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Association between general and central adiposity and development of hypertension in early childhood

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Abstract

Objectives: To evaluate the association of general and abdominal obesity with high blood pressure in young children.

Methods: Longitudinal study including 1796 participants from the Madrid region (Spain) with baseline at age 4 and a follow-up 2 years later. Blood pressure (BP), body mass index (BMI) and waist circumference were measured during a physical examination. We evaluated the association between obesity at baseline and weight changes between the ages of 4 and 6 and high BP. Data were analyzed using linear and logistic regressions adjusted for covariates.

Results: Obese 4 year-olds (general or abdominal obesity), experienced an average 4-5 mmHg increase in systolic BP and 2.5-3 mmHg increase in diastolic BP by the age of 6. Compared to children maintaining a non-excess weight (based on BMI) during follow-up, incident and persistent cases of excess weight (overweight or obesity) had an OR for high BP=2.49 (95%CI:1.50 to 4.13) and OR=2.54 (95%CI:1.27 to 5.07), respectively. Regarding abdominal obesity we estimated OR=2.81 (95%CI:0.98 to 8.02) for incident cases and OR=3.42 (95%CI:1.38 to 8.49) for persistent ones. Similar estimates for the waist-height ratio were observed. Individuals who experienced remission to non-excess weight did not have an increased risk for high BP.

Conclusions: We observed an increased risk for high BP among 4 year-olds who presented persistent or incident cases of excess weight (BMI) or abdominal obesity after two years of follow-up. Children with excess weight or obesity at baseline who remitted to non-excess weight did not exhibit an increased risk for high BP.

Key words: childhood, obesity, abdominal obesity, arterial hypertension.

Introduction

In 2010 the childhood obesity epidemic affected 43 million children worldwide. Further, overweight and obesity have increased between 2- and 3-fold in preschool age over the last three decades[1]. Similarly to other Southern European countries, Spain has a very high prevalence of childhood obesity[2].

Children and adolescents with excess body fat present with adverse cardiometabolic parameters that support the onset of cardiovascular complications, even if no clinical symptoms are detected in childhood[3]. Compared with children of normal weight, children with overweight and obesity show an average increase of 4.5 and 7.5 mmHg of systolic blood pressure (BP), respectively[3]. In addition, the presence of high BP in childhood increases the risk of adult hypertension[4]. Analyses of trajectories and effects of childhood overweight and obesity on BP conclude that as excess weight drops, so does high BP[5–11]. This evidence-based support for adequate weight control from an early age as a form of prevention of future cardiometabolic complications makes for a highly relevant public health message[12].

Because the use of the body mass index (BMI) as the single indicator of general adiposity is controversial, the collection of additional anthropometric measures is recommended. For instance, combining BMI and waist circumference, a better indicator of central adiposity and visceral fat, is likely to increase sensitivity in the detection of overweight and obesity[13]. This in turn, will enable a better assessment of the link between excess weight and cardiometabolic complications[14]. The overall objective of this study was to evaluate the association of general overweight, general obesity and abdominal obesity with high BP in a representative population-based sample of 4-year-old children after 2 years of follow-up.

Materials and Methods

Study Population

The Longitudinal Study of Childhood Obesity (ELOIN for its acronym in Spanish), is a population-based cohort of the Madrid region, Spain (population: 6.5 million). Study methodology and sample characteristics have been previously published[15]. A total of 2,627 children were involved in the original cohort. The number of participants who underwent a physical examination at 4 (baseline measurement) and 6 years of age were 1,796. The information was collected in two consecutive stages: the child´s standardized physical examination performed at the health center by the pediatricians participating in the study, followed by a computer-assisted telephone interview of the parents based on a structured questionnaire.

Anthropometric measurements

The physical examination included anthropometric measures collected in a standardized manner by the 32 pediatricians in the study. Weight was assessed using a digital scale (SECA® model 220, precision 0.1 kg); height was measured by means of telescopic stadiometer (SECA® model 220, precision 1.0 mm); waist circumference (WC) was measured with a validated inextensible metric tape with a buckle, just above the iliac crests with the tape horizontally and without compression of the tissues. Two measurements were collected for each participant, and the average was used for the analyses.

We calculated the children´s BMI (kg/m2) standardizing it for age in months and sex according to the WHO-2007 reference tables. Based on BMI z-scores, overweight was defined as z-BMI> +1 standard deviation (SD) and ≤ +2 SD whereas obesity was defined as z-BMI > +2 SD[(16)].

The mean WC value was standardized using the age (in months) and sex reference tables proposed by Fernández et al[(17)]. Abdominal obesity was defined using two criteria: 1) ≥90-percentile of WC according to the recommendations of the International Diabetes Federation (IDF)[(18)]; 2) ≥90-percentile of the WC-height ratio (cm/m)[(19)].

Individuals classified as overweight or obese based on their z-BMI were grouped under the variable "excess weight." Both maintenance and variation of excess weight were captured by defining four categories which took into account an individual´s classification at baseline and at follow-up: a) Maintenance of non-excess weight-BMI, i.e., presenting non-excess weight status at both time points; b) Maintenance of excess weight-BMI, i.e., presenting in-excess weight at both time points; c) Incidence, i.e., new cases of excess weight-BMI at follow-up; and d) Remission: recuperating a non-excess weight-BMI status by follow-up. The same categories were defined to evaluate changes in abdominal obesity during follow-up.

Blood pressure

Blood pressure (BP) was measured using the auscultatory method in the right arm. Participants remained seated at rest for 5 minutes before the assessment, with the back and feet supported. The right arm was resting on a firm surface in a horizontal position with the palm of the hand facing up so that the antero-cubital fossa was located at heart level. We measured BP 2 times separated by at least 2 minutes. When differences between both measures were greater than 5 mmHg a third measurement was taken. The average of the measurements was used for analytical purposes.

BP values were standardized according to height, age in months, and sex, using the reference tables on *The Fourth Report on High Blood Pressure in Children and Adolescents*[20]. According to the recommendations of the European Society of Hypertension for Children and Adolescents[21], high BP was defined using the 90th percentile as the cutoff point for systolic and/or diastolic blood pressure.

Covariables

Baseline sociodemographic variables collected when participants were 4 years old included sex, age in months, mother´s educational achievement, and family socioeconomic status (SES) based on the Family Affluence Scale (low, medium and high)[22]. Other covariables included time of exclusive breastfeeding, rest (hours of sleep and leisure), weekly physical exercise (hours at school and extracurricular), and weekly sedentary activities (hours spent in front of screens: television, playing with the computer or the console).

Statistical analysis

From the initial sample composed of 1796 participants with valid values for systolic and diastolic blood pressure, 15 children were excluded who did not report values for WC. An additional 170 children were excluded from all elevated BP analyses because of having altered BP already at age 4. After removing participants with missing values in the covariates of interest, the final sample sizes used in the different models of association between BP and overweight-general and abdominal obesity ranged between 1612 and 1796 individuals.

We applied linear regression modelling to estimate mean changes in systolic and diastolic BP. Second, we used logistic regression models to estimate the odds ratios (OR) of having high BP by age 6. These models also included the different anthropometric categories capturing weight changes during follow-up.

Models were adjusted for the covariates previously described, specifically, all analyses included sex, age, family SES, BP baseline values, as well as those covariates with p-values<0.20 at the bivariate level. Finally, we explored potential interactions of the indicators for overweight-general obesity and abdominal obesity with the variables for sex and SES. All the analyses were performed using Stata v.14 and its Survey Data module to take into account the characteristics of the cluster sampling (pediatric consultations).

Ethical considerations

The study protocol was approved by the Ethics Committee of the Ramón y Cajal Hospital in Madrid. Given that all participants were minors, their parents gave their informed consent in writing.

Results

The characteristics of the sample are described in Table 1. Higher systolic BP was observed in children with low SES, excess weight, and incident and persistent abdominal obesity.

Table 2 shows the mean systolic and diastolic BP changes by age 6, according to the classification of weight status and abdominal obesity at age 4 (baseline). Children with overweight at baseline were associated with an increase in BP in two years later, by age 6. Models estimate a β coefficient for systolic pressure = 1.79 (95% CI: 0.71 to 2.86) and β for diastolic pressure= 1.36 (95%CI: 0.15 to 2.58). Being obese at baseline was associated to a greater increase in BP, observing β coefficients of 4.77 (95%CI: 2.85 to 6.69) and 3.08 (95%CI: 0.63 to 5.52) for systolic and diastolic pressure respectively. Abdominal obesity according to WC was associated with an increase of 4.43 mmHg (95%CI: 3.01 to 5.85) and 2.48 mmHg (95%CI: 0.56 to 4.40) of the systolic and diastolic pressure respectively. The BP increase associated to baseline waist-height ratio was smaller, being the increase in systolic pressure=2.46 (95%CI: 0.97 to 3.95).

Table 3 shows the longitudinal analysis of the variation in excess weight and abdominal obesity, and the mean BP by age 6. Compared to children who maintained a non-excess weight based on BMI or abdominal obesity at either assessment, incident and persistent cases of excess weight or abdominal obesity presented a greater increase in mean BP. The greatest increases in systolic pressure were associated to WC for incident cases (β=7.21; 95%CI: 4.18 to 10.24) as well as for persistent cases (β=7.15; 95%CI: 5.12 to 9.18). In contrast, the greatest increases in diastolic BP were associated with the waist-height ratio, estimating a β=4.03 (95%CI: 2.10 to 5.95) for incident cases and β=4.59 (95%CI: 1.78 to 7.41) for persistent cases. Except regarding WC-based abdominal obesity, individuals experiencing obesity reversal showed similar values to those of participants who maintained a non-excess weight based on BMI or abdominal obesity, or slightly higher but without reaching statistical significance.

Table 4 shows crude and adjusted risks of having high BP at age 6, taking into account weight status and abdominal obesity at age 4. In the adjusted model, general obesity (BMI) and abdominal obesity (WC) were associated with high BP (OR=2.55; 95% CI: 1.24 to 5.24; OR=1.99; 95% CI: 1.00 to 3.95, respectively).

Table 5 shows the results of the longitudinal risk analysis of having high BP at age 6, with respect to the persistence or variation of excess weight and abdominal obesity. The association with the greatest magnitude was observed among persistent cases of WC-based abdominal obesity (OR=3.42; 95%CI: 1.38 to 8.49), followed closely by individuals with persistent obesity according to the waist-height quotient (OR=3.17; 95%CI: 1.12 to 8.91) and excess weight (BMI), OR=2.54 (95%CI: 1.27 to 5.07).

Incidence of both excess weight (according to BMI) and abdominal obesity (according to waist-height ratio) during the follow-up period were associated to increased risk of high BP presentation: OR=2.49 (95%CI: 1.50 to 4.13) and OR=3.01 (95%CI: 1.44 to 6.28), respectively. When compared to children who maintained non-excess weight, those who remitted excess weight did not present statistically significant differences in risk. We observed the same result regarding abdominal obesity. Finally, no statistically significant interactions with sex or family purchasing level were identified.

Finally, we examined how both indices contributed to increases in BP by introducing them simultaneously in the linear regression model (Supplementary Table 1). We observed independent effects on systolic BP increase despite the high correlation between the indices. We tested a model with the four combinations of obesity at 4 years of age and the increase in systolic BP was statistically significant in all of them. I.e., obese patients classified only by BMI had an increase of 3.98 mmHg of systolic BP; the obese classified by waist circumference showed an increase of 3.62 mmHg; and the obese classified by both measurements had an increase of 5.03 mmHg (Supplementary Table 2). These results support the combined use of both general and abdominal obesity measures as a determinant factor influencing BP.

Discussion

After two years of follow-up, children diagnosed with either general or abdominal obesity at the age of 4 showed an average increase of 4-5 mmHg systolic and 2.5-3 mmHg diastolic blood pressure. Based on the resulting odds ratios, the probability of having high blood pressure was 2-2.5 times higher in the obese children. Both the persistent and incident cases of excess weight, general and abdominal obesity, showed an increased risk of blood pressure elevation, whereas cases experiencing remission presented values similar to children with no-excess weight.

There is consistent evidence from numerous longitudinal studies supporting the relationship between excess weight and the increase in systolic and diastolic BP in children and adolescents[(5–11,23–27)]. Although comparisons with this literature are problematic due to substantial variations in age groups, lengths of follow-up, and indicators included, the average increase in BP observed in our study is quite similar to those reported by others.

Considering that an individual´s overweight or obese status can change throughout childhood and adolescence, the different categories of the anthropometric indicators and their effect on cardiometabolic risk, and more specifically, on BP have been analyzed[(5–11,23,25,26)]. Both persistent and incident cases of excess weight were associated with an increase in BP. In addition, when excess weight remitted during the follow-up, BP decreased[(5–11)]. Here we observed the same associations already at very early ages and with only two years of follow-up, underscoring the importance of controlling excess weight early in life to maintain healthy BP values.

Although in their systematic review Friedman et al. reported a greater effect of obesity both on systolic and diastolic pressure in girls than boys[(3)], our data pointed to similar effect in both sexes supporting findings reported in previous longitudinal studies[(5,8,23,24,27)]. It is possible that the detection of those sex differences by Friedman et al.,[(3)] could be the result of analyzing both longitudinal and cross-sectional studies together.

Nevertheless, an understudied question was to know if socioeconomic status could modify the association between adiposity and BP. Consistent with our results, Howe et al.,[(28)] reported that adiposity did not mediate the socioeconomic status differentials in BP.

What is also under discussion is the role the different anthropometric indicators play on cardiovascular risk. Recent work proposed waist circumference as a better marker of visceral adiposity than BMI, based on the former´s stronger association with obesity-related complications[(14)]. Other authors have proposed the waist circumference corrected for height as the better predictor of cardiometabolic risk. This measure has the obvious advantage of its applicability to different population subgroups without standardization according to reference values[(29)].

Studies examining both indicators of general and abdominal obesity failed to find significant differences in their associations with BP[(5,9,24)]. Similarly, we did not find substantial differences between these two indicators, except that the associations between waist circumference corrected by the height and high BP were, in general, of smaller magnitude. In addition, the area under the receiver operating characteristic (ROC) curves which, in this case, evaluated the indicators´ capacity to discriminate between children with and without elevated blood pressure, were similar across our three different adiposity measures at baseline and blood pressure values two years later: BMI (0.7093); WC (0.7059); and WC-height ratio (0.7033). Regardless, it is important to keep in mind that obesity, estimated based on BMI and waist circumference separately, has a sensitivity of 80-85%[30]. That is, either measurement separately fails to detect one of every 5-6 cases of obesity and, thus, the recommendation in pediatrics is the simultaneous use of both measures[13].

Limitations and strengths of the study

When interpreting our results, some limitations should be taken into consideration. First, children of foreign or low educational level mothers had a lower response rate at baseline introducing a moderate bias in the selection of the sample which may affect its representativeness at the population level. Second, most of the children in our study are Caucasians of Spanish origin, so our findings cannot be generalized to other ethnicities. Third, the 2-year follow-up does not allow the evaluation of how the association between BP and body weight changes in the mid- to long-term. Finally, given the low prevalence of obese 4-year olds at baseline (5%) and follow-up (9.7%) we combined the two categories, overweight and obese, into an “excess weight” category to maintain statistical power in the longitudinal analyses.

It should also be noted that the average systolic and diastolic BP data used to defined high BP came from a single visit to the pediatrician and not from 3 separate measurements, as recommended by the European Society of Hypertension. Finally, taking into account the model´s goodness-of-fit, adiposity would explain only 5-8% of variability (depending on the indicators) in unadjusted models, only improving to 7-10% in the adjusted ones. However, as this modest goodness-of-fit mirrors that of those reported in other studies[26], our results support previous evidence pointing to the existence of other factors, not included in the analysis, that may explain the residual variance and confound the results.

Among the study´s strengths, it is worth highlighting its longitudinal design allowing causal associations to be suggested. Another important characteristic is that the sample is representative of the 4-year-old population of the Madrid region, despite of the aforementioned selection bias. Finally, the anthropometric measures, which include various indices and BP, were based on objective tests performed in a standardized manner with baseline measurements at 4 years of age and a follow-up 2 years later. Individuals with high BP at baseline were excluded from the logistic regression analyses estimating incident cases during follow-up. Finally, all models were adjusted for baseline BP values.

Pediatricians play a key role in the prevention of adult cardiovascular diseases since the onset of many of the related risk factors occur in childhood. In fact, there is an ongoing heated debate about the pertinence of universal screening for hypertension in children. However, although recommended by numerous clinical guides, evidence supporting the implementation of such a program is still very limited[(12)]. Notwithstanding, the proposal of a screening program for hypertension, targeted at at-risk groups such as children with excess weight or with general or abdominal obesity, should be evaluated to be integrated into clinical practice.

In conclusion, 4 year-olds presenting excess weight based on BMI or abdominal obesity at the beginning of the study, displayed a higher risk of BP increase by the time they turned 6. Incident and persistent cases of excess weight and abdominal obesity were associated with an increased risk of high BP, whereas those who reverted to a normal weight decreased their BP to levels comparable to those with normal anthropometric values at the study´s baseline and throughout the follow-up. Therefore, early detection and control of childhood obesity may reduce the risk of high blood pressure.

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Author Contributions

Ortiz-Pinto MA and Galán I, conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Ortiz-Pinto MA, Ortiz-Marrón H and Galán I, designed the data collection instruments, collected data, carried out the initial analyses, Ortiz-Pinto MA, Ortiz-Marrón H, Esteban-Vasallo M, Ordobás-Gavin MA, Ferriz Vidal I, Martínez-Rubio MA and Galán I revised the manuscript.

Ortiz-Marrón H, Ordobás-Gavin MA, Ferriz Vidal I, Martínez-Rubio MA, collected data, and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Table 1. Systolic and Diastolic blood pressure at follow-up (age 6), according to the characteristics of the sample.

	N	Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)	
		Mean (SD)	p-value	Mean (SD)	p- value
Sex			<0.001		0.023
Males	908	93.4(8.4)		55.1(7.7)	
Females	888	91.8(8.5)		54.3(8.6)	
Maternal Educational level[a]			0.579		0.054
Primary or below	61	92.3(8.8)		54.4(8.7)	
First level secondary	330	93.0(8.8)		55.3(8.2)	
Second level secondary	608	92.9(8.5)		55.3(7.9)	
Some College/technical	249	92.1(8.2)		53.6(7.7)	
University level	542	92.2(8.3)		54.3(7.6)	
Family purchasing power			0.062		0.012
Low	817	93.1(8.7)		55.3(7.9)	
Medium	687	92.3(8.2)		54.2(7.9)	
High	291	91.9(8.4)		54.2(8.0)	
Number of months of breastfeeding[a]			0.553		0.310
No breastfeeding	181	92.3(8.5)		54.1(7.7)	
1 to 2 months	274	92.9(8.5)		54.7(8.0)	
3 to 5 months	712	92.7(8.5)		54.8(7.9)	
≥6 months	278	91.9(7.9)		54.2(7.5)	
TV and video games (hours/week)[a]			0.199		0.736
Under 6 hours	704	92.3(8.2)		54.6(7.6)	
6 to 9 hours	605	92.9(8.7)		54.9(8.0)	
> 9 hours	485	92.6(8.5)		54.7(8.2)	
Physical Activity (hours /week) [a]			0.343		0.372
< 2 hours	861	92.9(8.5)		55.0(7.9)	
2 to 4 hours	389	92.2(8.4)		54.2(7.8)	
> 4 hours	492	92.2(8.5)		54.6(7.9)	
Change in excess weight (BMI)[b] between ages 4 and 6			<0.001		<0.001
Persistent non-excess weight	1205	91.2(7.9)		53.8(7.5)	
Persistent excess weight	290	96.9(9.3)		57.5(8.6)	
Incident	201	95.9(8.0)		56.7(7.7)	
Remission	100	90.7(7.8)		53.8(8.3)	
Change in abdominal obesity between ages 4 and 6			<0.001		<0.001

according to waist circumference[a,c]					
Persistent non-abdominal obesity	1584	91.8(8.0)		54.2(7.6)	
Persistent abdominal obesity	77	99.4(9.7)		58.3(9.8)	
Incident	80	99.6(8.6)		59.1(7.4)	
Remission	40	95.5(10.1)		57.3(10.3)	
Change in abdominal obesity between ages 4 and 6 according to waist/height ratio[a,d]			<0.001		<0.001
Persistent non-abdominal obesity	1523	91.9(8.1)		54.2(7.7)	
Persistent abdominal obesity	96	99.1(9.3)		59.1(8.5)	
Incident	84	98.3(8.3)		58.5(7.3)	
Remission	78	91.6(9.3)		53.9(8.0)	

SD: Standard Deviation

[a] Variables with missing values

[b.] Excess weight (Body Mass Index) >+1 standard deviation according to WHO-2007 reference tables

[c] Abdominal obesity: ≥90th percentile according to reference tables by Fernández et al.[17]

[d] Abdominal obesity: ≥90th percentile of waist(cm)/height (cm) ratio

Table 2. Association between general overweight-obesity and abdominal obesity at 4 years of age, and systolic and diastolic blood pressure at 6 years of age

	Systolic blood pressure (mmHg)			**Diastolic blood pressure (mmHg)**		
	Coef. β[e]	**95%CI**	**p-value**	**Coef. β[e]**	**95%CI**	**p-value**
Body Mass Index (N=1796)						
Non-excess weight	(ref)			(ref)		
Excess weight [a]	1.79	(0.71 to 2.86)	0.002	1.36	(0.15 to 2.58)	0.029
Obesity [b]	4.77	(2.85 to 6.69)	<0.001	3.08	(0.63 to 5.52)	0.015
Waist Circumference (N=1788)						
Not obese	(ref)			(ref)		
Obese [c]	4.43	(3.01 to 5.85)	<0.001	2.48	(0.56 to 4.40)	0.013
Waist-height ratio (N=1788)						
Not obese	(ref)			(ref)		
Obese [d]	2.46	(0.97 to 3.95)	0.002	1.61	(0.01 to 3.21)	0.048

[a] Excess weight (Body Mass Index) >+1 standard deviation (SD) and ≤ +2 SD according to WHO-2007 reference tables

[b] Obesity (Body Mass Index) >+2 SD according to WHO-2007 reference tables

[c] Abdominal Obesity: $\geq 90^{th}$ percentile according to reference tables by Fernández et al. [17]

[d] Abdominal Obesity: $\geq 90^{th}$ percentile of waist(cm)/height(cm) ratio

[e] β coefficients: estimated using linear regression, adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4)

Table 3. Association between persistence and variation of general overweight-obesity and abdominal obesity between the ages of 4 and 6, and systolic and diastolic blood pressure at age 6

	Systolic blood pressure (mmHg)			**Diastolic blood pressure (mmHg)**		
	Coef. β[d]	**95%CI**	**p-value**	**Coef. β[d]**	**95%CI**	**p-value**
Body Mass Index (N=1632)[a]						
Persistent non-excess weight	(ref)			(ref)		
Persistent excess weight	5.06	(3.56 to 6.56)	<0.001	3.18	(1.49 to 4.87)	0.001
Incident	4.85	(3.49 to 6.20)	<0.001	2.77	(1.69 to 3.86)	<0.001
Remission	-0.81	(-2.62 to 0.99)	0.368	0.04	(-2.10 to 2.20)	0.963
Waist Circumference (N=1612) [b]						
Persistent non-abdominal obesity	(ref)			(ref)		
Persistent abdominal obesity	7.15	(5.12 to 9.18)	<0.001	3.59	(1.13 to 6.06)	0.006
Incident	7.21	(4.18 to 10.24)	<0.001	3.80	(1.57 to 6.04)	0.002
Remission	2.78	(0.18 to 5.39)	0.037	2.43	(-0.52 to 5.38)	0.103
Waist/height ratio (N=1612)[c]						
Persistent non-abdominal obesity	(ref)			(ref)		
Persistent abdominal obesity	7.07	(4.77 to 9.36)	<0.001	4.59	(1.78 to 7.41)	0.002
Incident	6.43	(3.97 to 8.90)	<0.001	4.03	(2.10 to 5.95)	<0.001
Remission	0.30	(-1.69 to 2.31)	0.757	0.26	(-1.21 to 1.75)	0.713

[a] Excess weight (Body Mass Index) >+1 standard deviation (SD) according to WHO-2007 reference tables

[b] Abdominal Obesity: ≥90th percentile according to reference tables by Fernández et al. [17]

[c] Abdominal Obesity: ≥90th percentile of waist(cm)/height(cm) ratio

[d] β coefficients: estimated using linear regression, adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4)

Table 4. Association between general overweight-obesity and abdominal obesity at baseline (age 4), and high blood pressure at follow-up (age 6)

	High Blood Pressure					
	OR[e]	**95%CI**	**p-value**	**OR[f]**	**95%CI**	**p-value**
Body Mass Index (N=1796)						
Non-excess weight	1 (ref)			1 (ref)		
Overweight [a]	1.65	(1.16 to 2.34)	0.007	1.35	(0.93 to 1.96)	0.102
Obesity [b]	3.72	(1.85 to 7.47)	0.001	2.55	(1.24 to 5.24)	0.012
Waist Circumference (N=1788)						
Non obese	1 (ref)			1 (ref)		
Obese [c]	2.92	(1.37 to 6.22)	0.007	1.99	(1.00 to 3.95)	0.048
Waist/height ratio (N=1788)						
Non obese	1 (ref)			1 (ref)		
Obese [d]	2.00	(0.91 to 4.38)	0.079	1.33	(0.61 to 2.90)	0.475

[a] Overweight (Body Mass Index) >+1 standard deviation (SD) and ≤ +2 SD according to WHO-2007 reference tables

[b] Obesity (Body Mass Index) >+2 SD according to WHO-2007 reference tables

[c] Abdominal Obesity: ≥90th percentile according to reference tables by Fernández et al. [17]

[d] Abdominal Obesity: ≥90th percentile of waist(cm)/height(cm) ratio

[e] Odds ratios: estimated using unadjusted logistic regression

[f] Odds ratios: estimated using logistic regression adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4)

Table 5. Association between persistence and variation of general overweight-obesity and abdominal obesity between the ages of 4 and 6, and high blood pressure at age 6

	High Blood Pressure					
	OR[d]	**95%CI**	**p-value**	**OR[e]**	**95%CI**	**p-value**
Body Mass Index (N=1632)[a]						
Persistent non-excess weight	1 (ref)			1 (ref)		
Persistent excess weight	2.77	(1.37 to 5.58)	0.006	2.54	(1.27 to 5.07)	0.010
Incident	2.55	(1.46 to 4.44)	0.002	2.49	(1.50 to 4.13)	0.001
Remission	1.32	(0.54 to 3.24)	0.523	1.31	(0.50 to 3.44)	0.562
Waist Circumference (N=1612)[b]						
Persistent non-abdominal obesity	1 (ref)			1 (ref)		
Persistent abdominal obesity	4.13	(1.58 to 10.75)	0.005	3.42	(1.38 to 8.49)	0.009
Incident	3.22	(1.19 to 8.68)	0.022	2.81	(0.98 to 8.02)	0.052
Remission	1.67	(0.41 to 6.70)	0.456	1.57	(0.41 to 5.94)	0.491
Waist/height ratio (N=1612)[c]						
Persistent non-abdominal obesity	1 (ref)			1 (ref)		
Persistent abdominal obesity	3.80	(1.36 to 10.59)	0.012	3.17	(1.12 to 8.91)	0.030
Incident	3.27	(1.50 to 7.10)	0.004	3.01	(1.44 to 6.28)	0.004
Remission	0.83	(0.23 to 3.03)	0.782	0.76	(0.21 to 2.69)	0.668

[a] Excess weight (Body Mass Index) >+1 standard deviation (SD) according to WHO-2007 reference tables

[b] Abdominal Obesity: ≥90th percentile according to reference tables by Fernández et al. [17]

[c] Abdominal Obesity: ≥90th percentile of waist(cm)/height(cm) ratio

[d] Odds ratios: estimated using unadjusted logistic regression

[e] Odds ratios: estimated using logistic regression adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4)

Supplementary Table 1. Association between general overweight-obesity and abdominal obesity at 4 years of age adjusted simultaneously, and systolic and diastolic blood pressure at 6 years of age.

	Systolic blood pressure (mmHg)			Diastolic blood pressure (mmHg)		
(N=1788)	**Coef. β [c]**	**95%CI**	**p-value**	**Coef. β [c]**	**95%CI**	**p-value**
Body Mass Index						
Non-excess weight	(ref)			(ref)		
Overweight [a]	1.49	(0.39 to 2.59)	0.009	1.21	(0.02 to 2.39)	0.045
Obesity [a]	2.96	(1.13 to 4.79)	0.002	2.32	(-0.25 to 4.89)	0.076
Waist circumference						
Non-obese	(ref)			(ref)		
Obese [b]	2.75	(1.40 to 4.10)	<0.001	1.14	(-0.75 to 3.04)	0.228

[a] Overweight (Body Mass Index): >+1 standard deviation (SD); obesity: >+2 standard deviation (SD) according to WHO-2007 reference tables

[b] Abdominal Obesity: ≥90th percentile according to reference tables by Fernández et al. [17]

[c] β coefficients: estimated using linear regression, adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4). Body Mass Index and waist circumference are introduced simultaneously

Supplementary Table 2. Association between general obesity and abdominal obesity at 4 years and systolic and diastolic blood pressure at age 6

	Systolic blood pressure (mmHg)			Diastolic blood pressure (mmHg)		
(N=1788)	**Coef. β [c]**	**95%CI**	**p-value**	**Coef. β [c]**	**95%CI**	**p-value**
Body Mass Index (BMI) and waist circumference (WC)						
Non-BMI or WC-obesity	(ref)			(ref)		
BMI-obesity [a]	3.62	(0.07 to 7.17)	0.046	1.38	(-1.70 to 4.48)	0.367
WC-obesity [b]	3.98	(1.98 to 5.97)	<0.001	1.40	(-1.21 to 4.03)	0.283
BMI & WC-obesity	5.02	(2.98 to 7.07)	<0.001	3.60	(1.00 to 6.21)	0.017

[a] Obesity (Body Mass Index) >+2 standard deviation (SD) according to WHO-2007 reference tables

[b] Abdominal Obesity: ≥90th percentile according to reference tables by Fernández et al. [17]

[c] β coefficients: estimated using linear regression, adjusted for sex, age, maternal educational level, family purchasing power, hours of TV screen or video games per week, hours of physical activity per week, breastfeeding, and baseline blood pressure (age 4)