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ARTICLE

Individual characteristics and public or private schools predict the body mass index of Brazilian children: a multilevel analysis

Características individuais e tipo de escola predizem o índice de massa corporal das crianças brasileiras: uma análise multinível

Características individuales y escuelas públicas o privadas predicen el índice de masa corporal: un análisis multinivel

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Abstract

The aim of this study was to determine the contribution of individual and school characteristics to the variability in body mass index (BMI) z-scores of 7 to 10 years old children. Anthropometric and sociodemographic data from two cross-sectional studies conducted with schoolchildren from the 2nd to the 5th grades of elementary schools were analyses (n = 2,936 in 2002, and n = 1,232 in 2007). Multilevel modeling was used to estimate variations in BMI at child and school levels. The contribution of the school context to the overall variability of BMI z-score was small but significant in 2002 (3.3%-4.4%) and in 2007 (2.4%-5.3%), showing that schoolchildren from private schools had a higher BMI compared to those from public schools. The monthly family income showed, in general, a negative association with BMI z-score in 2002 and a positive association in 2007, for both sexes. The consumption of sweets showed a negative effect in the BMIs of children. In both surveys, overweight/obese mothers and excessive birth weight were positively associated with BMI z-score. Mother's weight status had a higher influence on the overall variability of BMI in both surveys. In conclusion, school and child characteristics contributed to the variance in children's weight status. The results imply that overweight/obesity childhood prevention programs should focus on strategies of family engagement to be more effective.

Child; Body Mass Index; Nutritional Transition; School Health; Multilevel Analysis

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Introduction

In recent decades, efforts to address poverty and malnutrition led to many social programs being launched by the Brazilian government in order to diminish socioeconomic inequalities, with significant achievements [1]. At the same time, other health indicators showed a worrying scenario with a steady increase in the prevalence of obesity and other non-communicable diseases [2].

Childhood is a critical period, particularly when socioeconomic inequalities in issues of being overweight emerge and strengthen. In Brazil, the occurrence of being overweight among 5 to 9 years old children tripled between 1974 and 2009, rising from 11% to 33%. Among 10 to 19 years old the prevalence of being overweight has raised six-fold in boys and three-fold in girls. This continuous increase was observed in all socioeconomic strata, but it was greater in high-income groups and among boys [3].

The change observed in childhood obesity worldwide is due to individual, family and environmental factors. Some individual risk factors for childhood obesity include parental weight status, socioeconomic status, birth weight, low physical activity level, and dietary patterns with high consumption of energy-dense, high-fat, high-sugar, and low-fiber foods [4,5,6]. A systematic review of studies assessing the association between socioeconomic status and obesity in low- and middle-income countries evidenced that obesity is a problem of the rich in low-income countries for both men and women, while there is a mixed picture in middle-income countries. In studies with children this review found a positive association between socioeconomic status and obesity for both boys and girls, regardless of age, the level of gross national income per capita (GNI), the level of obesity, the socioeconomic status indicator chosen or the measure of fatness employed [7].

In recent years, epidemiological investigations conducted in high-income countries used multilevel approaches to evaluate the effect of family characteristics, neighborhoods and the school environment on changes in body mass index (BMI) of children and adolescents [8,9,10,11]. There is some evidence that variations in the school environment are associated with childhood obesity. O'Malley et al. [8] reported that 3% of the variation in BMI across the USA could be attributed to school characteristics. There was some modest variation by type of school, school size, region of the country, and population density. Higher variation was found as a function of school socioeconomic status and the racial/ethnic composition of the school [8]. Pallan et al. [11] reported that the variation in BMI z-scores that could be attributed to differences between school's physical activity characteristics in Birmingham (UK) were 4.2% for children in the reception year (4 to 5 years old) and 0.9% in year 6 children (10 to 11 years old).

In Brazil, one study investigated the combined effect of individual and school characteristics on the weight status of children and adolescents [12]. This study observed that the school environment did not explain the variation in the proportion of overweight students enrolled in the last year of primary education of the public schools of Rio de Janeiro.

Two cross-sectional studies conducted in 2002 and 2007 with representative samples of 7 to 10 years old Brazilian schoolchildren living in a city in southern Brazil provide the opportunity to fill this gap, allowing the influences of child and school characteristics on BMI to be investigated.

The aim of the present study is to analyze: (1) the variability in schoolchildren's BMI that can be attributed to differences between schools; and (2) to explore the associations of the individual and school characteristics on the variability of BMI. Studies carried out in 2002 and 2007 were analyzed separately. The monitoring of the factors affecting the children's weight status in a period of nutritional transition could provide information for the development of policies, actions and regulations related to the school environment.

Methods

Participants

Data were extracted from the database of two cross-sectional epidemiological studies designed to investigate the prevalence of overweight (including obesity), and obesity-related behaviors of schoolchildren from Florianópolis in 2002 and 2007 [13,14]. Florianópolis is the capital of Santa Catarina State in Southern Brazil. The Human Development Index (HDI) of the city was 0.847 in 2010 (the highest among the capitals in the country), showing an increase of 34.6% in a period of 10 years [15].

In 2002, 16 elementary schools stratified by type (public or private) and region of the city (central or coastal) were sampled from a total of 122 eligible schools. All children enrolled in the 2nd to 5th grades were invited to participate, but only 7 to 10 years old children were included. The final sample comprised of 2,936 schoolchildren (public schools = 1988; private schools = 948). Detailed sampling procedures can be found elsewhere [13,14].

All 16 schools were invited to participate in a second survey in 2007. Fourteen schools accepted the invitation and the two that refused were replaced by other schools with the same characteristics, and one more public school was included in the sample. The expected total number of children was divided proportionally by the type of school (public and private) and geographical area (central and coastal). In each school, the participants were selected using a systematic sampling method applied to a complete list of the pupils ordered by age. The list of selected children included possible substitutions in case of refusal (by the child or parent) or absence in school during the data collection period. The final sample consisted of 1,232 children from 17 schools (public schools = 782; private schools = 450). Detailed sampling procedures can be found in Leal et al. [14].

The information gathered in this study included anthropometric data and two questionnaires assessed at both time points. The children's questionnaires were paper-and-pencil validated instruments used to obtain information about physical activities and food choices. The parents' questionnaire gave information about themselves (socioeconomic status and self-reported weight and height and contained questions about the child's birth weight).

Written parental consent was obtained for their child in both studies, approved by the Ethics Committee of the Federal University of Santa Catarina (protocol numbers 037/02 and 028/06).

• Measurements

Trained research staff measured the weight and height of child participants following standard techniques [16] in both studies. Theoretical and practical workshops on measurement techniques were held to standardize the anthropometric measurements. Anthropometric measurements were undertaken with the children wearing light clothes and without shoes. Weight was measured with a digital 180kg scale (Marte, model PP, 50g precision, São Paulo, Brazil). Height was measured using a metric tape fixed to a wall without a baseboard, in 2002, and with a portable stadiometer (Alturexata, 1mm precision, Belo Horizonte, Brazil) in 2007. BMI was computed as weight (kg) divided by the square of height (m).

• Outcome variable

In both surveys, children's BMI data were converted into z-scores (according to age and sex) based on the World Health Organization Growth Standard References [17]. In the regression analysis, the BMI z-score was modeled as a continuous variable in order to consider the entire distribution of weight status among the whole study population.

• Child level variables

Socioeconomic status was evaluated using two indicators: number of persons per sleeping room (persons/room) and monthly family income. Persons/room were categorized as 1, 2 and 3 or more. Monthly family income was defined as a categorical variable taking into account the minimum wage at both time points (< 2.5; ≥ 2.5 and < 5; ≥ 5 and < 10; ≥ 10). Child's age was computed as the difference between the date of birth and the date of measurements. Four age groups (7 to 10 years old) were defined as decimal ages. For example, the age of 7 years corresponded to 6.50 to 7.49 years. Mother's weight status was assessed by BMI based on self-reported weight (kg) and height (m), and classified according to the recommendations of the World Health Organization (thinness – BMI < 18.5kg/m^2, normal weight – BMI 18.5-24.9kg/m^2, overweight non-obese – BMI 25-29.9kg/m^2, obese – BMI ≥

30kg/m2) [18]. Parents were instructed to record their child's birth weight from the data registered on the child's health records. Birth weight was classified as low (< 2,500g), insufficient (2,500-2,999g), appropriate (3,000-3,999g) or high (≥ 4,000g) [19].

At both time points the schoolchildren filled out illustrated and validated questionnaires aimed at collecting data on physical activity and food consumption. In 2002, they were asked to indicate the intake of foods/beverages and the performance of physical activity on a usual weekday using the questionnaire *Typical Physical Activity and Food Intake Day* [20]. In 2007 children were asked to recall what they ate and which physical activity they performed over the preceding day using the *Previous Day Food Questionnaire* [21] and the *Previous Day Physical Activity Questionnaire* [22]. Validity and reproducibility tests of these questionnaires were described elsewhere [20,21,22].

The foods and beverages were categorized in seven groups on the basis of nutrient content in order to assess the intake of healthy foods (milk and dairy products; meat, fish and sea foods; beans; rice, pasta, breads, crackers; leafy and cooked vegetables and fruits), and unhealthy foods with high energy density and low nutrient density such as salty snacks (french fries, pizza, hamburger sandwich, chips), sweets (lollipops, ice cream, cakes, biscuits), and sodas and fruit juices. For each food/food group and beverages, the daily frequency was calculated by averaging over the five daily eating events present in both questionnaires.

In the physical activity section of the questionnaires [20,22] schoolchildren were asked to report their physical activities (walking or running, playing with a dog, cycling, swimming, playing ball games, jumping rope, athletics, climbing stairs, roller skating/blading, dancing and helping with household chores). In the present study, metabolic equivalents (METs) were assigned to each activity reported using the *Compendium of Energy Expenditures for Youth* [23] and averaged over all physical activity reported by each child. Physical activity in terms of metabolic equivalents (physical activity MET) were categorized into tertiles (the first tertile was defined as lowest, second tertile as intermediary and third tertile as highest METs). This scoring method had been validated with Brazilian children in other study [24].

- **School level variable**

Type of school was defined as a dichotomous variable (public or private).

Statistical methods

Mean values and proportion distributions and their 95% confidence intervals (95%CI) were estimated for each category of sociodemographic variables in order to characterize the survey's populations.

Multilevel linear regression analyses using BMI z-score as the outcome were performed considering four models, separately for boys and girls, in 2002 and 2007. The analyses were stratified by gender since exploratory analyses revealed differences for the prevalence of being overweight (including obesity) and in the role that risk factors had in children's adiposity. First, the null model analysis was applied to identify the variability in BMI z-scores due to the school context using multilevel/hierarchical modeling with two levels (child at level 1 and schools at level 2). Second, multilevel linear regression analyzes were conducted in two steps. In the first step, univariate linear regression models were performed with the use of restricted maximum likelihood method. All variables that contributed to a variability reduction in BMI z-score by at least one percentage point compared to the null model were selected for the multiple models. In the second step, multiple linear regression models were performed using the maximum likelihood method to estimate the effects of the variables selected on BMI z-score.

Initially, the child-level variables were analyzed, followed by the school-level variable. For each regression model both fixed and random effects were present, keeping in mind that our interpretation of the results focused on the fixed effects. The Wald z-test was used to test the significance for random effects.

Missing values were treated as a separate category for exposure variables in order to prevent the loss of statistical power due to excluding individuals with incomplete information. The data were weighted to generate appropriate population estimates [14].

The statistical significance level was set at 5%. All analyses were performed with IBM SPSS for Windows version 21 (IBM Corp., Armonk, USA).

Results

Overall, children's characteristics were similar between surveys (Table 1). The proportion of children in each age and sex category was similar in both surveys and no statistically significant difference was observed. Approximately one-third of the children attended private schools, and this proportion was 3.2 percentage points higher in 2007 compared with 2002. The comparison of individual characteristics between 2002 and 2007 surveys were based on the assumption that the missing data were random.

The individual contribution of the child-level variables on overall variability in BMI z-score is presented in Table 2. Respecting the criterion for inclusion of the variables into the multiple models (variability reduction of at least one percentage point in BMI z-score compared to the null model), the variable which contributed most (individually and together with other variables) to the explanation of the overall variability in BMI was mother's weight status (overweight and obesity) in both surveys, for boys and girls, followed by high birth weight, mainly for boys in 2007. Among the variables of food consumption only the consumption of sweets explained the student variation in BMI z-score in a significant way. Physical activity and the remaining variables did not reduce the BMI variability and were excluded in the final model.

Table 3 shows the results in 2002 and 2007 surveys for boys from the two models (null model and variance components model with child and school variables in the fixed part). In the null models, the estimates of the variance of the random effects of schools were significantly different from zero ($s^2_{school} = 0.05$, $p < 0.01$; $s^2_{school} = 0.06$, $p < 0.01$, respectively for 2002 and 2007) indicating that 3.3 and 4.4% of the overall variability in BMI z-scores could be attributed to the school-level in 2002 and 2007, respectively.

In both surveys, each of the child-level variables were found to be significantly associated with BMI z-scores. In 2002, boys residing in households with three or more persons/room had lower BMIs on average ($\beta = -0.24$, $p < 0.001$) compared to the reference category (1 person/room). Monthly family income was negatively associated with BMI (i.e., the lower the income the higher the BMI). Overweight/obese mothers ($\beta = 0.41$ and 0.85, $p < 0.001$, respectively) and high birth weight ($\beta = 0.29$, $p < 0.001$) were found to be positively associated with BMI. Boys studying in private schools had 0.34 BMI z-score units higher than the BMI of public school children ($p = 0.001$). The higher the intake frequency of sweets the lower the BMI z-score ($\beta = -0.12$, $p < 0.001$).

In the 2007 survey, boys residing in households with three or more persons/room had lower BMIs on average ($\beta = -0.34$, $p < 0.001$). Boys with monthly family income ≥ 2.5 and < 5 minimum wages had 0.13 BMI z-score units lower compared to boys with family income > 10 minimum wages (reference) ($p < 0.001$). Similar to the 2002 survey, children with obese mothers (0.85, $p < 0.001$,) and those with high birth weight ($\beta = 0.45$, $p < 0.001$) had higher BMI. Higher daily intake frequency of sweets was also inversely associated with BMI ($\beta = -0.09$, $p < 0.001$).

The addition of the school-level variable (type of school) to the fixed part of the model explained the variance at the school level by half (50%) but it remained significantly different from zero ($s^2_{school} = 0.03$, $p < 0.05$), in the 2002 survey. Conversely, in the 2007 survey the type of school variable did not explain the variance at school level. The addition of the child-level variables to the fixed part of the model explained 9.5% of the variance at the child-level in 2002 and 12.6% in 2007.

Table 4 presents the 2002 and 2007 survey results in girls for both models (a null model and a variance components model with child and school variables in the fixed part). In the null models, the estimate of the variance of the random effects of schools was significantly different from zero ($s^2_{school} = 0.03$, $p < 0.05$; $s^2_{school} = 0.06$, $p < 0.01$) indicating that the school-level variance contributed 2.4-5.3% (2002 and 2007, respectively) to the overall variability in BMI.

In 2002, age ($\beta = -0.35$, $p < 0.001$) was inversely associated with BMI (i.e., older girls showed lower BMI). Similarly to boys, monthly family income was negatively associated with girl's BMI. Girls with overweight/obese mothers ($\beta = 0.39$ and 0.55, $p < 0.001$, respectively) and those with high birth weight

Table 1

Estimates of the proportions and respective 95% confidence intervals (95%CI) for sociodemographic and behavioral characteristics of children. Florianópolis, Santa Catarina State, Brasil, 2002 and 2007.

	2002 (n = 2,936)	**2007 (n = 1,232)**
	% (95%CI)	**% (95%CI)**
Age (years)		
7	23.2 (21.0-25.3)	22.4 (17.2-27.6)
8	26.1 (24.1-28.0)	23.3 (20.7-25.9)
9	27.0 (25.3-28.7)	28.3 (24.9-31.7)
10	23.7 (21.5-26.0)	26.1 (21.6-30.5)
Sex		
Boys	51.0 (48.9-53.0)	50.7 (47.8-53.6)
Girls	49.0 (47.0-51.1)	49.3 (46.4-52.2)
Child's weight status *		
Non-overweight	69.7 (65.9-73.5)	65.6 (61.5-69.8)
Overweight	30.3 (26.5-34.1)	34.4 (30.2-38.5)
School type		
Public	67.7 (46.8- 88.7)	63.5 (45.5- 81.6)
Private	32.2 (11.3- 53.2)	36.5 (18.4- 54.5)
Monthly family income (minimum wage) **,***		
< 2.5	28.2 (18.5-38.0)	29.9 (22.4-37.4)
≥ 2.5-5	27.1 (17.3-36.8)	30.2 (22.3-38.1)
≥ 5-10	16.3 (9.6-23.1)	14.6 (10.6-18.6)
≥ 10	28.4 (8.8-47.9)	25.3 (11.4-39.3)
Mother's weight status #		
Thin	4.9 (4.0-5.9)	4.2 (1.9-6.5)
Normal weight	66.5 (61.7-71.3)	68.4 (61.7-75.1)
Overweight	20.6 (16.7-24.4)	18.8 (15.4-22.3)
Obese	8.0 (6.4-9.6)	8.6 (5.5-11.6)
Birth weight ##		
Low	6.1 (5.1-7.1)	7.6 (5.2-10.1)
Insufficient	17.7 (16.7-18.7)	18.7 (16.1-21.3)
Appropriate	67.1 (64.6-69.6)	66.6 (63.9-69.3)
High	9.1 (7.8-10.3)	7.0 (5.6-8.5)
Tertiles of physical activity ###		
Lowest	33.7 (29.1-38.3)	35.0 (29.5-40.6)
Medium	32.7 (29.9-35.5)	32.1 (28.6-35.7)
Higher	33.6 (30.9-36.3)	32.9 (28.0-37.7)

(continues)

Table 1 (continued)

	Mean (95%CI)	Mean (95%CI)
Food consumption (frequency in times per day)		
Sweets	1.3 (1.2-1.3)	1.8 (1.8-1.9)
Dairy products	3.0 (2.9-3.1)	1.6 (1.5-1.6)
Meat and fish	1.9 (1.8-1.9)	1.1 (1.1-1.2)
Cereals	5.2 (5.1-5.3)	3.8 (3.7-3.9)
Fruits and vegetables	2.1 (2.0-2.2)	1.2 (1.1-1.3)
Salty snacks	1.6 (1.6-1.7)	0.6 (0.5-0.6)
Sodas and fruit juices	3.2 (3.2-3.7)	1.9 (1.8-1.9)

BMI: body mass index; MET: metabolic equivalents.

Note: missing monthly family income data: 2002 (21.9%); 2007 (18.1%); missing mother's weight status data: 2002 (29.0%); 2007 (4.0%); missing birth weight data: 2002 (24.4%); 2007 (3.4%).

* Overweight (including obesity BMI ≥ +1.0 z-scores – WHO Child Growth Standards, 2007);

** 1 minimum wage= USD 64 (BRL 200) monthly: September 2002 exchange rate;

*** 1 minimum wage= USD 204.30 (BRL 380) monthly: September 2007 exchange rate;

BMI based on self-reported data on weight and height and classified according to the WHO recommendations (thin BMI < 18.5kg/m^2, normal weight BMI 18.5-24.9kg/m^2, overweight non-obese BMI 25-29.9kg/m^2, obese BMI ≥ 30kg/m^2);

Birth weight classified according to the WHO recommendations (low birth weight < 2,500g, insufficient birth weight 2,500-2,999g, appropriate birth weight 3,000-3,999g, high birth weight ≥ 4,000g);

Based on MET.

Table 2

The individual contribution of the child-level variables on overall variability in BMI z-scores included into the adjusted model. Florianópolis, Santa Catarina State, Brazil, 2002 and 2007.

Variables	2002 (%)		2007 (%)	
	Boys	Girls	Boys	Girls
Persons/room	1.0	-	1.1	-
Monthly family income	1.5	1.0	1.0	1.4
Birth weight	1.9	2.5	4.3	1.9
Mother's weight status	5.6	3.6	5.3	7.5
Consumption of sweets	2.0	-	1.3	1.8

Table 3

Estimates of fixed effects (β) and variance components in two multilevel linear regression models for the association of body mass index (BMI) z-scores and child and school level variables for boys. Florianópolis, Santa Catarina State, Brazil, 2002 and 2007.

Variables	2002		2007	
	Null model	Adjusted model	Null model	Adjusted model
Fixed effects (SE)				
Intercept	0.51 (0.06) *	0.35 (0.09) *	0.72 (0.06) *	0.80 (0.09) *
Persons/room				
1 (reference)				
2		-0.04 (0.04)		0.08 (0.03) *
≥ 3		-0.24 (0.05) *		-0.34 (0.03) *
Monthly family income (minimum wage)				
≥ 10 (reference)				
≥ 5 - < 10		0.14 (0.05) *		0.10 (0.04) *
≥ 2.5 - < 5		0.38 (0.04) *		-0.13 (0.04) *
< 2.5		0.16 (0.04) *		0.07 (0.04) **
Mother's weight status				
Thin		-0.74 (0.06) *		-0.51 (0.04) *
Normal weight (reference)				
Overweight		0.41 (0.03) *		0.04 (0.03)
Obese		0.85 (0.05) *		0.85 (0.03) *
Birth weight				
Low		-0.15 (0.06) **		-0.36 (0.04) *
Insufficient		-0.23 (0.04) *		-0.31 (0.02) *
Appropriate (reference)				
High		0.29 (0.04) *		0.45 (0.03) *
Consumption of sweets		-0.12 (0.01) *		-0.09 (0.01) *
School type				
Public (reference)				
Private		0.34 (0.09) *		0.04 (0.12)
Variance components (SE)				
Child level	1.45 (0.02) *	1.31 (0.02) *	1.29 (0.01) *	1.13 (0.01) *
School level	0.05 (0.02) *	0.03 (0.01) **	0.06 (0.02) *	0.06 (0.02) *

SE: standard error.

* Significant effect at the level of 1%;

** Significant effect at the level of 5%.

(β = 0.53, $p < 0.001$) presented higher BMIs. Girls studying in private schools presented 0.25 BMI z-score units higher than the scores recorded in public school girls ($p < 0.05$).

In the 2007 survey, girls with monthly family income < 2.5 minimum wages had 0.13 BMI z-score units higher than the BMI z-score of girls with family income > 10 minimum wages (reference); however, those girls with monthly family income ≥ 5 and < 10 minimum wages had 0.27 BMI z-score units lower than the reference ($p < 0.001$). Girls with overweight/obese mothers (β = 0.51 and 0.74, $p < 0.001$, respectively) and those with high birth weight (β = 0.11, $p < 0.001$) presented higher BMI. The effect of higher intake frequency of sweets was inversely associated with BMI (β = -0.10, $p < 0.001$).

The addition of the school-level variable (type of school) to the fixed part of the model explained 38.4% of the variance at the school level in the 2002 survey, but it remained significantly different from zero ($s^2_{school} = 0.02$, $p < 0.05$). Similarly to boys, in the 2007 survey the type of school variable did not explain the variance at the school level. The addition of the child-level variables to the fixed part of the model explained 8.3% of the variance at the child-level in 2002 and 10.8% in 2007. Table 4

Table 4

Estimates of fixed effects (β) and variance components in two multilevel linear regression models for the association of body mass index (BMI) z-scores and child and school levels variables for girls. Florianópolis, Santa Catarina State, Brazil, 2002 and 2007.

Variables	2002		2007	
	Null model	Adjusted model	Null model	Adjusted model
Fixed effects (SE)				
Intercept	0.31 (0.05) *	0.15 (0.07) **	0.39 (0.06) *	0.32 (0.08) *
Age (years)				
7 (reference)				
8		-0.09 (0.03) *		-
9		-0.12 (0.03) *		-
10		-0.35 (0.03) *		-
Monthly family income (minimum wage)				
≥ 10 (reference)				
≥ 5 - < 10		0.18 (0.04) *		-0.27 (0.03) *
≥ 2.5 - < 5		0.36 (0.04) *		-0.01 (0.03)
< 2.5		0.18 (0.05) *		0.13 (0.03) *
Mother's weight status				
Thin		-0.61 (0.05) *		-0.25 (0.04) *
Normal weight (reference)				
Overweight		0.39 (0.03) *		0.51 (0.02) *
Obese		0.55 (0.04) *		0.74 (0.03) *
Birth weight				
Low		-0.20 (0.04) *		0.03 (0.03)
Insufficient		-0.17 (0.03) *		-0.23 (0.02) *
Appropriate (reference)				
High		0.53 (0.05) *		0.11 (0.04) *
Consumption of sweets		-		-0.10 (0.01) *
School type				
Public (reference)				
Private		0.25 (0.08) **		0.18 (0.12)
Variance components (SE)				
Child level	1.22 (0.02) *	1.12 (0.01) *	1.07 (0.01) *	0.95 (0.01) *
School level	0.03 (0.01) **	0.02 (0.01) **	0.06 (0.02) *	0.06 (0.02) *

SE: standard error.

* Significant effect at the level of 1%;

** Significant effect at the level of 5%.

Discussion

The multilevel analysis of the present study, conducted with schoolchildren aged 7 to 10 years from Florianópolis, in 2 cross-sectional studies 5 years apart (2002 and 2007) identified that both child's individual characteristics and attending public or private schools predicted the BMI in the 2002 survey. By contrast, in the 2007 survey, only the child's individual characteristics predicted the BMI. Mother's weight status explained the highest percentage of the variability in BMI z-scores in both surveys. Socioeconomic status, age group, birth weight and consumption of sweets also explained the individual variability of BMI z-scores in a significant way, but the effects were smaller than mother's weight status. Among the determinants of overweight, parental BMI has been firmly established as a proxy for genetic factors and also as a risk marker for parental lifestyle [25,26]. In addition, maternal

BMI may exert a stronger influence on offspring BMI than paternal BMI perhaps because mothers exert an important role in children's food choices or this could be due to gestational or epigenetic factors [26].

The influence of indicators of socioeconomic status showed inconsistent findings in the present study. According to the persons/room' indicator, a similar pattern to what is usually reported in low- and middle-income countries appears, i.e., the higher the socioeconomic status the higher the BMI [7]. By contrast, monthly family income presented an inverse relationship with BMI, more clearly observed in the 2002 survey, a pattern comparable to results from studies conducted in high-income countries [27]. Nevertheless, in the 2007 survey, boys from families with lower/intermediate monthly income level presented a lower BMI z-score compared to those with higher income levels.

In addition, children who attended private schools (those in Brazil probably experienced better socioeconomic conditions than those attending public schools) had higher BMIs compared to those in public schools, a result also supported by other Brazilian studies conducted with children [28] and adolescents [29]. When the interaction effect between monthly family income and school type was tested, schoolchildren whose parents had higher family income exhibited lower BMIs compared to those with lower incomes in the same schools (data not shown). Moreover, in 2007 survey the school type variable did not explain the variance of the random effects of schools on BMI z-scores. Thus, in this sample the higher income level (or higher socioeconomic status) seems to have more influence on child BMI, while the school type (public or private) does not seem to reduce health inequalities, at least in terms of the weight status indicator.

A relevant intervention for diminishing the consumption of soft drinks and high-fat ready-to-eat snacks by schoolchildren from public schools in the city of Florianópolis was "the canteen law" (*lei das cantinas*) launched in 2001 [30]. In view of that, the children that attended public schools may be less exposed to unhealthy foods and may have better access to a healthy diet in the school environment. Data from the *Brazilian National School Health Survey* (PeNSE) showed that students from private schools had more access to snack bars at school (94.8 vs. 39.4% in public schools), are less physically active (29.1 vs. 34.7% in public schools) [31] and are exposed to less time in physical education classes (40.1 vs. 52.5 % in public schools) [32].

In both surveys of the current study, the observation that lower BMI z-scores in children who reported higher sweet intake frequencies throughout the day compared with their counterparts who reported lower frequencies suggests a misreporting. This finding may be an example of "reverse causality" and/or the reflection of factors such as social desirability of reporting a healthy diet, a well-known confounder in nutritional epidemiology [33]. In addition, the self-reports of food intake may also reflect dietary restrictions adopted by overweight children or a downward reporting bias, likely due to parental and social pressure to avoid sweets and consume healthy foods to reduce weight [34]. The food questionnaires in the present study did not ask a specific question on child diet restriction motivated by weight loss, neither did it attempt to quantify the amounts of food consumed, so reporting higher frequency of consuming sweets does not necessarily mean this was part of an obesogenic dietary pattern. Nevertheless, a study conducted with 9 to 15 years old children from Sweden and Estonia reported that children's BMI was negatively associated with energy consumption from sweets and sugar [35].

Data driven methodologies such as cluster analysis or latent class analysis have been introduced in nutritional epidemiology in the last years to investigate the association between obesogenic behaviors and overweight/obesity, instead of individual foods or activities. A recent review [36] discussed the studies using empirical, data-driven methodologies, such as cluster analysis and latent class analysis, to identify clustering patterns of diet, physical activity and sedentary behavior (eight studies) among children or adolescents (≥ 9 years) and their associations with sociodemographic indicators, and overweight and obesity. Findings from this review suggest that these behaviors cluster together in complex ways that are not well understood and inconclusive to support an association between obesogenic cluster patterns and being overweight and obesity [36]. Following the tendency of use, data driven methodologies, we applied latent class analysis to derive discriminant dietary patterns associated with overweight/obesity in a secondary analysis of data from the 2007 survey [37]. Latent food patterns derived from specific eating events consumed according to the time-of-day were associated with the risk of obesity, independently of socioeconomic and sociodemographic factors [37].

In the present study, the school-level influence in the variability of BMI z-score was small, but statistically significant in girls and boys. Such results are consistent with other studies conducted in high-income countries, which showed that a small proportion of BMI variation (3-5%) is related to the school [8,9]. Although child-level variables explained a larger part of the variability in BMI z-scores, the findings still suggested that the modest school effect has the potential to exert a substantial impact on children's BMI at a population level.

Due to limitations of the available data, we were not able to elucidate the mechanisms by which schools influenced the weight status of students. The PeNSE conducted with a representative sample of adolescents attending 9th grade public and private schools analyzed characteristics of the school environments to which Brazilian students are exposed. The schools from the South Region showed a greater frequency of sports courts and free sports after school time, however, most of the students (98.6%) were exposed to unhealthy foods [38].

The *Strategic Action Plan to Tackle Non-Communicable Chronic Diseases in Brazil, 2011-2022* [39] launched by the Ministry of Health in 2010, defined and prioritized actions and investments necessary to address non-communicable diseases in the next 10 years based on three principles: (i) surveillance, information, evaluation and monitoring; (ii) health promotion; and (iii) integral care. In Brazil, all primary health centers and family health teams of the Brazilan Unified National Health System (SUS) are provided by a web-based platform to record anthropometric and food consumption data from primary care patients in all life stages [40]. This platform allows for the monitoring of the nutritional status and food consumption markers from the patients of the SUS [41]. Furthermore, surveillance systems for adolescents [31,32] and adults [41] are periodically conducted at national level providing data on nutritional status, food intake, physical activity, sedentary behavior and other risk factors for non-communicable diseases. However, it is necessary to develop surveillance and monitoring systems for 5 to 9 years old children to determine compliance with the obesity prevalence targets for this age range, set at 8% for boys and 5% for girls [39].

Although data on the prevalence of overweight and obesity can be extrapolated from research projects, it is routine surveillance that will provide the most robust information. Schools are practical platforms for implementing well designed intervention programs to promote healthy eating and to increase physical activity. On the other hand it is also recognized that the decrease of obesity rates does not depend solely on individual behavioral changes. The evidence indicates that effective obesity prevention is mainly achieved with community-based strategy/policy aimed at structural changes in the environment and family engagement [42]. Positive experiences in this direction were observed in the HENRY study (*Health Exercise and Nutrition for the Really Young*) in the UK, which obtained positive changes in dietary intake in both adults and children, many of which were sustained at follow-up, thereby reducing the probability of later obesity [43].

Among the positive aspects of the present study we highlighted the inclusion of child and school variables, allowing the analysis of changes in the socioeconomic context and structural changes in the school context. Another positive factor was the representative samples of 7 to 10 years old schoolchildren and the number of schools included, allowing for the application of multilevel analysis. Florianópolis city presents a good scenario to study the determinants of nutritional transition, as its Municipal Human Development Index (HDI-M) rose from 0.77 in 2002 to 0.85 in 2010, therefore reaching a level comparable to countries with medium (0.50-0.79) and high HDI (HDI > 0.80) [19]. In addition positive changes in social determinants of health occurred in Brazil over the period of the surveys [1].

Even though this is a cross-sectional investigation, where the design precludes inferences about causal relationships between the variability in BMI z-scores and individual and contextual correlates. The study design did not allow us to establish whether, for example, socioeconomic status, mother's weight status, food intake and physical activity precede the current children's weight status. Moreover, few variables were available to describe the school environment and missing data occurred in some independent variables. Behavioral and environmental variables related to obesity in Brazilian schools should be investigated, for example, the weekly frequency of physical activity classes, the availability of sports courts, the presence of high energy-dense foods and snacks in school meals and canteens. The assessment of school's compliance with the *Brazilian National School Feeding Program* (PNAE) [44], the law that regulates the commercialization of unhealthy food in school canteens [30] and the *Brazilian School Health Program* [32] are highly recommended topics to investigate in the school context. The evaluation of the adherence and acceptance of school meals, as well as their nutritional quality is another important issue that must be evaluated.

Conclusion

In summary, our results suggest that socioeconomic status, type of school (a proxy for socioeconomic conditions), age, birth weight, mother's weight status and consumption of sweets were associated with children's BMIs, in two cross-sectional surveys, confirming individual and school effects on the weight status of children. The variable with the greatest influence on children's BMIs was the mother's weight status. Based on these results, recommendations to policy-makers for the prevention of childhood overweight/obesity should include family engagement strategies in addition to school interventions. Clearly, targeting children of overweight/obese mothers and those of low socioeconomic status must be included in the intervention programs.

As diet, physical activity and sedentary behavior are important, yet modifiable, determinants of obesity, we intend to address data driven methodologies to evaluate obesogenic cluster patterns in a longitudinal study from childhood to adolescence in schoolchildren from the city of Florianópolis.

Contributors

D. B. Leal participated in the concept, data analysis and interpretation, and preparation of the paper. M. A. A. Assis participated in design, ethics submission, supervised the study implementation including recruitment, anthropometric measurements, interpretation and preparation of the paper. W. L. Conde, A. S. Lobo and F. Bellisle assisted with interpretation and reviewed the paper. D. F. Andrade assisted with data analysis, interpretation and reviewed the paper.

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Resumo

O estudo teve como objetivo medir a contribuição das características individuais do aluno e da escola à variabilidade dos escores-z do índice de massa corporal (IMC) em crianças brasileiras entre 7 e 10 anos de idade. Foram analisados dados antropométricos e sociodemográficos de dois estudos trnasversais conduzidos com escolares da segunda à quinta série de Ensino Fundamental (n = 2.936 em 2002 e n = 1.232 em 2007). A modelagem multinível foi utilizada para estimar as variações de IMC em nível individual e de escola. A contribuição do contexto escolar à variabilidade global do escore-z do IMC foi pequena, porém significativa, em 2002 (3,3%-4,4%) e em 2007 (2,4%-5,3%), mostrando que alunos de escolas particulares tinham IMC mais alto, comparado ao dos alunos de escolas públicas. A renda familiar mensal mostrou uma associação negativa com o escore-z do IMC em 2002 e uma associação positiva em 2007, para ambos sexos. O consumo de doces mostrou efeito negativo sobre o IMC das crianças. Em ambos estudos, filhos de mães com sobrepeso/obesidade e alunos com história de excesso de peso ao nascer mostraram associação positiva com o escore-z do IMC. Em ambos estudos, o estado nutricional materno mostrou influência maior sobre a variabilidade global do IMC. Em conclusão, as características da escola e do aluno contribuíram para a variância no IMC da criança. Os resultados sugerem que, para serem mais eficazes, os programas de prevenção de sobrepeso/obesidade na infância devem focar em estratégias com participação da família.

Criança; Índice de Massa Corporal; Transição Nutricional; Saúde Escolar; Análise Multinível

Resumen

A El objetivo de este estudio fue determinar la contribución de las características individuales y escolares en la variabilidad del índice de masa corporal (IMC) z-scores en niños de entre 7 a 10 años de edad. Se analizaron datos antropométricos y sociodemográficos de dos estudios transversales conducidos con escolares de la segunda a la quinta serie de la enseñanza fundamental (n = 2.936 en 2002 y n = 1.232 en 2007). Se utilizaron modelos multinivel para estimar variaciones en el IMC en los niveles infantiles y escolares. La contribución del contexto escolar para la variabilidad general de IMC z-score fue pequeña, pero significativa en 2002 (3,3%-4,4%) y en 2007 (2,4%-5,3%), indicando que los escolares de escuelas privadas tenían un IMC superior, comparados con los de las escuelas públicas. Los ingresos familiares mensuales mostraron, en general, una asociación negativa con el IMC z-score en 2002 y una asociación positiva en 2007, para ambos sexos. El consumo de dulces mostró un efecto negativo en el IMC de los niños. En ambas encuestas, las madres con sobrepeso/obesas y el peso excesivo al nacer se asociaron positivamente con el IMC z-score. El estatus del peso de la madre tuvo una influencia más alta en la variabilidad general del IMC en ambas encuestas. En conclusión, las características escolares y del niño contribuyeron a la variancia en el estatus de peso de los niños. Los resultados implican que los programas infantiles de prevención de sobrepeso/obesidad deberían enfocarse en estrategias de adhesión familiar para ser más efectivos.

Niño; Índice de Masa Corporal; Transición Nutricional; Salud Escolar; Análisis Multinivel

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