Tracking of General and Abdominal Obesity in Children Between 4 and 9 Years of Age: The Longitudinal Childhood Obesity Study (ELOIN)

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Abstract

Background

A relationship between obesity early life has been reported. The aim of this study was to evaluate the variations in general (GO) and abdominal (AO) obesity between 4 and 9 years of age.

Methods

Children who participated in all three follow-ups at 4, 6 and 9 years participating in ELOIN study (*N = 1902*). Measurements of BMI and waist circumference were taken by physical examination. Prevalence ratios (PRs) were estimated by sex and family affluence by generalized estimation equation models, and the relative risks (RRs) of obesity by Poisson regression.

Results

The prevalence of GO was 5.1%, 9.1%, and 15.6% at 4, 6, and 9 years, yielding a PR between 9 – 4 years of 3.05 (95%CI: 2.58–3.60). The prevalence of AO was 6.8%, 8.4%, 14.5%, and the PR (9 vs 4y) was 2.14 (95%CI: 1.85–2.48). GO and AO presented an inverse correlation with family affluence. Among participants who were in GO or AO at 4 years, 77.3% and 63.6% remained in obesity after 5 years. The RRs of GO and AO at 9 years were 4.6 and 4.1 if they were obese at 4 years ($p < 0.001$), which increased to 9.4 and 9.5 in children obese at 6 years ($p < 0.001$), and those with obesity at both 4–6 years had RRs of 10.3 and 9.9 ($p < 0.001$).

Conclusions

GO and AO begin at early age, persist with age and linked with low socioeconomic status. Obesity at 9 years is associated with early obesity, either stably or intermittently, so preventive interventions should be established very early.

Background

Childhood obesity continues to be a major public health problem in most countries[1]. Globally, it was estimated that in 2016 there were 124 million young people between 5 and 19 years of age with obesity and 213 million overweight[2]. In Europe, the prevalence of overweight and obesity in childhood is high, though there are large variations between regions, such as a higher prevalence in the Mediterranean basin[3]. In many countries, including Spain, there has been a trend towards stabilization in recent years[3]. According to the ALADINO study, the estimated prevalence for Spain in 2019 in the population aged 6 to 9 years was 23.3% and 17.3% for overweight and obese individuals[4], respectively, quite similar to those observed in the same study in 2011 (26.2% and 18.3%, respectively)[5].

Childhood obesity has been associated with higher blood pressure, myocardial dysfunction, dyslipidaemia, insulin resistance, fatty liver, stigmatization, and poor school performance[6,7]. Its tendency to persist brings a greater risk of comorbidities in adulthood, such as diabetes, cardiovascular diseases, some types of cancer, and premature death[8,9].

General obesity (GO) is frequently defined by body mass index (BMI), which is a good predictor of cardiovascular risk[10]. In children, the relationship between BMI and body fat varies with age and sex and should be compared with standard or reference populations[11,12]. Waist circumference (WC) is one of the parameters for diagnosing abdominal obesity (AO). It is defined from reference values and has a better correlation with subcutaneous and visceral fat than other indicators[13,14]. Childhood AO is considered an important predictor of cardiometabolic disorders independent of BMI[15,16].

GO tends to start at an early age and persist over time. Children in overweight/obesity are more likely to remain in obesity in adolescence and to be in obesity in adults[17,18]. AO also increases with age, but its longitudinal variations are less studied because the waist circumference is not routinely measured in primary-care paediatric programmes, and its validity is lower in children under 7 years[14]. More and more, there is consensus that in addition to BMI, it is necessary to monitor WC to detect its variations from childhood[19].

We aimed to evaluate the risk of and track GO and AO in the child population between 4, 6, and 9 years old in a longitudinal study with 5 years of follow-up.

Methods

Study design and participants

The Longitudinal Childhood Obesity Study (ELOIN for its acronym in Spanish)) is a population-based cohort in the Madrid region (population 6,7 million), whose methods have been previously published[20]. A total of 2627 4-year-old children were recruited for the baseline study.

In this analysis, 1902 participants underwent measurements at three physical examinations: the 4-year baseline measurement taken in 2012-2013, the 6-year in 2014-2015, and the 9-year in 2017-2018. The information was collected in two consecutive stages: 1) standardized physical examination performed in the

health centre by paediatricians of the sentinel network and primary care nurses; and 2) completion of a structured questionnaire answered by the parents through a computer-assisted telephone interview (CATI), covering data on sociodemographic variables and lifestyles.

Anthropometric measures

Weight was measured with a digital scale (SECA® model 220, precision 0.1 kg), height was measured using a telescoping stadiometer (SECA® model 220, precision 1 mm), and WC was measured using a standardized inextensible locking measing tape just above the iliac crest with the tape horizontal and without tissue compression. Two measurements were made per participant, whose mean was taken for the analyses.

BMI (kg/m^2) was adjusted by age (months) and sex according to the standardized tables of the WHO-2007[11]. From the BMI z-scores, normal weight was defined as zBMI ≤ 1 standard deviation (SD), overweight zBMI > 1 SD and ≤ 2 SD, and GO when zBMI > 2 SD[11]. WC was standardized by age (months) and sex according to reference tables of the International Diabetes Federation (IDF) metabolic syndrome consensus. To define AO, the ≥90 percentile was used as the cut-off point[21].

Four GO trajectories were estimated, taking into account the persistence or variation in the classification of obesity at 4, 6, and 9 years: 1) Stable without obesity: no obesity in any of the measurements; 2) Remitting obesity at 9 years: obesity at 4 and/or 6 years, but without obesity at 9 years; 3) Incident obesity at 9 years (4 or 6): obesity only at 9 years, or at 4 and 9 years, or at 6 and 9 years; and 4) Stable with obesity: obesity in all three measurements. The same trajectories were used to evaluate the changes in AO.

Covariates

The sociodemographic variables, evaluated from the baseline measurements at 4 years old, were sex, age (months), and the household affluence estimated by the *Family Affluence Scale*, classified according to score as low (0–3 points), medium (4-5), and high (6-9)[22,23].

Data analysis

An initial descriptive analysis was performed, where the quantitative variables are summarized as mean (SD), and the qualitative variables are summarized as relative frequency. The statistical association between qualitative variables was calculated with the χ^2 test, and the comparisons of means were performed by Student's t test. To facilitate the visual interpretation of the tracking, the flow diagrams were represented by a Sankey diagram. The prevalence ratios (PRs) were calculated using generalized estimating equation models under a binomial distribution. Then Poisson regression models were developed to estimate 1) the probability (relative risk, RR) of presenting GO and AO at 9 years based on obesity at 4-6 years of age and 2) the risk of GO at 6 and 9 years according to the presence of GO and/or AO at 4 years of age. The variables included sex, age (months), and family affluence. The interactions of the GO and AO indicators with sex and socioeconomic status were explored.

The analyses were performed in Stata v.16 (StataCorp, College Station, USA) taking into account the characteristics of cluster sampling (paediatric consultations) using the Survey Data module.

Results

A total of 1902 participants who completed all three measurements were included, which represented 60% of the children with physical examination and 72.4% of those examined with a questionnaire in the baseline study. A total of 49.6% were male, and the mean (SD) ages at the 4, 6, and 9-year measurements were 48.5 (1.8), 73.4 (3.3), and 110.7 (4.5) months, respectively. The mean follow-up time was 5.2 years.

Table 1 shows that weight and height were higher in boys than in girls of all ages. BMI was higher in boys at 6 and 9 years, while WC was only higher in boys at 9 years. In the participants with low household affluence, the weight, BMI, and WC were higher than in those with high household affluence.

Table 1
Distribution of anthropometric values at 4, 6, and 9 years of age

	N	Age (months) Mean (SD)	*p value*	Weight (kg) Mean (SD)	*p value*	Height (cm) Mean (SD)	*p value*	BMI (kg/m^2) Mean (SD)	*p* value	Waist (cm) Mean (SD)	*p value*
TOTAL											
4 years	1902	48.5 (1.8)		16.9 (2.3)		103.4 (4.4)		15.8 (1.5)		51.8 (3.8)	
6 years	1902	73.4 (3.3)		22.4 (4.1)		117.5 (5.3)		16.1 (2.0)		56.2 (5.6)	
9 years	1902	110.9 (4.5)		33.6 (8.0)		136.2 (6.6)		18.0 (3.3)		64.7 (8.9)	
AGE											
4 years			0.035		< 0.001		< 0.001		0.215		0.430
Boys	944	48.6 (1.9)		17.1 (2.3)		104.0 (4.4)		15.8 (1.5)		51.7 (3.6)	
Girls	958	48.4 (1.7)		16.7 (2.3)		102.9 (4.3)		15.7 (1.6)		51.9 (4.0)	
6 years			0.990		< 0.001		< 0.001		0.025		0.050
Boys	944	73.4 (3.3)		22.7 (4.1)		118.0 (5.4)		16.2 (2.0)		56.2 (5.3)	
Girls	958	73.4 (3.3)		22.1 (4.0)		117.1 (5.2)		16.0 (2.0)		56.2(5.8)	
9 years			0.819		< 0.005		0.004		0.006		0.014
Boys	944	110.9 (4.5)		34.1 (8.1)		136.7 (6.4)		18.1 (3.5)		65.1 (9.0)	
Girls	958	111.0 (4.5)		33.1 (7.8)		135.8 (6.7)		17.8 (3.0)		64.3 (8.7)	
HOUSEHOLD AFFLUENCE											
4 years			0.006		< 0.010		0.0666		< 0.010		< 0.001
Low	309	48.7 (2.2)		17.3 (2.7)		103.8 (4.6)		16.0 (1.8)		52.6 (4.4)	
Medium	589	48.3 (1.6)		16.8 (2.3)		103.1 (4.1)		15.8 (1.5)		51.7 (3.8)	
High	1004	48.5 (1.8)		16.9 (2.2)		103.5 (4.4)		15.7 (1.4)		51.6(3.6)	
6 years			0.417		< 0.010		< 0.064		< 0.001		< 0.001
Low	309	73.5 (3.1)		23.0 (4.8)		117.1 (5.6)		16.5 (2.4)		57.4 (6.3)	
Medium	589	73.2 (2.9)		22.2 (4.0)		117.1 (5.1)		16.1 (2.1)		56.2 (5.8)	
High	1004	73.4 (3.4)		22.2 (4.0)		117.7(5.4)		16.0 (1.8)		55.9 (5.0)	
9 years			0.352		< 0.001		0.274		< 0.001		< 0.001
Low	309	110.7 (4.1)		35.2 (9.2)		136.4 (7.0)		18.7 (3.6)		66.7 (9.8)	
Medium	589	110.9 (4.1)		33.4 (8.3)		135.9 (6.5)		18.0 (3.6)		64.8 (9.3)	
High	1004	111.1 (4.6)		33.2 (7.3)		136.4 (6.5)		17.7 (2.9)		64.0 (8.1)	

BMI: body mass index. SD: standard deviation

Table 2 shows the evolution of the standardized prevalence of overweight, GO, and AO. The prevalence of overweight increased between 4 and 9 years of age, from 16.8–21.8% (PR: 1.30; 95% CI: 1.16–1.45; $p < 0.001$), with a similar evolution by sex (PR: 1.25 in boys; 1.35 in girls; $p < 0.001$) and by family affluence (PR: low affluence: 1.23; medium: 1.31; high: 1.31; $p < 0.001$). GO increased from 5.1–15.6% between 4 and 9 years (PR: 3.05; $p < 0.001$), in boys from 5.5–19.3% (PR: 3.50; $p < 0.001$), and in girls from 4.7–11.9% (PR: 2.53; $p < 0.001$). Likewise, an increase was observed in the population with low, medium, and high family affluence (PR: 2.81; 3.0, and 3.26, respectively; $p < 0.001$). At 6 and 9 years, the prevalence of GO was higher in boys (11.3% and 19.3%) than in girls (6.9 and 11.9%) and in those with low household affluence than high at 4, 6, and 9 years (8.7% vs 3.9%, 14.6% vs 7.1% and 24.6% vs 12.6%, respectively).

Table 2
Evolution of the prevalence of overweight, general obesity, and abdominal obesity at 4, 6, and 9 years of age by sex and household affluence

	BMI										Waist circumference				
	Overweight[a]					General obesity[b]					Abdominal obesity[c]				
	N	%	95% CI	PR	95% CI	N	%	95% CI	PR	95% CI	N	%	95% CI	PR	95% CI
TOTAL															
4 years	319	16.8	(15.2–18.5)	(ref)		97	5.1	(4.2–6.2)	(ref)		129	6.8	(5.7-8.0)	(ref)	
6 years	326	17.1	(15.5–18.9)	1.02	(0.91–1.15)	173	9.1	(7.9–10.5)	1.78	(1.50–2.11)	160	8.4	(7.2–9.7)	1.24	(1.06–1.45)
9 years	414	21.8	(20.0-23.7)	1.30	1.16–1.45)	296	15.6	(14.0-17.3)	3.05	(2.58–3.60)	276	14.5	(13.0-16.2)	2.14	(1.85–2.48)
SEX															
Boys															
4 years	162	17.2	(14.9–19.7)	(ref)		52	5.5	(4.2–7.2)	(ref)		56	5.9	(4.6–7.6)	(ref)	
6 years	175	18.5	(16.2–21.1)	1.08	(0.91–1.28)	107	11.3	(9.5–13.5)	2.06	(1.63–2.60)	70	7.4	(5.9–9.3)	1.25	(0.97–1.61)
9 years	202	21.5	(18.9–24.1)	1.25	(1.06–1.46)	182	19.3	(16.9–21.9)	3.50	(2.78–4.40)	136	14.4	(12.3–16.8)	2.43	(1.92–3.06)
Girls															
4 years	157	16.4	(14.2–18.9)	(ref)		45	4.7	(3.5–6.2)	(ref)		73	7.6	(6.1–9.5)	(ref)	
6 years	151	15.8	(13.6–18.2)	0.96	(0.81–1.14)	66	6.9	(5.4–8.7)	1.47	(1.14–1.89)	90	9.4	(7.7–11.4)	1.23	(1.00-1.51)
9 years	212	22.1	(19.6–24.9)	1.35	(1.16–1.58)	114	11.9	(9.8–14.1)	2.53	(1.99–3.22)	140	14.6	(12.5–17.0)	1.92	(1.58–2.32)
HOUSEHOLD AFFLUENCE															
Low															
4 years	51	16.5	(12.8–21.1)	(ref)		27	8.7	(6.1–12.5)	(ref)		36	11.6	(8.5–15.7)	(ref)	
6 years	59	19.1	(15.1–23.9)	1.16	(0.85–1.56)	45	14.6	(11.0–19.0)	1.67	(1.21–2.28)	41	13.3	(10.0-17.5)	1.14	(0.85–1.52)
9 years	63	20.4	(16.2–25.3)	1.23	(0.92–1.66)	76	24.6	(20.1–29.7)	2.81	(2.08–3.82)	65	21.0	(16.8–25.9)	1.80	(1.38–2.36)
Medium															
4 years	98	16.6	(13.8–19.9)	(ref)		31	5.3	(3.7–7.4)	(ref)		33	5.6	(4.0-7.8)	(ref)	
6 years	92	15.6	(12.9–18.8)	0.94	(0.75–1.18)	57	9.7	(7.5–12.3)	1.84	(1.38–2.35)	53	9.0	(6.9–11.6)	1.62	(1.19–2.16)
9 years	129	21.7	(18.7–25.4)	1.31	(1.06–1.60)	93	15.8	(13.0–19.0)	3.00	(2.26–3.98)	91	15.4	(12.7–18.6)	2.75	(2.07–3.66)
High															
4 years	170	16.9	(14.7–19.4)	(ref)		39	3.9	(2.8–5.3)	(ref)		60	6.0	(4.7–7.6)	(ref)	
6 years	175	17.4	(15.2–19.9)	1.03	(0.88–1.21)	71	7.1	(5.6–8.8)	1.82	(1.37–2.42)	66	6.6	(5.2–8.3)	1.10	(0.860–1.41)
9 years	223	22.2	(19.7–24.9)	1.31	1.13–1.52)	127	12.6	(10.7–14.8)	3.26	(2.47–4.28)	120	11.9	(10.1–14.1)	2.00	(1.59–2.50)

[a] Overweight: BMI >1 standard deviation (SD) and ≤2 SD over the values in the WHO-2007 standardized tables

[b] Obesity: BMI >2 (SD) according to the WHO-2007 standardized tables

[c] Abdominal obesity: ≥90th percentile of waist circumference according to the consensus of the international Diabetes Foundation (IDF)[21]

PR: prevalence ratio; 95% CI: 95% confidence interval

The AO rate increased between 4 and 9 years of age from 6.8–14.5% (PR: 2.14; $p < 0.001$), with a fairly similar trend by sex (PR: 2.43: $p < 0.001$ in boys and PR: 1.92; $p < 0.001$ in girls) and family affluence, where the prevalence of AO was approximately twice as high in those of lower socioeconomic status as those of a high level.

Regarding the variations in obesity (Table 3), 82.4% and 82.1% of the participants remained without GO and AO, respectively; 12.1% (GO) and 11% (AO) had incident obesity; and 3.4% (GO) and 3.5% (AO) remained with obesity. The prevalence of stable boys without GO (78.6%) was lower than that of girls (86.1%). Participants with poorer socioeconomic status showed a higher prevalence of stable GO (6.2%) and AO (6.5%) than those of high status (2.3% for GO and 2.5% for AO), with children from medium-affluence households in an intermediate position.

Table 3
Variations in the prevalence of general and abdominal obesity in 4-, 6-, and 9-year-olds by sex and household affluence

	General obesity[a]			Abdominal obesity[b]		
Obese BMI or abdominal obesity	N	%	95% CI	N	%	95% CI
TOTAL						
Stable without obesity[c]	1.567	82.4	(80.6–84.0)	1562	82.1	(80.3–83.8)
Remitting obesity at 9 years[d]	39	2.1	(1.5–2.8)	64	3.4	(2.6–4.3)
Incident obesity at 9 and (4 or 6)[e]	230	12.1	(10.7–13.6)	209	11.0	(9.6–12.5)
Stable with obesity[f]	66	3.4	(2.7–4.4)	67	3.5	(2.8–4.5)
SEX						
Boys						
Stable without obesity[c]	742	78.6	(75.9–81.1)	780	82.6	(80.1–84.9)
Remitting obesity at 9 years[d]	20	2.1	(1.4–3.3)	28	3.0	(2.1–4.3)
Incident obesity at 9 and (4 or 6)[e]	145	15.4	(13.2–17.8)	112	11.9	(10.0–14.1)
Stable with obesity[f]	37	3.9	(2.9–5.4)	24	2.5	(1.7–3.8)
Girls						
Stable without obesity[c]	825	86.1	(83.8–88.2)	782	81.6	(79.0–84.0)
Remitting obesity at 9 years[d]	19	2.0	(1.3–3.1)	36	3.8	(2.7–5.1)
Incident obesity at 9 and (4 or 6)[e]	85	8.9	(7.2–10.8)	97	10.1	(8.3–12.2)
Stable with obesity[f]	29	3.0	(2.1–4.3)	43	4.5	(3.3-6.0)
HOUSEHOLD AFFLUENCE						
Low						
Stable without obesity[c]	226	73.1	(67.9–77.8)	229	73.0	(68.9–78.7)
Remitting obesity at 9 years[d]	7	2.3	(1.1–4.7)	15	5.4	(2.9–7.9)
Incident obesity at 9 and (4 or 6)[e]	57	18.5	(14.5–23.2)	45	15.1	(11.0–19.0)
Stable with obesity[f]	19	6.2	(3.9–9.5)	20	6.5	(4.2–9.8)
Medium						
Stable without obesity[c]	487	82.7	(79.4–85.5)	484	82.1	(78.9–85.1)
Remitting obesity at 9 years[d]	9	1.5	(0.8–2.9)	14	2.5	(1.4–4.0)
Incident obesity at 9 and (4 or 6)[e]	69	11.7	(9.4–14.6)	70	12.0	(9.5–14.8)
Stable with obesity[f]	24	4.1	(2.7–6.0)	21	3.4	(2.3–5.4)
High						
Stable without obesity[c]	854	85.1	(82.7–87.1)	849	84.8	(82.2–86.7)
Remitting obesity at 9 years[d]	23	2.3	(1.5–3.4)	35	3.4	(2.5–4.8)
Incident obesity at 9 and (4 or 6)[e]	104	10.4	(8.6–12.4)	94	9.3	(7.7–11.3)

[a]General obesity: BMI > 2 SD over the values in the WHO-2007 standardized tables

[b]Abdominal obesity: ≥90th percentile of waist circumference according to the consensus of the International Diabetes Federation (IDF)[21]

[c]No obesity in any of the measurements; [d]obesity at 4 and/or 6 years but no obesity at 9 years; [e]obesity only at 9 years, 4 and 9 years, or 6 and 9 years; [f]obesity in all three measurements

95% CI: 95% confidence interval

	General obesity[a]			Abdominal obesity[b]		
Stable with obesity[f]	23	2.3	(1.5–3.4)	26	2.5	(1.8–3.8)
[a]General obesity: BMI > 2 SD over the values in the WHO-2007 standardized tables						
[b]Abdominal obesity: ≥90th percentile of waist circumference according to the consensus of the International Diabetes Federation (IDF)[21]						
[c]No obesity in any of the measurements; [d]obesity at 4 and/or 6 years but no obesity at 9 years; [e]obesity only at 9 years, 4 and 9 years, or 6 and 9 years; [f]obesity in all three measurements						
95% CI: 95% confidence interval						

The Sankey diagram (Fig. 1) showed the tracking over the three measurements (see also Fig. 1S and 2S of supplementary material), highlighting that 77.3% of children with GO at 4 years old and 85,5% at 6 years old maintained GO at 9 years old. Only 1–3% remitted to normal weight. Of those classified with obesity at 9 years, approximately half were incident cases.

Table 4 shows that, with respect to stable patients without obesity, patients had a RR of GO at 9 years of 4.61 (95% CI: 2.35–9.06) if they were obese at age 4 but not age 6; 9.36 (95% CI: 7.09–12.36) if obese at 6 years but not at 4; and 10.27 (CI95: 7.63–13.81) if obese at 4 and 6 years. Similar results were found for the risk of presenting AO at 9 years, with estimated RRs of 4.14 (95% CI: 2.42–7.08), 9.56 (95% CI 7.04–12.98) and 9.88 (95% CI: 7.32–13.33), respectively.

Table 4
Risk of general and abdominal obesity at 9 years of age according to the presence of obesity at 4 and 6 years of age

	General obesity[a] at 9 years			Abdominal obesity[b] at 9 years		
	N	RR[c]	95% CI	N	RR[c]	95% CI
Obesity 4 and 6 years						
Stable without obesity at 4 and 6 years	1706	(ref)		1696	(ref)	
Obesity at 4, not at 6 years	23	4.61	(2.35–9.06)	46	4.14	(2.42–7.08)
No obesity at 4, obesity at 6 years	99	9.36	(7.09–12.36)	77	9.56	(7.04–12.98)
Obesity at 4 and 6 years	74	10.27	(7.63–13.81)	83	9.88	(7.32–13.33)
[a] General obesity: BMI > 2 SD over the values in the WHO-2007 standardized tables						
[b] Abdominal obesity: ≥90th percentile of waist circumference according to the consensus of the International Diabetes Federation (IDF)[21]						
[c] Relative risk estimated by Poisson regression and adjusted for age, sex, and household affluence						
95% CI: 95% confidence interval						

Finally (see Table 5), participants with joint obesity (GO and AO) at 4 years old had RRs of 16.10 (95% CI: 11.29–22.92) and 6.53 (95% CI: 4.79–8.91) for GO at 6 and 9 years, respectively, compared to children without obesity at 4 years old. Those who at 4 years old had only GO had RRs of 12.37 (95% CI: 7.64–20.06) and 5.64 (95% CI: 3.63–8.78) for an obese BMI at ages 6 and 9 compared to those who had AO but not GO, respectively.

Table 5
Risk of general obesity at 6 and 9 years of age according to the presence of general obesity and/or abdominal obesity at 4 years of age

		General obesity[a] at 6 years		General obesity at 9 years	
Obesity 4 years	N	RR[c]	95% CI	RR[c]	95% CI
No obese BMI/No abdominal obesity	1741	(ref)		ref	
Obese BMI/No abdominal obesity	32	12.37	(7.64–20.06)	5.64	(3.63–8.78)
No obese BMI/Abdominal obesity	64	5.19	(3.00-9.01)	3.14	(2.02–4.90)
Obese BMI/Abdominal obesity[b]	65	16.10	(11.29–22.92)	6.53	(4.79–8.91)

[a] General obesity: BMI > 2 SD over the values in the WHO-2007 standardized tables

[b] Abdominal obesity: ≥90th percentile of waist circumference according to the consensus of the International Diabetes Federation (IDF)[21]

[c] Relative risk estimated by Poisson regression and adjusted for age, sex, and household affluence

95% CI: 95% confidence interval

Discussion

This study describes the tracking of overweight and obesity using longitudinal data from a child cohort followed from 4 to 9 years of age. The high increase in GO and AO stands out, with prevalences three-fold and two-fold higher at 9 years old than 4 years old. This increase is due to the large number of incident cases compared to the low remission percentage and is observed for all socioeconomic levels, although the prevalence is twice as high in those with low household affluence. It is very important to detect obesity early, since its appearance at 4 or 6 years determines obesity at 9 years. The two indicators of obesity (GO and AO) are complementary, and their combined use in young children maximizes the detection of obesity.

Most studies show that GO increases until 9–10 years and in adolescence decreases until the beginning of adulthood[1,2]. In our study, the evolution of the prevalence of overweight and GO from 4 to 9 years of age were of similar magnitude and trend with respect to other cross-sectional studies of our environment[5,24]. In the measurements at 6 and 9 years, we estimated a higher prevalence of GO in boys than in girls. This difference may be due not so much to environmental or behavioural factors but instead to hormonal changes, adiposity rebound, and distribution of body and muscle fat, which vary with age and sex[25,26].

In our study, the prevalence of AO increased with age and was similar to that observed by Schröeder et al.[27] and lower than the recent data by Aranceta-Bartrina, which estimated a prevalence of 21.5%[24]. These differences could be explained by the different measurement criteria and cut-off points of the WC used to define AO; we chose the IDF consensus that allows for international comparisons[21]. International organizations should make an effort to have international reference populations given their importance in the detection of cardiometabolic risk from an early age.

Regarding socioeconomic status, in Western countries, childhood obesity follows a clear gradient, with a higher prevalence in children with lower socioeconomic status[28]. However, it is not clear that these differences are maintained or continue to increase, because while some studies describe increasing inequality, others note a fairly uniform evolution[29]. We found higher prevalences in children with low household affluence, though the age 4–9 growth trends of both GO and AO were similar in low-, medium-, and high-affluence children. In Spain, great disparity in numbers has been observed. The study by Albaladejo-Vicente et al.[30] based on the national health survey from 1997 to 2017 examined the population aged 5–15 years, showing a decreasing trend of obesity in children of parents of low socioeconomic status, while in girls, the trend was increasing. In a study from Andalusia, the social gradient of childhood obesity by socioeconomic indicators observed in 2011–2012 disappeared by 2015-2016[31]. However, a study conducted in Catalonia based on primary care electronic medical records noted an increase in inequality (estimated ecologically) between 2006 and 2016[32].

On the other hand, our estimates are consistent with studies suggesting that obesity frequently begins early on and that children with GO and AO tend to stay obese[33,34]. Children with or without GO at 4 or 6 years in our study tended to remain in the same category at 9 years. We also found that the risk of obesity at 9 years was greater if they had been obese at 4 and 6 years than if they had been obese at only one of the previous measurements. Similar results were reported by other studies, such as the one carried out in Norway, where children with excess weight at 2–4 years had an 11 times higher risk (odds ratio) of being overweight at 5–7 years than children with normal weight[35]. In Australia, 5-year-old children who were obese were 25 times more likely to be obese 3 years later than those who were not obese[36].

To compare the variations and risk of AO, little information is available for this age group in Spain or in other countries. Vogelezang et al.[34] found that the persistence of AO was very high at early ages. A recent study by Ochiai et al.[37] estimated that half of the children classified with AO remained in the same category in adolescence. We observed even greater persistence of AO; 60–80% of obese children at 4 or 6 years old remained in the same category at 9 (see supplementary material), and the risk of AO at 9 years was 10 times higher if the child had been obese at both 4 and 6 years. These results are in line with other studies, but comparisons should be made with caution given the differences in follow-up time, ages, and classification methods used[38,39].

A relevant aspect of important public health implications is the greater probability of having GO at 6 or 9 years in those children who at 4 had AO, but not GO, which represented 3.4% of our analysed children. Considering that children with a normal weight and BMI but with AO have a high cardiometabolic risk, the

combined measurement of weight, height, and WC will improve the predictive power to detect this health problem[40].

To correctly interpret the results of the study, several limitations must be taken into account. On the one hand, we do not have information on the weight status between birth and 4 years, which prevents the completion of the children's obesity trajectories. In the constitution of the ELOIN cohort, a moderate bias was observed in the selection of the sample that would affect its population representativeness: children with low educational level and foreign parents had a lower response rate at the baseline measurement[20]. However, those who participated in the three follow-up measurements maintained their similarity with respect to the sociodemographic variables of the baseline cohort.

As strengths, we highlight the longitudinal design of the study. In addition, the sample is representative of the population of Community of Madrid, even with the selection bias mentioned above. Anthropometric measurements are based on objective criteria and were performed in a standardized way in all measurements, so they are subject to fewer validity errors, such as self-reported measures or those provided by parents[41].

In conclusion, GO and AO begin at an early age, are associated with low socioeconomic status, and increase rapidly with age. Obesity at 9 years is closely correlated with having previously been obese, either stably or intermittently, so prevention and management interventions should be established very early. The combined use of GO and AO indicators maximizes the detection of this health problem.

Conclusions

This study provides recent data on the variations in the prevalence of general and abdominal obesity, in a representative cohort of Community of Madrid, followed from 4 to 9 years of age. The prevalence of general obesity at 9 years is 3 times higher than at 4 years, with a 2-fold increase in abdominal obesity.

General and abdominal obesity begin at an early age, are associated with low socioeconomic status, and increase rapidly with age. Obesity at 9 years is closely correlated with having previously been in obesity, either stably or intermittently, so prevention and management interventions should be established very early. The two indicators of general and abdominal obesity are complementary, and their joint use could maximize the detection and control of this health problem.

List Of Abbreviations

BMI
body mass index; CI:confidence interval; RR:relative risk; SD:standard deviation; WC:Waist circumference; AO:Abdominal obesity; GO:General obesity; WHO:World Health Organization. IDF:International Diabetes Foundation; ELOIN:Longitudinal Childhood Obesity Study.

Declarations

Ethics approval and consent to participate

The Ethics Committee of the Ramón y Cajal Hospital in Madrid approved the study (CIHURC- 122/11). Prior participation, all participants provided written informed consent. Written informed consent was obtained from their parents or legal guardians. The current study was conducted according to the Declaration of Helsinki and all methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and material

According to private and confidential clauses states in the informed consent, the dataset generated an analysed during the current study is ethically restricted and not publicly available. It would be available from Dr. Honorato Ortiz-Marrón (E-mail: honorato.ortiz@salud.madrid.org) on reasonable request.

Competing interest

The authors declare that there are no potential conflicts of interest regarding the research, authorship and/or publication of this article.

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Autors' contributions

H Ortiz-Marrón and I Galán conceptualized and designed the study, developed the initial manuscript with tables and figures, and checked and revised the final manuscript. H Ortiz-Marrón, I Galán, and MA Ortiz-Pinto designed the instruments for data collection, data collection, and initial analysis. MA Ortiz-Pinto, JG Martínez Mosquera, M Lorente Miñarro [c], F Menchero Pinos, and M Ordobás Gavín participated in the data collection and critically reviewed the manuscript by making important contributions to its content. All authors gave their approval to the final manuscript and agreed and assume responsibility for all aspects of the work.

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Figures

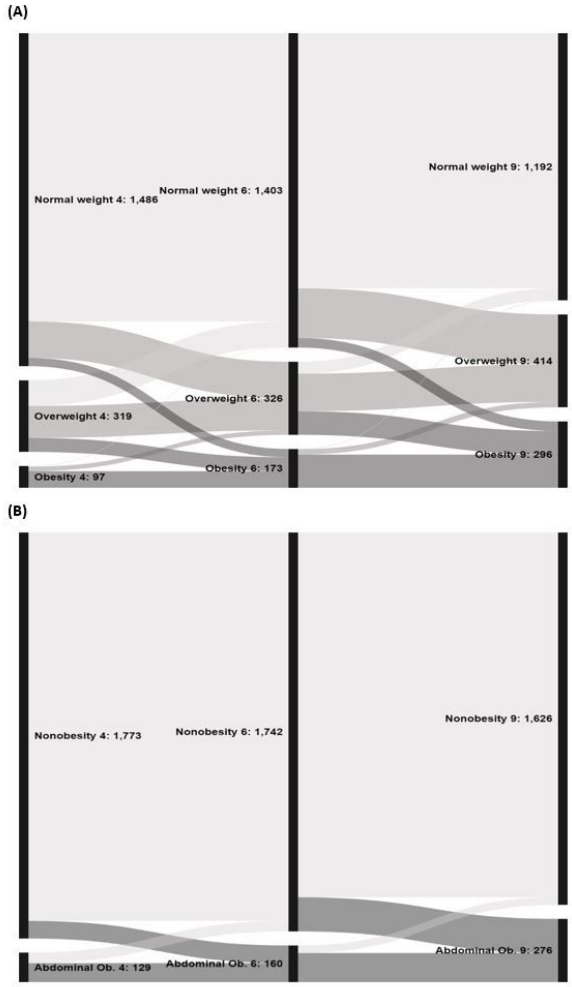

Figure 1

Sankey diagram. Variations in weight status based on body mass index: Normal weight, overweight an obesity (A); and abdominal obesity (B) at 4, 6, and 9 years of age.

Supplementary Files

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