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ORIGINAL PAPER

Preliminary data on the association between waist circumference and insulin resistance in children without a previous diagnosis

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Abstract The aim of the present work was to study the association between different anthropometric parameters and insulin resistance (IR) in Spanish schoolchildren without a previous diagnosis. A total of 443 Spanish schoolchildren (9–11 years of age) were studied in this cross-sectional study. The anthropometric measurements collected were weight, height, body circumferences and skinfolds. Body mass index (BMI), waist/hip ratio, percentage body fat and fat-free body mass were determined. Overnight-fasted blood lipids, insulin and glucose levels were analysed, and estimation of IR, taking into account the homeostasis model assessment (HOMA), was calculated. The children with IR had higher serum triglycerides and insulin levels, were heavier and taller, and had a higher BMI, a larger waist circumference, a larger hip circumference, a larger waist/hip ratio and thicker bicipital and tricipital skinfolds than those who did not have IR. Age, sex, BMI and waist circumference explained 32.0% of the variance in the HOMA values; only sex, triglycerides and waist circumference independently influenced this variable. A 1-cm increase in waist circumference was associated with approximately a 3.8% increase in the mean HOMA value. The children with a waist circumference of over the p90 for their age and sex were at greater risk of showing IR as measured by the HOMA: odds ratio=6.94 (2.01–23.91; $P<0.001$). In conclusion, according to these results, waist circumference is the best anthropometric parameter associated with IR in children, and those with a waist circumference of over the p90 for their age and sex would appear to be at particular risk.

Keywords Waist circumference · Central obesity · HOMA · Children

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Introduction

Insulin resistance (IR) is a clinical condition in which the uptake of glucose by the peripheral tissues (muscles, liver and adipose tissue) is reduced owing to their loss of sensitivity to the action of insulin [5, 60].

This condition can lead to different risk factors that contribute to the onset of cardiovascular disease and diabetes mellitus type 2 [18, 19, 32]. Indeed, IR is now recognised as an important public health problem in children and adolescents [4, 32, 45, 54]. The identification of children likely to develop IR—and therefore be at high risk of developing chronic diseases—is vital if preventive campaigns are to be successful [32, 36].

A number of methods for identifying IR in children exist; however, all require blood tests and the use of needles, which can frighten children [13]. High triglycerides and low levels of HDL can be a sign of IR [36, 61]. The measurement of the glucose homeostasis index (HOMA) [27] is also an index of IR and, although it is widely used, requires the determination of glucose and insulin in night-fasted subjects; it is therefore expensive as well as invasive [56]. A simpler, faster and non-invasive method for identifying children and adolescents with IR

would therefore be of great use; anthropometric measurements may provide such a method [44, 63].

The aim of the present work was to identify the best anthropometric variable associated with IR in a group of 9–11-year-old schoolchildren without a previous diagnosis.

Materials and methods

The study was carried out in 13 schools from Madrid (Spain), and they were randomly selected from a list of all primary schools from Madrid.

Subjects

Sample recruitment

The study subjects were 556 schoolchildren aged between 9 and 11 years. The school principals were contacted by phone to arrange an interview during which the characteristics and the importance of the study were explained. Permission was requested to meet with the parents of the children in the 9–11-year-old age group. Once permission was given, the parents were explained the details of the study, and all questions were answered. Signed permission was then sought to include their children in the study. All subjects took part voluntarily.

The exclusion criteria were:

- A lack of authorization to take part or the non-acceptance of any of the conditions required for the study to proceed;
- Non-attendance on days when tests or interviews were performed; and
- Having a pathology that might modify the results, that might alter food habits (and therefore nutrient intake) or that recommended non-inclusion.

The study was approved by the Human Research Review Committee of the Pharmacy Faculty, Complutense University of Madrid.

Methods

Anthropometric survey

All measurements were made at the schools in the morning and following the norms set out by the World Health Organization [65].

Weight and height were determined using a digital electronic balance (Seca Alpha, GmbH & Co., Igni, France) (range, 0.1–150 kg; precision, 100 g) and a Harpenden digital stadiometer (Pfifter, Carlstadt, NJ, USA) (range, 70–205 cm; precision, 1 mm), respectively. For these measurements, subjects were barefoot and wore only underwear. Subject BMI was calculated as weight (kilogramme)/height^2 (square metre).

Overweight and obesity were defined using the value of BMI-specific percentiles for age and sex in the reference population as the criteria. Cut-off for overweight was 85th percentile and for obesity the 97th percentile [21, 49].

Waist and hip circumferences and tricipital skinfold were determined according to the WHO description [65]. Biceps skinfold was measured according to Lohman et al. [34].

Abdominal (waist) circumference. Children stood comfortably with their weights evenly distributed on both feet, and the feet about 25–30 cm apart. The measurement was taken midway between the inferior margin of the last rib and the crest of the ilium, in a horizontal plane. Each landmark was palpated and marked, and the midpoint was determined with a tape measure and marked. The observer sat by the side of the subject and fitted the tape not so tightly as to compress underlying soft tissues. The circumference was measured to the nearest 0.1 cm at the end of normal expiration.

Hip (buttocks) circumference. The subject stood erect with arms at the sides and feet together. The measurer sat at the side of the subject so that the level of maximum extension of the buttocks could be seen, and placed the tape measure around the buttocks in a horizontal plane. The tape was snug against the skin but did not compress the soft tissues. The measurement was recorded to the nearest 0.1 cm.

Triceps skinfold. It was measured in the midline of the posterior aspect of the arm, over the triceps muscle, at a level midway between the lateral projection of the acromion process at the shoulder and the olecranon process of the ulna (at the point of the elbow). With the elbow flexed to 90°, the midpoint was determined by measuring the distance between the two landmarks using a tape measure; it was marked on the lateral side of the arm. The calliper was held in the measurer's right hand. A vertical fold of skin and subcutaneous tissue was picked up gently with the left thumb and index finger, approximately 1 cm proximal to the marked level, and the tips of the callipers were applied perpendicular to the skinfold at the marked level. Measurements were recorded to the nearest 0.2 mm.

Biceps skinfold. It was measured in the midline of the anterior aspect of the arm, over the biceps muscle, at a level midway between the lateral projection of the acromion process at the shoulder and the olecranon process of the ulna (at the point of the elbow). With the elbow flexed to 90°, the midpoint was determined by measuring the distance between the two landmarks using a tape measure; it was marked on the lateral side of the arm. The calliper was held in the measurer's right hand. A vertical fold of skin and subcutaneous tissue was picked up gently with the

left thumb and index finger, approximately 1 cm proximal to the marked level, and the tips of the callipers were applied perpendicular to the skinfold at the marked level. Measurements were recorded to the nearest 0.2 mm.

An assistant helped to hold the tape on the side of the subject's body opposite to the measurer. The mean of the three measurements was used for analysis.

The waist/hip ratio was expressed as a decimal fraction [65]:

$$\text{waist circumference (centimetre)}/\text{hip circumference (centimetre)}$$

The percentage of body fat (%BF) was determined using the equation of Parizkova [46]:

$$\text{girls:\% BF} = 39.032Y - 30.084$$
$$\text{boys:\% BF} = 32.914Y - 21.973$$

where Y=log (sum of skinfold thicknesses: biceps+triceps)

Using the value for % BF and subject body weight, the fat mass and fat-free masses were then calculated:

$$\text{fat mass (FM) (kilogramme)} = \%\,\text{BF} \times \text{body weight (kilogramme)}/100$$
$$\text{fat free mass (FFM) (kilogramme)} = \text{body weight} - \text{FM}$$

Biochemical survey

Blood samples were drawn by venipuncture after 12 h of fasting, between 8 and 9 am. Adequacy of the fasting period was checked by nurses before blood was collected.

Fasting insulin was measured by immunochemiluminometric assay (Abbott División Diagnósticos, Spain). Glucose concentrations were determined colorimetrically using the glucose oxidase–peroxidase method (Vitros GLU Slides, Rochester, New York, USA).

The HOMA value was used to reflect the degree of IR. This was estimated from fasting plasma glucose and serum insulin concentrations using the following formula [1, 59]:

$$\text{HOMA} = [\text{fasting plasma glucose (millimol per litre)}] \times [\text{fasting serum insulin (microunit per litre)}]/22.5.$$

The HOMA cut-off point for the diagnosis of IR was taken as 3.16 [29]. Of the 556 children studied, insulin data were obtained for 444; glucose data were obtained for 502. The HOMA was determined in a total of 443 (these 443 children are the sample studied in the present study).

Triglycerides were determined by enzyme colorimetry (GPO–PAP) (C.V.=2.8%) [7]. Total cholesterol (C.V.=2.2%) and HDL cholesterol (C.V.=2.4%) were determined by the cholesterol esterase method [2], the latter after precipitation from the serum with phosphotungstic acid and magnesium ions [9]. The concentration of VLDL cholesterol was obtained mathematically from the triglyceride level (dividing this by 5) [64], and the LDL-cholesterol concentration using the formula of Friedewald et al. [15]:

$$\text{LDL} - \text{cholesterol (milligramme per decilitre)} = \text{total cholesterol} - (\text{VLDL} - \text{cholesterol} + \text{HDL} - \text{cholesterol})$$

Statistical analysis

Ranges were calculated for all variables. Ranges are given as median and interquartile range [p50 (p25–p75)]. Normality of distribution was analysed by the Kolmogorov–Smirnov test. Student t test (if the distribution of results was homogeneous) or the Mann–Whitney test (if the distribution of results was not homogeneous) was undertaken for the comparison of two variables. The $\chi 2$ test was used to compare data and to determine the significances of differences between two proportions. Two-way ANOVA was used to identify significant differences between the groups as well as any interaction effects. Non-homogeneous variables were normalized by logarithmic transformation before performing the two-way ANOVA analysis. A stepwise logistic regression analysis was performed on the data to determine the variables associated with HOMA. Logistic regression analysis was used to identify risk or protection factors, expressing the odds ratio (OR) and the 95% confidence interval (95%CI). All calculations were made using RSIGMA BABEL Software (Horus Hardward, Madrid). Significance was set at $P<0.05$.

Results

Table 1 shows age, blood and anthropometric data of the whole sample, according to sex. Boys had higher fasting glucose values than girls. Fasting glucose remained statistically significant after adjusting for BMI and age [86.0 mg/dL (80.0–91.0 mg/dL) in boys vs. 83.0 mg/dL (76.3–88.0 mg/dL) in girls; $P<0.01$].

Although there were no differences in either HOMA or insulin values according to the sex, after adjusting for BMI and age, girls showed higher HOMA [1.14 (0.68–1.65) compared to 0.85 (0.55–1.36); $P<0.05$] and insulin [5.61 UI/mL (3.51–8.13 UI/mL) compared to 4.3 UI/mL (2.8–6.4 UI/mL); $P<0.01$] values than boys (Table 1).

HOMA values increased with age and were higher in 11-year-old than in 9- and 10-year-old boys and girls (Table 1; Fig. 1).

Boys had higher waist and waist/hip ratio than girls, and girls had higher tricipital and bicipital skinfolds than boys (Tables 1 and 2). The prevalence of overweight (BMI for age and sex≥85th percentile) was 13.4%, and there were no

Table 1 Age, blood data and anthropometric data for the studied children

	Boys (n=197)	Girls (n=246)	Total (n=443)
Age (years)	10 (9–11)	10 (9–11)	10 (9–11)
Insulin (UI/mL)	4.3 (2.8–6.4)*	5.61 (3.51–8.13)*	4.93 (3.11–7.55)
Glucose (mg/dL)	86 (80–91)**	83 (76.3–88)**	85 (78–90)
HOMA	0.85 (0.55–1.36)	1.14 (0.68–1.65)	1.00 (0.63–1.56)
9 years (n=127)	0.79 (0.44–1.20)	0.91 (0.53–1.49)	0.83 (0.47–1.43)
10 years (n=136)	0.79 (0.49–1.29)	0.99 (0.57–1.45)	0.92 (0.55–1.38)
11 years (n=153)	0.96 (0.67–1.55)	1.29 (0.84–1.87)	1.14 (0.75–1.78)
Total cholesterol (mg/dL)	175.5 (159–193)	174.5 (158.3–194)	175 (159–194.8)
LDL cholesterol (mg/dL)	99 (84.8–115.3)	101 (85–118)	100 (85–118)
HDL cholesterol (mg/dL)	63.6 (55–72)	64.5 (55.3–73.0)	64.0 (55.0–73.0)
Triglycerides (mg/dL)[a]	50.5 (41–69)*	57 (45–73)*	54.5 (42–71.8)
Weight (kg)	37 (31.6–43.3)	37.2 (32.4–43.4)	37.1 (31.85–43.35)
Height (m)[a]	1.42 (1.37–1.47)	1.44 (1.37–1.50)	1.43 (1.37–1.48)
BMI (kg/m^2)[a]	18.26 (16.32–20.88)	18.0 (16.6–20.0)	18.1 (16.5–20.3)
Waist (cm)[a]	64.4 (59.08–71.55)*	62.8 (58.53–67.9)*	63.4 (58.9–69.1)
Hip (cm)	76 (70.4–81)*	77.8 (72.5–82.93)*	76.7 (71–82.25)
Waist/hip ratio	0.86 (0.84–0.89)***	0.82 (0.79–0.85)***	0.84 (0.80–0.87)
Tricipital skinfold (mm)[a]	12.4 (8.8–18.9)**	15.0 (11.0–20.4)**	14.0 (9.95–20.0)
Bicipital skinfold (mm)[a]	6.9 (4.4–9.4)**	7.6 (5.5–10.3)**	7.2 (5.0–10.0)

Values are given as median and interquartile range [p50 (p25–p75)].

[a] Non-homogeneous variable (Mann–Whitney test was undertaken to compare variables between boys and girls)
In the rest of variables Student t test was undertaken to compare boys and girls

*P<0.05; **P<0.01; ***P<0.001

differences between girls (13.8%) and boys (14.2%). The prevalence of obesity (BMI for age and sex≥97th percentile) was 12.9%, and it was higher among boys (18.8%) than in girls (8.1%) (P<0.01) (Table 1).

In 3.6% of the final 443 children, the HOMA value was >3.16; these children showed IR.

The prevalence of IR was similar in both boys and girls (eight girls [3.3%], eight boys [4.1%] NS). The children with IR showed higher serum insulin and triglycerides concentrations than those without IR (Table 2).

The children with IR were heavier and taller, and had a higher BMI, a larger waist circumference, a larger hip circumference, a larger waist/hip ratio and thicker bicipital and tricipital skinfolds than those who did not have IR (Table 2). The percentage of children with IR was greater among those suffering from overweight/obesity (9.2%) than among those of normal weight (1.2%) (P<0.01).

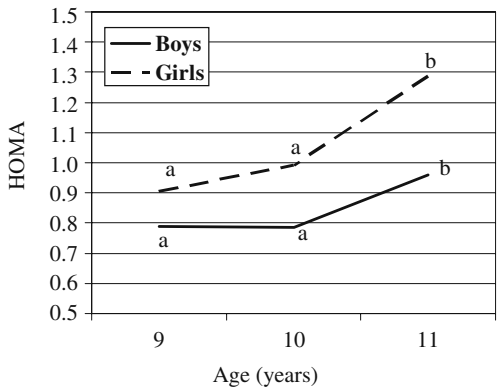

Fig. 1 HOMA values according to age and sex. *Different letters* indicate significant differences between ages. Homa values are represented as medians

Table 3 shows the results obtained in a stepwise multivariate regression analysis in a model including age, sex, triglycerides, BMI and waist circumference using the HOMA values as the dependent variable. This model explained 32.0% of the variance in the HOMA values. However, only sex, triglycerides and waist circumference were found to independently influence these values. A 1-cm increase in waist circumference was associated with an approximate 3.8% increase in the mean HOMA value. Nevertheless, it is worth mentioning that when only waist circumference was taken into account, it explained 23.6% of the variance in the HOMA values, and when triglycerides were also included in the equation, this percentage increased from 23.6% to 29.2%.

Table 3 shows that the measured variables (age, sex, BMI, triglycerides and waist circumference) were associated with the HOMA value (by 4.8%) in girls than in boys (R^2= 0.347 compared to R^2=0.299). Analysis by single sex showed that waist circumference had the highest association with the HOMA value for both sexes.

Table 4 shows the p50 and p90 for the waist circumference by sex and age. The children with a waist circumference of >p90 for their age and sex were at greater risk of IR: OR=6.94 (2.01–23.91; P<0.001). Similar results were

Table 2 Age, blood data and anthropometric results for the studied children depending on the presence of IR (measured in terms of the HOMA value)

	Children with IR			Children without IR			Two-way ANOVA
Age (years)	Boys (n=8) 10 (9.5–11)	Girls (n=8) 10 (9–11)	Total (n=16) 10 (9–11)	Boys (n=189) 10 (9–11)	Girls (n=238) 10 (9–11)	Total (n=427) 10 (9–11)	ns
Insulin (UI/mL)[a]	19.9 (16.9–22.0)	17.6 (16.9–19.4)	18.6 (16.9–20.5)	4.2 (2.7–6.1)	5.5 (3.5–7.7)	4.8 (3.1–7.2)	IR*
Glucose (mg/dL)	88.5 (85.5–93.3)	88 (79.8–89.3)	88 (83–90.5)	86 (80–91)	83 (76–88)	84 (78–90)	ns
HOMA[a]	4.4 (3.9–4.5)	3.8 (3.4–4.0)	4.0 (3.4–4.5)	0.83 (0.53–1.24)	1.08 (0.67–1.60)	0.96 (0.62–1.50)	IR*
Lipids (mg/dL)							
Total cholesterol	188 (173–208)	166 (147–172)	173 (161–191)	175 (159–192)	176 (159–196)	175 (159–154)	ns
LDL cholesterol	109 (104–118)	92.5 (80.3–98.3)	99.5 (88.3–110.3)	98.5 (83.8–115.3)	101 (85.3–119)	100 (85–118)	ns
HDL cholesterol	66.5 (55.8–70.5)	61 (48.3–63.3)	63 (51.8–67.3)	63.1 (55–72)	65 (56–73)	64 (55–73)	ns
Triglycerides[a]	86 (48.3–100.3)	73 (65.5–122.8)	81 (58.3–107)	50 (41–67.3)	56 (45–72.8)	54 (42–71)	IR*
Weight (kg)	46.3 (42.0–48.2)	52.5 (46.4–55.8)	47.1 (42.3–54.4)	36.8 (31.5–42.6)	36.6 (32.1–42.8)	36.7 (31.7–42.8)	IR*
Height (m)	1.46 (1.42–1.48)	1.52 (1.49–1.56)	1.49 (1.45–1.53)	1.42 (1.37–1.46)	1.43 (1.37–1.49)	1.42 (1.37–1.48)	IR**
BMI (kg/m^2) [a]	23.3 (19.1–24.7)	23.0 (20.6–24.0)	23.1 (20.3–24.2)	18.1 (16.3–20.7)	18.0 (16.5–19.8)	18.0 (16.4–20.1)	IR*
Waist (cm)	75.1 (68.3–80.4)	75.6 (72.6–79.3)	75.1 (71.0–80.4)	64 (59–70.6)	62.5 (58.5–67)	63 (58.5–68.8)	IR*
Hip (cm)	83.2 (78.6–86.7)	88.2 (84.2–92.3)	86 (80.3–89.0)	75 (70.2–81)	77.5 (72.0–82.3)	76.5 (71–82)	IR*
Waist/hip ratio[a]	0.89 (0.87–0.94)	0.86 (0.82–0.92)	0.88 (0.84–0.92)	0.86 (0.83–0.89)	0.81 (0.79–0.85)	0.84 (0.80–0.87)	IR***S*
Tricipital (mm)[a]	20.5 (9.8–25.3)	22.3 (19.3–27.2)	22.3 (16.5–25.9)	12.4 (8.6–18.9)	14.8 (11–20)	13.8 (9.9–19.5)	IR***S**
Bicipital (mm)[a]	11.0 (6.7–13.8)	12.4 (8.2–14.9)	12.4 (8.0–14.9)	6.8 (4.3–9.2)	7.4 (5.4–10.2)	7.1 (4.9–10.0)	IR***
BF (%)	27.1 (18.1–30.4)	30.5 (26.0–32.6)	29.4 (24.2–31.8)	20.2 (14.6–25.8)	22.2 (17.3–27.9)	21.5 (16.2–27.0)	IR***S**
FFBM (%)	72.9 (69.6–81.9)	69.5 (67.4–74.0)	70.6 (68.2–75.8)	79.8 (74.2–85.4)	77.8 (72.1–82.7)	78.5 (73.0–83.8)	IR***S**

Values are given as ranges. Range is given as median and interquartile range [p50 (p25–p75)]. Two-way ANOVA was used to identify significant differences between children with and without IR as well as any interaction effects

BF body fat, *FFBM* fat free body mass, *IR* differences with respect to presence of IR. *S* differences with respect to sex, *ns* not significant

*P<0.001; **P<0.05; ***P<0.01

[a] Non-homogeneous variable (these variables have been normalized by logarithmic transformation before performing the two-way ANOVA analysis)

Table 3 Regression results using the HOMA value as the dependent variable

	Total			Boys			Girls		
	β	Error	*P*	β	Error	*P*	β	Error	*P*
Constant	−2.877	0.502	0.000	−2.260	0.768	0.002	−2.939	0.631	0.000
Age (years)	0.050	0.044	0.258	0.058	0.072	0.422	0.044	0.056	0.430
Sex[a]	0.216	0.073	0.003	–	–	–	–	–	–
Triglycerides (mg/dL)	0.008	0.001	0.000	0.009	0.002	0.000	0.007	0.002	0.000
BMI (kg/m^2)	0.013	0.027	0.624	−0.010	0.052	0.842	0.024	0.030	0.418
Waist	0.038	0.010	0.000	0.039	0.019	0.043	0.045	0.012	0.000
R^2	0.320			0.299			0.347		
P	0.000			0.000			0.000		

β constant or intercept

[a] Only applicable for the equation involving the entire sample

obtained in both boys (OR=3.82 (0.64–22.86; $P<0.05$)) and girls (OR=12.28 (2.16–70.31; $P<0.01$)) in separate analyses and adjusting, in all cases, for triglycerides levels.

Discussion

Prevalence of overweight and obesity (13.4% and 12.9%, respectively) found in the present study was similar to the national rate observed in the enKid study (it was 12.4% and 13.9%, respectively), which was carried out from 1998 to 2000 in Spanish population from 2 to 24 years old [52]. Furthermore, like in the present study, the prevalence of obesity among boys was higher than among girls in the enKid study (15.6% vs. 12%) [52].

The percentage of children with IR in the present study agrees with that reported for schoolchildren and adolescents by other authors in other countries [12, 24, 36, 53]. The prevalence of IR was similar in girls and boys. However, after controlling for potentially confounding factors, the girls had higher HOMA values, which also agrees with that reported by others [22, 36, 40]. This might be owed to the fact that girls reach puberty before boys [23], a time of life when a reduction in insulin sensitivity is known to occur [16, 40] as a consequence of hormonal changes [41]. Hirschler et al. [23], who studied 1,009 children, observed that the mean HOMA and fasting serum insulin concentration were higher among 10.0–13.9-year-old girls than boys. However, only 8% of these girls were pre-pubertal (i.e. 92% had reached puberty) compared to 51% of the boys (i.e. only 49% had reached puberty).

In the present study, as has been reported by other authors [3, 39], children who were 9-year-old had the lowest HOMA values, and it increased with age (Table 1, Fig. 1). This finding might be explained by the lowering in insulin sensitivity associated with the onset of puberty [16, 40]. The mean HOMA values obtained in 9-year-old boys and girls were similar to those found by Allard et al. [3] (0.95 and 1.13, respectively) and Morales et al. [39] (1.09 and 1.15, respectively). Nevertheless, the values obtained in 10- and 11-year-old boys and girls were lower than that observed in other studies [8, 39], it could be due to the achievement of different pubertal stages at these ages.

Boys had higher fasting blood glucose than girls (Table 1). It agrees with that of Cao et al. [10] who found, after studying 19,593 children and adolescents aged 6 to 18 years, that blood glucose level of children was associated with age, gender (it was 4.7±0.5 mmol/L vs. 4.5±0.5 mmol/L in boys and girls, respectively; $P<0.01$) and obesity.

The onset of puberty also conditions changes in body composition. Boys develop a greater arm muscle mass and larger and stronger bones, and limb fat becomes reduced. Men and women have a similar degree of central abdominal fat, but women have a more peripheral distribution of fat in early adulthood [62]. This might explain why, in the present study, differences were found in certain anthropometric variables between the boys and girls (Tables 1, 2).

Table 4 Percentiles 50 and 90 for waist circumference (centimetre) according to age and sex

Age (years)	Boys		Girls	
	P50	P90	P50	P90
9	60.0	79.6	61.6	71.5
10	65.2	80.5	60.8	70.9
11	66.5	80.4	65.0	74.1

People with IR are hyperinsulinaemic—a consequence of increased pancreatic activity in an attempt to maintain an appropriate blood glucose concentration. Over time, this can cause the appearance of diabetes mellitus type 2 if the β cells become dysfunctional [48]. This may be why high insulin—but not glucose—concentrations were seen in the present subjects with IR.

According to the results found in the present study, triglyceridaemia has been proved to be a good predictor of IR in children [36, 42]. This parameter can be tested using low-cost portable analyzers, making it easily possible to use this measurement for the prediction of IR in children. Nevertheless, it requires the use of needles, which could frighten or terrify some children [13]. This is why anthropometric measurements might be a better method to suspect IR in this population.

The children with IR showed higher values for the entire anthropometric variables measured for assessing the level of obesity. Similar findings have been reported by other authors, who indicate a relationship to exist between the suffering of infantile obesity and the presence of IR [11, 12, 31, 36, 47, 53]. In a number of studies performed with children, it has been reported that both HOMA values and fasting insulin concentrations are positively associated with total body fat and waist circumference [31, 42, 50]. Krekouria et al. [31], who studied 27 children between 9 and 11.5 years of age, reported that both total and central adiposity (measured via the BMI and waist circumference) were positively related to the HOMA value (r=0.66; P<0.01 and r=0.69; P<0.01) after adjusting for age.

Although some studies have suggested that fat distribution may be related to the development of IR (given that many children with central obesity suffer this metabolic disorder), it has been suggested that overall adiposity may be a better marker of the problem [12, 17, 23, 33, 35, 47]. However, the results of the present work show that although BMI and waist circumference were the best anthropometric parameters related to the HOMA value (Table 3), only the waist circumference (which is a powerful marker of abdominal fat accumulation and visceral adiposity in children [6, 14, 37, 58]) was significantly associated to this index. BMI, an indicator of total body fat, [37] did not show this property. This was true for both sexes but more strongly so among girls (Table 3).

For adults of both sexes, a waist circumference cut-off value exists, above which the risk of metabolic and cardiovascular risk is greater. For children, however, sex and age tables have been developed since the waist circumference increases as children become older [22]. Table 4 shows the p50 and p90 for waist circumference for the present subjects in terms of age and sex. The values recorded are higher than those reported by Moreno et al. [43] in Spanish children, by McCarthy et al. [38] in British children, by Hatipoglu et al. [20] in Turkish children and by Inokuchi et al. [28] in Japanese children. These differences may be due to the increase in child obesity being seen around the world [51].

Defining central obesity as a waist circumference ≥p90 for age and sex [38], the children of the present study who suffered central obesity were at a greater risk of IR as measured by the HOMA. The risk for boys and girls was similar. Thus, the measurement of the waist circumference provides a rapid, inexpensive and non-invasive way of identifying the presence of IR.

Abdominal fat may be related to the appearance of IR via the former's release of adipokines, including tumour necrosis factor alpha (TNF-α) and interleukin 6 (IL-6). Via different mechanisms, these molecules may favour the appearance of IR [25, 26, 30, 55].

The study has some limitations. First, the present study suffers from the limitation that no information was recorded on the degree of sexual maturity of the children studied (Tanner stage) [57]. This could act as a confounding factor since puberty may have started in some but not all children. Second, the cross-sectional design makes it difficult to establish a cause–effect relationship. Finally, equations from Parizkova were used to calculate body fat and fat free mass percentage because only biceps and triceps skinfold were measured. If additional skinfold thickness had been measured, more precise formulae would have been used.

Conclusion

The present results show that, of the variables measured, waist circumference is the best anthropometric parameter associated with IR in children without a previous diagnosis. The children at greatest risk are those who suffer central obesity, defined as a waist circumference of ≥p90 for their corresponding age and sex.

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