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Patterns of lifestyle-related behaviors and parents' overweight are associated with increased body adiposity in schoolchildren: a cross-sectional study in Portugal

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Abstract

Background: This study evaluated the association between lifestyle-related behavior patterns and weight status indicators in schoolchildren.

Methods: Cross-sectional study includes nationally representative sample of Portuguese schoolchildren (6–9 years old; $n = 10{,}258$). Weight status was assessed using the body mass index (BMI) and waist circumference (WC). Principal component analysis was used to identify lifestyle-related behavior patterns. Multiple linear regression models were used to estimate the association between behavior patterns, BMI, and WC.

Results: Six lifestyle-related behavior patterns were identified: pattern 1: consuming iced tea and soft drinks ≥2 times/week, having a television (TV) in the bedroom, watching TV ≥2 h/day, and consuming <2 portions of fruits/day; pattern 2: parents and children remaining physically inactive during leisure time; pattern 3: consuming ≤1 portion of vegetables and milk/day; pattern 4: having parents with excess weight; pattern 5: consuming ≤3 daily meals and skipping breakfast; and pattern 6: not participating in physical education classes. After the adjustment, all of the patterns were associated with increased BMI *z*-score ($P \leq 0.02$) and WC ($P \leq 0.03$).

Conclusions: Lifestyle-related behavior patterns were associated with an increased risk of excess weight and the central distribution of body fat. Taking a public health perspective toward preventing childhood obesity, special attention should be given to identify subgroups with simultaneous occurrence of multiple risk behaviors, which is useful for planning prevention programs.

Keywords: Childhood obesity, Lifestyle, Risk behaviors, Schoolchildren, Adiposity indices, Principal component analysis

Background

The childhood obesity epidemic has become one of the most challenging public health issues in recent decades, with increasing prevalence worldwide [1, 2]. In Portugal, Padez et al. [3] observed a 31.5% prevalence of excess weight (including obesity) among children, which is similar to the prevalence rates found in other countries in Europe [4].

Childhood obesity is associated with the early development of metabolic changes and cardiovascular disease as well as with a greater probability of developing obesity and chronic diseases in adulthood [1, 5]. However, obesity is a complex condition with a multifactorial etiology involving non-modifiable factors and modifiable factors, especially lifestyle-related behaviors such as dietary intake and physical activity [6, 7].

Lifestyle-related behaviors, including inadequate dietary habits [8–11], low physical activity levels [12], and sedentary behaviors [13, 14], are strongly associated with an

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increased risk of obesity, cardiovascular disease, and diabetes mellitus [5, 14–18].

In most studies, the associations between excess weight and these behaviors have been investigated individually. However, they are highly interrelated [19, 20], being necessary to identify multidimensional patterns to better understand the complexity of the relationship between these behaviors and weight status [21]. The principal component analysis (PCA) has become a common approach because it considers the possible synergy of these factors by grouping strongly related behaviors in different patterns [19, 21–23].

The present study aimed to identify lifestyle-related behavior patterns using a PCA and to determine the association between these patterns and weight status indicators.

Methods

The *Portuguese Prevalence Study of Obesity in Childhood* (PPSOC) is a cross-sectional study carried out with Portuguese schoolchildren in 2009–2010. The sample was randomly selected from each district of mainland Portugal using a proportional sampling strategy stratified by the age and sex of the children. In the present study, 10,624 children between 6 and 9 years old who reside in 18 districts in mainland Portugal were evaluated. Details can be found in Jago et al. [24]. In summary, the study was designed to obtain a nationally representative sample of 3- to 10-year-old children living in Portugal. First, the public and private schools in each district were randomly selected from the database of the Ministry of Education, and then, the groups of children within the schools were randomly selected. The participation rate was 57.4% (49.3% for pre-school children and 63.6% for schoolchildren).

The present study was approved by the Directorate-General for Innovation and Curriculum Development (*Direção Geral de Inovação e Desenvolvimento Curricular*) (a branch of the Ministry of Education). The Portuguese Commission for Data Protection determined that analyses of these anonymized data were exempt from review. Permission to collect the data was also obtained from the principal's office of the schools and from the parents or guardians of the children, who signed an informed consent form indicating their consent to participate in the study.

Data collected

Data were collected in the classrooms, through interviews, with a standardized questionnaire. The questionnaire used in the present study was designed specifically for this research and was designed to study the different aspects of the following characteristics: demographic and socioeconomic, lifestyle-related behaviors, eating habits, and other information on health and nutrition. The questionnaire content was evaluated by conducting a pilot test on a group of children similar to those in the study, and the questionnaire was revised based on the pilot results. To reduce the nonresponse rate, three visits were made to each school to examine previously absent students.

In this study, the following issues were considered with respect to the children: breakfast consumption and the number of daily meals, the frequency of food consumption (fruits, vegetables, soft drinks, iced tea, and milk), physical activity outside of school and physical education classes in school, daily time spent watching television (TV), and the presence of a TV in the bedroom. With regard to the parents, the following issues were considered: educational level, physical activity, and weight status.

Breakfast consumption was ascertained by the yes/no question: "Does your child eat breakfast regularly?" Breakfast, lunch, snacks, and dinner were considered in the assessment of the number of daily meals.

Dietary intake was assessed by measuring the frequency of consumption of specific healthy and unhealthy eating markers with the question: "How often does your child consume the following foods?", including soft drinks (for example, Coca-Cola), iced tea, milk, and vegetables. The question had six response options for reporting the frequency of consumption ranging from never to two to three times/day. Fruit intake was measured with the question: "In the last week, how many portions of fruit did your child eat, on average, every day?"

To evaluate the weekly time spent watching TV, the following question was used: "Indicate the time (in hours) that the child spends watching TV on weekdays, Saturday and Sunday." For the analyses, TV-watching time was categorized as <2 and ≥2 h/day [25]. In addition, the child was asked if there was a TV in his/her bedroom (response options: yes and no).

The mother's and the father's physical activity levels were assessed separately by the yes/no question: "Do you regularly practice any sport?" The parents' weekly time spent watching TV was assessed in the same way it was assessed for the children. Finally, parental education was assessed according to the highest level reached by each parent; the results were grouped as follows: 1st and 2nd cycles (6 years of study), 3rd cycle (9 years of study), secondary (12 years of study), and university (13 years or more).

Lifestyle-related risk behaviors for excess weight

The following risk behaviors related to children's lifestyles and parents' characteristics were considered: soft drink and iced tea consumption (≥2 times/week); milk consumption (<1 portion/day); fruit consumption (<2 portions/day); vegetable consumption (<1 portion/day); physical activity (not engaging in leisure-time physical activity outside of school and not participating in physical education classes in school); TV use (spending ≥2 h/day watching TV and having a TV in the bedroom); meal consumption (consuming ≤3 meals/day and skipping breakfast); and characteristics of the parents (not engaging in leisure-time physical activity and having excess weight).

Patterns of lifestyle-related behaviors

To identify lifestyle-related behavior patterns, a PCA was performed by conducting an exploratory factor analysis that parsimoniously representing the information present in different variables and identifying the constructs (i.e., factors or patterns) [26]. Initially, the *Bartlett Test of Sphericity* (BTS) and the *Kaiser-Meyer-Olkin Measure of Sampling Adequacy* (KMO) were applied to evaluate the applicability of the factorial method to the dataset.

The orthogonal rotation (varimax option) was used to obtain independence of the factors and to facilitate the interpretation of the results. The determination of the number of factors to be extracted was based on the Kaiser criterion (i.e., the number of factors having eigenvalues ≥1). The behaviors with factor loadings ≥0.30 remained within the patterns because the factor loadings represent the correlations between each behavior and the score in which it was retained, and higher values indicate that the behavior contributes more to the construction of this specific pattern.

Anthropometric measurements and weight status

The anthropometric measurements were taken by a trained team using standard techniques [27]. Weight was measured using a digital scale (Seca 770), and height was measured in duplicate using a portable stadiometer (Seca 217). Waist circumference (WC) was measured in duplicate with a flexible and inextensible tape measure (Seca) at the midpoint between the anterior superior iliac crest and the last rib. The weight status was assessed by using the BMI (weight/stature^2) *z*-scores according to specific age and sex distributions from the World Health Organization [28].

The parents' weight status was assessed according to the cutoff points proposed by the World Health Organization [29], using the BMI values calculated from the self-reported weight and height measurements. It is worth noting that the use of these measures has been validated by other authors [30].

Statistical analysis

Student's *t* test was used for assessing the differences in the age according to excess weight (according to the BMI). The association between children and parents' characteristics, and excess weight was assessed by the chi-square test.

The associations between the weight status indicators (BMI *z*-score and WC, dependent variables) and the lifestyle-related risk behavior pattern scores (independent variables) were analyzed using multiple linear regression models adjusted for sex, age, and parental education. The first models were developed separately for each of the patterns, and then, the combined effect of all the patterns was evaluated.

In addition, another construct, the parents' education level, was used to fit the linear regression models. This variable was operationalized because of the observed correlation between the manifest variables and the parental education level (Spearman correlation coefficient = 0.67). The PCA revealed a construct that represented 82% of the shared variance, with factor loadings equal to 0.91 (for both the education of the father and the mother) and high communality (0.82 for both), revealing that this construct adequately described the correlation between the original variables.

The statistical analyses were performed using the statistical program *Statistical Package for the Social Science* version 19.0 (SPSS Inc., Chicago, IL, USA).

Results

Of all the children between 6 and 9 years old who were assessed in the PPSOC ($n = 10{,}624$), 3 (0.03%) were missing weight and height measurements and 363 (3.4%) were missing the WC measurement. Thus, the present study included 10,258 children (mean age 8.03 years, SD = 1.12), and 51% of them were girls. The prevalence of excess weight was 30.8% according to the BMI values; it was significantly higher among the girls than among the boys ($P < 0.01$) and among the children over 8 years old ($P < 0.01$) (Table 1).

The children in the sample displayed the following lifestyle-related risk behaviors: 18.9% did not participate in physical education classes in school; 49.3% were not doing any physical activity outside of school; 30.5% spent ≥2 h/day watching TV; 52.2% had a TV in the bedroom; 38.2% consumed <2 portions of fruit/day; 20.1% did not consume vegetables daily; 9.5% did not consume milk daily; 30.6 and 51.7% drank soft drinks and iced tea ≥2 times/week, respectively; 3.5% were not in the habit of having breakfast regularly; and 1.8% ate <4 meals/day (Table 1).

There were significant differences between the children with and without excess weight in the parental characteristics (excess weight and educational level), the physical activity of the mother, and the children's lifestyle-related risk behaviors, except for the frequency

Table 1 Characteristics of the Portuguese schoolchildren (6–9 years old) according to children's weight status (excess weight = overweight + obesity) (2009–2010)

Characteristics	Total N (%)	Child has excess weight		P value*
		No	Yes	
		N (%)		
Total[a]	10,258	69.2	30.8	–
Child characteristics				
Sex				
Boys	5014 (48.9)	3580 (71.4)	1434 (28.6)	<0.01
Girls	5244 (51.1)	3519 (67.1)	1725 (32.9)	
Age (years)				
Mean age (SD)	8.03 (1.12)	7.99 (1.13)	8.11 (1.10)	<0.01
Father characteristics				
Excess weight				
No	3229 (38.9)	2509 (77.7)	720 (22.3)	<0.01
Yes	5074 (61.1)	3257 (64.2)	1817 (35.8)	
Physical activity during leisure time				
Yes	2790 (30.9)	1970 (70.6)	820 (29.4)	0.09
No	6229 (69.1)	4286 (68.8)	1943 (31.2)	
Educational level				
1° and 2° cycles	2600 (27.9)	1708 (65.7)	892 (34.3)	<0.01[b]
3° cycle	1873 (20.1)	1262 (67.4)	611 (32.6)	
Secondary	2569 (27.6)	1737 (67.6)	832 (32.4)	
University	2278 (24.4)	1750 (76.8)	528 (23.2)	
Mother characteristics				
Excess weight				
No	6272 (67.7)	4672 (74.5)	1600 (25.5)	<0.01
Yes	2997 (32.3)	1762 (58.8)	1235 (41.2)	
Physical activity during leisure time				
Yes	2118 (22.1)	1548 (73.1)	570 (26.9)	<0.01
No	7477 (77.9)	5096 (68.2)	2381 (31.8)	
Educational level				
1° and 2° cycles	1955 (19.9)	1288 (65.9)	667 (34.1)	<0.01[b]
3° cycle	1715 (17.5)	1152 (67.2)	563 (32.8)	
Secondary	2933 (29.9)	1987 (67.7)	946 (32.3)	
University	3202 (32.7)	2363 (73.8)	839 (26.2)	
Child lifestyle-related behaviors				
Physical education classes at school				
Yes	8252 (81.1)	5778 (70.0)	2474 (30.0)	<0.01
No	1925 (18.9)	1268 (65.9)	657 (34.1)	
Physical activity during leisure time				
Yes	5032 (50.7)	3570 (70.9)	1462 (29.1)	<0.01
No	4890 (49.3)	3294 (67.4)	1596 (32.6)	
Time watching TV				
<2 h/day	6039 (69.5)	4273 (70.8)	1766 (29.2)	<0.01
≥2 h/day	2652 (30.5)	1760 (66.4)	892 (33.6)	

Table 1 Characteristics of the Portuguese schoolchildren (6–9 years old) according to children's weight status (excess weight = overweight + obesity) (2009–2010) *(Continued)*

TV in the bedroom				
Yes	4859 (52.2)	3240 (66.7)	1619 (33.3)	<0.01
No	4446 (47.8)	3214 (72.3)	1232 (27.7)	
Fruit consumption				
≥2 portions of fruit/day	6053 (61.8)	4216 (69.7)	1837 (30.3)	0.40
<2 portions of fruit/day	3736 (38.2)	2572 (68.8)	1164 (31.2)	
Vegetables consumption				
≥1 portion/day	7773 (79.9)	5417 (69.7)	2356 (30.3)	0.10
<1 portion/day	1956 (20.1)	1325 (67.7)	631 (32.3)	
Soda consumption				
<2 times/week	6567 (69.4)	4649 (70.8)	1918 (29.2)	<0.01
≥2 times/week	2890 (30.6)	1905 (65.9)	985 (34.1)	
Iced tea consumption				
<2 times/week	4519 (48.3)	3186 (70.5)	1333 (29.5)	0.03
≥2 times/week	4839 (51.7)	3311 (68.4)	1528 (31.6)	
Milk consumption				
≥1 portion/day	8831 (90.5)	6170 (69.9)	2661 (30.1)	<0.01
<1 portion/day	927 (9.5)	593 (64.0)	334 (36.0)	
Skipping breakfast				
No	9558 (96.5)	6662 (69.7)	2896 (30.3)	<0.01
Yes	347 (3.5)	206 (59.4)	141 (40.6)	
Daily meals				
≥4 meals/day	8673 (98.2)	6000 (69.2)	2673 (30.8)	0.23
<4 meals/day	162 (1.8)	105 (64.8)	57 (35.2)	

**P* value by chi-square test for all characteristics and Student's *t* test for age
[a]Given as row percentage
[b]Given as linear trend *P* value

of fruit and vegetable consumption and the number of daily meals (Table 1).

The KMO (0.64) and the BTS ($P < 0.01$) indicated that the correlations between the items were sufficient and adequate to perform the factor analysis. Based on the Kaiser criterion, six factors (patterns) were retained and defined as follows: pattern 1 (consuming iced tea and soft drinks >2 times/week, consuming <2 portions/day of fruit, having a TV in the bedroom and spending ≥2 h/day watching TV); pattern 2 (physical inactivity of parents and children during leisure time); pattern 3 (consumption of milk and vegetables ≤1 portion/day); pattern 4 (parents' excess weight); pattern 5 (≤3 daily meals and skipping breakfast); and pattern 6 (lack of participation in physical education classes). Together, the six patterns explained 49.37% of the variability in the children's lifestyle-related risk behaviors and the parental characteristics (Table 2).

Finally, multiple linear regression models were developed using the patterns as the independent variables and BMI *z*-score and WC as the dependent variables (Table 3). After adjusting for sex, age, and the educational level of parents, pattern 1 was significantly associated with increased BMI *z*-score ($P = 0.01$) and WC ($P = 0.02$). Pattern 2 did not significantly increase the risk for any of the indicators ($P > 0.05$ for both). Pattern 3 was significantly associated only with increased BMI *z*-score ($P = 0.01$). Pattern 4 was associated with increased BMI *z*-score ($P < 0.01$) and WC ($P < 0.01$). Pattern 5 was associated with increased BMI *z*-score ($P = 0.03$) and WC ($P = 0.03$), and pattern 6 was significantly associated with increased BMI *z*-score ($P = 0.02$) and WC ($P = 0.01$). In addition, the effect of each pattern was assessed. When they were considered simultaneously, all of the patterns were associated with increased BMI *z*-score (β ranging from 0.04 to 0.28, $P \leq 0.01$), except for

Table 2 Patterns of lifestyle-related behaviors, factor loads, and communalities (h_2) resulting from a factor analysis (extraction method: principal component analysis) with Portuguese schoolchildren, Portugal, 2009–2010 (6–9 years old; $n = 10,258$)

Behavioral risk factors	Patterns of lifestyle-related behaviors						h_2
	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6	
Iced tea consumption (≥2 twice/week)	0.70						0.49
Sodas consumption (≥2 twice/week)	0.58						0.35
TV in the bedroom	0.52						0.34
Time of watch TV (≥2 h/day)	0.40						0.25
Fruit consumption (<2 portions/day)	0.31						0.17
Mother's physical inactivity		0.69					0.50
Father's physical inactivity		0.69					0.50
Physical inactivity outside school		0.60					0.42
Milk consumption (<1 portions/day)			0.82				0.69
Vegetables consumption (<1 portions/day)			0.79				0.66
Father's excess weight				0.79			0.63
Mother's excess weight				0.65			0.46
Daily meals (≤3 per day)					0.76		0.58
Skipping breakfast					0.65		0.45
No physical education classes at school						0.95	0.91
Eigenvalues	1.88	1.25	1.18	1.09	1.02	1.00	
% of explained variance	12.52	8.30	7.84	7.24	6.79	6.68	
% of accumulated explained variance	12.52	20.82	28.66	35.90	42.69	49.37	

pattern 2 ($P = 0.21$), and WC (β ranging from 0.19 to 1.50, $P \leq 0.03$) (Table 3).

Discussion

The PCA identified six patterns related to the lifestyle habits and the characteristics of the parents of Portuguese children. The six patterns identified were significantly associated with increased BMI and WC, regardless of sex, age, and the educational level of the parents. The present study support the hypothesis that there are synergistic effects of lifestyle-related behaviors on the indicators of weight status and body fat distribution beginning in childhood. In a recent theory proposed by Marks [31], called the Homeostatic Theory of Obesity, this synergistic effect is similar to the mechanism one called "Circle of Discontent," which consists of a system of feedback loops linking weight gain, body dissatisfaction, negative affect, and overconsumption. According to this theory, one way to reduce the currently observed high prevalence of obesity, involving lifestyle-related behaviors, is the reduction in the consumption of high energy-dense and nutrient-poor foods [31].

The lifestyle patterns of the Portuguese children were similar to those observed among Greek children and adolescents [19, 22, 23]. Yannakoulia et al. [19] found that the pattern characterized by consumption of vegetables, cooked meals, and eating dinner was inversely associated with BMI, WC, and the triceps skinfold, and the pattern characterized by consumption of whole-grain, legumes, and low consumption of sugar-sweetened drinks was inversely associated with the triceps skinfold. Kontogianni et al. [22] found that the pattern characterized by higher consumption frequency, breakfast consumption, and greater adherence to the Mediterranean diet was inversely associated with BMI.

According to Seth and Sharma [32] and Gupta et al. [33], apart from etiologic causes from genetic and prenatal factors and socio-cultural practices, the major risk factors for childhood obesity and nutrition-related noncommunicable diseases are the consumption of high-calorie food, lack of physical activity, and increased screen time.

Among Portuguese schoolchildren, the lifestyle pattern that included consumption of sugar-sweetened beverages >2 times/week was associated with increased BMI and WC. These findings are supported by evidence from studies from several countries. According to Popkin [10], the consumption of sugar-sweetened beverages increases total caloric intake and serves as an important cause of chronic diseases. In the USA, the increase in the consumption of calories from sugar-sweetened drinks and fruit juices among children and adolescents 2–18 years old between 1977/1978 and 2005/2006 [34] parallels the increase in the prevalence of obesity and its

Table 3 Regression models for the association between patterns of lifestyle-related behaviors and adiposity indicators in Portuguese schoolchildren (6–9 years old; $n = 10,258$), Portugal, 2009–2010

Patterns[a]	Body mass index *z*-score		Waist circumference	
	β (95% CI)	*P* value	β (95% CI)	*P* value
Pattern 1				
0	0.08 (0.04, 0.11)	<0.01	0.57 (0.38, 0.76)	<0.01
1	–[b]		0.41 (0.24, 0.59)	<0.01
2	0.05 (0.02, 0.08)	0.01	0.22 (0.04, 0.40)	0.02
Pattern 2				
0	0.03 (0.003, 0.07)	0.03	0.30 (0.11, 0.49)	<0.01
1	–[b]		0.37 (0.20, 0.55)	<0.01
2	−0.004 (−0.04, 0.03)	0.83	0.12 (−0.07, 0.30)	0.22
Pattern 3				
0	0.06 (0.03, 0.09)	<0.01	0.28 (0.10, 0.47)	<0.01
1	–[b]		0.23 (0.06, 0.41)	0.01
2	0.05 (0.01, 0.08)	0.01	0.14 (−0.04, 0.32)	0.12
Pattern 4				
0	0.28 (0.25, 0.31)	<0.01	1.62 (1.44, 1.81)	<0.01
1	–[b]		1.55 (1.38, 1.72)	<0.01
2	0.27 (0.24, 0.31)	<0.01	1.47 (1.30, 1.65)	<0.01
Pattern 5				
0	0.04 (0.01, 0.07)	0.01	0.25 (0.06, 0.44)	0.01
1	–[b]		0.24 (0.06, 0.42)	0.01
2	0.04 (0.01, 0.07)	0.03	0.20 (0.03, 0.38)	0.03
Pattern 6				
0	0.04 (0.01, 0.07)	0.01	0.24 (0.05, 0.43)	0.01
1	–[b]		0.28 (0.10, 0.46)	<0.01
2	0.04 (0.01, 0.07)	0.02	0.25 (0.08, 0.43)	0.01
Simultaneously adjusted model[c]				
Pattern 1	0.06 (0.03, 0.10)	<0.01	0.31 (0.13, 0.49)	<0.01
Pattern 2	0.02 (−0.01, 0.05)	0.21	0.24 (0.06, 0.42)	0.01
Pattern 3	0.05 (0.02, 0.08)	<0.01	0.19 (0.02, 0.36)	0.03
Pattern 4	0.28 (0.25, 0.31)	<0.01	1.50 (1.33, 1.68)	<0.01
Pattern 5	0.04 (0.01, 0.07)	0.01	0.22 (0.05, 0.39)	0.01
Pattern 6	0.04 (0.01, 0.07)	0.01	0.27 (0.10, 0.44)	<0.01

Model 0 = crude, Model 1 = adjusted by sex and age of the child (age in years as a continuous variable), Model 2 = Model 1 + latent education level of the parents

[a]Pattern 1: consumption of iced tea and sodas (≥2 twice/week), have TV in the bedroom, spent ≥2 h/day watching TV, consumption of fruit (<2 portions/day); pattern 2: physical inactivity of parents and children in leisure time; pattern 3: consumption of vegetables and milk (<1 portions/day); pattern 4: parents' excess weight; pattern 5: ≤3 daily meals and skipping breakfast; pattern 6: no physical education classes at school

[b]This model was not estimated since the *z*-score is already adjusted for age

[c]Adjusted as model 2

associated comorbidities [1, 8]. Vartanian et al. [15] performed a meta-analysis of 88 articles and found significant associations between soft drink consumption and increased caloric intake and body weight.

Milk and dairy products serve as one of the best sources of dietary calcium with high bioavailability [23], and they have consistently been associated with reduced body fat [35, 36]. Skinner et al. [35] monitored children beginning when they were 2 months old and found that the intake of dairy products was associated with a lower body fat percentage at 8 years old. However, there are still questions about the association between increased consumption of dairy products and weight and body fat reduction [37]. The consumption of dairy products may be viewed as a marker of a better quality diet, and it is possible that consumption of this food group may be an indicator of a healthy lifestyle and may not necessarily protect against weight gain in children per se [36, 37].

In the present study, two other markers of healthy eating habits, fruit consumption and vegetable consumption, were retained in the first and third patterns, respectively. The protective effect of regular fruit and vegetable consumption on body weight may be due to the reduction in the energy density of the diet and the increased satiety induced by consuming foods with high-fiber content [5, 38, 39].

Irregular meal consumption and skipping breakfast were associated with childhood obesity among Portuguese children. Similar results were observed among Dutch [11], German [40], and Finnish populations [41]. Koletzko and Toschke [42] reported that skipping main meals is associated with increased risk of obesity in children, and Szajewska and Ruszczynski [43] found that regular breakfast consumption is associated with a lower incidence of excess weight and a lower BMI in children and adolescents from Europe. A possible explanation is that skipping main meals contributes to inadequate food intake and nutritional imbalance [44, 45].

Skipping breakfast, in particular, has short- and long-term effects on children [46, 47], and researchers have observed a tendency for this behavior to persist from childhood into adulthood, and was associated with a greater WC, higher fasting insulin, a higher BMI, and higher total cholesterol and LDL-cholesterol concentrations [9]. An association between skipping breakfast and poor-quality diets that influence the weight status of children has also been observed [47, 48].

Physical inactivity and sedentary behaviors have been considered persistent challenges that must be overcome to promote public health [14]. Excessive time spent watching TV is one of the most prevalent sedentary behaviors in contemporary society, and evidence suggests that many children exceed the maximum recommended TV watching time of 2 h/day [5, 14]. Several studies support the hypothesis that prolonged exposure to this risk behavior is associated with the risk of childhood obesity [11, 16, 17, 49] and the development of risk markers for cardiovascular disease [14, 18].

Another sedentary behavior that has gained prominence is the presence of a TV in children's bedrooms, which, as observed in this study, has been consistently associated with more excess weight, adiposity, and the development of risk markers for cardiovascular diseases [13, 49]. Sisson et al. [13] observed that 49.3% of the children and adolescents had a TV in their bedroom and that they had a higher prevalence of problematic social behaviors and excess weight, lower frequency of regular meal consumption, less involvement in school and less participation in extracurricular activities, and among other behaviors, regardless of the total time spent watching TV.

Not participating in physical education classes was associated with increased adiposity indicators, regardless of the other lifestyle patterns of Portuguese children. According to Rosenkranz et al. [50], teachers play a key role in motivating children to participate in physical education classes and physical activity. Sigmund et al. [51] conducted a study of a school-based intervention that lasted 2 years and found that increased physical activity in schools had a positive impact on physical activity during leisure time and on weekends in the intervention group. In addition, family characteristics, such as parents' weight status, physical activity, and education, have a significant relationship with the weight status and lifestyle-related behaviors of the children [11, 41, 52, 53].

Wilkie et al. [54] compared BMI z-scores of children who met health guidelines for lifestyle behaviors with those who did not comply with these guidelines. The authors explored the impact of interactions between lifestyle behaviors on BMI z-score and found that meeting moderate-to-vigorous physical activity (MVPA) guidelines was significantly associated with a lower BMI z-score, and significant two-way interactions were observed for physical activity and sleep, screen time and sleep, and physical activity and diet; thus, it is possible to conclude that MVPA, sleep, and screen time are important lifestyle behaviors associated with overweight/obesity among children [54].

The main strength of the PPSOC is that it includes a nationally representative sample of Portuguese schoolchildren. Furthermore, the analyses showed that adjusting for potential confounding factors that are commonly associated with the anthropometric indicators assessed (such as gender, age, and the parents' educational level) [11, 17, 22, 40, 52, 53] resulted in more accurate results, enabling a deeper understanding of the lifestyle-related risk behaviors for children and the family characteristics that can be modified in future intervention studies.

However, some limitations of the present study must be acknowledged. The results are based on a cross-sectional study, which limits the ability to identify a causal relationship between the independent variables and the outcomes observed. Nevertheless, associations similar to the ones observed between lifestyle-related behaviors and indicators of weight status have also been found in longitudinal studies [9, 16–18, 46].

Another limitation concerns the technique used to derive the lifestyle patterns. PCA requires arbitrary decisions even though they may be based on scientific knowledge about the dietary habits and the lifestyles of the population. Thus, the ability to compare the patterns extracted from different populations is limited because the patterns are specific to the population studied. However, PCA is an approach that has become common for identifying groups of closely related behaviors [19, 21–23], enabling the assessment of multidimensional exposures to gain a broader understanding of lifestyles [22].

Conclusion

The present study showed that unhealthy lifestyle-related behaviors (inadequate eating habits, physic al inactivity, and more time spent on sedentary behaviors) and parents' overweight were associated with increased body weight and fat accumulation in the abdominal region in schoolchildren. Thus, taking a public health perspective toward preventing childhood obesity, the holistic approach of the present study successfully identified subgroups with modifiable risk behaviors, which is useful for planning prevention programs.

Abbreviations

BMI: Body mass index; BTS: Bartlett Test of Sphericity; KMO: Kaiser-Meyer-Olkin Measure of Sampling Adequacy; MVPA: Moderate-to-vigorous intensity physical activity; PCA: Principal component analysis; PPSOC: Portuguese Prevalence Study of Obesity in Childhood; SD: Standard deviation; TV: Television; WC: Waist circumference

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Availability of data and materials

Not applicable.

Authors' contributions

PRMR contributed to the analysis and interpretation of data, drafting, writing, and revision of the manuscript, and final approval of the manuscript. RAP contributed to the analysis and interpretation of data, critical revision of the manuscript, and final approval of the manuscript. AMSS, AG, IMC, HN, and VRM designed the data collection instruments, reviewed and revised the manuscript, and contributed to the final approval of the manuscript. CP contributed to the conception and design of the study, coordinated and supervised the data collection, reviewed and revised the manuscript, and contributed to the final approval of the manuscript.

Ethics approval and consent to participate
Ethical approval for *Portuguese Prevalence Study of Obesity in Childhood* (PPSOC) was given by the Portuguese Commission for Data Protection which requires anonymity and nontransmissibility of data, corroborated by the *Direcção Geral de Inovação e Desenvolvimento Curricular* (Portuguese Institution of the Ministry of Education). In addition, the study was conducted according to the guidelines in the Declaration of Helsinki protocols, and the permission to collect the data was also obtained from the principal's office of the schools and from the parents or guardians of the children, who signed an informed consent form indicating their consent to participate in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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