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Original Article (short paper)

Cluster and simultaneity of modifiable risk factors for cardiovascular diseases in adolescents of Southeast Brazil

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Abstract - Aim: This study aimed to evaluate the cluster of the five major modifiable risk factors for cardiovascular diseases (CVD) and their associated factors and to identify patterns of concurrency of modifiable obesogenic risk factors associated with overweight in Brazilian adolescents. **Methods:** A survey was conducted (2015) with 1,055 (boys, n = 475; girls, n = 580) high school (public and private schools) adolescents (14-20 years old) in a medium-sized city in Southeast Brazil. The observed prevalence ratio (O) for the expected (E) risk factors (smoking, alcohol, insufficient physical activity, sedentary behavior, and poor diet) greater than one (O/E > 1) was considered as a cluster. We use multinomial and binary logistic regressions (stratified by sex) in the analyzes. **Results:** Almost 30% of adolescents had three or more risk factors (no factor = 5.4%). The five risk factors tended to cluster in boys (O/E = 2.5; 95% CI = 1.6-3.5). In both sexes, smoking and alcohol consumption persisted in O/E > 1 ratio. **Conclusions:** Boys showed a consistent pattern of association for risk factors. Overweight was associated with pairs of obesogenic risk factors in both sexes. The results indicate the need for health interventions that consider the cluster and the simultaneity of risk factors for CVD among Brazilian youth.

Keywords: risk factors, cluster analysis, health behavior.

Introduction

Excessive alcohol consumption, smoking, unhealthy diet, insufficient physical activity[1], and sedentary behavior[2] (SB) are among the main modifiable risk factors for cardiovascular diseases (CVD) in both developed and developing countries[2]. In 2016, CVD accounted for 17.9 million deaths (31% of all global deaths)[3]. Although the manifestation and lethality of CVD typically occur in adulthood or old age[3], the most influential factors begin with exposure to risk factors or behaviors learned in childhood or adolescence[4]. This reinforces the concern regarding detecting the exposure to risk factors in adolescence, in order to promote health interventions[5].

Clustering of risk factors is the cause of greater concern than isolated risk factors[6] and it exists when the observed proportion of risk factors exceeds the expected proportion of the combination of factors in the study population[7]. The clustering is supported by a rationale that multiple lifestyle behaviors occur in a multifactorial and interactive way[6,7]. For example, smoking, alcohol consumption, low fruit intake, and insufficient physical activity (PA) tended to come together among adolescents from the south and northeast of Brasil[8,9]. In addition, multiple risk behaviors, such as insufficient physical activity and (SB), tend to cluster and are on the route of pediatric obesity[10]. Although SB is a modifiable risk factor for CVD[2] that favors negative combination patterns[10], it is still poorly investigated in studies involving young people, especially in Brazil[11].

In addition to clustering, some risk behaviors seem to be more prone than others to obesity in young people. A recent review showed that risk factors involving unhealthy diet patterns (e.g. high-fat/high-sugar snacks), SB, and insufficient physical activity in young people tend to converge on healthy and unhealthy patterns for obesogenic pathways, but results were inconclusive[10]. Five of the studies included in the review showed unhealthy behavior patterns (e.g. insufficient PA + high SB) positively associated with excess body weight, but two other studies found an unexpected inverse association[12,13]. Moreover, a gap that persists since the review by Leech et al.[10] is the exploration of specific combinations of risk factor simultaneity involving unhealthy diet (e.g. low consumption of fruits and vegetables) and insufficient PA or unhealthy diet and SB and their obesogenic relationships. No study of clustering of factors conducted with Brazilian youth[8,9,11,14] ever investigated this relationship.

The clustering analysis of behavioral risk factors can facilitate the proposition of multicomponent health programs, with guidelines directed to the modification of risk behaviors. Strategies focusing on multiple aspects may be more efficient than those directed to a single risk factor[5,15]. Thus, the present study aimed to analyze the cluster of the five main modifiable risk factors for CVD and their associated factors; and identify patterns of simultaneity of modifiable obesogenic risk factors associated with overweight in adolescents from a municipality in southeastern Brazil.

Methods

The report of this study is guided by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement.

Study design

This cross-sectional study is derived from the epidemiological survey Assessment of Adolescent Health and Lifestyle Behaviors in Uberaba (ACtVU) whose population were adolescents of both sexes enrolled in the public and private high schools of Uberaba, Minas Gerais in 2015. Uberaba has a high municipal human development index (HDI [0.772]), Gini index of 0.50, and life expectancy at birth of 75.7 years. In 2010, the population of the municipality was 295,988 inhabitants and the expected schooling was of 9.94 years.

Data of the study ACtVU were collected between May and October 2015. The sample size was calculated considering the reference population (N = 10,903), the prevalence of the primary outcome (P = 50%), a 95% confidence level, an acceptable error of 5%, a two-point design effect and addition of 20% and 10% for loss/refusal and analysis for confounding factors, respectively. The final sample calculated in Epi Info was 979 participants. The complex sampling process was a double-stage proportional conglomerate with random draws. In the first stage, 15 schools were drawn out of 36 eligible schools, of which nine were public and six privates. In the second stage, 50 classes were drawn out of the 362 eligible ones. A spreadsheet editor was used to generate random numbers in both draws. One public school refused to participate and there was no replacement.

Ethical considerations

The procedures of the ACtVU study were approved by the local Research Ethics Committee (process number: 994,772/2015) and each parent and participant provided written consent before starting the study. The Department of Education of the State of Minas Gerais (SEEMG) and the Regional Superintendency of Education of Uberaba (SRE) authorized the study. The SRE provided the data regarding the school census. The survey was conducted following the Declaration of Helsinki.

Data collection

The adolescents self-completed anonymously a previously validated questionnaire[16], applied in the selected schools during the class period by a pair of trained applicators, between May and October 2015. The questionnaire used in this study was composed of six sections covering sociodemographic information, physical activities and sedentary behaviors, perception of the school environment and physical education classes, eating habits and weight control, alcohol and tobacco use, and perception of health and preventive behavior. A test-retest procedure showed reproducibility rates from 0.51 to 0.96[16].

Study variables

Modifiable risk factors for CVD

Smoking: the participant was asked whether he/she was a current smoker. The participant was considered a smoker if he/she smoked any amount of cigarette regularly on a daily basis[9];
Excessive alcohol consumption: the participant was asked which the number of doses/days he/she consumed in a typical week. Participants were considered exposed when reported consuming at least one dose of alcohol per day[11]. A beer can (350 ml), for example, was considered a dose of alcohol;
Low consumption of fruits and vegetables: the participant was asked about the frequency (number of days/week) with which the participant consumed fruits (or natural fruit juice), vegetables, and greens. Participants were considered exposed when reported frequency of consumption less than five times a week[9];
Insufficient PA: the participant was asked about the duration (minutes) and frequency (number of days) of moderate to vigorous leisure-time physical activity. Participants were considered exposed when they did not meet the minimum of 300 min/week[17];
SB: the participant was asked about the amount of time in hours and minutes spent in a typical weekday on SB (screen time). Participants were considered exposed when they had a time greater than or equal to two hours/day[18].

Each modifiable risk factor for CVD was coded as absent = 0 and present = 1. The prevalence of simultaneity of risk factors was estimated by summing the individual risk factors, coded from 0 (absence of factors) to 5 (five factors). Low fruit and vegetable intake, insufficient PA, and SB were considered as modifiable obesogenic risk factors[10].

Exploratory variables

Demographic and socioeconomic status: sex (boys and girls), age (full years at the date of collection), family income (up to two minimum wages and two minimum wages or more), traineeship/work (yes and no). The adolescents were instructed to consider as "work" any occupational bond even if unpaid (e.g. traineeship), except for domestic activities. Data from adolescents aged 14-20 years were used in the analyzes of the present study.

Students: school administrative status (public and private), school shift (day and night), participation in physical education classes (yes and no).

Health: self-rated health (excellent/good and poor/very poor - the "regular" option was not counted). Body mass index (BMI) was obtained by dividing the values of body mass (kg) by height (m) squared (BMI = kg/m^2), and the following cutoff points were adopted: leanness (degrees 3, 2 and 1) normal weight, overweight, obesity and morbid obesity[19]. Body mass was measured using a digital scale (Wiso® w949, graduation 100 g) and height using a portable stadiometer (WCS® Wood Portable Compact, graduation 1mm). The participants were evaluated only once, using light clothes and preferably barefoot.

Data recording

EpiData® Entry 3.1 (www.epidata.dk/) was used for double-entry of data. The validation function was used to compare typing, and inconsistencies were corrected by accessing the original paper questionnaires.

Statistical procedure

Continuous variables were reported as means and standard deviations (SD). The prevalence was expressed as absolute frequency and percentages. The independent t-test was used to compare BMI values and the χ^2 test to compare proportions.

The clustering analyses were divided into two steps. First, the cluster of the five modifiable risk factors for CVD was examined. A cluster was considered to be present when the observed (O) combination of risk factors exceeded its expected (E) prevalence, i.e., clustering = O/E > 1, with a significant confidence interval of 95% (95% CI). The expected prevalence of each combination of risk factors was calculated by multiplying the individual probability of each risk factor based on its occurrence in the study population[7].

In the second stage, the demographic, socioeconomic, health, and school-related characteristics associated with the simultaneity of modifiable risk factors for CVD were analyzed. Multinomial logistic regression was used to identify the odds ratio (OR) and 95% CI using the forced-entry model (adjusted for all demographic, socioeconomic, school-related, and health variables). Simultaneity was categorized in a score ranging from 0 (absence of risk factors [reference category in the analysis]) to 3 or more (sum of three, four, and five risk factors). Considering the low prevalence of some BMI categories in our sample (Table 1), comparisons were made between normal weight (leanness + normal weight) to overweight (overweight + obesity + morbid obesity). The Pearson χ^2 Goodness-of-fit test was used to test the significance of the model. The Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) were used to compare the final model and the null model (lower BIC and AIC

Table 1 - Sample characteristics. ACtVU Study. Uberaba, Brazil (2015).

Variables	**All (n=1055)**		**Boys (n=475)**		**Girls (n=580)**		χ^{2*}
	n	**%**	**n**	**%**	**n**	**%**	
Modifiable risk factor for CVD							
Smoking[a]	33	3.7	21	5.1	12	2.6	<0.001
Excessive alcohol consumption[b]	307	30.0	141	29.6	166	30.4	0.096
Low consumption of fruits and vegetables[c]	773	73.4	356	73.7	417	73.2	0.327
Insufficient PA[d]	545	50.0	244	50.4	301	49.7	0.164
Sedentary behavior[e]	441	40.1	201	41.5	240	38.8	<0.001
Simultaneous risk factors for CVD [**]							<0.001
3 or more	314	28.8	150	30.0	164	27.9	
2	401	38.1	178	38.1	223	38.1	
1	282	27.7	121	26.6	161	28.6	
0	58	5.4	26	5.3	32	5.4	
BMI (mean [SD] kg/m^2)[†]			22.04	[4.17]	22.26	[4.05]	<0.001
BMI[** ◆]							<0.001
Grade 3 thinness	6	0.4	2	0.3	4	0.4	
Grade 2 thinness	19	2.2	6	1.5	13	2.9	

(*continued*)

Table 1 - continued

Variables	**All (n=1055)**		**Boys (n=475)**		**Girls (n=580)**		χ^{2*}
	n	**%**	**n**	**%**	**n**	**%**	
Grade 1 thinness	64	6.8	26	6.2	38	7.4	
Normal weight	647	64.6	304	66.7	343	62.7	
Overweight	196	20.8	86	19.4	110	22.0	
Obesity	34	3.4	20	4.3	24	2.7	
Morbid obesity	16	1.8	8	1.6	8	1.9	
Family income[$]							<0.001
Up to 2 minimum wages	395	38.6	152	32.7	243	43.5	
2 minimum wages or more	660	61.4	323	67.3	337	56.5	
Traineeship/work							<0.001
No	721	64.3	286	56.3	435	71	
Yes	334	35.7	189	43.7	145	29	
School administrative status							<0.001
Private	204	12.5	68	9.4	136	15.1	
Public	851	87.5	407	90.6	444	84.9	
School shift							<0.001
Day	789	70.5	338	65.5	451	74.7	
Night	266	29.5	137	34.5	129	25.5	
Physical education classes							<0.001
No	258	20.2	73	12.4	185	26.7	
Yes	797	79.8	402	87.6	395	73.3	
Self-rated health							<0.001
Excellent/good	71.1	70.6	379	79.8	375	64.5	
Poor/very poor	28.9	29.4	104	21.1	210	35.5	

CVD: cardiovascular diseases.
BMI: body mass index.
Symbol (◆) indicates missing values (n = 86 [BMI = 73, out of age = 13]).
Symbol (†) indicates *t* independent test.
Symbol (*) indicates χ^2 de Pearson.
Symbol (**) indicates linear trends χ^2.
Symbol ($) indicates minimum wage value: R$ = 788.0; 1R$ ≈3.4 US$ during the data collection period.
[a]Any number of cigarettes currently smoked.
[b]Consumption ≥ 1 dose per day.
[c]Frequency <5 times a week.
[d]Perform < 300 min per week moderate to vigorous leisure-time physical activity.
[e]Time ≥ 2 h per day in front of the TV.

values indicate the best-adjusted model). The likelihood ratio χ^2 test was used to inform the model fit.

Following the gap identified by Leech et al.[10], simultaneous pairs among the modifiable obesogenic risk factors (insufficient PA, SB, and low fruit and vegetable intake) and BMI (normal weight [reference] vs. overweight) were explored. Binary logistic regression was used to identify the Odds Ratio (OR) and confidence interval (95% CI) with backward variable selection (Wald $\chi^2 \leq 0.10$ for permanence in the model). The presence of simultaneity (presence of simultaneity of risk factors = 1) was the reference category in the paired combinations of obesogenic risk factors.

The Little test for test of missing completely at random (MCAR) values indicated that the data were non-MCAR [χ^2 (121) = 199.42, $p < 0.001$], and therefore the missing values for outcome and exploratory variables [family income (n = 30), traineeship/work (n = 8), marital status (n = 8), participation in physical education classes (n = 14), and self-rated health (n = 9)] of this study were imputed by multiple imputation. Descriptive and inferential analyses were performed for the entire sample and stratified by sex using the SPSS® 21. Sample weights were calculated and entered in the multivariate analyses, considering $p < 0.05$ as the significance level for all analyses.

Results

Participants and descriptive analysis

One thousand three hundred and sixty-three adolescents from eight public schools and six private schools were invited to participate in the ACtVU Study. Two hundred and ninety-five adolescents did not consent to participate. Thirteen participants were older than 20 years and were excluded from the analysis of this study. Data from 1,055 (77.4% of the total) adolescents were analyzed.

More than half of the sample consisted of girls (54.5%). Participants' age ranged from 14 to 20 (mean ± SD = 16.1 ± 1.29); 16.0 ± 1.24 years for girls and 16.2 ± 1.35 years for boys (t = 13.8, $p < 0.001$). All demographic and socioeconomic, school, and health variables showed differences between sexes (Table 1).

Individual risk factors for CVD

Table 1 shows the prevalence of each of the five CVD risk factors for the entire sample and stratified by sex. Low consumption of fruits and vegetables was the most prevalent risk factor in the entire sample (73.4%) followed by insufficient PA and SB. Boys were more prone to smoking and SB than girls (5.1% *vs*. 2.6% and 41.5% *vs*. 38.8%, $p < 0.001$, respectively - Table 1).

The simultaneity of risk factors for CVD

In the entire sample, only 5.4% of adolescents had no risk factors for CVD (Table 1). Regarding sex, 5.3% of boys and 5.4% of girls did not have any risk factors for CVD. Approximately three out of ten (28.8%) adolescents had three or more risk factors. In both sexes, the simultaneity of two factors was the most prevalent (Table 1). A linear trend was identified by comparing the number of risk factors between sexes ($p < 0.001$).

Clustering of risk factors for CVD

Table 2 shows the clusters of modifiable risk factors for CVD stratified by sex. The clustering of the five risk factors was present in boys (O/E ratio = 2.54, 95% CI: 1.6-3.5). This result shows that the proportion at which the five risk factors occur was 154% higher among boys than the expected proportion if the five risk factors occurred independently. The absence of clustering of the five risk factors was equal to the expected based on the odds of individual risk factors for both sexes (O/E = 1). Among boys, the most expressive cluster was 740% above the expected by chance (O/E ratio = 8.4, 95% CI: 6.8-10.1). Among girls, the highest cluster value was 560% above the expected by chance (O/E ratio = 6.6, 95% CI: 5.3-8.3). As shown in Table 2, smoking and excessive alcohol consumption were present in all combinations of risk factors, with significant O/E. In fact, the cluster of this pair of fac-

Table 2 - Clustering of modifiable risk factors for CVD stratified by sex. ACtVU Study. Uberaba, Brazil (2015).

Risk factors	Smoking[a]	Alcohol[b]	PA	SB[d]	Fruits and vegetables[e]	Boys		Girls	
						O%	O/E	O%	O/E
5	●	●	●	●	●	0.6	**2.5 (1.6-3.5)**	0.1	1.2 (0.6-1.9)
4	∅	●	●	●	●	5.2	1.2 (0.6-1.8)	4.3	1.0 (0.5-1.6)
	●	∅	●	●	●	*	–	*	–
	●	●	∅	●	●	0.8	**3.6 (2.5-4.7)**	0.7	**6.6 (5.3-8.3)**
	●	●	●	∅	●	0.2	0.5 (0.1-0.9)	1.00	**5.5 (4.1-6.7)**
	●	●	●	●	∅	*	–	*	–
3	∅	∅	●	●	●	11.4	1.1 (0.5-1.7)	10.9	1.1 (0.5-1.7)
	∅	●	∅	●	●	4.9	1.1 (0.5-1.8)	4.0	0.9 (0.4-1.5)
	∅	●	●	∅	●	3.0	0.5 (0.1-0.9)	5.4	0.8 (0.3-1.3)
	∅	●	●	●	∅	1.0	0.6 (0.2-1.1)	0.8	0.5 (0.1-0.9)
	●	∅	∅	●	●	*	–	*	–
	●	∅	●	∅	●	*	–	*	–
	●	∅	●	●	∅	*	–	*	–
	●	●	∅	∅	●	2.7	**8.4 (6.8-10.1)**	0.7	**4.2 (3.0-5.3)**
	●	●	∅	●	∅	0.2	**2.6 (1.7-3.6)**	*	–
	●	●	●	∅	∅	*	–	*	–
2	∅	∅	∅	●	●	9.2	0.9 (0.4-1.5)	8.9	0.9 (0.4-1.5)
	∅	∅	●	∅	●	17.0	1.2 (0.6-1.8)	14.8	1.0 (0.4-1.5)

(*continued*)

Table 2 - continued

Risk factors	Smoking[a]	Alcohol[b]	PA	SB[d]	Fruits and vegetables[e]	Boys		Girls	
						O%	O/E	O%	O/E
	⌀	⌀	●	●	⌀	2.7	0.7 (0.2-1.2)	3.6	1.0 (0.4-1.6)
	●	⌀	⌀	⌀	●	*	–	*	–
	●	⌀	⌀	●	⌀	*	–	*	–
	●	●	⌀	⌀	⌀	0.6	**5.1 (3.7-6.3)**	*	–
	⌀	●	⌀	⌀	●	5.8	1.0 (0.4-1.5)	6.5	0.9 (0.4-1.5)
	⌀	●	●	⌀	⌀	1.9	0.9 (0.3-1.4)	2.3	0.9 (0.4-1.5)
	●	⌀	●	⌀	⌀	*	–	*	–
	⌀	●	⌀	●	⌀	0.9	0.6 (0.2-1.0)	2.2	1.4 (0.7-2.1)
1	●	⌀	⌀	⌀	⌀	*	–	*	–
	⌀	●	⌀	⌀	⌀	1.9	0.9 (0.3-1.4)	2.5	1.0 (0.5-1.6)
	⌀	⌀	●	⌀	⌀	7.4	1.4 (0.7-2.1)	6.7	1.2 (0.6-1.8)
	⌀	⌀	⌀	●	⌀	4.7	1.3 (0.6-2.0)	4.3	1.2 (0.6-1.8)
	⌀	⌀	⌀	⌀	●	12.8	0.9 (0.4-1.4)	16.1	1.0 (0.5-1.6)
0	⌀	⌀	⌀	⌀	⌀	5.3	1.0 (0.5-1.6)	5.4	1.0 (0.4-1.5)

O: Observed combination.
O/E: Ratio of the observed combination by expected prevalence (values in bold indicate O/E> 1 and a significant 95% CI).
PA: Insufficient physical activity.
SB: Sedentary behavior.
Symbol (●) indicates the presence of the risk factor.
Symbol (⌀) indicates the absence of the risk factor.
Symbol (*) indicates O = zero.
Symbol (–) indicates O/E not calculated.
[a]Any number of cigarettes currently smoked.
[b]Consumption ≥1 dose per day.
[c]Perform <300 min per week moderate to vigorous leisure-time physical activity.
[d]Time ≥ 2 h per day in front of the TV.
[e]Frequency <5 times a week.

tors showed to be 410% above the expected by chance in boys.

Multinomial analyses of risk factors for CVD

Table 3 and Table 4 show multinomial analyses of modifiable risk factors for CVD and associated factors among boys and girls, respectively. In both sexes, overweight was associated with increased odds for all categories of CVD risk factor simultaneity except for the presence of three or more factors in boys (Table 3).

In the case of boys, age was positively associated with the presence of one (OR = 1.11), two (OR = 1.14), and three or more risk factors (OR = 1.25) for CVD when compared to the absence of risk factors (Table 3). Additionally, those with a family income of up to two salaries, who did not work, from private schools, who did not attend physical education classes and those overweight showed increased chances to present all risk factor categories when compared to the absence of factors. On the other hand, day-shift students and those with positive self-rated health were less likely to have any number of risk factors than the reference category (Table 3).

Among girls, age was associated with a reduced chance of two risk factors (OR = 0.90) for CVD (Table 4). In addition, the chances of girls having two or three or more risk factors compared to the reference group were up to twice higher among girls who did not attend physical education classes. The likelihood of a risk factor was 39% higher among private school students. Girls with positive self-rated health were up to 42% less likely to have CVD risk factors. Overweight girls were more likely to have one, two, or more than three risk factors for CVD. Other isolated associations are shown in Table 4.

BMI and pairs of specific combinations of obesogenic risk factors

The combination that includes insufficient PA and SB was positively associated with overweight in both sexes (Table 5). Among overweight youth, the chance for this pair of risk factors increased by 66% in boys and 10% in girls. Boys also showed an 82% increased chance for the pair of risk factors that included SB and low consumption of fruits and vegetables.

Table 3 - Multinomial analysis[₡] of modifiable risk factors for CVD and associated factors in boys. ACtVU Study. Uberaba, Brazil (2015).

Variables	1 risk factor		2 risk factors		≥3 risk factors	
	%	OR (95%CI)	%	OR (95%CI)	%	OR (95%CI)
Age		**1.11 (1.04-1.18)** [b]		**1.14 (1.08-1.23)** [c]		**1.25 (1.17-1.34)** [c]
Income[$]						
Up to 2 minimum wages	20.8	**1.42 (1.19-1.69)** [c]	44.0	**2.32 (1.96-2.75)** [c]	31.8	**2.33 (1.96-2.76)** [c]
2 minimum wages or more	29.4	**1**	35.2	**1**	29.2	**1**
Traineeship/work						
School						
Public	26.5	**1**	38.4	**1**	29.4	**1**
Private	27.1	**4.34 (2.70-7.28)** [c]	35.2	**5.19 (3.17-8.49)** [c]	36.5	**6.06 (3.70-9.92)** [c]
School shift						
Day	28.9	**0.34 (0.27-0.43)** [c]	34.7	**0.19 (0.15-0.23)** [c]	29.2	**0.23 (0.18-0.29)** [c]
Night	22.1	**1**	44.5	**1**	31.7	**1**
Physical education classes						
Yes	27.2	**1**	37.6	**1**	29.3	**1**
No	22.5	**2.60 (1.58-4.27)** [c]	41.2	**2.81 (1.72-4.60)** [c]	35.4	**2.86 (1.75-4.69)** [c]
Self-rated health						
Positive	27.7	**0.77 (0.62-0.94)** [a]	40.1	**0.78 (0.63-0.96)** [a]	26.3	**0.37 (0.30-0.46)** [c]
Negative	22.2	**1**	30.4	**1**	44.0	**1**
BMI						
Normal weight	26.8	**1**	40.7	**1**	26.9	1
Overweight	21.2	**1.56 (1.32-1.84)** [c]	31.4	**1.59 (1.35-1.87)** [c]	41.4	0.87 (0.74-1.02)

BMI: Body mass index.
Bold OR (95%CI) values indicate statistical significance (a: $p < 0.05$; b: $p < 0.01$; c: $p < 0.001$).
Symbol ($) indicates minimum wage value: R$ = 788,00; 1R$ ≈3,4 US$ during the data collection period.
Symbol (₡) indicates a forced entry model adjusted for all demographic, socioeconomic, school and health variables (reference category = absence of risk factors).
Pearson χ^2 Good-of-fit test (df = 483) = 17,356.67, $p < 0.001$.
BIC (intercept vs. final) = 18,062.33 vs. 26,553.72.
AIC (intercept vs. final) = 18,039.15 vs. 16,345.13.
χ^2 test of likelihood ratio (df = 24) = 1,742.02, $p < 0.001$.

Regarding the pair of risk factors that included low consumption of fruits and vegetables and insufficient PA among overweight girls, girls were presented lower probability (31%) for this pair of factors (Table 5).

Discussion

According to the results, the clustering of the five modifiable risk factors for CVD in boys was much higher than expected by chance, always with the presence of smoking and excessive alcohol consumption in O/E > 1. In boys, a consistent pattern related to factors associated with simultaneous risk factors for CVD was identified. Finally, specific combinations of CVD risk factors involving SB, insufficient PA, and low fruit and vegetable intake showed associations with worse BMI status in both sexes. Clustering is based on the rationale that behavioral influences on lifestyle do not occur in a univariate manner, but, instead, are interactive and multifactorial influences[6,7]. Fundamentally, this understanding of clustering has important public health implications because it can indicate which obesogenic behaviors tend to aggregate and in which groups of people (girls and boys, for example), and, thus, better direct efforts and resources towards obesity prevention and coping initiatives[5,15].

In this study, only 5.4% of the adolescents did not have any risk factor against almost 30% who had three or more. The proportions were similar between boys and girls. Two studies conducted in different cities in southern Brazil found prevalence rates of 19% for two or more risk factors[14] and 14.5% for three or more risk factors for chronic diseases[8]. In the Northeast region of Brazil, Tassitano et al.[9] showed a prevalence of approximately 9% for the presence of three or more risk factors. The most recent study involving northeastern students showed a prevalence value near to 8% for the presence of three or more

Table 4 - Multinomial analysis₡ of modifiable risk factors for CVD and associated factors in girls. ACtVU Study. Uberaba, Brazil (2015).

Variables	1 risk factor		2 risk factors		≥3 risk factors	
	%	OR (95%CI)	%	OR (95%CI)	%	OR (95%CI)
Age		1.05 (0.99-1.11)		**0.90 (0.85-0.96)** [b]		1.00 (0.95-1.07)
Income$						
Up to 2 minimum wages	28.6	0.94 (0.82-1.07)	38.1	1.14 (1.00-1.30)	27.7	0.94 (0.82-1.08)
2 minimum wages or more	28.7	1	38.0	1	28.0	1
Traineeship/work						
Yes	29.6	**1**	38.3	1	27.0	1
No	28.3	**0.84 (0.72-0.99) a**	37.9	1.01 (0.86-1.18)	28.2	1.08 (0.92-1.27)
School						
Public	29.0	**1**	37.9	1	27.3	1
Private	26.3	**1.39 (1.07-1.79) a**	38.9	1.07 (0.83-1.37)	31.0	1.15 (0.89-1.49)
School shift						
Day	29.5	1.01 (0.82-1.25)	37.0	**0.82 (0.69-0.97)** [a]	27.9	0.86 (0.72-1.03)
Night	26.1	1	41.3	**1**	27.7	1
Physical education classes						
Yes	31.2	1	35.9	**1**	26.7	**1**
No	21.7	1.01 (0.82-1.25)	43.8	**2.31 (1.89-2.84)** [c]	31.2	**2.02 (1.64-2.48)** [c]
Self-rated health						
Positive	29.4	**0.42 (0.36-0.50)** [c]	38.4	**0.36 (0.31-0.43)** [c]	25.2	**0.34 (0.29-0.40)** [c]
Negative	27.3	**1**	37.4	**1**	32.8	**1**
BMI						
Normal weight	29.3	**1**	38.8	**1**	26.4	**1**
Overweight	31.8	**1.28 (1.12-1.47)** [c]	31.4	**1.87 (1.61-2.12)** [c]	29.3	**1.36 (1.19-1.57)** [c]

BMI: Body mass index.
Bold OR (95%CI) values indicate statistical significance (a: $p < 0.05$; b: $p < 0.01$; c: $p < 0.001$).
Symbol ($) indicates minimum wage value: R$ = 788,00; 1R$ ≈3,4 US$ during the data collection period.
Symbol (₡) indicates a forced entry model adjusted for all demographic, socioeconomic, school and health variables (reference category = absence of risk factors).
Pearson χ^2 Good-of-fit test (df = 552) = 20,949.56, $p < 0.001$.
BIC (intercept vs. final) = 20,624.25 vs. 19,977.65.
AIC (intercept vs. final) = 20,600.63 vs. 19,765.14.
χ^2 test of likelihood ratio (df = 24) = 883.50, $p < 0.001$.

modifiable risk factors[11]. In contrast, a survey of young Canadians (10-17 years) of both sexes showed 37% of the sample had three or more risk factors for chronic diseases[20]. Studies that assess the simultaneity of risk factors show wide methodological variation (e.g. different cutoff points and/or definitions of risk factors). Nevertheless, investigating the simultaneous presence of risk factors can be crucial for proposing health promotion actions in schools[5], especially intervention components such as those outlined for coping with overweight[15].

Despite the low prevalence of the presence of the five risk factors in boys in the present study (0.6%), the clustering of the five risk factors in boys was higher (154%) than expected by chance. Another study involving Brazilian adolescents showed a significant cluster of four risk factors (excluding SB) in boys and girls[8]. Alamian and Paradis[20] also showed a high O/E ratio for five modifiable risk factors (excluding low fruit and vegetable intake) among Canadian adolescents of both sexes. Taken together, these results indicate that behavioral risk factors appear to be synergistic in nature, a result found only among boys in this study.

The results showed the presence of smoking and excessive alcohol consumption simultaneously in all significant clusters, although they were not more prevalent than expected when analyzed as individual risk factors. Alamian and Paradis[20] also identified this cluster pattern in a representative sample of Canadian adolescents. The same pattern was shown in other studies with Brazilian adolescents[8,9]. This is a particularly alarming result because both risk factors share acute and chronic, and probably additive and negative effects on the adolescents'

Table 5 - Association between BMI and pairs of specific combinations of obesogenic risk factors, sex-stratified ACtVU Study. Uberaba, Brazil (2015).

Variables	Boys		Girls	
	OR (95%CI)	*p*	OR (95%CI)	*p*
		Sedentary behavior & Low consumption of fruits and vegetables		
Normal weight	**1**	<0.001[a]	1	0.117[b]
Overweight	**1.82 (1.69-1.96)**		1.06 (0.99-1.14)	
		Insufficient physical activity & Sedentary behavior		
Normal weight	**1**	<0.001[c]	**1**	0.022[d]
Overweight	**1.66 (1.53-1.81)**		**1.10 (1.01-1.19)**	
		Low consumption of fruits and vegetables & Insufficient physical activity		
Normal weight	1	0.234[e]	**1**	<0.001[f]
Overweight	0.96 (0.89-1.03)		**0.69 (0.61-0.77)**	

Adjusted analysis:
[a]Age, family income, traineeship/work, school type, school shift, physical education classes, self-rated health.
[b]Age, traineeship/work, school type, school shift, physical education classes, self-rated health.
[c, e]Age, family income, traineeship/work, school type, school shift, physical education classes, self-rated health.
[d]Age, family income, school type, school shift, physical education classes, self-rated health.
[f]Age, family income, traineeship/work, school shift, physical education classes, self-rated health.

health (e.g. intoxication, coma, vehicle accidents, addiction, cancer, reduced lung and kidney function, and mortality)[21,24]. Moreover, as shown in a recent systematic review, these two risk factors also tend to cluster in adulthood[22] and are among the major modifiable risk factors for chronic noncommunicable diseases (NCDs), which in 2016 accounted for 71% of the causes of death worldwide and 74% in Brazil[3]. Thus, rather than focusing on isolated risk behaviors, health care programs, including school programs[5], should direct efforts to prevent or stop these two behaviors together.

The results showed a consistent pattern of factors associated with the presence of one, two, and three or more modifiable risk factors for CVD in boys. Older, lower-income, unemployed boys, who did not participate in physical education classes, and especially from private schools were more likely to be identified with risk factors, in any number. School administrative status (public and private) is an inherent feature of the Brazilian basic education system. However, previous school-based studies that investigated the clustering or simultaneity of risk factors in young Brazilian students have neglected this fundamental feature[9,11,14]. The exception was the Adolescent Nutritional Assessment Longitudinal Study[23], which investigated the co-occurrence of behavioral risk factors for NCDs in students from public and private schools in the metropolitan region of Rio de Janeiro (non-probabilistic sample). In the analysis adjusted for sex and skin color, the authors found that there was a greater likelihood of simultaneous risk factors for NCDs among adolescents from private schools when compared to peers from public schools[23]. However, the result of the study[23] should be viewed with caution, considering that the reference category for simultaneity was poorly understood (agglutination no one or a single factor) and there was no adjustment for family income. The study by Azeredo et al.[24], based on the 2012 National School Health Survey (PeNSE 2012), did not find an association between "behavioral problems" pattern and public schools compared to private schools in the country's capitals and macroregions. The result found in the PeNSE 2012[24] study, regarding the presence of alcohol consumption and smoking, as constituent factors of the "behavioral problems" pattern, does not seem to be reflected in the context of other cities with good development rates (such as the one investigated in this study) and which is not a capital of a state or macroregion of Brazil, as seen in the present study.

The results showed that non-participation in physical education classes was associated with a higher probability of simultaneity of CVD risk factors, with similar association patterns in both sexes. Tassitano et al.[9], in a study conducted with 600 adolescents from public schools in Caruaru, Pernambuco, also identified higher chances of simultaneity of three or more risk factors among adolescents who did not participate in physical education classes. Participation in physical education classes is believed to provide a favorable environment for PA practice during class time and also in other contexts of daily PA[25]. In addition, the school curriculum, especially applied to physical education classes, may be designed to address key concepts for health promotion and adoption of a healthy lifestyle, such as healthy eating habits[5], thus benefiting only the students who participate in the classes.

For both sexes, positive self-rated health was inversely associated with the presence of one, two, and three or more CVD risk factors. Self-rated health is a key concept in adolescent health, considering that they self-rated their health as a broad construct anchored in medical, lifestyle, social, and psychological factors, especially overall well-being[26]. No studies were identified evaluating the clustering of behavioral risk factors and self-rated health in adolescents. Nevertheless, previous studies showed that SB[27] and low fruit consumption[28], as individual risk factors, were negatively associated with bad self-rated health. The relationship between high PA levels and positive self-rated health in adolescents has an apparent positive dose-response relationship[29].

Overweight young people of both sexes were more likely to present the simultaneity of modifiable risk factors for CVD. Overweight was also associated with insufficient PA and SB in both sexes, and only boys showed increased odds of SB and low fruit and vegetable intake. The results found that the simultaneity of insufficient PA and SB are in agreement with a previous review[10]. Leech et al.[10] identified a higher frequency of simultaneity of these two risk factors, but the studies did not present analyses stratified by sex, unlike the present study. We increased the data in an attempt to fill the gap identified in the previous review[10] by showing that the simultaneity of SB and low fruit and vegetable intake happens only in overweight boys. A previous systematic review[30] showed that unhealthy diet habits were routinely associated with SB in adolescents, especially low consumption of fruits and vegetables. Moreover, considering that SB was present in two of the three possible simultaneity combinations, it seems that this risk factor has a higher obesogenic relationship in adolescents, and this needs to be further explored.

Surprisingly, overweight girls showed low chances for the pair of risk factors that included low fruit and vegetable intake and insufficient PA. In the review by Leech et al.[10] of the 13 studies that investigated associations between cluster sets of behavioral risk factors and weight status or BMI, two studies[12,13] found inverse associations with some unhealthy cluster pattern. In the first study, a cross-sectional analysis of the longitudinal study Add Health (n = 8,686) showed that the "junk food and smoking" cluster was associated with a lower chance of obesity (OR = 0.49) only among boys[12]. In the study Fruits and Vegetables Make the Marks (n = 713), van de Sluis et al.[13] showed that the unhealthy clustering pattern (low fruit and vegetables, high snacking and soda, high sedentary behavior and low physical activity) was negatively related to BMI (β = -1.27) in young Norwegian people. The authors of the studies speculated that these associations may have emerged due to the BMI (inability to distinguish muscle mass) measurement bias[12,13] or the measurement or self-report bias of the unhealthy cluster components[13]. It is believed that something similar to this may have occurred to the girls in our study sample. For example, they may have reported socially accepted responses to outcomes of low fruit and vegetable intake and insufficient PA.

The study has limitations and strengths. First, this is a cross-sectional study, so causal inferences cannot be made. Second, cutoff points and categorizations of modifiable risk factors for CVD may differ significantly in the literature in cluster studies, and this represents a limitation of the study. However, cutoff points and categorization ways were adopted to better represent risk factors with standardized cutoff points[2,19,20] and also allow some comparison of our results with those from other studies involving young Brazilian people[8,9,11,14,26]. Third, the difficulty of obtaining consent from parents or adolescents can be understood as a limitation of the study design. In addition, we did not record each reason for not participating in this study; however, it was common for them to report that "my parents do not allow me to participate" or just "I do not want to participate" - although we reinforce for both parents and students about anonymity and confidentiality of information. Despite this, the sample size achieved exceeded the calculated sample, guaranteeing power for the analyzes. The probabilistic sampling and analysis procedure allows the extrapolation of results for adolescents of both sexes from private and public schools to a medium-sized city in southeastern Brazil. Although some of the risk factor combinations did not have significant O/E ratios, multinomial analyses are pertinent, maintaining risk factors in order to identify subgroups that are most vulnerable to simultaneity. In addition, the obesogenic relationship of some combination pairs involving SB, low fruit and vegetable intake, and insufficient PA was explored. Although metabolic/physiological risk factors (high blood pressure, hyperinsulinemia, and hypercholesterolemia, for example) represent the central axis in the burden of CVD[2], the focus of this study on modifiable risk factors was intentional. These factors may precede the former[2,4] and tend to be clustered among young people[10] and in adulthood[6,7]. In addition, they are recognized as more accessible for interventions in the pediatric population[5].

Conclusion

Approximately one-third of the adolescents in this study had three or more CVD risk factors. Risk factors tended to cluster, especially in the presence of smoking and excessive alcohol consumption. Boys presented a consistent pattern of factors associated with the simultaneity of risk factors. The largest obesogenic relationship seems to exist in the presence of SB behavior. These results point to the need to develop and implement health care programs among young people. Additionally, such programs should consider that risk factors do not occur isolated in this population. Therefore, programs focused on multiple factors may be more efficient.

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