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ORIGINAL CONTRIBUTION

Prevalence and lifestyle determinants of central obesity in children

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Abstract
Purpose Central obesity is a strong risk factor for metabolic disorders and cardiometabolic diseases in children and adolescents. The aim of the present study was to evaluate the prevalence of central obesity and to determine its cross-sectional association with lifestyle habits in a sample of school-aged children in Greece.
Methods The study sample consisted of 124,113 children (9.9 ± 1.1 years old, 51 % boys) attending the third and fifth grade of primary school. Anthropometric measurements were performed by trained physical education teachers, and central obesity was defined as waist-to-height ratio ≥0.5. Children's lifestyle habits were assessed through 7-day recall questionnaires.
Results Of the participating children, 33.4 % were classified as centrally obese. Central obesity was significantly more prevalent in boys than in girls (36.0 vs. 30.7 %, $P < 0.001$) and was present in 95 % of obese children, as well as in a significant percentage of overweight (69.5 %) and normal-weight ones (12.0 %). Children with central obesity, compared to their non-centrally obese counterparts, reported poorer dietary habits and were less physically active. According to multiple logistic regression analysis, frequent breakfast (OR 0.72, 95 % CI 0.69–0.75) and snack consumption (OR 0.70, 95 % CI 0.67–0.74), as well as frequent participation in sedentary activities (OR 1.10, 95 % CI 1.07–1.14), were the strongest lifestyle determinants of central obesity.
Conclusion Strategies for the prevention of central obesity and associated comorbidities are urgently needed, for both obese and non-obese children. Our results suggest the need for a shift towards a healthier environment for our children, with emphasis on specific lifestyle habits, such as regular meal consumption and low sedentariness.

Keywords Childhood central obesity · Abdominal adiposity · Lifestyle · Dietary habits · Physical activity · Sedentary activities

Introduction

Obesity in childhood presents a major public health challenge for the twenty-first century, increasing the burden of non-communicable diseases [1–3]. Although research during the past decades has focused on assessing the epidemic of childhood obesity, central obesity is less well studied. Focus on central obesity is of considerable public health importance given that it has emerged as a strong risk factor—and possibly a stronger one than "general" obesity—for cardiometabolic disorders (e.g. hypertension, insulin resistance, hyperlipidaemia, etc.) not only in adults but also in children [4–9]. At the same time, growing evidence suggests that abdominal adiposity is quite common among children and has demonstrated an increasing trend worldwide [10, 11], suggesting a parallel increase in the cardiometabolic risk of the paediatric population.

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It is widely accepted that the aetiology of childhood obesity is multifactorial, involving a complex interaction between genetic and environmental factors, such as lifestyle habits, social and built environment [12]. Among the aforementioned factors, it has been suggested that the shift towards a westernized dietary pattern and sedentariness mostly account for the rise in the global pandemic of obesity during the last decades [13, 14]. Regarding abdominal adiposity, the dietary habits of breakfast skipping and regular consumption of westernized fast food, energy-dense foods and high-caloric beverages (e.g. pastries, sweets, confectionery, salty snacks, processed meat products, sugar-sweetened soft drinks, etc.) have been positively associated with the likelihood of central obesity in children and adolescents, while beneficial dietary behaviours (including a high consumption of dairy products, fruits, vegetables and grains, as well as a high adherence to a Mediterranean-style diet) have been inversely associated [15–24]. In addition, both a high physical activity or cardiorespiratory fitness level and a low time spent in sedentary activities (e.g. television watching, computer use, etc.) have been inversely associated with the likelihood of central obesity in children and adolescents [25–31]. However, the association between lifestyle habits and the presence of central obesity in childhood remains vague, given that most of the available data come from cross-sectional studies confined to particular geographical areas and with relatively small sample sizes [17–19, 21, 24–26, 29]. In addition, the majority of the above-mentioned studies have focused on either children's dietary intake or physical/inactivity activity level, limiting our current understanding of its complex association with lifestyle habits.

The present study aimed to determine the prevalence of central obesity and its association with dietary and physical activity habits in a large sample of Greek schoolchildren participating in a nationwide school-based health survey.

Materials and methods

The study sample consisted of Greek children attending the third and fifth grade of primary school who participated in a national school-based health survey during 2010–2011. The 124,113 children who participated in the study (mean age 9.9 ± 1.1 years) included approximately 91 % of the relevant student population in Greece. The study was approved by the Ethics Committee of Harokopio University of Athens and was carried out in accordance with the Declaration of Helsinki [32]. All students enrolled, as well as their families, were informed in detail about the aims and procedures of the study, a verbal assent was obtained from each participating child, and a written consent was obtained from the guardian/parent.

Anthropometric measurements were performed by trained physical education professionals, and a standardized procedure was implemented, along with a systematic calibration of the devices (e.g. weight scales), in order to ensure maximum accuracy. Students' body weight and height were measured in the morning, without shoes and lightly dressed. Body weight was measured with electronic scales with a precision of 100 g, while standing height was determined to the nearest 0.1 cm with the children's weight equally distributed on their feet and their head, back and buttocks on the vertical line of the height gauge. Based on the aforementioned measurements, children's body mass index (BMI) was calculated, as the ratio of the body weight (kg) to the square of body height (m^2). International age- and gender-specific BMI cut-off points for underweight, normal weight, overweight and obesity developed for 2- to 18-year-old children were used to evaluate children's weight status [33, 34]. Waist circumference (WC) was measured to the nearest 0.1 cm midway between the lowest rib and the superior border of the iliac crest at the end of normal expiration with the use of a non-elastic measuring tape positioned at a level parallel to the floor and with the student in a standing position [35]. The evaluation of abdominal adiposity was based on waist-to-height ratio (WHtR), calculated as the ratio of WC (cm) to height (cm). Central obesity was defined as WHtR $\geq$0.5, given that this specific cut-off point has been found suitable for the prediction of obesity-related cardiometabolic abnormalities in children [36–38].

Children's lifestyle habits were assessed through a 7-day recall questionnaire that was completed at school with the assistance of their teachers (previously trained on its completion), in order to provide an accurate reflection of their habits. With regard to dietary habits, the questionnaire included closed questions with multiple choice answers about the frequency of breakfast consumption during schooldays (i.e. never, sometimes or every day) and weekends (i.e. yes/no), the type of breakfast consumed (i.e. only milk, milk with cereals, milk and sandwich, or milk and bread with margarine and honey/jam), the frequency of food group consumption during main meals (i.e. never, 1–2 times/week, 3–6 times/week or every day), the consumption of snacks at school or in the afternoon (i.e. yes/no) and the type of snacks usually consumed (i.e. fruits or fruit juice, toast or sandwich, dairy products, salty snacks and sweets). Snack was considered any food or beverage consumed either at midday between breakfast and lunch (consumed at school during schooldays) or in the afternoon between lunch and dinner, irrespective of the exact hour and environment of consumption, its energy content or its nutritional value. In addition, the frequency of fast food (i.e. never, sometimes or every day) and soft drink consumption (i.e. never, 1–2 times/week, 3–6 times/week or

every day) was recorded. Regarding physical activity habits, children were asked whether they participated in sports activities (i.e. yes/no), and how often (i.e. never, 1–2 times/week, 3–6 times/week or every day). Moreover, the questionnaire included questions on the frequency of active play during leisure time and weekends (i.e. never, sometimes or every day), as well as the frequency of sedentary activities (such as television watching and playing video games) during weekdays (i.e. never, sometimes or every day) and weekends (never, 1 of the 2 days or both days). For each individual lifestyle parameter, a binary score (i.e. 0 and 1) was applied (for example, breakfast frequency received the value 1 if breakfast was consumed at least 4 days a week). The questionnaire was previously tested for its reliability and validity in a subsample of the study ($n = 50$). Specifically, the questionnaire was completed two times over a 10-day period, and its results were highly repeatable ($r = 0.75$, $P < 0.01$); it was also compared to a 3-day food record and found to have a good reliability ($r > 0.5$, $P < 0.001$ for most dietary variables).

Statistical analysis

Data are presented as mean ± standard deviation (SD) for continuous variables and as frequencies for categorical ones. Normality of continuous variables was verified through the Kolmogorov–Smirnov test. Continuous variables were compared between groups using the Student's *t* test, while differences in categorical variables were tested using the Chi-square test. Correlations between continuous variables were tested using the Pearson's correlation coefficient (*r*). A combined variable using BMI categories and the presence of central obesity was computed including six categories (i.e. normal weight with and without central obesity, overweight with and without central obesity, and obese with and without central obesity). Multiple logistic regression analysis was used to explore the relationship between lifestyle habits and the likelihood of central obesity, with results presented as odds ratios (OR) with their corresponding 95 % confidence intervals (95 % CI) for each independent variable. The Hosmer–Lemeshow statistic was used to test models' goodness-of-fit, and the Wald test was used to determine the hierarchy of independent variables regarding their contribution to the prediction of central obesity. All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., IBM Hellas, USA). The significance level was set up at 0.05.

Results

The total study sample consisted of 124,113 children, of which 50.8 % were boys and 49.2 % were girls. Children's anthropometric characteristics are presented in Table 1. In total, 1.5 % of the children were underweight, 24.8 % were overweight, and 8.8 % were obese. The prevalence of underweight was higher in girls compared to boys ($P < 0.001$), more boys were obese compared to girls ($P < 0.001$), and overweight rates were similar for both sexes. The prevalence of central obesity (WHtR ≥ 0.5) was 33.4 % in the total study sample and was significantly higher in boys than in girls ($P < 0.001$). With regard to weight status, central obesity was present in the vast majority of obese children (i.e. 95 %), in more than half of overweight children (i.e. 69.5 %) and in 12.0 % of normal-weight ones. In total, 27.5 % of non-obese children were centrally obese. In both genders, WHtR correlated strongly with body weight (boys $r = 0.62$, girls $r = 0.52$, both $P < 0.001$) and BMI (boys $r = 0.76$, girls $r = 0.72$, both $P < 0.001$).

Table 1 Anthropometric characteristics, presented by gender

	Boys ($n = 63,064$)	Girls ($n = 61,049$)	P*
Height (m)	1.43 ± 0.1	1.42 ± 0.1	
Weight (kg)	39.2 ± 10.5	38.8 ± 10.4	
Waist circumference (cm)	68.9 ± 10.7	67.1 ± 10.1	<0.001
Body mass index (kg/m^2)	19.1 ± 3.7	18.9 ± 3.6	<0.001
Prevalence of underweight (%)	1.2	1.8	<0.001
Prevalence of normal weight (%)	64.5	65.3	0.002
Prevalence of overweight (%)	24.7	24.9	0.44
Prevalence of obesity (%)	9.6	8.0	<0.001
Waist-to-height ratio	0.49 ± 0.06	0.47 ± 0.1	<0.001
Prevalence of central obesity (%)	36.0	30.7	<0.001

Results are presented as mean ± standard deviation for continuous variables and frequencies (%) for categorical variables

* P values derived from Pearson's Chi-square test for categorical variables and Student's *t* test for continuous ones

Children's anthropometric and lifestyle characteristics, stratified by the presence of central obesity, are presented in Table 2. Children with central obesity had higher overweight and obesity rates and lower underweight or normal-weight rates, compared to those not classified as centrally obese (all $P < 0.001$). Children with central obesity compared to their non-centrally obese counterparts reported poorer dietary habits, mostly with regard to less frequent breakfast consumption, less frequent snack consumption and lower total meal frequency (all $P < 0.001$). Statistically significant differences between the two groups—although not as clinically significant—were also observed in other lifestyle habits, such as breakfast and

Table 2 Anthropometric and lifestyle characteristics, presented by the presence of central obesity

	Presence of Central obesity		*P**
	Yes ($n = 41{,}526$)	No ($n = 82{,}587$)	
Weight status (%)			
Underweight	0.1	2.1	<0.001
Normal weight	23.2	85.8	<0.001
Overweight	51.7	11.4	<0.001
Obesity	25.0	0.7	<0.001
Dietary habits (%)			
Frequent breakfast consumption[a]	80.0	86.0	<0.001
Consumption of a high-quality breakfast[b]	56.5	58.7	<0.001
Frequent snack consumption[c]	85.3	89.6	<0.001
Consumption of high-quality snacks[d]	72.9	75.5	<0.001
High total meal frequency[e]	45.2	54.6	<0.001
Daily consumption of fruits and vegetables[f]	33.9	34.9	0.003
Frequent fast food consumption[g]	65.7	65.0	0.02
Frequent soft drink consumption[h]	75.6	75.2	0.08
Physical activity habits (%)			
Participation in sports activities	64.9	67.2	<0.001
High frequency of participation in sports activities[i]	40.6	42.4	<0.001
High frequency of active play[j]	95.2	95.9	<0.001
High participation in sedentary activities[k]	50.9	48.3	<0.001

* *P* values derived from Pearson's Chi-square test

[a] Breakfast consumption at least 4 days a week

[b] Habitual consumption of breakfast that included milk with cereals or milk and sandwich, or milk and bread with margarine and honey/jam

[c] Habitual snack consumption both at midday and in the afternoon

[d] Habitual consumption of high-quality snacks (e.g. snacks that included fruits or fruit juice, toast or sandwich and milk or yoghurt)

[e] Habitual consumption of breakfast (at least 4 days a week) and snacks (both at midday and in the afternoon)

[f] Daily consumption of fruits and vegetables during main meals and snacks

[g] Fast food consumption less than a few days per week

[h] Consumption of soft drinks at least 1 day a week

[i] Participation in sports activities at least 3 days a week

[j] Active play during leisure time and weekends at least 3 days a week

[k] Participation in sedentary activities at least 4 days a week

snack quality, frequency of fruit and vegetable consumption, physical activity level (frequency of participation in sports activities and active play) and participation in sedentary activities (Table 2). Children's lifestyle characteristics according to both weight status and the presence of central obesity are presented in Table 3. Obese children had poorer dietary habits and were less physically active compared to normal-weight and overweight ones, independently of the presence of central obesity. However, within the groups of normal-weight and overweight children, centrally obese ones had significantly poorer lifestyle habits compared to their non-centrally obese counterparts. Similar differences were not observed within the group of obese children, except for a difference in the frequency of snack consumption (obese and centrally obese children reported a lower snack frequency compared to obese but non-centrally obese ones).

Results from multiple logistic regression analysis revealed that breakfast consumption, quality of breakfast, snack consumption, fruit and vegetable consumption and level of physical activity were significantly associated with the likelihood of central obesity, but not the quality of snacks, fast food or soft drink consumption (Table 4). Specifically, children consuming breakfast ≥4 times a week (compared to <4 times), those who consumed a high-quality breakfast (compared to a breakfast that included only milk), those who habitually consumed snacks throughout the day (compared to those not consuming snacks) and

Table 3 Lifestyle characteristics, presented by category of body mass index and the presence of central obesity

	Normal weight ($n = 80,549$)			Overweight ($n = 30,780$)			Obese ($n = 10,922$)		
	NCO ($n = 70,883$)	CO ($n = 9666$)	P*	NCO ($n = 9388$)	CO ($n = 21,392$)	P*	NCO ($n = 546$)	CO ($n = 10,376$)	P*
Dietary habits (%)									
Frequent breakfast consumption[a]	86.4	83.6	<0.001	82.2	80.8	0.003	78.1	75.1	0.12
Consumption of a high-quality breakfast[b]	58.9	56.8	<0.001	55.9	55.6	0.68	61.1	57.9	0.16
Frequent snack consumption[c]	90.1	87.8	<0.001	86.5	85.3	0.01	87.4	83.5	0.02
Consumption of high-quality snacks[d]	75.7	73.7	<0.001	74.3	72.9	0.02	73.7	72.3	0.52
High total meal frequency[e]	55.5	51.2	<0.001	48.3	45.8	<0.001	40.7	38.5	0.33
Daily consumption of fruits and vegetables[f]	34.7	33.0	0.003	37.0	33.8	<0.001	34.3	35.4	0.65
Frequent fast food consumption[g]	65.2	66.3	0.05	63.8	65.0	0.05	66.3	66.8	0.83
Frequent soft drink consumption[h]	75.3	75.2	0.94	73.6	75.1	0.008	77.2	77.2	0.99
Physical activity habits (%)									
Participation in sports activities	67.4	64.1	<0.001	69.4	66.8	<0.001	60.0	62.5	0.26
High frequency of participation in sports activities[i]	42.6	39.8	<0.001	43.8	41.8	0.002	36.4	39.4	0.19
High frequency of active play[j]	96.1	95.5	0.01	95.2	95.3	0.81	94.3	95.1	0.42
High participation in sedentary activities[k]	48.5	50.5	<0.001	46.7	50.5	<0.001	50.5	52.3	0.42

* P values derived from Pearson's Chi-square test for the comparison between non-centrally obese (NCO) and centrally obese (CO) children

[a] Breakfast consumption at least 4 days a week

[b] Habitual consumption of breakfast that included milk with cereals or milk and sandwich, or milk and bread with margarine and honey/jam

[c] Habitual snack consumption both at midday and in the afternoon

[d] Habitual consumption of high-quality snacks (e.g. snacks that included fruits or fruit juice, toast or sandwich and milk or yoghurt)

[e] Habitual consumption of breakfast (at least 4 days a week) and snacks (both at midday and in the afternoon)

[f] Daily consumption of fruits and vegetables during main meals and snacks

[g] Fast food consumption less than a few days per week

[h] Consumption of soft drinks at least 1 day a week

[i] Participation in sports activities at least 3 days a week

[j] Active play during leisure time and weekends at least 3 days a week

[k] Participation in sedentary activities at least 4 days a week

those consuming fruits and vegetables on a daily basis (compared to a less frequent consumption) had a 28, 6, 30 and 5 % lower probability of being centrally obese, respectively. In addition, children participating in sports activities or active play ≥3 days a week (compared to <3 days) had a 8 and 12 % lower odds of central obesity, respectively, while those engaging in sedentary activities ≥4 days a week (compared to <4 days) had a 10 % higher odds. According to Wald test values, high frequency of breakfast (OR 0.72, 95 % CI 0.69–0.75) and snack consumption (OR 0.70, 95 % CI 0.67–0.74), as well as high frequency of participation in sedentary activities (OR 1.10, 95 % CI

Table 4 Multiple logistic regression analysis model of the association between lifestyle characteristics and the likelihood of central obesity ($n = 124{,}113$)

	Wald	OR (95 % CI)
Age	5.25	1.02 (1.00; 1.03)
Sex (males)	250.09	1.29 (1.25; 1.33)
Dietary habits (%)		
Frequent breakfast consumption[a]	227.38	0.72 (0.69; 0.75)
Consumption of a high-quality breakfast[b]	13.87	0.94 (0.92; 0.97)
Frequent snack consumption[c]	151.18	0.70 (0.67; 0.74)
Consumption of high-quality snacks[d]	2.97	0.97 (0.93; 1.00)
Daily consumption of fruits and vegetables[e]	9.97	0.95 (0.92; 0.98)
Frequent fast food consumption[f]	2.62	1.03 (0.99; 1.06)
Frequent soft drink consumption[g]	0.20	0.99 (0.96; 1.03)
Physical activity habits (%)		
Participation in sports activities	9.43	0.94 (0.91; 0.98)
High frequency of participation in sports activities[h]	22.80	0.92 (0.88; 0.95)
High frequency of active play[i]	10.15	0.88 (0.82; 0.95)
High participation in sedentary activities[j]	37.78	1.10 (1.07; 1.14)

Results are presented as odds ratio (OR) (95 % CI)

[a] Breakfast consumption at least 4 days a week

[b] Habitual consumption of breakfast that included milk with cereals or milk and sandwich, or milk and bread with margarine and honey/jam

[c] Habitual snack consumption both at midday and in the afternoon

[d] Habitual consumption of high-quality snacks (e.g. snacks that included fruits or fruit juice, toast or sandwich and milk or yoghurt)

[e] Daily consumption of fruits and vegetables during main meals and snacks

[f] Fast food consumption less than a few days per week

[g] Consumption of soft drinks at least 3 days a week

[h] Participation in sports activities at least 3 days a week

[i] Active play during leisure time and weekends at least 3 days a week

[j] Participation in sedentary activities at least 4 days a week

1.07–1.14), was the most significant lifestyle predictors of central obesity.

Discussion

In the present study, central obesity (defined as WHtR $\geq$ 0.5) was found present in 33.4 % of a nationwide sample of Greek schoolchildren, was more prevalent in boys compared to girls and was evident not only in the majority of obese children, but also in 27.5 % of non-obese ones. Children with central obesity, compared to their non-centrally obese counterparts, reported poorer dietary habits and were less physically active. Among all lifestyle habits assessed, frequency of breakfast and snack consumption, as well as frequency of participation in sedentary activities, showed the strongest cross-sectional association with the prevalence of childhood central obesity. Our results suggest the need for a shift towards a healthier environment for school-aged children, including non-obese ones, and could be a valuable tool for public health policy makers in the context of preventing a further increase in the epidemic of childhood abdominal adiposity.

Given its cross-sectional design, our study cannot provide causal relationships but only generate hypotheses for associations between lifestyle and central obesity. Information regarding children's lifestyle habits is subject to recall bias and the case of under- or overreporting cannot be excluded, even though information was gathered with the assistance of previously trained teachers. In addition, the 7-day recall questionnaires used, although appropriate for a large-scale epidemiological study, are characterized by many limitations compared to more accurate assessment tools, such as 24-h dietary recalls or pedometers. Regarding anthropometry, WC measurement is also subject to bias (e.g. inconsistency based on the site of measurement), although teachers were trained to implement a standardized measurement protocol. Moreover, one matter of concern is the influence of stature on WC in children, which we tried to overcome by calculating WHtR. WHtR has been proposed as a convenient and clinically valuable index for assessing central obesity in children, on the basis that it is relatively age- and sex independent [39] and superior to BMI for the prediction of cardiometabolic risk [40–43]. Nevertheless, it remains an indirect index for evaluating abdominal adiposity compared to body composition analysis, and further research is required to identify its optimal cut-off point for defining central obesity in childhood.

Even though central obesity was mostly considered an adult burden in the past, nowadays its prevalence has proven to be particularly high among children as well, in both developed and developing countries [44–53]. Moreover, despite the attention given to the epidemic of childhood obesity, WC has increased at a higher rate than total body weight over the past 10–30 years in children [54–56], suggesting a parallel increase in their cardiometabolic risk. Only a few studies have so far examined the prevalence of childhood central obesity in Greece, and most have been confined to particular geographical areas. To our knowledge, the only large-scale study was conducted in 2003 and reported that the prevalence of central obesity based on WHtR was 20.0 % in girls and 25.6 % in boys, among a sample of 3140 6- to 12-year-old Greek children [49]. However, major limitations of this study included self-reported anthropometric measurements and that the study sample was not representative for the whole country.

Seven years later, using objectively measured anthropometric data from a large student population, we demonstrate a significantly higher prevalence of central obesity in Greek schoolchildren based on WHtR (boys 36.0 %, girls 30.7 %) in accordance with the increasing trend observed in other countries, and confirm that male gender is a strong predictor, as Tzotzas et al. [49] have already reported.

An interesting finding of our study is that central obesity was also evident in a significant percentage of normal-weight and overweight children (i.e. 12.0 and 69.5 %, respectively). This observation might suggest that BMI, which is widely used to assess children's weight status, although strongly related to central obesity, may underestimate cardiometabolic risk in non-obese children. According to results from the Bogalusa Heart Study, centrally obese children within the normal BMI category (9.2 % of normal-weight children) had higher cardiometabolic risk (adverse blood lipid and insulin levels, as well as higher likelihood of the metabolic syndrome) than non-centrally obese children within the normal BMI category [43]. The adverse metabolic profile of non-obese but centrally obese children could also indicate poor lifestyle habits as suggested by our results. It therefore seems that the presence of abdominal adiposity is an alarming phenomenon associated with an adverse metabolic profile even in non-obese children. Our results support the use of WHtR or other indices to assess abdominal adiposity in the routine paediatric practice, and children presenting with central obesity should undergo a further lifestyle and cardiometabolic risk assessment, as other authors have previously suggested [52, 57].

The aetiology of childhood obesity and abdominal adiposity is multifactorial, including a complex interaction between genetic predisposition, psychosocial factors, and the characteristics of home (family characteristics and parental practices), school and neighbourhood environment, all leading to poor lifestyle habits that promote a positive energy balance [1, 58]. In line with our results, it has been shown that children frequently consuming breakfast and presenting a high total meal frequency have lower total and abdominal adiposity indices, compared to breakfast skippers or those consuming fewer but larger meals during the day [17–20]. This fact could be attributed to the beneficial effect of increased meal frequency on appetite regulation, on postprandial metabolic and endocrine responses, as well as on non-excise physical activity, although results of the scientific literature on this topic remain largely controversial and are not so far supported by interventional studies [59–61]. Our findings also confirm previous results that physical activity level, cardiorespiratory fitness level and time spent in sedentary activities are associated with the presence of childhood obesity and central obesity [25–31]. It is noteworthy that in our study, sedentariness was a stronger predictor of childhood central obesity compared to physical activity level, suggesting that besides a lack of physical activity it could also reflect other unhealthy habits. These might include an increased energy intake during television watching and the negative effects of food advertising on children's dietary choices [62, 63].

In conclusion, our results indicate that the prevalence of central obesity is particularly high among Greek schoolchildren, not only among obese but also overweight and normal-weight ones, and support the need for a routine assessment of the presence of central obesity in paediatric primary care practice. Certain lifestyle habits, such as the frequency of breakfast and snack consumption, along with sedentariness, showed the strongest association with WHtR, and their contribution to the aetiology of childhood abdominal adiposity should be further studied.

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Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest to disclose.

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