-age z score [WAZ] < -2 standard deviations [SD]), whilst 32% (178 million) were categorized as stunted (height-for-age z score [HAZ] < -2 SD).[1]

Large-scale epidemiological studies have revealed that children who had suffered retarded growth in the uterus or during early infancy exhibit an increased risk of developing a non-communicable disease in adulthood.[2-4] The overall level of risk is apparently dependent on the environmental conditions in which the children grow and develop,[2-5] and may be exacerbated by the onset of obesity in later life.[5-7]

A number of studies have shown that early undernutrition is associated with overweight, especially with increased abdominal fat. Respiratory quotient (RQ) and total energy expenditure in stunted and non-stunted children were

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compared in a cross-sectional study carried out by Hoffman et al.[3] in low-income areas within the city of São Paulo. The stunted group exhibited significantly higher RQ and, consequently, lower fat oxidation, demonstrating that stunting is associated with important metabolic changes, and indicating a higher susceptibility of stunted children to accumulate body fat. In support of this suggestion, Walker et al.[7] reported that the accumulation of abdominal fat was higher in stunted children with low body mass index (BMI) and low body fat, compared with that of normal stature. Moreover, Martins et al.[8] demonstrated that stunted adolescents of both genders from a poor area showed greater body fat accumulation and lower lean body mass than those of normal stature. In addition, an investigation carried out in Guatemala established a positive association between stunting in childhood and increased abdominal fat in adulthood.[4] Lastly, a longitudinal study in Senegal, in which body composition was evaluated using the skinfold method, revealed that stunted adolescent females exhibited increased body fat in the upper body compared with girls of normal stature, independent of total body fat.[9]

Since there is considerable evidence that increased abdominal fat represents a primary factor in body composition for predicting metabolic alterations and non-communicable diseases,[10] an early assessment of changes in the distribution of body fat is crucial for implementing strategies in public health.

The WHO recommendation of 2008 amends that of 1983 and classifies children and adolescents with HAZ and WAZ between -2 and -1 as normal rather than with mild undernutrition (the previous classification). The hypothesis tested in the present study was that individuals having HAZ within this range present higher body fat content, and therefore should not be categorized as having normal nutritional status. Based on this proposition, this investigation aimed to determine whether pre-pubertal and pubertal individuals with mild stunting (< -1 and ≥ -2 z scores) presented alterations in body composition that were similar to those described for subjects with more severe stunting. If this hypothesis is correct, it would clearly be essential to consider more sensitive cut-off points in the classification of stature, in order to allow an increased vigilance of the metabolic changes that occur in mild nutritional stunting.

Materials and methods

The study population consisted of 96 pre-pubertal and pubertal individuals in the age range 9 to 19 years who were attending government-funded schools and other institutions located in impoverished areas near the *campus* of the Universidade Federal de São Paulo (UNIFESP). This study is part of a larger health survey that investigated pre-adolescents and adolescents with stunting, carried out in the city of São Paulo, with approximately 400 individuals. The sample size of this study was calculated using the statistical odds ratio (OR), with a significance α level of 0.05, power of 0.80, sampling ratio of 1:1 between exposed and unexposed to the predictor. It was assumed an OR in the source population equal to 2.5 and prevalence of stunted equal to 0.08 among the unexposed population. Due to high costs for assessment of body composition by dual-emission X-ray absorptiometry (DXA), it was considered that a sample around 20% of the survey population was sufficient to test the hypothesis of the study. The maximum acceptable beta error was 0.20. Subjects were selected for the study according to their nutritional status.

Since the purpose of the study was to detect early changes occasioned by mild stunting, the sample population was divided into two groups according to HAZ, namely stunted (HAZ < -1 and ≥ -2) and non-stunted (HAZ ≥ -1). Participants were further classified as to BMI-for-age percentiles as overweight (≥ 85th), normal (> 5th and < 85th), or underweight (≤ 5th), according to the standard reference values based on the Centers for Disease Control and Prevention (CDC) 2000 growth charts for the United States.[11]

Prior to the commencement of the study, all potential participants were submitted to a clinical examination and anamnesis, as well as laboratory tests, which included blood, urine, and parasitological investigations. Subjects presenting infectious or parasitic diseases were treated according to standard protocols of the Hospital de São Paulo, UNIFESP, and subsequently included in the study.

Individuals diagnosed with genetic syndromes, neurological problems, dementia, or cardiovascular, respiratory or metabolic disorders were excluded from the study, as well as those using corticosteroids or presenting any physical limitations. Participants were examined by a trained pediatrician and classified according to pubertal development by Tanner's[12] recommendations. Individuals who had attained the appropriate WHO cut-off points (breast stage 2 for girls and genitalia stage 3 for boys) were considered pubertal.[13] It was not found any individual with early or delayed puberty in the study. Measurements of LH, FSH and testosterone were not done.

The weight of each participant was obtained by single measurement using a Country Technologies (Gays Mills, WI, USA) model SD-150 platform scale with a capacity of 150 kg and an accuracy of 10 g. Stature was assessed using an AlturExata (TBW, São Paulo, Brazil) portable stadiometer with a precision to the nearest 0.1 cm. BMI values were determined as the quotient between weight and height squared (kg/m^2). In order to evaluate waist circumference, subjects were asked to assume a standing position with the abdomen relaxed and arms relaxed alongside the body, and a flexible measuring tape (0.1 mm accuracy) was placed horizontally at the midpoint between the bottom edge of the last rib and the iliac crest. Measurements were taken with the tape firmly applied on the skin, but without compression of tissues.

Body composition, including fat mass, fat-free soft tissue and abdominal fat, was analyzed by DXA using a Hologic (Bedford, MA, USA) model QDR-4500 A densitometer. A body composition phantom, provided by the manufacturer, was used to calibrate the equipment before each set of measurements. Total body fat and lean mass were estimated with the aid of Hologic enhanced whole body software (version 8.26). The abdominal region of interest was defined manually by adjusting the lines between upper L1 and lower L4 and the inner costal margin of the whole body scan.

The height-for-age (z score), BMI (kg/m^2) and BMI-for-age (percentile) were calculated by the program Epi-Info for Windows, using the National Center for Health Statistics reference.[11] For nutritional status variables, differences between stature groups were examined by Mann-Whitney test, whilst differences in body composition were calculated using analysis of covariance adjusted for age and weight. The significance level was fixed on 0.05. SPSS for Windows version 16.0 (SPSS, Chicago, IL, USA) was used for statistical analyses.

The study was submitted to, and approved by, the Committee of Ethics in Research of the Universidad Federal de São Paulo (UNIFESP, protocol no. 0284/08). All procedures employed complied with the ethical principles contained in the Declaration of Helsinki as stated by the World Medical Association. Written informed consent was obtained from the participants, or their parents or legal guardians where appropriate, prior to the commencement of the study.

Results

The study population (n = 96) comprised 45.8% females and 54.2% males. Of the 96 participants, 57.3% had already reached puberty. The socioeconomic characteristics of the population (Table 1) revealed that, although the families of the participants were poor, the mean daily *per capita* income was above the poverty level (generally considered to be of US$ 1.25 in the region). However, illiteracy amongst mothers was quite high, at around 11%, and a significant number of homes comprised inadequate shacks built wholly or partly with scrap wood.

Pre-pubertal stunted males presented mean weight, BMI, as well as BMI-for-age percentiles, significantly lower than those of their non-stunted counterparts (Table 2). In pubertal male and pre-pubertal and pubertal female groups, however, there were no significant differences in these parameters between stunted and non-stunted individuals (Table 2). In all groups, HAZ were significantly different, as well as the selection criteria for the groups (Table 2). The distribution of the study population according to nutritional status, based on CDC BMI-for-age percentiles, is shown in Table 3. With respect to the pre-pubertal groups, the prevalence of overweight among boys was higher than among girls, whereas the opposite was the case for the pubertal groups. In pubertal groups of both genders, the prevalence of overweight was higher among individuals with normal stature compared with stunted individuals.

Table 1 - Socioeconomic characteristics of the study population (n = 96

Parameter	Value
Schooling (measured as percentage of illiteracy)	
Mother	10.6
Father	5.6
Family size	
Average number of people per dwelling	6±3.6
Income	
Monthly family income (US$)	484±328.0
Daily *per capita* income (US$)	4±2.7
Type of abode (%)	
Wooden house	6.0
Wooden + brick house	3.9
Brick house	90.2

The results of DXA analyses of body composition of the pre-pubertal and pubertal groups are shown in Table 4. The mean values of body and abdominal fat (in absolute terms and as percentage values) and of waist circumference of stunted pre-pubertal girls were significantly larger than those of non-stunted girls, whilst no differences in any of the evaluated parameters were observed between stunted and non-stunted pre-pubertal boys. Considering the pubertal groups, stunted girls presented significantly higher mean levels of body fat (in absolute terms) and abdominal fat (in absolute terms and as percentage values) in comparison with non-stunted females. A tendency towards larger waist circumference was observed among stunted girls. Pubertal stunted boys, on the other hand, exhibited significantly higher mean levels of body and abdominal fat (in absolute terms and as percentage values), lower fat-free mass (in absolute terms and as percentage), and greater waist circumference in comparison with non-stunted males.

Discussion

The rate of nutritional transition in developing countries remains a matter of considerable debate, since some studies reveal very rapid shifts from undernutrition to obesity amongst teenagers,[14,15] while others show a clear co-existence of undernutrition and obesity.[1,16] The association between undernutrition and obesity is of particular importance, since it has been reported that the combination of undernutrition-related diseases, infections and obesity-related syndromes contributes significantly to the disease burden in many countries.[1]

In the past, it has been suggested that children with mild to moderate undernutrition (defined by HAZ and WAZ between -2 and -1) are likely to present mortality rates that are more than two-fold higher than those of healthy children.[17-19] It has also been shown that children with mild undernutrition exhibit impaired immunocompetence and tend to suffer more severe infections than healthy individuals.[18,19] It is reasonable to expect higher mortality

Table 2 - Nutritional status of the study population

	Girls			Boys		
Pubertal stage	**Non-stunted***	**Stunted†**	**p**	**Non-stunted***	**Stunted†**	**p**
Pre-pubertal	(n = 10)	(n = 4)		(n = 20)	(n = 7)	
Age (years)	7.9±1.4	8.7±1.0	0.3	9.0±1.7	9.9±1.3	0.1
Height (cm)	132.6±9.0	124.5±4.1	0.1	136.8±8.7	131.0±7.3	0.3
Weight (kg)	28.4±7.8	25.3±4.0	0.4	36.8±13.4	25.7±4.5	0.01
BMI (kg/m^2)	16.0±3.3	16.3±1.9	0.7	19.1±4.2	14.9±2.1	0.01
BMI-for-age percentile	40.9±30.6	44.1±31.8	1.0	70.4±24.3	22.13±31.7	0.01
HAZ	0.52±1.08	-1.6±0.2	0.01	0.13±0.85	-1.31±0.23	0.01
Pubertal	(n = 21)	(n = 9)		(n = 15)	(n = 10)	
Age (years)	12.1±2.6	12.6±1.0	0.6	12.8±2.3	13.3±0.9	0.3
Height (cm)	155.1±9.4	146.1±5.2	0.02	158.8±13.4	149.1±6.1	0.1
Weight (kg)	56.3±18.3	48.3±12.7	0.4	50.3±12.6	42.7±9.0	0.2
BMI (kg/m^2)	23.0±5.7	22.4±5.2	0.8	19.7±3.1	19.2±3.8	0.7
BMI-for-age percentile	73.30±24.36	70.02±39.50	0.9	55.4±30.2	45.5±42.7	0.2
HAZ	0.46±0.6	-1.6±0.3	0.01	0.3±0.98	-1.73±0.14	0.01

BMI = body mass index; HAZ = height-for-age z score.
Values are expressed as mean ± standard deviation. Mean values were significantly different according to Mann-Whitney test ($p < 0.05$).
* HAZ ≥ -1.
† HAZ < -1 and ≥ -2.

Table 3 - Nutritional status of the pre-pubertal and pubertal groups classified according to body mass index

	Girls		Boys		Total
Pubertal stage	**Non-stunted* n (column %) [row %]**	**Stunted† n (column %) [row %]**	**Non-stunted* n (column %) [row %]**	**Stunted† n (column %) [row %]**	**n [row %]**
Pre-pubertal					
Undernutrition (≤ 5th percentile)	1 (3.2) [20]		1 (2.8) [20]	3 (17.6) [60]	5 [100]
Normal (> 5th to < 85th percentile)	7 (22.6) [28]	4 (30.8) [16]	10 (28.6) [40]	4 (23.6) [16]	25 [100]
Overweight (≥ 85th percentile)	2 (6.5) [18.2]		9 (25.7) [81.8]		11 [100]
Pubertal					
Undernutrition (≤ 5th percentile)		2 (15.4) [40]		3 (17.6) [60]	5 [100]
Normal (> 5th to < 85th percentile)	12 (38.7) [44.4]	1 (7.7) [3.7]	10 (28.6) [37.0]	4 (23.6) [14.8]	27 [100]
Overweight (≥ 85th percentile)	9 (29.0) [39.1]	6 (46.1) [26.1]	5 (14.3) [21.7]	3 (17.6) [13.0]	23 [100]
Total n (column %)	31 (100)	13 (100)	35 (100)	17 (100)	

Data based on standard reference of the Centers for Disease Control and Prevention.[11]
* Height-for-age z score ≥ -1.
† Height-for-age z score < -1 and ≥ -2.

Table 4 - Body composition of the study population

Pubertal stage	Girls			Boys		
	Non-stunted*	**Stunted†**	**p**	**Non-stunted***	**Stunted†**	**p**
Pre-pubertal	(n = 10)	(n = 4)		(n = 20)	(n = 7)	
Body fat (kg)	7.2±0.6	9.1±0.8	0.01	8.8±1.8	10.0±1.8	0.2
Body fat (%)	24.5±1.9	29.9±2.2	0.03	23.3±4.5	23.2±5.0	0.1
Lean body mass/height (g/cm)	158.0±10.4	158.2±11.6	0.9	191.1±12.0	183.2±13.7	0.2
Fat-free mass (kg)	20.1±0.9	18.6±1.2	0.06	24.9±1.8	23.6±1.8	0.1
Fat-free mass (%)	21.1±0.9	19.4±1.2	0.05	26.1±1.8	24.7±1.8	0.1
Abdominal fat (kg)	0.4±0.03	0.7±0.02	0.03	0.5±0.4	0.6±0.2	0.3
Abdominal fat (%)	20.7±1.9	27.4±2.0	0.01	20.3±4.4	20.3±5.0	0.1
Waist circumference (cm)	54.7±1.3	59.7±2.6	0.02	61.8±4.4	61.5±5.3	0.9
Pubertal	(n = 21)	(n = 9)		(n = 15)	(n = 10)	
Body fat (kg)	17.1±2.7	19.9±2.7	0.01	8.6±2.7	13.4±2.8	0.01
Body fat (%)	30.4±5.0	33.6±5.1	0.1	18.1±4.6	26.3±4.7	0.01
Lean body mass/height (g/cm)	231.4±21.1	245.8±21.3	0.1	246.4±12.0	243.2±12.3	0.5
Fat-free mass (kg)	34.4±3.20	34.8±3.0	0.7	37.8±1.93	34.6±1.9	0.02
Fat-free mass (%)	36.1±3.20	36.4±3.3	0.8	39.7±1.93	36.3±2.2	0.01
Abdominal fat (kg)	1.2±0.5	1.6±0.3	0.02	0.4±0.4	0.7±0.3	0.01
Abdominal fat (%)	29.8±6.9	37.6±6.9	0.01	15.7±5.0	24.6±5.4	0.01
Waist circumference (cm)	71.8±6.4	77.0±6.3	0.06	66.2±4.6	73.4±4.7	0.01

Values are expressed as mean ± standard deviation. Mean values were significantly different according to analysis of covariance ($p < 0.05$; adjusted for age and weight).
* Height-for-age z score ≥ -1.
† Height-for-age z score < -1 and ≥ -2.

rates among children with mild undernutrition in comparison to normal children, since they are more likely to descend into severe undernutrition than their healthy counterparts.[17] Additionally, Rao et al.[19] have reported that between 16 to 80% of all nutrition-related deaths are associated with mild to moderate undernutrition rather than with severe undernutrition. The same authors described that 85% of Indian children suffer from mild to moderate undernutrition while only 10% are severely malnourished.

According to the most recent WHO standards, pre-adolescent and adolescent subjects presenting HAZ and WAZ in the range between -2 and -1 are now considered normal,[20] whereas previous standards considered z scores between these limits to represent mild undernutrition.[21] Probably the concern regarding mild undernutrition, which formed the basis of earlier studies, has now diminished owing to a worldwide reduction in the prevalence of undernutrition and to an increase in obesity amongst children and adolescents. However, accurate and precise cut-off points are very important in the early detection of nutritional disorders, since they allow rapid intervention and also assist in avoiding or minimizing the development of such conditions and the consequent risk of contracting non-communicable diseases in later life.

Previous studies have shown that moderate to severely undernourished pre-adolescent and adolescent subjects exhibit alterations in body composition.[4,5,8] In order to examine the hypothesis that pre-adolescent and adolescent subjects with mild undernutrition also exhibit alterations in body composition, body fat, abdominal fat, fat-free mass, and lean body mass/height have been determined in pre-pubertal and pubertal individuals presenting HAZ in the range between < -1 and ≥ -2.

In the present study, the stature of the parents of the participants was not taken into consideration, since many reports have demonstrated that genetic profile is only useful as a predictor of offspring stature for high socio-economic groups, within which the growth potential can be fully expressed.[22,23] In low socio-economic groups, however, parental stunting may arise from the cumulative effect of poverty endured by several family generations. As recognized by WHO and other authors, stunting may be considered primarily as a good measure of overall social deprivation.[24,25]

The results reported herein showed that pre-pubertal stunted girls, but not boys, presented higher average body and abdominal fat content and larger waist circumference in comparison with their counterparts of normal stature (in spite of the small number of individuals in the female pre-pubertal groups), independent of BMI. Within the pubertal groups, stunted girls showed a greater accumulation of abdominal fat than non-stunted females, while stunted boys presented higher body and abdominal fat content, and also larger waist circumference, than their non-stunted counterparts. It has been reported that waist circumference is more representative of central adiposity than BMI. And is a better parameter for indicating morbidity and risk factors.[26] In the present study, both waist circumference and abdominal fat in pubertal individuals were evaluated in order to improve the diagnosis of central adiposity.

Among stunted individuals, only pubertal girls showed percentage of body fat (33%) above recommended means (30%) for gender and age.[27] Non-stunted pubertal girls showed a lower value, but within the maximum limit of 30% that could be considerate inadequate or excessive for the age.[28] In addition, it called our attention the fact that a high percentage of pre-pubertal non-stunted boys and pubertal non-stunted girls were diagnosed as overweight. The higher percentage of overweight pre-pubertal non-stunted boys (mean percentile 70.4) could be explained by the typical "fat wave" at this age group that disappears with the onset of puberty, as seen for the pubertal group.

A number of researchers[4,8,9] have reported associations between stunting, accumulation of abdominal fat and lower levels of lean body mass in Guatemalan, Brazilian and African youngsters, and such findings are similar to those presented in this study. It is important to emphasize, however, that, in these studies, more rigorous cut-off points were employed to diagnose stunting. Our results show, however, that metabolic changes such as increased abdominal fat can be observed using a cut-off point that includes mild cases of stunting. On this basis, it is clearly essential to consider more sensitive cut-off points (< -1 and ≥ -2 z scores) in the classification of stature, in order to allow an increased vigilance of the metabolic changes that occur in mild nutritional stunting.

It has been proposed that nutritional deprivation during the fetal period and early childhood may lead to adaptations that could result in the development of obesity during later life.[15] The results presented herewith not only support this hypothesis, but further suggest that the alterations in metabolism and body composition observed during the pre-pubertal and pubertal stages of development may predict the later development of non-communicable diseases.

In summary, pre-pubertal and pubertal stunted girls and pubertal stunted boys showed mean levels of abdominal fat that were significantly higher than those of their non-stunted counterparts. Additionally, pre-pubertal and pubertal stunted males exhibited increased body fat in comparison with their corresponding non-stunted groups. These results show that it is possible to detect significant changes in body composition, particularly with respect to abdominal fat, in adolescents with mild stunting (HAZ < -1 and ≥ -2). It is imperative, therefore, to diagnose and treat teenagers presenting mild stunting in order to preclude or minimize negative consequences in later life.

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