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ORIGINAL ARTICLE

Cluster of risk and protective factors for obesity among Brazilian adolescents

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Abstract

Objectives This study aims to identify and analyze clusters formed by risk and protective factors for obesity among Brazilian adolescents.

Methods Cross-sectional data collected in a national representative sample of adolescents by the Brazilian National School Health Survey of 2012 were used ($n = 109{,}104$). Cluster analysis was applied to identify clusters involving dietary intake, eating behavior, physical activity and sedentary behaviors. Logistic regression was employed to contextualize the clusters according to students' sociodemographics and schools' characteristics.

Results Two clusters were identified. Cluster 1 was predominantly characterized by the low frequency of both risk and protective factors for obesity; Cluster 2 was characterized by high frequency of both of these factors. None was essentially healthy or unhealthy. Adolescents from less developed regions and with mothers with lower education level were associated to Cluster 1.

Conclusions The identification of two mixed clusters indicate wide spread obesity risk among scholars in the country. The association between the clusters and sociodemographic characteristics of the population allows a greater refinement of health promotion and obesity prevention and combat actions in Brazil.

Keywords Obesity · Multivariate analysis · Health behavior · Risk factors · Adolescent · Public health

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Introduction

The increase in prevalence of obesity in recent decades, in developed and developing countries, elevated this health condition to the status of global pandemic (Swinburn et al. 2011). It affects not only adults, but also youngsters (WHO 2009a). In Brazil, evidence indicates the increase in prevalence of obesity among the adolescent population since 1974 (IBGE 2010). In 2009, 20.5% of the adolescents were overweight, with one quarter of these already considered obese (IBGE 2010). This situation is especially alarming since adolescence is a critical period for the adoption of healthy behaviors (Craigie et al. 2011). Thus, in the past decades, the Brazilian government has invested in health promotion programs among students aiming to promote healthy eating and active lifestyles (Brasil 1998, 2009).

While inadequate food consumption and sedentary lifestyle are generally recognized as the main drivers of obesity (Stephens et al. 2014), a much larger list of factors must also be considered (Davison and Birch 2001). Obesity has a complex etiology, being influenced not only by physiological and other individual factors, but also by environmental conditions (Davison and Birch 2001; Mendes et al. 2013). Indeed, evidences from several countries indicate that the adoption of simple practices—such as eating breakfast every day and having meals in family—can reduce obesity risk among adolescents (Larson et al. 2013; Slater et al. 2011), while other—such as eating in front of the TV or computer or having too much screen time during the day—may increase it (Mamun et al. 2012; Slater et al. 2011; Vandewater et al. 2015).

Although enough evidence identifying several risk and protective factor for obesity is already available (Boone-Heinonen et al. 2008; Larson et al. 2013; Mamun et al. 2012; Van Der Sluis et al. 2010), understanding the behavior of these factors in the population remains challenging. The high complexity of this scenario demands multifactorial approaches, considering that several risk and protective factors may occur simultaneously. This kind of approach has already been applied in studies involving populations from developed countries (Boone-Heinonen et al. 2008; Burke et al. 1997; Ottevaere et al. 2011; Spengler et al. 2012), remaining underexplored in developing countries.

Therefore, the aim of the present study was to identify and analyze clusters formed by risk and protective factors for obesity among Brazilian adolescents. This proposal supports the development of more effective public policies targeting the reduction of obesity rates and associated non-communicable diseases (NCDs) in Brazil.

Methods

Data collected for the National School Health Survey (Pesquisa Nacional de Saúde do Escolar–PeNSE), conducted by a partnership between the Brazilian Institute of Geography and Statistics (IBGE), the Ministry of Health and the Ministry of Education, between April and September 2012, were used. The aim of PeNSE (2012) was to assess risk and protective factors for health in a population of students in the final year of elementary education (9th grade) at public and private schools throughout Brazil (IBGE 2013).

PeNSE (2012) relied on a complex sample based on the stratification of national territory. In each unit of the federation (States and Federal District), two geographic strata were defined. The first included the capital and the second the set of all other municipalities. In the capitals, cluster sampling was performed in two stages; the schools and the 9th grade classes were the primary and secondary sampling units, respectively. In the set of the remaining municipalities of the state, three stages were used; the primary sampling unit was a group of municipalities (defined according to population size and economic development level), the schools were the secondary unit, and the 9th grade classes were the third unit. The classrooms were randomly selected in the chosen schools and all students from the selected classrooms were invited to participate in the study. Of the 3004 eligible schools, 162 were excluded due to lack of 9th grade classes, strikes or school board refusal to participate. Eighty-four percent ($n = 110{,}873$) of the students registered in the selected classes attended school in the data collection day. Only 1651 of them refused to participate and 118 did not report their gender or age; therefore, being excluded (response rate = 82.7%). Thus, the final sample was composed by 109,104 students from 2842 schools.

Students used a smartphone to complete a self-answered electronic structured questionnaire (divided by thematic modules). The questionnaire was based on the ones used in similar surveys [such as the Global School-Based Student Health Survey (WHO 2009b)]. It was adapted to the Brazilian setting and tested in previous surveys (IBGE 2009). Additional details about PeNSE can be found elsewhere (IBGE 2013).

Among data available in PeNSE, the main outcomes of interest were those related to dietary intake, eating behavior, physical activity and sedentary behaviors, identified in the literature as protective and risk behaviors for obesity among adolescents (Boone-Heinonen et al. 2008; Larson et al. 2013; Mamun et al. 2012; Pearson and Biddle 2011; Van Der Sluis et al. 2010). The dietary intake was defined based on weekly frequency of intake (days/week) of food groups recognized as indicators of healthy and unhealthy food consumption, specifically: beans, vegetables, fruits, milk, sweets, cookies, crackers, bagged salty snacks, fried salty snacks, processed meats and sweetened beverages. Eating behavior information included weekly frequency of the following practices: having breakfast, having lunch/dinner with parents/guardians, and eating in front of the TV or while studying. Physical activity was determined based on the weekly frequency of activities in each of three domains: physical education at school, leisure time physical activity, and commuting (to and from school). Sedentary behavior was determined by the daily frequency (h/day) of TV watching and sitting time (since these behaviors are assumed in PeNSE to occur every day). Finally, a set of information about the students and schools characteristics were also included: gender, age, mother's education level, ethnicity/skin color, geographical area, type of school management (public or private) and region.

The frequency of missing cases was negligible ($< 5\%$) for all variables of interest, except for mothers' education

(17%; $n = 18{,}527$). In this case, multiple imputations (by chained equations) were employed. Missing values and the details of this procedure are described elsewhere (Rezende et al. 2014). The Monte Carlo error analysis showed satisfactory statistical reproducibility of the imputed data (Royston and White 2011).

Statistical analysis

The clusters of risk and protective factors for obesity were identified through cluster analysis using k-means non-hierarchical method. This exploratory analytical method explicitly addressed the formation of mutually exclusive clusters sets for study units presenting similar behaviors on those addressed variables (Hair et al. 2010).

All selected data—11 indicators of dietary intake, 3 indicators of eating behaviors, 3 indicators of physical activity and 2 indicators of sedentary behaviors—were initially included in this analysis. Cronbach's alpha coefficient was estimated for each one of the 4 domains (dietary intake, eating behavior, physical activity, sedentary behavior) to avoid redundancies and allow data reduction in the cluster analysis (variables identified at this stage as redundant were excluded from further analysis).

Computer simulations were used to identify the best solutions for the cluster analysis. A thousand random seeds were evaluated and solutions with 2–7 clusters were then analyzed. The final solution (the one maximizing heterogeneity among clusters and homogeneity within them) was identified based on the maximum value of Calinski/Harabasz tests and on the size and interpretation of the clusters. The reliability and stability of the cluster analysis were tested in repeated analyses applied to three random subsamples (50%) of total sample. The kappa coefficient was estimated to analyze the agreement between the identified clusters in each repeated analysis (kappa > 0.99 was found in the three assessed subsamples, and it indicated excellent agreement). Hypothesis tests (T test) were performed to compare the means of the variables employed between the different clusters.

Multiple regression models (logistic regression) were used to contextualize each cluster (the cluster identified was analyzed as outcome, and the characteristics of the students and schools were assessed as explanatory variables). Models were adjusted using forward technique (variables were inserted in increasing order of significance value (p value) in the adjusted model).

All analyses were carried out for the entire population and per gender.

The Stata statistical software (version 13.1) was used in data organization and analysis, considering the complex sampling of the survey.

Results

The population studied consisted of 109,104 9th grade students, most of them were females (52.2%) and in the age group 14–15 years (63.9%). Most students were from public schools (82.8%), self-declared black/brown (55.6%) and with mothers that did not complete high school (39.0% did not attend school or had incomplete elementary school and 17.8% completed elementary school but had incomplete high school). Two-third of the students lived in the center–south (Southeast, South and Center-West) regions of the country (66.8%) (most developed), and approximately three-quarters of them lived outside the state capital (77.6%). These trends were similar for males and females (Table 1).

In relation to dietary intake, the highest frequencies of consumption were observed for bean (5.28 days/week) and milk (4.13 days/week) among the indicators of healthy food consumption, and for sweets (3.74 days/week), salty biscuit (3.44 days/week) and soda (3.33 days/week) among the indicators of unhealthy consumption. Similar scenario was found in the analysis per gender, with slight differences in the consumption for both healthy and unhealthy indicators between male and female. However, a difference greater than 20% was observed only for the consumption of sweets (3.32 days/week (95% CI 3.17–3.46) for males vs 4.13 days/week (95% CI 3.98–4.28) for females) (Table 2). Healthy eating behavior such as having meals (lunch or dinner) with parents or guardian (4.92 days/week) and having breakfast (4.55 days/week) were more frequent than the undesirable habit of eating in front of the TV or while studying (4.08 days/week). Boys had a higher frequency of healthy eating behaviors when compared to girls ($p < 0.05$) (Table 2).

Low frequency of physical activity was observed, either commuting (1.02 days/week), in the school (2.84 days/week) or during the leisure time (2.55 days/week), whereas sedentary activities accounted for more than 3 h of the day (TV time 3.64 h/day and sitting time 3.83 h/day). Similar values were observed among males and females. However, it is worth noting that in comparison to males, females presented lower frequency of physical activity at school and at leisure time, and higher of both sedentary behaviors ($p < 0.05$) (Table 2).

From the 19 variables initially selected, two were discarded due to rejection in initial tests (Cronbach's alpha, see "Methods") for cluster analysis ("active commuting" and "time watching TV").

Two clusters were identified for total population and by gender. None was considered essentially healthy or unhealthy (Table 3). Cluster 1 was predominantly characterized by low frequency (below average and, also, in

Table 1 Sociodemographic characteristics (absolute and relative frequency) for the entire population of 9th grade Brazilian students and according to gender

Characteristics	Total			Male			Female		
	N	%[a]	95% CI	*N*	%[a]	95% CI	*N*	%[a]	95% CI
Age									
13 years or younger	22,443	22.9	17.0–28.8	9148	19.8	13.8–25.8	13,295	25.8	19.8–31.8
14–15 years	72,005	63.9	61.8–66.0	34,471	64.4	63.1–65.7	37,534	63.4	60.3–66.5
16 years or older	14,656	13.2	8.4–18.0	8396	15.8	9.9–21.8	6260	10.8	6.7–14.8
School management									
Private	22,504	17.2	12.6–21.8	11,066	17.7	12.3–23.1	11,438	16.7	12.7–20.6
Public	86,600	82.8	78.2–87.4	40,949	82.3	76.9–87.7	45,651	83.3	79.4–87.3
Ethnicity/skin color									
White	37,674	36.8	31.5–42.0	18,770	38.7	33.2–44.1	18,904	35.0	30.1–39.9
Black or brown	62,750	55.6	51.4–59.8	29,269	54.0	49.3–58.6	33,481	57.0	53.3–60.8
Asian or American Indian	8680	7.7	6.3–9.1	3976	7.4	6.3–8.5	4704	8.0	6.2–9.7
Mother's educational level									
Did not study, incomplete ES	42,533	39.0	36.0–42.0	19,184	36.7	34.4–39.1	23,349	41.0	37.2–44.8
Complete ES, incomplete HS	19,391	17.8	17.2–18.4	9346	17.9	17.2–18.6	10,046	17.7	16.8–18.5
Complete HS, incomplete HE	33,499	30.7	28.2–33.2	16,503	31.6	29.3–34.0	16,996	29.9	27.1–32.6
Complete HE	13,681	12.5	11.4–13.7	7169	13.7	12.7–14.7	6513	11.4	10.2–12.7
Geographical region									
Southeast, South, Midwest	55,029	66.8	64.8–68.7	27,086	69.0	68.2–69.8	27,943	64.7	61.1–68.4
North, Northeast	54,075	33.2	31.3–35.2	24,929	31.0	30.2–31.8	29,146	35.3	31.6–38.9
Area									
Capital	61,145	22.4	21.1–23.7	29,393	23.0	22.3–23.8	31,752	21.8	19.8–23.9
Not capital	47,959	77.6	76.3–78.9	22,622	77.0	76.2–77.7	25,337	78.2	76.1–80.2
Total	109,104	100.0		52,015	47.8	45.8–49.9	57,089	52.2	50.1–54.2

Pesquisa Nacional de Saúde do Escolar (PeNSE), Brazil, 2012

ES elementary school, *HS* high school, *HE* higher education, *CI* confidence interval

[a]Weighted values. See "Methods" section for further explanation

comparison with Cluster 2) of both risk and protective factors, except for the two protective eating behaviors, while the Cluster 2 was characterized by the high frequency of these factors, i.e., both clusters had, at some level, risk factors for obesity. Cluster 1 presented lower protective factors frequency and Cluster 2 showed higher risk factors frequencies. More than half of the students belonged to Cluster 1 (57.13% for total population, 57.78% for males, 55.90% for females) (Table 3).

The students in Cluster 2, when compared to those in Cluster 1, presented higher frequency of both healthy—fruits (3.64 vs. 2.57 days/week) and vegetables (3.61 vs. 3.03 days/week), and unhealthy food consumption indicators—cookies (5.18 vs. 1.83 days/week) and processed meats (3.07 vs. 1.42 days/week). Students in Cluster 2 also presented smaller frequency of both healthy eating behaviors—eating with the parents/guardians (4.73 vs. 5.07 days/week) and having breakfast (4.41 vs. 4.65 days/week)—and higher frequency of the unhealthy one—eating while studying or watching TV (4.94 vs. 3.44 days/week)—than those in Cluster 1 (Table 3). Cluster 2 students also presented higher frequency of physical activity at school and at leisure times (2.91 vs. 2.80 days/week; 2.82 vs. 2.35 days/week, respectively) and of sedentary behavior (time sitting) (4.74 vs. 3.14 h/day) than those belonging to Cluster 1.

The same cluster composition (mixed) identified for total population was observed in stratified analysis by gender (Table 3).

In general, in the adjusted analysis (multivariate), female students (OR 1.32; $p < 0.001$), those whose mothers had at least complete ES (OR 1.17; $p < 0.001$), who were in the age group 14–15 years (OR 1.14; $p < 0.001$), self-declared black/brown (OR 1.11; $p < 0.001$) and who did not live in the North and Northeast regions (OR 0.72, $p < 0.001$) had higher chance of belonging to Cluster 2 (higher weekly risk frequency and protective factors for obesity) (Table 4). The type of school management (public

Table 2 Mean frequency (and 95% CI) of indicators of dietary intake, eating behavior, physical activity and sedentary behavior for the entire population of 9th grade Brazilian students and according to gender

Variables	Total Mean (95% CI)	Male Mean (95% CI)	Female Mean (95% CI)
Dietary intake (days/week)			
Healthy foods			
Fruits	3.03 (2.95–3.10)	3.04 (2.97–3.10)	3.02 (2.93–3.11)
Vegetables	3.28 (3.15–3.41)	3.26 (3.15–3.37)	3.30 (3.15–3.45)
Bean	5.28 (5.13–5.43)	5.54 (5.39–5.69)	5.04 (4.87–5.21)
Milk	4.13 (3.93–4.33)	4.35 (4.13–4.57)	3.93 (3.74–4.12)
Unhealthy foods			
Fried salty snacks	2.20 (2.13–2.28)	2.12 (2.03–2.21)	2.27 (2.19–2.36)
Processed meats	2.13 (2.07–2.19)	2.09 (2.00–2.17)	2.17 (2.11–2.22)
Crackers	3.44 (3.35–3.52)	3.33 (3.27–3.38)	3.54 (3.42–3.66)
Cookies	3.26 (3.22–3.31)	3.13 (3.08–3.18)	3.38 (3.32–3.44)
Bagged salty snacks	1.74 (1.68–1.79)	1.59 (1.51–1.66)	1.87 (1.81–1.94)
Sweets	3.74 (3.61–3.87)	3.32 (3.17–3.46)	4.13 (3.98–4.28)
Beverages	3.33 (3.23–3.43)	3.40 (3.32–3.49)	3.26 (3.13–3.38)
Eating behavior (days/week)			
Eating with the parents/guardians	4.92 (4.79–5.05)	5.09 (5.00–5.19)	4.77 (4.60–4.93)
Eating in front of the TV or studying	4.08 (3.78–4.38)	4.14 (3.85–4.42)	4.03 (3.71–4.35)
Having breakfast	4.55 (4.39–4.70)	5.05 (4.94–5.16)	4.09 (3.91–4.27)
Physical activity (days/week)			
Active commuting	1.02 (1.00–1.05)	0.95 (0.92–0.97)	1.10 (1.06–1.13)
PA at school	2.84 (2.75–2.93)	2.96 (2.91–3.01)	2.74 (2.62–2.85)
PA at leisure times	2.55 (2.50–2.60)	3.12 (3.04–3.19)	2.03 (1.98–2.08)
Sedentary behavior (h/day)			
TV watching	3.64 (3.57–3.71)	3.43 (3.40–3.46)	3.82 (3.71–3.94)
Time sitting	3.83 (3.73–3.92)	3.62 (3.55–3.68)	4.02 (3.87–4.17)

Pesquisa Nacional de Saúde do Escolar (PeNSE), Brazil, 2012

CI confidence interval, *PA* physical activity

Weighted values. See "Methods" section for further explanation

or private) and location area (capital or non-capital) were the only variables not associated with clusters, either in unadjusted or adjusted models. Similar scenario was observed in the stratified analysis by gender (Table 4).

Discussion

This is the first study to present the coexistence of risk and protective factors for obesity among Brazilian adolescents. Two clusters of factors were identified, but none of them could be defined as healthy or unhealthy. Cluster 1 was predominantly characterized by the low frequency of both risk and protective factors for obesity. Cluster 2 was featured mostly by the high frequency of these factors. Through multiple regression models, was identified that students in the age group 14–15 years, self-declared black/brown, living in more developed regions (Southeast, South and Midwest) and having mothers with higher education levels were more likely to belong to Cluster 2.

A significant portion of the knowledge available at the time of the conclusion of the presented study was limited to the investigation of individual risk and protective factors for obesity (Baranowski et al. 2011; Stephens et al. 2014). These studies did not consider the possibility of factors coexisting in a single sample (or individual) affecting obesity risk. The multifactorial approach was herein adopted to help understanding these factor's behaviors allowing the creation of more effective health promotion strategies targeting specific groups (Boone-Heinonen et al. 2008; Burke et al. 1997; Ottevaere et al. 2011; Pearson and Biddle 2011; Spengler et al. 2012; Steele et al. 2013; Van Der Sluis et al. 2010).

A study aiming at identifying and describing the diet and eating patterns of adolescents in Brazil (from all state capitals) performing cluster analysis using PeNSE 2009 data (similar questionnaire to PeNSE 2012) (Tavares et al.

Table 3 Mean frequency (weekly or daily) of risk and protective factors for obesity according to the behavior clusters for the entire population of 9th grade Brazilian students and according to gender

Variables	Total		Male		Female	
	Cluster 1	Cluster 2	Cluster 1	Cluster 2	Cluster 1	Cluster 2
Dietary intake (days/week)						
Healthy foods						
Fruits	2.57	3.64*	2.47	3.81*	2.62	3.53*
Vegetables	3.03	3.61*	2.88	3.78*	3.13	3.52*
Bean	5.19	5.40*	5.35	5.78*	4.98	5.12**
Milk	3.72	4.68*	3.78	5.13*	3.58	4.38*
Unhealthy foods						
Fried salty snacks	1.38	3.29*	1.38	3.14*	1.39	3.40*
Processed meats	1.42	3.07*	1.41	3.01*	1.41	3.13*
Crackers	2.11	5.20*	2.05	5.07*	2.16	5.28*
Cookies	1.83	5.18*	1.77	4.99*	1.87	5.30*
Bagged salty snacks	0.85	2.92*	0.79	2.67*	0.90	3.11*
Sweets	2.53	5.36*	2.18	4.88*	2.90	5.69*
Beverages	2.36	4.62*	2.49	4.66*	2.22	4.57*
Eating behavior (days/week)						
Eating with the parents/guardians	5.07	4.73*	5.15	5.02	4.94	4.54*
Eating in front of the TV or studying	3.44	4.94*	3.59	4.89*	3.31	4.94*
Having breakfast	4.65	4.41*	4.97	5.16*	4.27	3.87*
Physical activity (days/week)						
PA at school	2.80	2.91*	2.87	3.08*	2.71	2.77*
PA at leisure times	2.35	2.82*	2.74	3.63*	1.88	2.23*
Sedentary behavior (h/day)						
Time sitting	3.14	4.74*	3.04	4.41*	3.26	4.99*
Total (%)	57.13	42.87	57.78	42.22	55.90	44.10

Pesquisa Nacional de Saúde do Escolar (PeNSE), Brazil, 2012

Weighted values. See "Methods" section for further explanation

PA physical activity

*$p < 0.001$; **$p < 0.05$

2014a) identified three patterns (healthy, unhealthy and mixed). The lowest prevalence of the pattern called healthy (27.7%) already indicated the expressive presence of obesogenic behaviors among Brazilian students, and corroborated the findings of the present study. However, the comparison of number and structure of clusters with the present study is not recommended given the difference in the number and nature of variables involved in the analysis.

Our results showed higher frequency of sedentary behavior among adolescents in Cluster 2, along with higher frequency of physical activity. Although this result may seem contradictory, some studies aiming at identifying cluster of risk and protective behavior for obesity among German adolescents have already indicated the hypothesis that the time spent in sedentary behaviors was not necessarily a barrier to physical activity (Ottevaere et al. 2011; Spengler et al. 2012). It could be explained by the fact that physical activity and sedentary behaviors were not typically developed in the same period of the day. Physical activities are often held at day light; and the second, in the evening. Thus, the physical activity among adolescents would only reduce once facing extremely high duration sedentary activities (> 6 h/day) (Spengler et al. 2012). Such information is meaningful as it exposes that the increase of physical activity would not necessarily reduce sedentary behavior, which may demand specific actions and policies.

The mixed composition of the two clusters herein identified also expand and complement the results of studies conducted in developed countries (Boone-Heinonen et al. 2008; Spengler et al. 2012), where it is common identifying mixed clusters involving health behaviors in adolescents. Even in studies wherein healthy and unhealthy clusters were identified, the mixed clusters represented

Table 4 Multivariate logistic regression involving behavioral clusters concerning obesity and sociodemographic characteristics of Brazilian 9th grade students stratified by gender

Characteristics	Total		Male		Female	
	OR crude[a]	OR ajust.[b]	OR crude[a]	OR ajust.[b]	OR crude[a]	OR ajust.[b]
Gender						
Male	1	1	–	–	–	–
Female	1.29*	1.32*	–	–	–	–
Mother's educational level						
Did not study, incomplete ES	1	1	1	1		1
Complete ES, incomplete HS	1.19*	1.17*	1.20**	1.17*	1.21*	1.17*
Complete HS, incomplete HE	1.24*	1.23*	1.25*	1.23*	1.27**	1.23*
Complete HE	1.17**	1.21*	1.23**	1.25*	1.18**	1.18*
Age						
13 years or younger	1	1	1	1	1	1
14–15 years	1.12*	1.14*	1.17*	1.18*	1.11**	1.13*
16 years or older	0.93	1.05	1.04	1.13**	0.85	0.94
Geographical region						
Southeast, South, Midwest	1	1	1	1	1	1
North, Northeast	0.72*	0.72*	0.68*	0.68*	0.72*	0.73*
Ethnicity/skin color						
White	1	1	1	1	1	1
Black or brown	1.05**	1.11*	1.04	1.10*	1.02	1.10*
Asian or American Indian	1.04	1.09	0.93	0.98	1.10	1.16
School management						
Private	1	1	1	1	1	1
Public	1.03	1.10	1.04	1.12	0.97	1.04
Area						
Capital	1	1	1	1	1	1
Not capital	0.95	0.96	0.91	0.92	0.98	1.01

Pesquisa Nacional de Saúde do Escolar (PeNSE), Brazil, 2012

Weighted values. See "Methods" section for further explanation

The reference in this analysis was Cluster 1

ES elementary school, *HS* high school, *HE* higher education

*$p < 0.001$; **$p < 0.05$

[a]Unadjusted Odds ratio obtained through logistic regression model. More details in the "Methods" section

[b]Adjusted Odds ratio for all variables of the sociodemographic characteristics obtained through logistic regression model. More details in the "Methods" section

most of the population's behavior (Jago et al. 2010; Ottevaere et al. 2011). The most accepted hypotheses state that, no matter if consciously or not, young people try to compensate unhealthy behaviors in one dimension by having healthy behaviors in other dimensions (Ottevaere et al. 2011) or even that same conditions capable of moving away risk factors may also influence protective ones (for example, a reduced number of supermarkets in the neighborhood can affect, in different proportions, both the consumption of unhealthy and healthy foods).

The structure of each mixed cluster identified in the present study and its association with the sociodemographic characteristics of Brazilian adolescents also provided important information for health promotion and obesity prevention in Brazil. The Cluster 1 was positively associated with adolescents with inappropriate age for the 9th grade of ES ($\leq$ 13 or $\geq$ 16 years), from less developed regions (North and Northeast) and with mothers in the lower level of education ($\leq$ incomplete ES), indicating the lowest socioeconomic status of these individuals; and the Cluster 2 was associated to those adolescents aged between 14 and 15 years old (appropriate age for 9th grade of ES), from more developed regions (Southeast, South and Midwest) and with mothers in the higher level of education ($\geq$ complete HE), indicating the highest socioeconomic status of these individuals.

Opportunities to engage in physical activities and access both healthy and unhealthy foods seem to be influenced by socioeconomic status (Laxy et al. 2015; Levy et al. 2012; Sherar et al. 2016). In this study, adolescents with the highest socioeconomic status presented higher consumption of both healthy and unhealthy foods. That can be found in studies on food acquisition and family income among Brazilians, in which the participation of healthy food groups (milk and dairy products, fruits and vegetables) and unhealthy ones (animal fat and ready meals) tends to increase uniformly with income level (Levy et al. 2012). In addition, more developed regions are known to have greater food availability, of both healthy and unhealthy products (Levy et al. 2012; Laxy et al. 2015). Cluster 2 adolescents (the highest socioeconomic status) also presented greater physical activity and sedentary behaviors compared to those from Cluster 1. In Brazil, more developed geographic regions are also more urbanized, which has been linked to more risky lifestyles in middle-income and low-income countries (Popkin 1999) which may favor the adoption of sedentary behavior.

This evidence reinforces the importance of more targeted actions to prevent and to control the obesity and other chronic non-communicable diseases among adolescents in Brazil. The adaptation of policies and programs already in course in Brazil as well as the implementation of new actions are necessary. The National Program of School Feeding (PNAE) (Brasil 2009)—requiring public school to provide meals based on fresh foods and, at least, three servings of fruits and vegetables per week (200 g/student/week) (Brasil 2009)—and the mandatory physical education classes in elementary schools—although the legislation does not establish their frequency and duration of classes (Brasil 1998), they are often offered two to three times a week and last 50 min—seem to be insufficient to ensure the adoption of healthy behaviors in an expressive share of the population. Thus, more rigorous actions may be required, such as restricting the type products sold inside schools (in canteens and cafeterias) and in their surroundings (Brasil 2012), and a regulation for publicity targeting this group (García and Díez 2009).

This is the first study to identify clusters of risk and protective factor for obesity among students in a developing country. Brazil is currently the seventh bigger economy in the world, with a population of more than 200 million individuals. A large national representative sample of 9th grade students served as basis for a multivariate analysis (cluster analysis) that remains little explored in Brazil. Meaningful results were obtained, expanding current knowledge about clustering of risk and protective factor for obesity. Besides, the methodological rigor applied in the analyses, which involve thousands of simulations for the choice of the ideal unit of study to start the cluster analysis and the verification of reliability and stability of the solutions adopted, reinforces the validity of the results presented.

Some potential limitations should be observed in relation to the results of the present study. PeNSE is based on self-reported information and uses a self-administered questionnaire that does not allow detailed analysis of adolescents' behavior. This approach is often used in large surveys about health conditions and lifestyle (WHO 2009b; Brener et al. 2013) due to their simplicity and low cost. Moreover, in PeNSE's specific case, such approach minimized the ethical implications for the investigation, since respondents were not identifiable. It is also important to notice that although the questionnaire used by PeNSE was not fully validated, all studies conducted up to this moment ensured the validity of data concerning dietary intake, eating behavior (Tavares et al. 2014b), physical activities and sedentary behaviors (Tavares et al. 2014c). In addition, weight and height information had measurement errors beyond the acceptable limit and thus IBGE does not recommend its use. However, we strongly believe that this issue does not compromise the relevancy of the study, since all factors used are already recognized as obesity-related.

Finally, the identification of two mixed clusters indicates wide-spread obesity risk among scholars in the country. Cluster 1, was predominantly characterized by the low frequency of both the risk and protective factors for obesity; Cluster 2, was featured by the high frequency of these factors. Sociodemographic characterization of the population in each cluster (students from less developed regions and with mothers with low level of education were associated to Cluster 1, while those from more developed regions and with mothers with higher education level were associated to Cluster 2) allows a greater refinement of health promotion and obesity prevention and combat actions in Brazil.

Compliance with ethical standards

Ethical standards The PeNSE was approved by the National Commission for Research Ethics (protocol 16,805). Microdata are freely available at IBGE website and makes impossible to identify the respondents. Informed consent was obtained from all participants. All procedures were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments.

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