European Journal of Clinical Nutrition (2017) **71,** 536–543

www.nature.com/ejcn

ORIGINAL ARTICLE

Anthropometric indicators as predictors of total body fat and cardiometabolic risk factors in Chilean children at 4, 7 and 10 years of age

FD Vásquez[1], CL Corvalán[1], RE Uauy[1,2] and JA Kain[1]

BACKGROUND/OBJECTIVE: To compare the association between anthropometric indicators of global and central obesity as predictors of total body fat (TBF) and cardiometabolic risk factors in children.

SUBJECTS/METHODS: A total of 1044 children were evaluated at 4 years ($n = 320$), 7 years ($n = 1044$) and 10 years ($n = 483$). The following anthropometric indices were determined: body mass index (BMI) for age (BAZ, WHO), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). To estimate TBF we used validated predictive equations. We measured blood sample concentrations of glucose, insulin, triglycerides, total cholesterol, Low-density lipoprotein (LDL) and High-density lipoprotein (HDL), adiponectin, C-reactive protein (CRP) and Insulin-like growth factor-1 (IGF-1).

RESULTS: Adiposity and cardiometabolic markers, particularly those related to glucose metabolism increased from 4 years to 10 years. BAZ and WC were highly correlated to body fat at all ages (all $r > 0.8$) but at 10 years WC was more strongly correlated than BAZ ($r = 0.94$ WC vs $r = 0.88$ BAZ, $P < 0.05$); conversely, WHtR was significantly associated with body fat from 7 years ($r = 0.85$) and 10 years ($r = 0.88$). WHR was unrelated all over the period studied at all ages. Anthropometrical adiposity indicators became associated to cardiometabolic markers only from 7 years on with associations being slightly higher at 10 years, particularly for adiponectin and lipid markers. At all ages, BAZ, WC and WHtR performed similarly as cardiometabolic markers ($P < 0.05$) while WHR was a slightly weaker marker.

CONCLUSIONS: Relationship between anthropometrical indicators of adiposity and cardiometabolic markers becomes stronger from 7 years onwards; BAZ, WC and WHtR perform similarly as markers of cardiometabolic risk at least until 10 years of age.

European Journal of Clinical Nutrition (2017) **71,** 536–543; doi:10.1038/ejcn.2016.213; published online 9 November 2016

INTRODUCTION

In recent decades childhood obesity has become a major global public health problem.[1,2] The prevalence of childhood obesity has increased in most countries, independent of income level, especially in urban areas.[3] In Chile, not only the prevalence of obesity is very high (25.3% in 6-year-old children), but the proportion of overweight children who develop early metabolic complications is also high.[4,5] In a study involving 3325 children (11.4 ± 1 years of age) attending Chilean public schools the metabolic syndrome (Cook definition) was present in almost 10% of overweight children (9.1%) and in almost a third of obese children (28.5%).[5] High triglycerides $\geqslant 110$ mg/dl was the most frequent metabolic abnormality (26.6%).[5]

In adults, there is convincing evidence that there is an increased likelihood of metabolic syndrome, diabetes and heart disease with increasing body mass index (BMI), particularly above the obesity cut-off.[6–8] Conversely, in children the association between obesity and cardiovascular risk is somewhat controversial. It has been suggested that childhood obesity would not have a direct effect on cardiometabolic health but rather most of the effect would be the result of adiposity tracking: however, most of from the evidence of these reviews is based on studies conducted before the advent of the obesity epidemic.[9] More recent articles, show that in 4-year-old children, there is only a weak relationship between anthropometric adiposity indicators and metabolic markers,[10–12] whereas after 7 years of age the associations seem to start to emerge when using insulin resistance, type 2 diabetes, lipid disorders, systemic inflammation or high blood pressure as outcomes.[13–16]

Moreover, BMI is a global indicator of nutritional status that does not provide information on body composition, particularly abdominal fat. Several studies in children indicate that increased body fat (BF), mostly centrally distributed, is responsible for early cardiometabolic alterations and premature mortality in adulthood.[7,16–18] Thus, anthropometric indicators that incorporate a waist measurement may be more useful in predicting cardiometabolic disease risk compared with BMI.[19–26] The skinfold thicknesses equations are also widely used to assess body fat among children and adolescents as the skinfold thicknesses provide a more direct and accurate estimate of body fat than BMI does.[27–30]

Longitudinal studies assessing relationships over a longer childhood period using several anthropometrical measurements of total and central adiposity and different cardiometabolic markers may advance our understanding of the relationships between adiposity and the appearance of cardiometabolic risk. We have followed more than 1000 low-middle income children in the Growth and Obesity Chilean Cohort Study since 4 years of age collecting anthropometrical and cardiometabolic measurements

[1]Institute of Nutrition and Food Technology (INTA), University of Chile, Santiago, Chile and [2]The London School of Hygiene and Tropical Medicine, London, UK. Correspondence: Professor JA Kain, Institute of Nutrition and Food Technology (INTA), University of Chile, 56-2-29781453, Av. El Líbano 5524, Santiago, Macul 7830490, Chile.
E-mail: jkain@inta.uchile.cl
Received 14 April 2016; revised 10 September 2016; accepted 26 September 2016; published online 9 November 2016

at different moments of childhood. Therefore, the aim of this study was to compare the association between anthropometric indicators of global and central obesity as predictors of total body fat (TBF) and cardiometabolic risk factors in 1044 children measured at 4 years ($n = 320$), 7 years ($n = 1044$) and 10 years ($n = 483$).

SUBJECTS AND METHODS

Subjects

The sample included 1044 children who participated in the Growth and Obesity Chilean Cohort Study (GOCS) at 4 years ($n = 320$), 7 years ($n = 1044$) and beginning of puberty (mean age 10 years, $n = 483$). The initial objective of the GOCS study was to evaluate the interaction between the rate of infant growth (changes in size and BMI between 0–2 years) and obesity at 4 years of age. Children who attended public day care center of the South–East area of Santiago, and those who fulfilled the inclusion criteria were as follows: singletons between >37 and $\leqslant 42$ week gestational age, of birth weight $\geqslant 2500$ g, and who were free from conditions that could affect growth, were invited to participate; final sample size was 1195 children (50% girls). For this study, we included all children who had complete anthropometric and metabolic measurements at 4 years or 7 years, or the beginning of puberty defined as the appearance of breast bud in girls and testis volume above or equal to 4 ml in boys (mean age = 10 years). Exclusion criteria included use of medications that could alter body composition or biochemical parameters of children. The Ethics Committee of the Institute of Nutrition and Food Technology (INTA), University of Chile approved the study.

Anthropometric measurements

Two nutritionists using standardized procedures measured weight, height, waist, circumference hip and triceps, biceps, subscapular and suprailiac skinfold thicknesses. Weight (kg) and height (cm) were measured in the morning. Weight was taken with children asked to wear minimal clothing (underwear only) while standing on a portable electronic scale (Seca 770, SECA, Hamburg, Germany), with capacity of 200 kg and accuracy of 10 g. Height was measured with a portable stadiometer (Harpenden 603; Holtain Ltd, Crosswell, UK) with a scale of 1–200 cm and accuracy of 0.5 cm. Waist circumference (cm) was measured over the rim of the iliac crest, through the umbilicus. Hip circumference (cm) was measured in standing position, in the widest part of the gluteal region, at the level of the greater trochanter. For both waist and hip measurements, inextensible, metal, self-locking tape (Lufkin W606PM; Cooper Tools, Raleigh, North Carolina, USA), with accuracy of 0.1 cm, was used. Skinfold thicknesses (mm) (biceps, triceps, subscapular and suprailiac) were measured with a millimeter precision Lange Caliper (1 mm), according to Lohman *et al.*[31] These skinfolds were used to determine TBF in anthropometric models. The intra-observer technical error of measurement and mean observer bias were within the limits suggested by the World Health Organization (WHO).[32]

Blood samples

A trained nurse collected a sample of fasting venous blood (25 ml) in children. Mothers were called the day before to confirm the absence of fever (>37.5 °C) or any symptom of acute infection in children as well as to remind them not to provide food or liquid to their children the following morning. These conditions were re-checked by the nurse at the time of the blood collection, and exams were rescheduled if conditions were not met. Blood samples were analyzed at the Nutrition Laboratory of the Catholic University. This laboratory conducts daily assessments of the accuracy of the measurements using quality control software (Bio-Rad Laboratories Inc, Hercules, CA, USA); and it has a Certificate of Traceability periodically updated by the Centers for Disease Control and Prevention (CDC).[33,34] Insulin-like growth factor-1 (IGF-1) concentration was measured by using a standardized locally developed radioimmunoassay requiring removal of the sample as a first step (sensitivity: 5 ng/ml; intraassay and interassay CV: 8.6 and 10.2%, respectively).[35]

Serum adiponectin determination was performed by ELISA method (BioVendor Laboratory Medicine, INC., Asheville, NC, USA). C-reactive protein (CRP) was assessed with a highly sensitive enzyme immunoassay kit (Biomerica Inc., Newport Beach, CA). Serum glucose levels were measured using enzymatic colorimetric techniques (HUMAN; Gesellschaft für Biochemical und Diagnostica, Wiesbaden, Germany) and serum insulin, with a radioimmunoassay kit (Linco Research Inc., St Charles, MO). Homeostatic model assessment of insulin resistance (HOMA-IR) was estimated as fasting glucose (mmol/l) × fasting insulin (mU/ml)/22.5. Total cholesterol and triglycerides were measured using enzymatic colorimetric techniques (HUMAN). High-density lipoprotein (HDL) cholesterol was isolated by precipitation with a solution of sodium phosphotungstate magnesium chloride.[36] Low-density lipoprotein (LDL) cholesterol was calculated according to the Friedewald formula (that is, all concentrations of triglycerides were <400 mg/dl).[37]

Anthropometric indices calculated

BMI was estimated as weight in kilograms divided by height in meters squared. Standard *z*-scores of weight for age (WAZ), height for age (HAZ) and BMI for age (BAZ) were estimated comparing these values with the WHO reference 2006[ref. 32] and 2007.[38] We defined overweight: ($1 \leqslant$ BAZ $\leqslant 2$), obesity (BAZ $>$ 2SD) and central obesity based on the NHANES 2004 Hispanic population: Boys WC $\geqslant$ 90th percentile in 4 years (57.6 cm), 7 years (67.8 cm) and 10 years (78.0 cm). Girls: WC $\geqslant$ 90th percentile in 4 years (58.3 cm), 7 years (67.5 cm) and 10 years (76.6 cm), respectively.[39] WC divided by height and hip was used to calculate the waist–height and waist–hip ratios, respectively. Triceps, biceps, subscapular and suprailiac and the abdominal, subscapular and suprailiac thicknesses were used to estimate TBF and BF trunk, respectively. To estimate the BF at 4, 7 and 10 years, we used predictive equations, calculated for Chilean children. At 4 years, the predictive equation used was: (–1.524+(0.371 × weight (kg)) +0.114 × (triceps thicknesses mm+subscapular thicknesses (mm))–(0.238 × age (years))+(0.378 × gender 1 boys, 2 girls)–(0.105 × calf circumference)).[40] At age 7 and 10 years a prediction equation previously developed in a subsample of children in the GOCS cohort (7–9 years) and validated by deuterium dilution. The equation is as follows: (1.826 × ZBMI) +(0.783 × triceps skinfold)+(0.3073 × biceps skinfold)+15.558, against 3C model ($R^2 = 0.78$).[41]

Statistical analyses

Mean values and s.d. were calculated for continuous variables and frequency distributions for categorical variables. Student's *t*-test was performed to assess differences in continuous variables and χ^2 for categorical variables.

Pearson's partial correlation coefficients were used to assess the associations of anthropometric indicators (BAZ, WC, WHR and WHtR) and cardiometabolic markers in the three different age groups of children.

Univariate linear regression analyses were performed with BF (kg) as the dependent variable and BAZ, WC, WHR and WHtR as the independent variable. In the multivariate linear regression analyses, sex and age were added to the model as independent variables. Effect modification by sex or age on BAZ, WC, WHR and WHtR was examined.

A *P*-value of <0.05 was considered statistical significant. Analyses were performed using STATA version 12.0 (StataCorp 2011 Stata Statistical Software. Release 12 College Station, TX, USA. StataCorp LP).

RESULTS

Anthropometric characteristics of the sample are shown in Table 1. Obesity and central obesity increased with age (11.9% at 4 years to 20.3% at 10 years obesity, and 11.3% at 4 years to 20.5% at 10 years central obesity); conversely, overweight prevalence decreased over the years (31.3% at 4 years to 17.6% at 10 years). At 4 years and 7 years, girls showed a statistically greater sum of four skinfold thicknesses, trunk fat, total fat and BF index compared with boys (all $P < 0.05$) whereas at 10 years boys were fatter than girls, although not all differences reached statistical significance. At 4 and 7 years, girls and boys did not differ significantly in terms of central adiposity whereas at 10 years boys were significantly more centrally obese ($P < 0.05$).

Cardiometabolic characteristics of the sample are presented in Table 2. Fasting glucose, insulin, HOMA-IR, HDL-cholesterol and TG increased with age whereas total and LDL-cholesterol decreased in the same period. IGF-1 also increased from 4 years to 7 years whereas adiponectin decreased; CRP concentrations were higher at 4 years and 10 years and lowest at 7 years of age. At 4 years, girls had higher levels of IGF-1, total cholesterol and triglycerides,

whereas at 7 years, boys had higher levels of IGF-1, adiponectin and fasting glucose. At 10 years, girls had significantly higher levels of adiponectin, however, boys had significantly higher levels of CRP, fasting glucose, LDL and total cholesterol.

Table 3 shows the associations of BF (kg) with BAZ, WC, WHR and WHtR at different ages. BAZ and WC were highly correlated to body fat at all ages (all $r > 0.8$) but at 10 years WC was more strongly correlated than BAZ ($r = 0.94$ WC vs $r = 0.88$ BAZ, $P < 0.05$); conversely, WHtR was significantly associated with body fat from 7 years on ($r = 0.85$) and 10 years ($r = 0.88$) whereas WHR was unrelated all over the period studied at all ages. Table 4 and Table 5 show the correlations between anthropometric and metabolic variables at 4, 7 and 10 years in boys and girls, respectively. At 4 years we only observed weak linear associations between BAZ and WC and IGF-1 (both sexes), and insulin and HOMA-IR (only girls). At 7 years, all anthropometrical indicators were positively associated to cardiometabolic risk factors except for the case of adiponectin, CRP and HDL-cholesterol (both sexes) and total and LDL-cholesterol (only girls). In both sexes, correlations were all weak (below 0.3) without significant differences between total and central adiposity indicators. At 10 years, all anthropometrical indicators were associated with cardiometabolic risk factors expect for IGF-1 and HDL-cholesterol (both sexes) and glucose and total-cholesterol (girls only). In boys, correlations were all weak (below 0.3) whereas in girls, correlations with insulin, HOMA-IR and TG were moderate (between 0.24 and 0.42). Total and central adiposity indicators were similarly associated to the cardiometabolic markers studied, except for WHR in boys that was a slightly weaker marker (that is, at 10 years BAZ and HOMA-IR 0.27 and WHR and HOMA-IR 0.29).

Table 1. Anthropometric characteristics in children at 4, 7 and 10 years of age

Anthropometric characteristic	*4 years* (n = *320, 54.1% boys*)			*7 years* (n = *1044, 49.6% boys*)			*10 years* (n = *483, 48.0% boys*)		
	Boys (n = *173*)	*Girls* (n = *147*)	P-*value*[a]	*Boys* (n = *518*)	*Girls* (n = *526*)	P-*value*[a]	*Boys* (n = *232*)	*Girls* (n = *251*)	P-*value*[a]
Age (years)	4.25 ± 0.3[b]	4.26 ± 0.3	0.83	6.71 ± 0.03	6.71 ± 0.1	0.99	10.29 ± 0.5	10.16 ± 0.6	0.02
Weight (kg)	17.84 ± 2.5	18.11 ± 2.8	0.36	25.42 ± 4.9	25.19 ± 4.7	0.44	41.03 ± 8.8	37.04 ± 8.3	0.00
Weight for age *z*-score	0.39 ± 1.0	0.48 ± 0.9	0.38	0.76 ± 1.2	0.75 ± 1.0	0.95	1.43 ± 1.2	0.67 ± 1.0	0.00
Height (cm)	103.82 ± 4.1	103.86 ± 4.6	0.93	121.17 ± 5.5	120.48 ± 5.4	0.03	141.97 ± 5.5	139.14 ± 5.9	0.00
Height for age *z*-score	−0.25 ± 0.9	−0.18 ± 0.9	0.54	0.14 ± 0.9	0.19 ± 0.9	0.34	0.41 ± 0.9	−0.08 ± 0.9	0.00
BMI (kg/m^2)	17.84 ± 2.5	18.11 ± 2.8	0.36	17.21 ± 2.4	17.26 ± 2.4	0.70	20.26 ± 3.6	19.02 ± 3.4	0.00
BMI-for-age *z*-score	0.82 ± 1.1	0.87 ± 1.0	0.67	0.95 ± 1.3	0.86 ± 1.1	0.25	1.30 ± 1.3	0.71 ± 1.1	0.00
Waist circumference (cm)	52.79 ± 3.7	52.78 ± 4.1	0.97	59.04 ± 6.7	59.11 ± 6.5	0.86	71.57 ± 9.8	67.32 ± 8.9	0.00
Waist-to-hip ratio	0.93 ± 0.0	0.90 ± 0.0	0.00	0.90 ± 0.0	0.89 ± 0.1	0.02	0.89 ± 0.1	0.86 ± 0.1	0.00
Waist-to-height ratio	0.51 ± 0.0	0.51 ± 0.0	0.95	0.48 ± 0.1	0.49 ± 0.1	0.24	0.50 ± 0.0	0.48 ± 0.1	0.00
Sum of four skinfold thicknesses (mm)[c]	24.80 ± 9.6	31.32 ± 12.8	0.00	26.18 ± 10.5	30.6 ± 10.8	0.00	56.65 ± 26.6	53.78 ± 24.4	0.22
Trunk fat (mm)[d]	20.53 ± 9.2	27.33 ± 12.6	0.00	23.32 ± 10.6	27.43 ± 10.6	0.00	55.27 ± 29.2	52.34 ± 26.5	0.25
Total fat (%)[e, f]	19.56 ± 3.8	22.99 ± 6.5	0.00	24.83 ± 4.9	25.85 ± 4.6	0.00	33.59 ± 8.4	31.47 ± 7.5	0.00
Body fat index (kg/m^2)	3.28 ± 1.0	3.92 ± 1.4	0.00	4.38 ± 1.6	4.56 ± 1.5	0.06	7.09 ± 3.0	6.22 ± 2.6	0.00
BMI-for-age *z*-score > 1 s.d. (% (*n*))[g]	29.5 (51)	33.3 (49)	0.68	23.5 (117)	28.3 (141)	0.38	17.7 (41)	17.5 (44)	0.99
BMI-for-age *z*-score > 2 s.d. (% (*n*))[g]	11.6 (20)	12.2 (18)	0.95	21.4 (107)	14.5 (72)	0.00	29.7 (69)	11.6 (29)	0.04
Waist circumference > 90th percentile[h]	10.4 (18)	12.2 (18)	0.60	15.8 (82)	17.7 (93)	0.42	26.7 (62)	14.7 (37)	0.00

Abbreviation: BMI, body mass index. Girls: waist circumference 90th percentile in 4, 7 and 10 years = 58.3 cm, 67.5 cm and 76.6 cm, respectively. Boys: waist circumference 90th percentile in 4, 7 and 10 years = 57.6 cm, 67.8 cm and 78.0 cm, respectively.[39] [a]Sex differences assessed by using Student's *t*-test or χ^2 test. [b]Mean ± s.d. [c]Calculated by adding biceps, triceps, suprailiac and subscapular skinfold thicknesses. [d]Calculated by adding abdominal, suprailiac and subscapular skinfold thicknesses. [e]Estimated on the basis of a predictive equation that uses age, sex, weight, calf circumference and triceps and subscapular skinfold thicknesses in 4 years. [f]Estimated on the basis of a predictive equation that uses BMIZ, biceps and triceps skinfold thicknesses in 7 and 10 years. [g]WHO 2006. World Health Organization; NHANES III. Third National Health and Nutrition Examination Survey.[32] [h]NHANES III, third National Health and Nutrition Examination Survey.

Table 2. Cardiometabolic characteristics in children at 4, 7 and 10 years of age

Cardiometabolic characteristics	*4 years* (n = *320, 54.1% boys*)			*7 years* (n = *1044, 49.6% boys*)			*10 years* (n = *483, 48.0% boys*)		
	Boys (n = *173*)	*Girls* (n = *147*)	P-*value*[a]	*Boys* (n = *518*)	*Girls* (n = *526*)	P-*value*[a]	*Boys* (n = *232*)	*Girls* (n = *251*)	P-*value*[a]
IGF-1 (ng/ml)	106.09 ± 61.0[b]	126.38 ± 57.6	0.00	188.22 ± 61.92	176.64 ± 43.2	0.00	207.69 ± 58.2	220.53 ± 60.1	0.05
Adiponectin (mg/l)	20.85 ± 5.7	21.68 ± 5.7	0.19	18.34 ± 7.2	17.50 ± 6.2	0.04	15.87 ± 7.7	18.47 ± 7.4	0.00
Fasting insulin (μU/ml)	6.33 ± 2.3	6.57 ± 2.4	0.38	5.46 ± 2.0	5.60 ± 1.7	0.24	8.14 ± 2.6	8.71 ± 3.8	0.08
C-reactive protein (mg/l)	2.64 ± 3.4	2.77 ± 3.5	0.74	1.39 ± 2.9	1.39 ± 2.1	0.99	2.65 ± 4.7	1.89 ± 2.8	0.04
Fasting glucose (mg/dl)	80.66 ± 8.6	78.34 ± 7.2	0.01	90.34 ± 6.5	89.06 ± 6.4	0.00	92.39 ± 8.7	89.36 ± 7.0	0.00
HOMA-IR	1.28 ± 0.6	1.29 ± 0.6	0.85	1.22 ± 0.6	1.23 ± 0.4	0.81	1.87 ± 0.7	1.93 ± 0.8	0.44
Total cholesterol (mg/dl)	162.47 ± 27.4	168.75 ± 26.6	0.04	165.22 ± 27.5	168.16 ± 25.7	0.08	157.53 ± 25.5	151.78 ± 28.4	0.03
LDL cholesterol (mg/dl)	109.87 ± 26.2	114.06 ± 26.0	0.16	95.75 ± 27.8	98.82 ± 25.5	0.06	88.45 ± 21.5	81.09 ± 27.9	0.00
HDL cholesterol (mg/dl)	36.99 ± 9.6	37.34 ± 9.1	0.74	50.61 ± 14.8	50.34 ± 12.6	0.74	49.67 ± 9.4	50.61 ± 10.7	0.36
Triglycerides (mg/dl)	77.94 ± 32.9	86.68 ± 34.9	0.02	94.25 ± 46.1	95.01 ± 41.5	0.78	95.74 ± 49.7	101.41 ± 49.6	0.26

Abbreviations: HDL, high-density lipoprotien; HOMA-IR, homeostatic model assessment of insulin resistance; IGF-1, Insulin-like growth factor-1; LDL, low-density lipoprotien. [a]Sex differences assessed by using Student´s *t*-test. [b]Mean ± s.d.

Table 3. Associations of body mass index for age, waist circumference, waist-to-hip ratio and waist-to-height ratio with body fat (kg) in children at 4, 7 and 10 years of age

	Body fat (kg)											
	4 years				*7 years*				*10 years*			
	B	*(95% CI)*	R^2 *model*	*Pearson r (95% CI)*	B	*(95% CI)*	R^2 *model*	*Pearson r (95% CI)*	B	*(95% CI)*	R^2 *model*	*Pearson r (95% CI)*
BAZ												
Crude	1.10	1.01 1.19	0.66*	0.81*	2.00	1.94 2.05	0.84*	0.91*	4.40	4.19 4.62	0.77*	0.88*
Gender	1.09	1.00 1.17	0.73*	0.77 0.85	2.00	1.95 2.05	0.84*	0.88 0.93	4.44	4.22 4.66	0.77*	0.85 0.90
Gender (age)	1.08	1.00 1.15	0.75*		2.00	1.95 2.05	0.86*		4.49	4.28 4.70	0.80*	
WC												
Crude	0.31	0.28 0.33	0.71*	0.84*	0.37	0.36 0.37	0.88*	0.94*	0.62	0.60 0.64	0.89*	0.94*
Gender	0.31	0.29 0.32	0.79*	0.80 0.87	0.37	0.36 0.37	0.88*	0.93 0.95	0.62	0.60 0.64	0.89*	0.93 0.95
Gender (age)	0.30	0.29 0.32	0.80*		0.37	0.36 0.37	0.88*		0.62	0.60 0.64	0.89*	
WHR												
Crude	−4.73	−8.61 −0.85	0.02**	−0.13**	9.57	7.28 11.86	0.06*	0.42	74.41	65.96 82.87	0.38*	0.62*
Gender	−1.55	−5.50 2.39	0.09*	−0.24 −0.02	9.71	7.42 12.00	0.06*	0.32 0.51	73.68	64.93 82.43	0.38*	0.56 0.67
Gender (age)	−1.03	−4.93 2.87	0.12*		9.48	7.21 11.75	0.09*		73.67	65.00 82.35	0.40*	
WHtR												
Crude	26.05	22.35 29.75	0.38*	0.62*	46.28	44.49 48.07	0.71*	0.85*	89.65	85.24 94.05	0.77*	0.88*
Gender	25.84	22.39 29.30	0.46*	0.54 0.68	46.28	44.48 48.07	0.71*	0.82 0.88	89.03	84.57 93.50	0.77*	0.85 0.90
Gender (age)	26.78	23.49 30.07	0.52*		46.22	44.50 47.94	0.74*		88.74	84.33 93.15	0.78*	

Abbreviations: BAZ, body mass index for age, WHO 2006 reference; CI, confidence interval; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio. *$P < 0.0001$, **$P < 0.01$.

DISCUSSION

In this study we found that anthropometrical adiposity indicators were unrelated to cardiometabolic risk factors at 4 years whereas at 7 years and 10 years associations became stronger and positive (insulin, CPR, glucose, HOMA-IR, total cholesterol, LDL cholesterol and triglycerides) and negative for adiponectin. We also found that during these periods total and central adiposity indicators were similarly associated to the markers studied.

BAZ and WC were highly correlated to body fat at all ages (all $r > 0.8$) but at 10 years WC was more strongly correlated than BAZ ($r = 0.94$ WC vs $r = 0.88$ BAZ, $P < 0.05$); conversely, WHtR was significantly associated with body fat from 7 years on ($r = 0.85$) and 10 years ($r = 0.88$) whereas WHR was unrelated all over the period studied at all ages. Our study show that in this cohort of children with measurements at 4, 7 and 10 years of age, the anthropometric indicators most associated with TBF were BAZ and WC. In contrast, at all ages the smallest association with BF was observed with WHR in all age groups. In this same cohort, we had already reported similar results at 4 year of age[12] but here we extend those observations to 7 years and 10 years of age using a longitudinal approach. Several studies have assessed the association between anthropometrical indicators and BF. Recently, it has been reported in a systematic review that BMI and WC are strongly correlated to BF as calculated by bioelectrical impedance or skinfolds, and that there is a moderate positive correlation with percent body fat as calculated by DEXA, air-displacement plethysmography or isotope dilution. There was a moderate positive correlation between WtHR and BF, as estimated by air-displacement plethysmography and skinfolds.[42]

A study of 2773 Australian school children between 8–16 years, whose aim was to develop WHtR cutoffs for overweight and obesity based on the 85th and 95th percentiles for BF percentage, found a positive correlation between the % BF and waist-to-height ratio (boys, $r = 0.73$ and girls $r = 0.60$, $P < 0.01$). These correlation coefficients were lower than those found in this study in the group 10–11 years ($r = 0.88$, $P < 0.01$).[43] Another study of 422 10-year-old Japanese school children, whose objective was to evaluate the validity of BMI, WC and WHtR to determine abdominal adiposity concluded that WHtR indicator shows better correlation with abdominal fat than BMI.[44]

The research in 439 Australians preschool (mean age 3.5 years), whose purpose was to assess whether WHtR was a better predictor of systolic and diastolic blood pressure than BMI, also showed that WHtR is a weak predictor of systolic and diastolic blood pressure not better than BMI.[45,46]

Similar results presented in an extensive review of 78 prospective and cross-sectional studies established that BMI, WC and WHtR are probably the best anthropometric predictors of cardiovascular disease, diabetes and related risk factors.[47]

The research of Huang *et al.*[48] in 15 000 Chinese children (6–18 year olds), whose objective was to determine the distribution characteristics of WC, WHtR and establish the WC and WHtR appropriate values on the basis of cardiovascular disease risk factor assessment. The results showed that WC and WHtR as a relatively simple inspection method, can well predict cardiovascular diseases, and be used in the conventional measuring items among students. Another cross-sectional study of 3850 German children (3–11 years) that examined the predictive capability of BMI, WC, WHtR and skinfold thickness related to cardiovascular risk factors in children, concluded that among the four-fat patterning variables an increased WtHR was the strongest predictor of cardiovascular risk factors, followed by skinfold thickness and BMI.[49]

According to the results reported by Hrafnkelsson *et al.*[50] serum fasting insulin, systolic blood pressure, HDL and glucose were strongly associated with BMI. Calcaterra *et al.* determined the prevalence of metabolic syndrome in children and adolescents ($n = 191$) with different degrees of obesity. Higher BMI *z*-score increased the prevalence of cardiometabolic risk factors and metabolic syndrome. Similar to the study conducted at 7 year of age were the values of glucose, HOMA and cardiovascular risk factors.[51] Also, Ferreira *et al.*[52] also showed similar results; increased BMI and WC were both significantly associated with metabolic abnormalities. Similarly, obese children with lower

Table 4. Pearson's correlation coefficients among anthropometric indicators and cardiometabolic markers in boys at 4, 7 and 10 years of age

	4 years				*7 years*				*10 years*			
	BAZ	*WC*	*WHR*	*WHtR*	*BAZ*	*WC*	*WHR*	*WHtR*	*BAZ*	*WC*	*WHR*	*WHtR*
IGF-1 (ng/ml)	0.28*	0.29*	−0.05	0.18*	0.29*	0.27*	0.02*	0.21*	0.12	0.13	0.10	0.12
	0.13 0.42	0.14 0.43	−0.21 0.10	0.02 0.33	0.21 0.37	0.18 0.35	−0.07 0.11	0.12 0.23	−0.05 0.27	−0.03 0.29	−0.07 0.26	−0.05 0.27
Adiponectin (mg/l)	0.13	0.02	−0.10	0.07	0.005	−0.02	−0.06	0.003	−0.13	−0.21*	−0.20*	−0.20*
	−0.03 0.27	−0.13 0.17	−0.24 0.05	−0.08 0.22	−0.08 0.09	−0.11 0.06	0.14 0.03	−0.08 0.09	−0.27 0.02	−0.34 −0.06	−0.33 −0.05	−0.33 −0.05
Fasting insulin (μU/ml)	−0.06	−0.07	−0.06	−0.11	0.25*	0.29*	0.20*	0.28*	0.25*	0.24*	0.27*	0.24*
	−0.21 0.09	−0.22 0.08	−0.21 0.09	−0.25 0.04	0.16 0.33	0.20 0.36	0.11 0.28	0.20 0.36	0.11 0.38	0.10 0.38	0.13 0.40	0.10 0.38
C-reactive protein (mg/l)	0.02	0.004	0.03	0.07	0.03	0.02	0.08	0.06	0.08	0.33*	0.28*	0.30*
	−0.13 0.17	−0.15 0.15	−0.12 0.18	−0.08 0.21	−0.13 0.19	−0.14 0.18	−0.08 0.24	−0.10 0.21	−0.07 0.22	0.20 0.46	0.14 0.41	0.16 0.42
Fasting glucose (mg/dl)	−0.13	−0.06	−0.05	−0.17*	0.21*	0.25*	0.08	0.18*	0.15*	0.17*	0.21*	0.21*
	−0.28 0.02	−0.21 0.09	−0.19 0.10	−0.31 −0.02	0.12 0.29	0.17 0.33	−0.008 0.17	0.10 0.26	0.005 0.29	0.03 0.31	0.07 0.35	0.06 0.34
HOMA-IR	−0.09	−0.08	−0.06	−0.13	0.24*	0.27*	0.18*	0.26*	0.27*	0.26*	0.29*	0.27*
	−0.24 0.06	−0.22 0.07	−0.20 0.10	−0.28 0.02	0.15 0.32	0.19 0.35	0.10 0.27	0.18 0.34	0.13 0.40	0.12 0.40	0.15 0.42	0.13 0.40
Total cholesterol (mg/dl)	0.01	−0.006	0.03	0.04	0.17*	0.19*	0.08*	0.17*	0.28*	0.29*	0.25*	0.32*
	−0.14 0.16	−0.16 0.14	−0.12 0.18	−0.11 0.19	0.08 0.25	0.10 0.27	−0.01 0.16	0.08 0.25	0.14 0.41	0.15 0.41	0.11 0.38	0.19 0.45
LDL cholesterol (mg/dl)	−0.004	−0.02	0.02	0.02	0.11*	0.11*	0.02	0.09*	0.20*	0.21*	0.20*	0.23*
	−0.15 0.15	−0.16 0.13	−0.13 0.17	−0.13 0.17	0.02 0.20	0.02 0.19	−0.07 0.11	0.005 0.18	0.05 0.33	0.06 0.34	0.05 0.33	0.09 0.37
HDl cholesterol (mg/dl)	0.04	−0.005	0.01	0.05	−0.001	0.02	0.001	0.004	0.05	0.02	−0.02	0.05
	−0.11 0.19	−0.15 0.14	−0.14 0.16	−0.09 0.20	−0.08 0.09	−0.07 0.11	−0.09 0.09	−0.08 0.09	−0.09 0.19	−0.12 0.17	−0.16 0.13	−0.10 0.19
Triglycerides (mg/dl)	0.01	0.05	0.03	0.03	0.17*	0.21*	0.16*	0.21*	0.24*	0.26*	0.23*	0.27*
	−0.14 0.16	−0.10 0.20	−0.12 0.18	−0.12 0.18	0.08 0.25	0.12 0.29	0.08 0.25	0.13 0.29	0.09 0.37	0.12 0.39	0.09 0.37	0.13 0.40

Abbreviations: BAZ, body mass index for age, WHO 2006 reference; HDL, high-density lipoprotien; HOMA-IR, homeostatic model assessment of insulin resistance; IGF-1, Insulin-like growth factor-1; LDL, low-density lipoprotien; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio. *$P \leqslant 0.001$.

Table 5. Pearson's correlation coefficients among anthropometric indicators and cardiometabolic markers in girls at 4, 7 and 10 years of age

	4 years				*7 years*				*10 years*			
	BAZ	*WC*	*WHR*	*WHtR*	*BAZ*	*WC*	*WHR*	*WHtR*	*BAZ*	*WC*	*WHR*	*WHtR*
IGF-1 (ng/ml)	0.29*	0.20*	−0.08	0.12	0.25*	0.28*	0.06	0.16*	0.15*	0.04	−0.08	0.02
	0.12 0.43	0.03 0.35	−0.24 0.09	−0.06 0.28	0.16 0.33	0.19 0.35	−0.03 0.15	0.08 0.25	0.005 0.29	−0.11 0.18	−0.22 0.07	−0.13 0.16
Adiponectin (mg/l)	0.02	−0.06	−0.08	−0.04	−0.04	−0.04	−0.09*	−0.06	−0.22*	−0.25*	−0.33*	−0.28*
	−0.14 0.18	−0.22 0.11	−0.24 0.09	−0.20 0.12	−0.12 0.05	−0.13 0.05	−0.18 −0.009	−0.15 0.03	−0.34 −0.09	−0.37 −0.12	−0.44 −0.21	−0.39 −0.15
Fasting insulin (μU/ml)	0.23*	0.18*	0.13	0.21*	0.26*	0.29*	0.16*	0.26*	0.34*	0.38*	0.24*	0.35*
	0.08 0.38	0.01 0.33	−0.03 0.29	0.05 0.36	0.18 0.34	0.21 0.37	0.08 0.25	0.17 0.34	0.22 0.45	0.26 0.49	0.11 0.36	0.23 0.46
C-reactive protein (mg/l)	−0.03	0.004	0.02	0.02	0.19*	0.22*	0.30*	0.28*	0.14*	0.18*	0.09	0.15*
	−0.19 0.13	−0.16 0.17	−0.15 0.18	−0.14 0.18	0.009 0.36	0.04 0.39	0.13 0.46	0.10 0.44	0.01 0.27	0.05 0.30	−0.04 0.22	0.02 0.28
Fasting glucose (mg/dl)	0.07	0.04	0.05	−0.008	0.18*	0.18*	0.04*	0.14*	0.21*	0.10	0.07	0.12
	−0.08 0.23	−0.12 0.20	−0.12 0.21	−0.17 0.16	0.10 0.26	0.09 0.26	−0.05 0.13	0.05 0.23	0.08 0.33	−0.03 0.23	−0.07 0.20	−0.01 0.25
HOMA-IR	0.20*	0.15	0.13	0.17*	0.28*	0.31*	0.16*	0.27*	0.37*	0.39*	0.25*	0.37*
	0.04 0.35	−0.02 0.30	−0.03 0.29	0.01 0.33	0.20 0.36	0.23 0.39	0.07 0.25	0.18 0.35	0.25 0.48	0.28 0.50	0.13 0.37	0.25 0.48
Total cholesterol (mg/dl)	0.06	−0.06	−0.12	−0.01	0.06	0.03	0.007	0.06*	0.08	0.16*	0.14*	0.15*
	−0.11 0.22	−0.22 0.09	−0.28 0.04	−0.18 0.15	−0.03 0.14	−0.06 0.11	−0.08 0.09	−0.03 0.15	−0.05 0.21	0.03 0.29	0.005 0.26	0.02 0.28
LDL cholesterol (mg/dl)	0.07	−0.05	−0.11	0.02	0.01	−0.02	−0.03	0.02	0.002	0.08	0.04	0.06
	−0.09 0.23	−0.21 0.11	−0.26 0.06	−0.15 0.18	−0.08 0.10	−0.10 0.07	−0.12 0.06	−0.07 0.10	−0.13 0.13	0.12 0.40	−0.09 0.18	−0.07 0.19
HDL cholesterol (mg/dl)	−0.13	−0.10	−0.05	−0.14	−0.06	−0.06	−0.03	−0.06	−0.10	−0.11	−0.11	−0.10
	−0.28 0.04	−0.26 0.06	−0.21 0.11	−0.30 0.02	−0.15 0.03	−0.15 0.03	−0.12 0.06	−0.15 0.03	−0.23 0.03	−0.24 0.02	−0.24 0.02	−0.23 0.03
Triglycerides (mg/dl)	0.12	0.07	−0.002	0.07	0.24*	0.22*	0.16*	0.23*	0.38*	0.42*	0.41*	0.40*
	−0.04 0.28	−0.09 0.23	−0.16 0.16	−0.09 0.23	0.15 0.32	0.14 0.31	0.07 0.24	0.15 0.31	0.26 0.49	0.30 0.52	0.30 0.52	0.28 0.50

Abbreviations: BAZ, body mass index for age, WHO 2006 reference; HDL, high-density lipoprotien; HOMA-IR, homeostatic model assessment of insulin resistance; IGF-1, Insulin-like growth factor-1; LDL, low-density lipoprotien; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio. *$P \leqslant 0.001$.

insulin sensitivity had higher mean values of waist circumference and BAZ.[53,54]

In conclusion, the relationship between anthropometrical indicators of adiposity and cardiometabolic markers becomes stronger from 7 years onwards; BAZ, WC and WHtR perform similarly as markers of cardiometabolic risk at least until 10 years of age.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This research was funded by FONDECYT (Postdoctoral Grant no. 3140344), FONDECYT (Grant no. 1090252), FONDECYT (Grant no. 1120326) and World Cancer Research Fund 2010/245.

REFERENCES

1 Popkin BM, Adair LS, Ng SW. NOW AND THEN: the global nutrition transition: the pandemic of obesity in developing countries. *Nutr Rev* 2012; **70**: 3–21.
2 Fergusson D, Webb E, Janson S. Burden and consequences of child maltreatment in high-income countries. *Lancet* 2009; **373**: 68–81.
3 Wang Y, Chen X, Klag MJ, Caballero B. Epidemic of childhood obesity: implications for kidney disease. *Adv Chronic Kidney Dis* 2006; **13**: 336–351.
4 National Council for School Assistance. Map Nutritional 2014. Available at: URL http://bpt.junaeb.cl:8080/MapaNutricionalGx/.accessed on 23 January 2015.
5 Mardones F, Arnaiz P, Barja S, Giadach C, Villarroel L, Domínguez A *et al*. Nutritional status, metabolic syndrome and insulin resistance in children from Santiago (Chile). *Nutr Hosp* 2013; **28**: 1999–2005.
6 Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. The Evidence Report. National Institutes of Health. *Obes Res* 1998; **6S**: 51S–209S.
7 Geib HC, Parhofer KG, Schwandt P. Parameters of childhood obesity and their relationship to cardiovascular risk factors in healthy prepubescent children. *Int J Obes* 2001; **25**: 830–837.
8 Demerath EW, Reed D, Rogers N, Sun SS, Lee M, Choh AC *et al*. Visceral adiposity and its anatomical distribution as predictors of the metabolic syndrome and cardiometabolic risk factor levels. *Am J Clin Nutr* 2008; **88**: 1263–1271.
9 McMullen S. Childhood obesity: the impact on long-term risk of metabolic and CVD is not necessarily inevitable. *Proc Nutr Soc* 2014; **73**: 389–396.
10 Voss LD, Metcalf BS, Jeffery AN, Wilkin TJ. IOTF thresholds for overweight and obesity and their relation to metabolic risk in children (EarlyBird 20). *Int J Obes (Lond)* 2006; **30**: 606–669.
11 Garemo M, Palsdottir V, Strandvik B. Metabolic markers in relation to nutrition and growth in healthy 4-y-old children in Sweden. *Am J Clin Nutr* 2006; **84**: 1021–1026.
12 Corvalán C, Uauy R, Kain J, Martorell R. Obesity indicators and cardiometabolic status in 4-y-old children. *Am J Clin Nutr* 2010; **91**: 166–174.
13 Adair LS, Gordon-Larsen P, Du SF, Zhang B, Popkin BM. The emergence of cardiometabolic disease risk in Chinese children and adults: consequences of changes in diet, physical activity and obesity. *Obes Rev* 2014; **15**: 49–59.
14 Ali O, Cerjak D, Kent Jr JW, James R, Blangero J, Zhang Y. Obesity, central adiposity and cardiometabolic risk factors in children and adolescents: a family-based study. *Pediatr Obes* 2014; **9**: e58–e62.
15 Díez-Fernández A, Sánchez-López M, Gulías-González R, Notario-Pacheco B, Cañete García-Prieto J *et al*. BMI as a mediator of the relationship between muscular fitness and cardiometabolic risk in children: a mediation analysis. *PLoS One* 2015; **10**: e0116506.
16 Warolin J, Coenen KR, Kantor JL, Whitaker LE, Wang L, Acra SA *et al*. The relationship of oxidative stress, adiposity and metabolic risk factors in healthy Black and White American youth. *Pediatr Obes* 2014; **9**: 43–52.
17 Goran MI, Alderete TL. Targeting adipose tissue inflammation to treat the underlying basis of the metabolic complications of obesity. *Nestle Nutr Inst Workshop Ser* 2012; **73**: 49–60.
18 Dulloo AG, Montani JP. Body composition, inflammation and thermogenesis in pathways to obesity and the metabolic syndrome: an overview. *Obes Rev* 2012; **13S**: 1–5.
19 Lee CM, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. *J Clin Epidemiol* 2008; **61**: 646–653.
20 Gelber RP, Gaziano JM, Orav EJ, Manson JE, Buring JE, Kurth T. Measures of obesity and cardiovascular risk among men and women. *J Am Coll Cardiol* 2008; **52**: 605–615.
21 Freedman DS, Kahn HS, Mei Z, Grummer-Strawn LM, Dietz WH, Srinivasan SR *et al*. Relation of body mass index and waist-to-height ratio to cardiovascular disease risk factors in children and adolescents: The Bogalusa heart study. *Am J Clin Nutr* 2007; **86**: 33–40.
22 Maffeis C, Banzato C, Talamini G. Waist-to-height ratio, a useful index to identify high metabolic risk in overweight children. *J Pediatr* 2008; **152**: 207–213.
23 Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N *et al*. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *Int J Obes Relat Metab Disord* 2000; **24**: 1453–1458.
24 Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *J Pediatr* 2005; **146**: 482–488.
25 Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. Risk factors and adult body mass index among overweight children: the Bogalusa heart study. *Pediatrics* 2009; **123**: 750–757.
26 Arnaiz P, Marín A, Pino F, Barja S, Aglony M, Navarrete C *et al*. Waist height ratio, ultrasensitive c reactive protein and metabolic syndrome in children. *Rev Med Chil* 2010; **138**: 1378–1385.
27 Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. *Am J Clin Nutr* 1999; **70**: 1090–1095.
28 Bray GA, DeLany JP, Volaufova J, Harsha DW, Champagne C. Prediction of body fat in 12-y-old African American and white children: evaluation of methods. *Am J Clin Nutr* 2002; **76**: 980–990.
29 Steinberger J, Jacobs DR, Raatz S, Moran A, Hong CP, Sinaiko AR. Comparison of body fatness measurements by BMI and skinfolds vs dual energy X-ray absorptiometry and their relation to cardiovascular risk factors in adolescents. *Int J Obes* 2005; **29**: 1346–1352.
30 Bigornia SJ, LaValley MP, Benfield LL, Ness AR, Newby PK. Relationships between direct and indirect measures of central and total adiposity in children: what are we measuring? *Obesity (Silver Spring)* 2013; **21**: 2055–2062.
31 Lohman TG, Boileau RA, Slaughter RA. *Human Body Composition*. In: Lohman TG (ed). Human Kinetics: New York, NY, USA, 1984, pp 29–57.
32 World Health Organization. *WHO child growth standards: methods and development: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age*. WHO: Geneva, Switzerland, 2006.
33 Myers GL, Kimberly MM, Waymack PP, Smith SJ, Cooper GR, Sampson EJ. To reference method laboratory network for cholesterol: a model for standardization and improvement of clinical laboratory measurements. *Clin Chem* 2000; **46**: 1762–1772.
34 Centers for Disease Control and Prevention. Clinical laboratory measurements traceable to the National Reference System for cholesterol. *MMWR Morb Mortal Wkly Rep* 1994; **43**: 149–151.
35 Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; **320**: 1240–1243.
36 Seigler L, Wu WT. Separation of serum high-density lipoprotein cholesterol for determination: ultracentrifugation vs precipitation with sodium phosphotungstate and magnesium chloride. *Clin Chem* 1981; **27**: 838–841.
37 Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem* 1972; **18**: 499–502.
38 De Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; **85**: 660–667.
39 Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and the american-arabs children and adolescents. *J Pediatr* 2004; **145**: 439–444.
40 Velásquez M, Salazar G, Vio F, Díaz N, Anziani A. Validation of equations to assess body composition using anthropometric data in Chilean preschool children. *Rev Med Chil* 2008; **136**: 433–441.
41 Aguirre CA, Salazar GD, Lopez de Romaña DV, Kain JA, Corvalán CL, Uauy RE. Evaluation of simple body composition methods: assessment of validity in prepubertal Chilean children. *EJCN* 2015; **69**: 269–273.
42 Jensen NS, Camargo TF, Bergamaschi DP. Comparison of methods to measure body fat in 7-to-10-year-old children: a systematic review. *Public Health* 2016; **133**: 3–13.

43 Nambiar S, Hughes I, Davies PS. Developing waist-to-height ratio cut-offs to define overweight and obesity in children and adolescents. *Public Health Nutr* 2010; **13**: 1566–1574.

44 Fujita Y, Kouda K, Nakamura H, Iki M. Cut-off values of body mass index, waist circumference, and waist-to-height ratio to identify excess abdominal fat: population-based screening of Japanese school children. *J Epidemiol* 2011; **21**: 191–196.

45 Bo Campagnolo PD, Hoffman DJ, Vitolo MR. Waist-to-height ratio as a screening tool for children with risk factors for cardiovascular disease. *Ann Hum Biol* 2011; **38**: 265–270.

46 Whitrow MJ, Moore VM, Davies MJ. Waist-to-height ratio is not a predictor of systolic blood pressure in 3-year-old children. *J Pediatr* 2011; **159**: 501–503.

47 Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. *Nutr Res Rev* 2010; **23**: 247–269.

48 Huang R, Su Z, Zhao Z, Kong W, Mai Y, She W. Diagnosis boundary values of metabolic syndrome obesity index for Children and adolescents. *Zhong Nan Da Xue Xue Bao Yi Xue Ban* 2014; **39**: 718–722.

49 Haas GM, Liepold E, Schwandt P. Predicting cardiovascular risk factors by different body fat patterns in 3850 German children: the PEP Family Heart Study. *Int J Prev Med* 2011; **2**: 15–19.

50 Hrafnkelsson H, Magnusson KT, Sigurdsson EL, Johannsson E. Association of BMI with insulin and fasting for cardiovascular disease risk factors in seven-year-old Icelandic children. *Scand J Prim Health Care* 2009; **27**: 186–191.

51 Calcaterra V, Klersy C, Muratori T, Telli S, Caramagna C, Scaglia F *et al.* Prevalence of metabolic syndrome (MS) in children and adolescents with varying degrees of obesity. *J Clin Endocrine (Oxf)* 2008; **68**: 868–872.

52 Ferreira AP, Ferreira C, Brito C, Gondim F, Moraes C, Ships L *et al.* Prediction of metabolic syndrome in children through anthropometric indicators. *Arq Bras Cardiol* 2011; **96**: 121–125.

53 Burrows R, Leiva L, Weisstaub G. Metabolic syndrome in children and adolescents: association with insulin sensitivity and magnitude and distribution of obesity. *Rev Med Chil* 2007; **135**: 174–181.

54 Burrows R, Burgueño M, Leiva L, Ceballos X, Guillier I, Gattas V *et al.* Cardiovascular risk and metabolic profile in obese children and adolescents with low insulin sensitivity. *Rev Med Chil* 2005; **133**: 795–804.