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RESEARCH

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Twenty-year trend in the prevalence of increased cardiometabolic risk, measured by abdominal obesity, among Spanish children and adolescents across body mass index categories

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Abstract

Background Identifying children and adolescents with cardiometabolic risk at an early stage is crucial for effective treatment and prevention. From a practical perspective, this could be accomplished by assessing the presence of abdominal obesity, which serves as a surrogate indicator of increased cardiometabolic risk and is easy to measure. However, the assessment of abdominal obesity via waist circumference has not yet become a standard procedure in pediatric healthcare. The present study aimed to analyze the secular trends in increased cardiometabolic risk, as indicated by waist circumference among Spanish children and adolescents.

Methods This study included 4861 children and adolescents aged 8 to 16 years from two nationwide representative cross-sectional surveys, the EnKid study and the PASOS study, conducted in 1998–2000 and 2019–2020, respectively. Anthropometric variables were measured in both surveys by trained personnel. Three different waist-to-height (WHtR) cutoffs were used to define abdominal obesity as criteria for cardiometabolic risk. BMI categories were defined according to the IOTF and WHO growth charts.

Results Abdominal obesity [waist to height ratio (cm/cm) > 0.49] significantly increased from 40.7 to 56.1% and 93.8 to 97.2% in participants with overweight and obesity, respectively, between 1998–2000 and 2019–2020 ($p < 0.05$). Logistic regression analysis, adjusted for sex and age, revealed that the odds of being at increased cardiometabolic risk in 2019–2020 was 1.99 (95% CI 1.48–2.67) in participants with overweight in comparison with 1998–2000. The effect

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size was comparable among the three WHtR criteria for abdominal obesity or the BMI categories according to IOTF and WHO boundaries.

Conclusions The prevalence of Spanish children with increased cardiometabolic risk, identified by abdominal obesity, significantly increased among those with overweight during the last two decades. This finding underlines the need of including the measurement of waist circumference as a standard procedure in pediatric practice.

Keywords Cardiometabolic risk, Abdominal obesity, Children, Adolescents, Secular trends

Background

Abdominal or central obesity indicates an excessive accumulation of fat around the abdominal area. Abdominal obesity is highly prevalent not only in adults but also in pediatric populations [1–3], and it has been consistently linked to a range of cardiometabolic risk factors (CMR), such as insulin resistance, type 2 diabetes, hypertension, dyslipidemia, and other early markers of cardiovascular disease, even in younger populations [1, 4, 5]. Therefore, measuring abdominal obesity can be considered a first step in identifying children and adolescents at cardiometabolic risk [4] and a recent, Consensus Statement from the International Atherosclerosis Society and International Chair on Cardiometabolic Risk recommended that health professionals be trained in measuring waist circumference and consider it a crucial vital sign in clinical practice [4]. Weight and height are regularly assessed in Spanish pediatric clinics to identify children at risk of obesity, requiring tailored treatment approaches. However, despite abdominal obesity being a stronger predictor of cardiometabolic alterations than overall obesity defined by a body mass index of equal or more than 30 kg/m^2, waist circumference is not frequently measured during pediatric visits. Even though BMI and waist circumference typically correlate closely, a significant number of children with normal or overweight BMI may also have abdominal obesity [6]. Unfortunately, if this at-risk subgroup is not identified, these children may not receive the appropriate treatment or interventions they need.

The results from a Spanish nationwide representative survey conducted in 1998/2000, the EnKid study, showed that 49.2% and 44.1% of Spanish children aged 6 to 11 years and adolescents aged 12 to 17 years with overweight were at increased cardiometabolic risk, measured through the concurrent prevalence of abdominal obesity (WHtR > 0.49) [7]. Despite these findings, no recent nationwide data from Spain has been published on this topic. Hence, this study aimed to first assess the prevalence of increased cardiometabolic risk, in terms of abdominal obesity, among Spanish children and adolescents across different BMI categories. Second, it aimed to analyze the secular trend of increased cardiometabolic risk over the past two decades.

Methods

Study population

A comparative analysis was conducted on two cross-sectional studies: EnKid from 1998 to 2000 [8] and PASOS (Physical Activity, Sedentarism and Obesity in Spanish Youth) from 2019 to 2020 [9]. Both studies employed a multistage sampling procedure. While the EnKid study randomized individuals based on the population census, the PASOS study used the Spanish Education Ministry's school registry to select classroom settings and find participants. Randomization in the PASOS study followed a four-stage multistage sampling procedure to select 4508 children/adolescents. Assuming 18–20 pupils per classroom, 242 classrooms were needed from Spain's 17 autonomous communities: 121 from primary schools (grades 3–6) and 121 from secondary schools (levels 1–4). First, 121 municipalities were randomized across three population strata (2000–30,000; 30,001–200,000; and over 200,000 inhabitants) proportional to each community's share of Spain's youth population. Second, 242 schools were randomly chosen from these municipalities, with up to three replacements per school. Third, a scholar-year per school was randomized. Finally, a classroom per scholar-year was randomized and invited to participate. Comprehensive methodologies have been described in earlier works [8, 9]. In brief, the EnKid study evaluated 3534 participants, ranging in age from 2 to 24 years old, in their homes. The PASOS study aimed at children and adolescents aged 8 to 16 years, spanning from the 3rd grade in primary education to the 4th grade in secondary education, according to the Spanish educational system. The PASOS study comprised 3802 participants aged between 5.7 and 18.4 years who received a pediatric visit in a private setting within their school. For the current analysis, children below 8.0 years and above 16.9 years were excluded. Finally, 4861 participants aged between 8.0 and 16.9 years with complete data were chosen from both studies (EnKid $n = 1140$; PASOS $n = 3721$). Written consent from parents or legal guardians was obtained for each child in both studies. Minors also had the right to decline participation, even if informed consent was positive. The EnKid study's protocol received approval from the ethics committee of the Spanish Society of Community Nutrition, while the PASOS study was approved by the ethics committee of Fundació Sant Joan de Déu (ID: C.I. PIC-179–18). Both committees are based in Barcelona, Spain.

Anthropometric measurements

In both studies, weight, height, and waist circumference were measured by trained professionals following the standardized WHO protocol [10]. Anthropometric data were collected on the day of the interview, with the subject in underwear without shoes. Body weight, height, and waist circumference were measured with the children in light clothing, without shoes. The measurements were performed using an electronic SECA 899 scale (recorded to the nearest 100 g), a portable SECA 217 stadiometer (to the nearest 1 mm), and a flexible, non-stretch SECA 201 metric tape (to the nearest 1 mm), respectively. Waist circumference was measured in the narrowest zone between the lower costal rib and iliac crest, in the supine decubitus and horizontal positions. BMI categories were defined based on the standards set by both the International Obesity Task Force (IOTF) [11] and the World Health Organization (WHO) [12]. The IOTF cutoffs for child overweight and obesity are an extrapolation of the adult BMI cutoff points for overweight (25–29.9 kg/m^2) and obesity (30.0 kg/m^2). The WHO system defines overweight as a BMI exceeding one standard deviation (SD) from the mean of the WHO reference population, while obesity is categorized as a BMI surpassing two SDs from the mean. The waist-to-height ratio (WHtR) has been proposed as an alternative measure to waist circumference for identifying abdominal obesity [6, 7] in children. The WHtR offers a straightforward index, especially in the pediatric population, that avoids the need for age- and sex-specific reference charts. The National Institute for Health and Care Excellence (NICE) endorsed WHtR as an easily self-measurable metric, allowing individuals to determine their health risk levels [8]. Abdominal obesity was used as surrogate marker for increased cardiovascular risk in children and adolescents. Abdominal obesity was determined using the waist-to-height ratio (WHtR), with a threshold value of greater than 0.49 [13]. Additionally, two alternative boundaries of WHtR were calculated to define abdominal obesity with the aim to evaluate the robustness of the findings: (a) age 8 to 11 years WHtR ≥ 0.55 [14] and 12 to 16 years WHtR ≥ 0.50 and (b) WHtR ≥ 0.49 [15].

Other variables

Sex and age variables were also dichotomized for the stratified analysis as girls/boys and children (8.0 to 12.9 years old)/adolescents (13.0 to 16.9 years old), respectively.

Statistical analysis

A univariate analysis was performed to describe the characteristics of the study sample. Differences in continuous variables and categorical variables between the surveys were analyzed using Student's *t*-test and the χ^2 test, respectively. The proportions of abdominal obesity within BMI categories between the surveys were compared using the χ^2 test.

Logistic regression models were fitted to assess the likelihood of having increased cardiovascular risk, in terms of abdominal obesity, among children and adolescents with normal weight, overweight, and obesity in 2019/2020 compared to 1998/2000. Obesity phenotype calculation utilized BMI categories based on IOTF and WHO growth charts, in combination with abdominal obesity. The primary boundary for defining abdominal obesity was set at WHtR > 0.49, as this widely used criterion is a better predictor for increased cardiovascular disease risk in children than BMI [13]. The study year was included in these models as the exposure. Three obesity phenotypes were calculated (1) normal weight (IOTF) and abdominal obesity (WHtR > 0.49) no/yes; (2) overweight (IOTF) and abdominal obesity (WHtR > 0.49) no/yes; and (3) obesity (IOTF) and abdominal obesity (WHtR > 0.49) no/yes and included in the models as outcomes. The models were adjusted for sex and age. Furthermore, strata analysis of sex was adjusted for age, and age strata analysis for sex. Finally, we hypothesized that using somewhat different WHtR boundaries will lead to slightly different results. Therefore, to determine the robustness of our findings, two additional proposed WHtR boundaries [14, 15] for abdominal obesity were chosen and combined with BMI categories resulting in six additional outcomes.

Differences were considered significant if $p < 0.05$. Statistical analysis was performed using SPSS version 18.0 (SPSS Inc. Chicago, IL, USA).

Results

Participants of the EnKid study were older, heavier, taller, had a lower WHtR, and showed a lower prevalence of abdominal obesity within overweight and obesity categories than those of the PASOS group (Table 1).

Abdominal obesity significantly increased by 37.8% and 3.6% in participants with overweight and obesity, respectively, from 1999/2000 to 2019/2020 (Table 2). Furthermore, abdominal obesity significantly increased between both surveys in boys (30.4%), girls (66.9%), children (35.5%), and adolescents (39.7%) with overweight as well as in girls (14.9%) with obesity (Table 2). These trends were similar for BMI categories calculated according to the WHO grow charts (Additional file 1: Table S1).

Table 1 Study population characteristics

	EnKid ($n = 1140$)	PASOS ($n = 3721$)	p[1]
Girls	569 (49.9)	1918 (51.5)	0.335
Boys	571 (50.1)	1803 (48.5)	
Age, years	13.0 (2.5)	12.5 (2.3)	< 0.001
Weight, kg	50.9 (15.3)	48.5 (14.1)	< 0.001
Height, cm	158.3 (14.1)	152.9 (13.4)	< 0.001
BMI, kg/m^2	20.4 (3.6)	20.3 (4.0)	0.500
Waist, cm	69.9 (9.9)	70.6 (10.8)	0.074
WHtR[2], cm/cm	0.45 (0.05)	0.46 (0.06)	< 0.001
Abdominal obesity[3]	182 (16.0%)	842 (22.6%)	< 0.001
- And normal weight	19 (1.7%)	40 (1.1%)	0.110
- And overweight	65 (5.7%)	371 (10.0%)	< 0.001
- And obesity	98 (8.6%)	431 (11.6%)	0.005

Continuous variables are presented as mean and standard deviation (SD) and categorical as number of participants and percentages

[1] Differences between cohorts were determined by Student's *t*-test and chi-square test for continuous and categorical variables, respectively

[2] WHtR: waist to height ratio

[3] WHtR > 0.49

Table 2 Secular trends of prevalence of abdominal obesity[a] according to BMI categories[b]

	EnKid 1998/2000		
	Normal weight	Overweight	Obese
All ($n = 1140$)	23 (2.9%)	98 (40.7%)*	61 (93.8%)*
Sex			
Boys ($n = 571$)	14 (3.9%)	69 (47.6%)*	46 (97.9%)
Girls ($n = 569$)	9 (2.1%)	29 (30.2%)*	15 (83.3%)*
Stage			
Children ($n = 538$)[c]	15 (4.2%)	56 (43.1%)*	25 (89.3%)
Adolescents ($n = 602$)[d]	8 (1.9%)	42 (37.8%)*	36 (97.3%)
	PASOS 2019/2020		
All ($n = 3721$)	92 (3.8%)	470 (56.1%)*	280 (97.2%)*
Sex			
Boys ($n = 1803$)	52 (4.6%)	258 (61.9%)*	148 (98.7%)
Girls ($n = 1918$)	40 (3.2%)	212 (50.4%)*	132 (95.7%)*
Stage			
Children ($n = 2144$)	56 (4.9%)	288 (58.4%)*	180 (96.8%)
Adolescents ($n = 1577$)	38 (3.4%)	182 (52.8%)*	100 (98.0%)

Values are expressed as the number of cases in the BMI category and the corresponding proportion

* $p < 0.05$ between surveys

[a] Waist to height ratio > 0.49

[b] BMI categories were calculated according to the IOTF growth charts

[c] 8.0 to 12.9 years

[d] 13.0 to 16.9 years

Table 3 shows the secular trends of children and adolescents at increased cardiometabolic risk measured by abdominal obesity. Logistic regression analysis, adjusted for sex and age, showed that in 2019/2020, the likelihood of increased cardiometabolic risk, in terms of abdominal obesity (WHtR > 0.49), was significantly higher for participants with overweight (OR 1.99, 95% CI 1.48–2.67) than for those in 1999/2000. Strata analysis supported these results, showing higher risks for boys (OR 1.76, 95% CI 1.20–2.57), girls (OR 2.33, 95% CI 1.45–3.76), children (OR 2.00, 95% CI 1.34–2.99), and adolescents (OR 1.91, 95% CI 1.22–2.97) with overweight (Table 3).

Furthermore, the likelihood of abdominal obesity was significantly higher in girls (OR 4.59, 95% CI 1.02–20.72) and children (OR 5.08, 95% CI 1.09–23.65) with obesity. For all groups except boys and children with normal weight, using the two alternative WHtR boundaries to define abdominal obesity did not significantly change the results compared to the threshold of WHtR > 0.49. But the strength of the associations varied based on the criteria applied. Furthermore, there were no changes in the direction of these associations when using WHO growth charts to calculate BMI categories. However, the magnitude of these associations and their statistical significance did show some differences (Additional file 1: Table S2).

Discussion

The main finding of the present study, based on logistic regression analysis, was that the likelihood of having increased cardiometabolic risk, defined by abdominal obesity (WHtR of > 0.49), significantly increased in the first two decades of the twenty-first century in children and adolescents with overweight in Spain. This trend was more pronounced in girls with overweight or obesity and in children with obesity than in boys and adolescents with the same weight status.

Abdominal obesity is closely associated with insulin resistance, type 2 diabetes, dyslipidemia, and hypertension [16]. Additionally, it promotes inflammation and endothelial dysfunction, which are precursors to atherosclerosis and subsequent cardiovascular events [17]. Given these associations, abdominal obesity has been considered a surrogate marker for cardiometabolic risk. Abdominal obesity has increased in several, but not all, pediatric populations at the nationwide level [3, 18, 19]. Based on five national cross-sectional population surveys, an Australian study indicated that the prevalence of abdominal obesity in children aged 7–15 years rose from 8.6% in 1985 to 23.3% in 2015 [3]. A somewhat smaller increase in abdominal obesity was reported in Chinese children and adolescents aged 6 to 17 years. In this population, abdominal obesity rose from 6.4% in 1993 to 14.5% in 2015 [19]. In contrast, there was no significant trend

Table 3 Odds ratio and 95% CI of children and adolescents at increased cardiometabolic risk (iCMR) in 2019/2020 compared with 1998/2000

	Reference[a]	Normal weight OR (95% CI)	Overweight	Obesity
All[b] (*n* = 4861)				
iCMR 1	1	1.27 (0.80–2.02)	**1.99 (1.48–2.67)**	3.51 (0.97–12.71)
iCMR 2	1	1.81 (0.93–3.50)	**1.80 (1.28–2.54)**	**3.09 (1.32–7.24)**
iCMR 3	1	**1.98 (1.54–2.55)**	**1.91 (1.42–2.56)**	4.10 (0.90–18.60)
Sex[c]				
Boys (*n* = 2374)				
iCMR 1	1	1.12 (0.61–2.05)	**1.76 (1.20–2.57)**	1.41 (0.11–17.67)
iCMR 2	1	1.00 (0.46–2.19)	**1.62 (1.06–2.49)**	2.21 (0.67–7.38)
iCMR 3	1	**1.74 (1.11–2.73)**	**1.78 (1.20–2.64)**	2.21 (0.12–41.10)
Girls (*n* = 2487)				
iCMR 1	1	1.50 (0.72–3.13)	**2.33 (1.45–3.76)**	**4.59 (1.02–20.72)**
iCMR 2	1	**5.73 (1.34–24.4)**	**2.13 (1.18–3.83)**	**4.41 (1.26–15.78)**
iCMR 3	1	**2.16 (1.58–2.96)**	**2.04 (1.30–3.20)**	4.34 (0.72–26.20)
Stage[d]				
Children (*n* = 2682)				
iCMR 1	1	0.97 (0.54–1.74)	**2.00 (1.34–2.99)**	**5.08 (1.09–23.65)**
iCMR 2	1	1.39 (0.40–4.81)	1.58 (0.95–2.62)	**3.59 (1.45–8.58)**
iCMR 3	1	0.91 (0.51–1.60)	**1.86 (1.24–2.78)**	**5.25 (0.83–33.25)**
Adolescents (*n* = 2179)				
iCMR 1	1	1.85 (0.46–1.51)	**1.91 (1.22–2.97)**	1.28 (0.10–15.73)
iCMR 2	1	1.85 (0.86–4.02)	**1.91 (1.22–2.97)**	1.28 (0.10–15.73)
iCMR 3	1	**2.03 (1.55–2.65)**	**1.89 (1.22–2.93)**	1.82 (0.11–30.25)

Logistic regression analysis with anthropometric variables as outcome and survey as exposure. Values are expressed as odds ratio (OR) and the corresponding 95% confidence interval (CI), in bold $p < 0.05$

Increased cardiometabolic risk (iCMR) was calculated as:

iCMR 1: waist to height ratio (cm/cm) > 0.49

iCMR 2: waist to height ratio (cm/cm) 8–11 years ≥ 0.55 and 12–16 years > 0.49

iCMR 3: waist to height ratio (cm/cm) ≥ 0.49

[a] Enkid 1998/2000 as reference; [b]adjusted for sex and age; [c]adjusted for age; [d]adjusted for sex; BMI categories were calculated according to the IOTF growth charts

in US children and adolescents aged 6 to 19 years from 2011–2012 to 2017–2018 [18]. However, the prevalence of abdominal obesity was 34.1% in 2011–2012 and 36.2% in 2017–2018, which was much higher among US children and adolescents than among their Chinese and Australian peers, specially at baseline. However, comparisons of these numbers are somewhat limited due to the different timeframes and classifications of abdominal obesity of these studies. In the present study, we found a significant increase in abdominal obesity, defined as a WHtR ratio equal to or above 0.50, from 16% in 1999/2000 to 22.6% in 2019/2020, which is somewhat comparable to the findings of the Spanish ENPE study [20].

Several studies have documented a notable prevalence of abdominal obesity in children [21, 22]. Maffeis and colleagues [21] found that 38% of children and adolescents aged 5 to 15 years who had overweight exhibited abdominal obesity. Another study conducted among Portuguese children aged 6 to 10 years [22] indicated that 59.5% of children with overweight had abdominal obesity. The non-representative study population designs and varying age ranges in these studies may account for these different prevalence rates.

The prevalence and secular trends of abdominal obesity were heterogeneous among BMI categories in the present study. As expected, the most substantial increase in abdominal obesity, 37.8% and 3.4%, between 1999/2000 and 2019/2020 was found in children and adolescents with overweight or obesity, respectively. In contrast, there were no meaningful changes in the prevalence of abdominal obesity among normal-weight children and adolescents. It is important to note that the rise in abdominal obesity among children with overweight and adolescents began at a high baseline level, specifically at 40.7% in 1999/2000.

Abdominal obesity is a strong predictor for cardiometabolic health in each BMI category in adults [4]. However, cardiometabolic risk increases with the concomitant presence of abdominal obesity in children and adolescents with excessive weight [23, 24]. Data from the Bogalusa Heart Study [23] revealed that children and adolescents aged 4 to 18, regardless of whether they were of normal or excessive weight, showed an elevated cardiometabolic risk if they had abdominal obesity compared to their peers without abdominal obesity. It is noteworthy that 5.88% of those with both abdominal obesity and normal weight exhibited metabolic syndrome, whereas only 0.26% of their normal-weight peers without central obesity had this condition. In line with these findings, Khoury and colleagues [24] reported a higher prevalence of most cardiovascular risk factors analyzed among children with abdominal obesity independent of BMI categories in a pooled analysis of 5 cross-sectional National Health and Nutrition Examination Surveys from 1999 to 2008. Therefore, the measurement of waist circumference in pediatric populations is increasingly recognized as an important indicator of cardiometabolic risk. The adverse cardiometabolic patterns observed in children with abdominal obesity are alarming. The current study's finding shows that the likelihood of having cardiometabolic risk increased by 80% in children with overweight and 209% in children with obesity in 2019/2020 compared to 1999/2000. The increase in cardiometabolic risk was especially worrying among girls and children with overweight and children with obesity. A WHtR boundary of equal to or greater than 0.5, the same as in adults, has been proposed to identify children and adolescents with increased cardiometabolic risk [25]. However, the optimal cutoffs to predict cardiometabolic risk in children vary significantly, making it challenging to choose a singular threshold. For this reason, we presented data using alternative boundaries of WHtR to calculate cardiometabolic risk. However, we did not find any meaningful differences in predicting cardiometabolic risk in 2019/2020 with these alternative WHtR boundaries.

Regular waist circumference measurements in pediatric care are crucial for monitoring growth, especially in children at risk of obesity. Weight stigma is prevalent among youth with obesity and can lead to anxiety, particularly during anthropometric assessments [26]. Additionally, weight stigma is common among healthcare professionals with harmful psychological consequences for family members [27]. Training healthcare professionals should prioritize addressing weight bias, especially in pediatric care, to ensure inclusive and bias-free healthcare. An inclusive and body-positive approach in clinical settings can yield numerous benefits, such as minimizing the experience of anxiety derived from being exposed to anthropometric measurements.

Because abdominal obesity is linked to adverse cardiometabolic outcomes, regardless of BMI category, we advocate for routine waist circumference measurements in pediatric care. These measurements can easily be integrated into standard visits within the Spanish Health Care System for all children and adolescents until 14 years old. Those identified as at risk based on waist circumference should undergo blood analysis and blood pressure checks. Treatment strategies can then be tailored based on the presence and severity of cardiometabolic alterations detected. For instance, promoting healthy lifestyle changes may suffice for those without cardiometabolic alterations, while those with alterations may require more comprehensive interventions in pediatric hospitals or specialized primary care centers staffed by multidisciplinary health experts.

Importantly, this study is not without limitations. The study was not sufficiently powered to detect significant differences between surveys in the prevalence of abdominal obesity children and adolescents with normal weight. The low statistical power in both the strata analysis and the global analysis of this obesity phenotype increases the risk of a type II error, where the study fails to detect a true effect. The strengths of the study were the measurement of anthropometric variables by trained personnel. Additionally, the response rates of the PASOS and the EnKid study were 71.9% and 64.3%, respectively, which can be considered adequate. An adequate response rate of participation in population-based studies is important because it helps ensure that the study sample is representative of the entire population, thereby enhancing the accuracy, reliability, and generalizability of the study's findings.

Conclusions

The prevalence of abdominal obesity based on the assessment of waist circumference significantly increased among Spanish children and adolescents with overweight and obesity from 1999/2000 to 2019/2020. Abdominal obesity is considered a significant indicator of cardiometabolic risk, and the findings of the current study in this regard are concerning. The rise of 99% in the likelihood of increased cardiometabolic risk in children and adolescents with overweight, independent of age and sex, at the nationwide scale is alarming. Therefore, early first-step screening of children at cardiometabolic risk is paramount and could be easily performed in routine pediatric practice by measuring waist circumference. In addition to weight and height, the measurement of waist circumference should become a standard part of pediatric practice.

Abbreviations

BMI	Body mass index
CI	Confidence interval
CMR	Cardiometabolic risk
EnKID	Estudio enKid de Nutrición y Hábitos Alimentarios en la Población Infantil y Juvenil Española
ENPE	Estudio Nutricional de la Población Española
IOTF	International Obesity Task Force
OR	Odds ratio
PASOS	Physical Activity, Sedentarism and Obesity of Spanish youth
WHO	World Health Organization
WHtR	Waist to height ratio

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-024-03719-y.

Additional file 1: Tables S1 and S2. Table S1. Secular trends of prevalence of abdominal obesity 1 across BMI categories. Values are expressed as the number of cases in the BMI category and the corresponding proportion. * $p < 0.05$ between surveys; 1 Waist to height ratio > 0.49; 2 BMI categories were calculated according to the WHO growth charts; 38.0 to 12.9 years; 413.0 to 16.9 years. Table S2. Odds ratio and 95% CI of children and adolescents at increased cardiometabolic risk (iCMR) in 1998/2000 compared with 2019/2020. Logistic regression analysis with anthropometric variables as outcome and survey as exposure. Values are expressed as odds ratio (OR) and the corresponding 95% confidence interval (CI). BMI categories were calculated according to the WHO growth charts. 1 Enkid 1999/2000 as reference; 2 adjusted for sex and age; 3 adjusted for age; 4 adjusted for sex; 5 adjusted for sex and age. In bold $p < 0.05$. Increased cardiometabolic risk (iCMR) was calculated as: iCMR 1: waist to height ratio (cm/cm) > 0.49; iCMR 2: waist to height ratio (cm/cm) 8–11 years ≥ 0.55 and 12–16 years > 0.49; iCMR 3: waist to height ratio (cm/cm) ≥ 0.49.

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Authors' contributions

All authors (H.S., C.J., M.I.G., J.W., M.O., M.G.G., N.G., S.A., E.M.C., M.G.V., E.H.R., N.T., J.A.T., M.S., M.F., L.R.B., I.P.C., L.P.Q., P.B., J.C.B.M., I.L, A.G.Z., J.S.G., F.J.Z., P.E.A., M.S.S., S.P., C.B., L.S.M., and S.F.G.) made substantial contributions to the study concept or the data analysis or interpretation; HS drafted the manuscript; H.S.,.L.S.M., and S.F.G. were involved in methodology and supervision; all authors revised it critically for the important intellectual concept; H.S., L.S.M., and S.F.G. agreed to be accountable for all aspects of the work. All authors read and approved the final manuscript.

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Data availability

The datasets generated and analyzed during the current study are not publicly available due to data regulations and ethical reasons. However, collaboration for data analyses can be requested by sending a letter to the PASOS Steering Committee (sgomez@gasolfoundation.org). The request will then be passed to all the members of the PASOS Steering Committee for deliberation.

Declarations

Ethics approval and consent to participate

The EnKid study's protocol received approval from the ethics committee of the Spanish Society of Community Nutrition, while the PASOS study was approved by the ethics committee of Fundació Sant Joan de Déu (ID: C.I. PIC-179–18). Both committees are based in Barcelona, Spain. Written consent from parents or legal guardians was obtained for each child in both studies. Minors also had the right to decline participation, even if informed consent was positive.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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