

Waist:height ratio, waist circumference and metabolic syndrome abnormalities in Colombian schooled adolescents: a multivariate analysis considering located adiposity

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Very few large studies in Latin America have evaluated the association between waist:height ratio (W-HtR) and cardiometabolic risk in children and adolescents. Further, multivariable analyses verifying the independence of located subcutaneous fat have not been conducted so far. The aim of this study was to evaluate the associations of W-HtR and waist circumference (WC) with metabolic syndrome abnormalities and high LDL-cholesterol levels in schooled adolescents before and after adjusting for trunk skinfolds and BMI. The sample consisted of 831 boys and 841 girls aged 10–17 years. Biochemical, blood pressure and anthropometrical variables were measured. Age- and sex-specific quartiles of W-HtR and WC were used in Poisson regression models to evaluate the associations. High WC values (highest quartile *v.* quartiles 1–3) were associated with high TAG levels in both sexes (prevalence ratio, boys: 2.57 (95% CI 1.91, 3.44); girls: 1.92 (95% CI 1.49, 2.47); $P < 0.05$), and with high blood pressure specifically in female adolescents (3.07 (95% CI 1.58, 5.98); $P < 0.05$), independently of trunk skinfolds or BMI ($P < 0.05$). Associations of high WC with high fasting glucose (boys), low HDL-cholesterol and having at least two abnormalities did not remain significant in most of the adjustments for trunk skinfolds or BMI ($P > 0.05$). High W-HtR (highest quartile *v.* quartiles 1–3) was only independently associated with high TAG in female adolescents (1.99 (95% CI 1.55, 2.56); $P < 0.05$). In conclusion, WC showed better association with cardiometabolic risk than W-HtR in the children of this study. This observation does not support W-HtR as a relevant adiposity marker for cardiovascular and metabolic risk in adolescence.

Key words: Waist:height ratio: Cardiovascular risk: Children: Adolescents

At present, childhood obesity represents a challenge for healthcare providers as it has been widely shown that general and abdominal fat are significantly associated with the development of ischaemic cardiac events⁽¹⁾, type 2 diabetes mellitus in adults⁽²⁾ and risk prediction of cardiometabolic disease in children and adolescents⁽³⁾. Obesity is considered as a state of sub-clinical inflammation characterised by the secretion of cytokines that promote atherosclerotic plaque formation and consequent endothelial dysfunction⁽⁴⁾. Consequently, it has been necessary to develop diagnostic tools for early detection of obesity in the paediatric population as a public health prevention strategy. BMI and waist circumference (WC) have been widely used as measures to evaluate the impact of obesity on the risk for cardiometabolic diseases in children⁽⁵⁾.

There has been a growing interest in the waist:height ratio (W-HtR) as an adiposity index, with two recent meta-analyses

showing that W-HtR has a greater predictive ability of cardiovascular and metabolic risk than classic anthropometric indicators^(6,7). A W-HtR ≥ 0.50 has been proposed as the cut-off point for predicting the risk for CVD and diabetes⁽⁸⁾. In addition, some authors state that W-HtR can be the most useful clinical tool for the global detection of abdominal obesity and cardiometabolic risk screening in children and adults⁽⁹⁾. However, very few large studies have evaluated the association between W-HtR and cardiometabolic risk in children and adolescents in Latin America. Moreover, multivariate analyses verifying whether this association is independent of located subcutaneous fat have not been conducted so far. The aim of the present study was to evaluate the association of W-HtR and WC with metabolic syndrome (MetS) abnormalities and high LDL-cholesterol in schooled adolescents by considering adjustments for trunk skinfolds and also BMI.

Abbreviations: MetS, metabolic syndrome; SS, subscapular skinfold; W-HtR, waist:height ratio; WC, waist circumference.

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Methods

The study's sample consisted of individuals from a cross-sectional study, the IFRECNTEC Study (identification of risk factors for adult non-communicable chronic disease in schooled population), conducted in Cali, Colombia⁽¹⁰⁾. The IFRECNTEC Study evaluated a sample of 2807 subjects aged 5–18 years. Our analysis excluded children aged <10 years (n 628), adult individuals (≥ 18 years, n 91) and cases with missing values for the study variables (n 416). The final remaining sample consisted of 1672 adolescents. Informed written consent was obtained from both the parent and the child. The study was reviewed and approved by the Ethics Committee at Universidad del Valle.

Blood was collected via venepuncture after an overnight fast. Concentrations of fasting glucose, total cholesterol, HDL-cholesterol and TAG were determined using enzymatic-colorimetric assays. LDL-cholesterol level was estimated using the Friedwald equation⁽¹¹⁾. Blood pressure was measured using mercury sphygmomanometers with an appropriately sized cuff in a sitting position after 15 min of rest. Phase I and V (disappearance) Korotkoff sounds were used to identify systolic blood pressure (SBP) and diastolic blood pressure (DBP)⁽¹²⁾. Body weight and height were measured using standard techniques and instruments⁽¹³⁾. BMI was calculated as weight/height²⁽¹⁴⁾. WC was measured from the midpoint between the lateral iliac crest and the lowest rib using a flexible steel tape measure⁽¹⁵⁾. W-HtR was calculated as WC divided by height. The subscapular skinfold (SS), abdominal skinfold (AS) and supra-iliac skinfold (SIS) were measured using skinfold calipers in the specific locations⁽¹³⁾.

Metabolic syndrome abnormalities and high LDL-cholesterol

We used the abnormalities of MetS according to the criteria by Cook *et al.* for paediatrics as follows^(16,17): high levels of TAG as levels ≥ 110 mmol/l, low HDL-cholesterol as levels ≤ 40 mmol/l and high blood pressure as SBP and/or DBP at or above the 90th percentile for age, sex and height according to the National Heart, Lung, and Blood Institute tables⁽¹⁸⁾. However, for high fasting glucose, we avoided using Cook *et al.*'s cut-off point of glucose as ≥ 110 mmol/l, as even the current adult guidelines recommend lower cut-off points. Therefore, we adopted the criterion from the International Diabetes Federation definition, which suggests high glucose levels as values ≥ 100 mmol/l⁽¹⁹⁾. In addition, high levels of LDL-cholesterol were also studied and defined as values ≥ 130 mmol/l⁽²⁰⁾. A clustering of two or more of the variables mentioned above was similarly evaluated.

Data analyses

As most of the variables presented an abnormal distribution, medians and their interquartile ranges were used for the description of the study population by sex, and difference between these groups was estimated via the Mann–Whitney U test. Values of WC and W-HtR were evaluated as age- and sex-specific quartiles. In each sex, Poisson regressions were

performed to assess associations of highest quartiles of WC and W-HtR with MetS components and high LDL-cholesterol and with the fact of having two or more of these abnormalities. Each association was adjusted for the highest quartiles (also age- and sex-specific) of each trunk skinfold and BMI in separated models. Additional adjustment for age (continuous) was also evaluated. However, this covariate did not modify the effect estimates from unadjusted and adjusted models, presumably due to stratification by age in quartiles of WC, W-HtR, trunk skinfolds and BMI. All the analyses were processed using STATA 8.0 software (Statistics/Data Analysis, Stata Corp.).

Results

Study variables are described by sex in Table 1. Boys had higher values of WC and W-HtR, as well as higher prevalence of high fasting glucose and blood pressure. The prevalence of high levels of TAG and values of all the skinfold thickness measurements were higher in girls. There were no differences by sex regarding the prevalence of the cluster of abnormalities (≥ 2) or overweight/obesity. An additional description of the study variables by age groups is shown in online Supplementary Table S1. Overall, the number of male and female adolescents in each age group was comparable. All the biochemical variables tended to decrease across age groups, whereas blood pressure and all the anthropometrical variables tended to increase with age.

The highest quartile of WC (*v.* the other quartiles) was positively associated with high levels of TAG in all the adjustment models for both sexes (Table 2), and with high blood pressure in female adolescents. In girls, having at least two abnormalities was significantly associated with high WC before and after adjusting for each trunk's skinfold but not when adjusting for BMI. In boys, significant associations between high WC and high fasting glucose and low HDL-cholesterol were no longer significant in most of the adjustments for adiposity markers (Table 2). In girls, a significant association between high WC and low HDL-cholesterol was attenuated when SS or BMI scores were covariates in the regression models. Unexpectedly high WC became inversely associated with high fasting glucose in the SS-adjusted model and with high LDL-cholesterol in the BMI-adjusted model (Table 2).

The highest quartile of W-HtR (*v.* the other quartiles) was positively and significantly associated with high levels of TAG, despite adjustments for trunk's skinfolds and BMI in girls, whereas in boys this association was attenuated after adjustments, except in the SIS-adjusted model (Table 3). In both sexes, a significant relationship between having at least two abnormalities and high W-HtR was lost after adjusting for SS, SIS or BMI. In girls, an initial significant association between high W-HtR and low HDL-cholesterol did not remain significant after further adjustment for other adiposity markers (Table 3).

Discussion

In the present study, we evaluated the association between WC and W-HtR and cardiovascular risk factors. In addition, we



Table 1. Description of the study population (Medians and their interquartile ranges, number of subjects and percentages)

	Boys		Girls		P
	n	%	n	%	
n	831		841		
Age (years)					
Median	14.2		13.9		0.120
Interquartile range	12.4–16		12.3–16		
WC (cm)					
Median	67		63.5		<0.001
Interquartile range	62–71.5		59–68		
Waist:height ratio					
Median	0.42		0.41		<0.001
Interquartile range	0.40–0.44		0.39–0.44		
Metabolic syndrome components and high LDL-cholesterol					
Glucose \geq 100 mmol/l	50	6.0	23	2.7	0.001
HDL-cholesterol \leq 40 mmol/l	256	30.8	245	29.1	0.455
TAG \geq 110 mmol/l	140	16.8	183	21.8	0.011
SBP and/or DBP \geq 90th percentile	103	12.4	33	3.9	<0.001
LDL-cholesterol \geq 130 mmol/l	89	10.7	142	16.9	<0.001
\geq 2 abnormalities	144	17.3	153	18.2	0.644
Skinfold thickness					
Subscapular (cm)					
Median	9.5		13		<0.001
Interquartile range	7.0–12.0		10–17		
Abdominal (cm)					
Median	12		20		<0.001
Interquartile range	9.0–19		15–25		
Supra-iliac (cm)					
Median	9.0		15		<0.001
Interquartile range	7.0–15		10–21		
Overweight/obesity					
BMI > 85th percentile	123	14.8	120	14.3	0.757

WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.

assessed whether these associations were independent of located subcutaneous adiposity and BMI. High WC values were found to be consistently and independently associated with high TAG levels in both sexes, and with high blood pressure specifically in female adolescents. The W-HtR was scarcely associated with MetS components, although it was independently associated with high TAG levels in female adolescents.

WC – but not W-HtR – was significantly and independently associated with high blood pressure in our study, and previous studies have presented conflicting results. Mirmiran *et al.*⁽²¹⁾ reached similar conclusions in 134 Iranian adolescents (10–18 years old). Moreover, two studies with Mexican and Dutch children reported associations with both adiposity markers, but WC was better associated with high blood pressure than W-HtR^(22,23). In addition, W-HtR was deemed unsuitable as a screening tool for high blood pressure in German adolescents aged 11–17 years⁽²⁴⁾, and Bailey *et al.*⁽²⁵⁾ did not find any association between WC and W-HtR and SBP in 234 British children aged 10–19 years. Likewise, these associations have also been inconclusive in adults. For instance, although Li *et al.*⁽²⁶⁾ and Park *et al.*⁽²⁷⁾ found a stronger association of blood pressure with W-HtR than with WC in Asian adult populations, Valenzuela and Bustos reported comparable associations with both adiposity markers in young Chilean adults⁽²⁸⁾.

High WC values were found to be consistently and independently associated with high levels of TAG in both sexes. This finding is in line with studies by Sijtsma *et al.*⁽²³⁾ and

Harrington *et al.*⁽²⁹⁾, who reported significant positive associations between WC and TAG in pre-pubertal and pubertal children. This finding was also related to WC as a good predictive factor of hypertriglyceridaemia in a sample of 41 087 adults⁽³⁰⁾. In this study, we have extended the knowledge about this relationship by finding it to be independent of other adiposity markers.

Previous studies have reported associations between high levels of TAG and W-HtR in paediatric populations. Graves *et al.*⁽³¹⁾ reported a prospective association between W-HtR in childhood and cardiometabolic outcomes in adolescents, with an increased risk in boys. A cross-sectional study by Balas-Nakash *et al.*⁽²²⁾ describes a similar finding, adjusting for age, sex, physical activity, hours per week of television, video games or computer, energy consumption and percentage of dietary lipids. In contrast, this association was NS in an unadjusted analysis carried out by Feliciano Pereira *et al.*⁽³²⁾, and in another study WC was found to be more strongly related to the levels of TAG than W-HtR⁽²¹⁾, adjusting for sex and physical activity. Our study, with regard to the relationship between W-HtR and high TAG levels, is in line with most of the studies mentioned above based on associations not adjusted for other adiposity markers. However, a sex-specific relationship was evident, as only in the female adolescents the association remained significant, despite adjustment for skinfolds or BMI.

High LDL-cholesterol was the abnormality less associated with WC and W-HtR in the adolescents from our study, even in

Table 2. Prevalence ratios for metabolic syndrome components and high LDL-cholesterol by age- and sex-specific quartiles (Q) of waist circumference (highest quartile v. quartiles 1–3) in the adolescents (Prevalence ratios and 95 % confidence intervals)

	Q1–Q3	Q4 unadjusted		Q4 adjusted for Q4 of AS		Q4 adjusted for Q4 of SS		Q4 adjusted for Q4 of SIS		Q4 adjusted for Q4 of BMI		
		Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	
Boys												
High fasting glucose	1.0	1.87*	1.08, 3.24	1.58	0.77, 3.23	2.00*	1.03, 3.89	1.75	0.88, 3.48	1.11	0.41, 2.99	
Low HDL-cholesterol	1.0	1.33*	1.07, 1.65	1.17	0.90, 1.53	1.11	0.83, 1.47	1.19	0.90, 1.56	1.21	0.89, 1.65	
High LDL-cholesterol	1.0	1.12	0.72, 1.75	0.77	0.44, 1.34	0.92	0.53, 1.62	1.01	0.62, 1.65	1.10	0.60, 2.01	
High TAG	1.0	2.57*	1.91, 3.44	1.87*	1.26, 2.77	1.82*	1.19, 2.78	2.07*	1.39, 3.10	1.95*	1.16, 3.27	
High blood pressure	1.0	1.64*	1.12, 2.38	1.88*	1.15, 3.08	1.38	0.87, 2.21	1.54	0.95, 2.48	0.91	0.56, 1.47	
≥2 abnormalities	1.0	2.05*	1.53, 2.76	1.44	0.99, 2.10	1.39	0.94, 2.06	1.60*	1.09, 2.33	1.28	0.82, 1.99	
Girls												
High fasting glucose	1.0	0.43	0.13, 1.44	0.39	0.10, 1.49	0.23*	0.05, 0.88	0.26	0.07, 1.02	0.58	0.13, 2.42	
Low HDL-cholesterol	1.0	1.59*	1.28, 1.96	1.37*	1.01, 1.70	1.16	0.90, 1.51	1.33*	1.04, 1.70	1.14	0.86, 1.52	
High LDL-cholesterol	1.0	1.09	0.78, 1.53	0.96	0.64, 1.42	0.92	0.62, 1.35	1.09	0.73, 1.62	0.61*	0.40, 0.93	
High TAG	1.0	1.92*	1.49, 2.47	1.58*	1.16, 2.14	1.57*	1.16, 2.12	1.61*	1.20, 2.16	1.52*	1.08, 2.13	
High blood pressure	1.0	3.07*	1.58, 5.98	2.50*	1.11, 5.59	2.90*	1.45, 5.79	3.05*	1.37, 6.79	3.47*	1.49, 8.08	
≥2 abnormalities	1.0	1.97*	1.48, 2.61	1.58*	1.11, 2.24	1.49*	1.05, 2.10	1.55*	1.10, 2.18	1.35	0.93, 1.97	

AS, abdominal skinfold; SS, subscapular skinfold; SIS, supra-iliac skinfold.
* Significant associations ($P < 0.05$).

Waist:height ratio and metabolic syndrome

Table 3. Prevalence ratios for metabolic syndrome components and high LDL-cholesterol by age- and sex-specific quartiles (Q) of waist:height ratio (highest quartile v. quartiles 1–3) in adolescents (Prevalence ratios and 95 % confidence intervals)

	Q1–Q3	Q4 unadjusted		Q4 adjusted for Q4 of AS		Q4 adjusted for Q4 of SS		Q4 adjusted for Q4 of SIS		Q4 adjusted for Q4 of BMI		
		Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	Prevalence ratio	95 % CI	
Boys												
High fasting glucose	1.0	1.41	0.79, 2.51	1.04	0.51, 2.11	1.26	0.65, 2.45	1.11	0.56, 2.21	0.74	0.35, 1.55	
Low HDL-cholesterol	1.0	1.22	0.98, 1.52	1.04	0.80, 1.36	1.00	0.77, 1.30	1.03	0.78, 1.36	1.04	0.78, 1.38	
High LDL-cholesterol	1.0	1.24	0.80, 1.91	0.94	0.53, 1.65	1.11	0.63, 1.95	1.18	0.71, 1.95	1.30	0.74, 2.27	
High TAG	1.0	2.13*	1.58, 2.87	1.42	0.97, 2.08	1.40	0.96, 2.04	1.51*	1.01, 2.28	1.37	0.87, 2.14	
High blood pressure	1.0	1.42	0.96, 2.08	1.47	0.90, 2.39	1.13	0.73, 1.73	1.22	0.77, 1.93	0.79	0.47, 1.30	
≥2 abnormalities	1.0	1.65*	1.22, 2.23	1.06	0.73, 1.55	1.05	0.72, 1.51	1.11	0.74, 1.65	0.92	0.60, 1.39	
Girls												
High fasting glucose	1.0	0.63	0.21, 1.83	0.62	0.16, 2.39	0.36	0.12, 1.04	0.41	0.14, 1.15	0.94	0.27, 3.19	
Low HDL-cholesterol	1.0	1.59*	1.24, 1.90	1.24	0.95, 1.62	1.11	0.86, 1.43	1.26	0.98, 1.63	1.14	0.87, 1.48	
High LDL-cholesterol	1.0	1.13	0.81, 1.58	1.00	0.68, 1.46	0.96	0.67, 1.39	1.14	0.78, 1.68	0.74	0.51, 1.08	
High TAG	1.0	1.99*	1.55, 2.56	1.66*	1.20, 2.28	1.65*	1.23, 2.25	1.69*	1.25, 2.28	1.62*	1.19, 2.23	
High blood pressure	1.0	1.95	0.98, 3.85	1.29	0.65, 2.53	1.55	0.79, 3.02	1.68	0.78, 3.63	1.53	0.73, 3.22	
≥2 abnormalities	1.0	1.83*	1.37, 2.44	1.41*	1.00, 2.01	1.35	0.97, 1.88	1.39	0.99, 1.95	1.26	0.90, 1.77	

AS, abdominal skinfold; SS, subscapular skinfold; SIS, supra-iliac skinfold.
* Significant associations ($P < 0.05$).

unadjusted associations. With regard to this relationship, there are conflicting results in previous studies as well. In pre-pubertal children, Sijtsma *et al.* did not find correlations between WC, W-HtR and LDL-cholesterol, whereas Hara *et al.*⁽³³⁾ reported significant association in boys and girls aged 9–13 years. Recently, White and Jago⁽³⁴⁾ found a strong and significant association between the change in WC and the change in LDL-cholesterol levels in a cohort of 617 female adolescents during the 10 years of follow-up. On the other hand, LDL-cholesterol was the risk marker less associated with WC in a large epidemiological study in adults⁽³⁵⁾.

The unexpected inverse associations of WC with high fasting glucose levels in the SS-adjusted model and with high LDL-cholesterol in the BMI-adjusted model could be chance findings. This is due to the fact that these associations were not consistently significant throughout the rest of the adjustment models. Alternatively, it is also possible that some confounder not evaluated in this study might have had an influence on these findings.

Despite adjustments for other adiposity markers attenuating some relationships, our general finding is that WC itself is a better indicator of cardiometabolic risk than W-HtR, especially based on vascular and lipid risk factors. In other words, our results do not support W-HtR as a relevant adiposity marker related to cardiometabolic risk in adolescence. This agrees with a body of literature in young children and adults in which W-HtR was not found to be better associated with cardiometabolic risk factors or MetS than WC^(23,36). In addition, the conflicting reports from studies mentioned above regarding associations with blood pressure and LDL-cholesterol could be explained by differences in statistical power, methodological approaches (e.g. adjustments, laboratory tests) and populations (e.g. young children/adolescents, ethnicity). Multicentre studies are warranted for a better interpretation of the associations between WC, W-HtR and cardiometabolic risk markers.

Data on pubertal changes, ethnicity and physical activity were not available for this analysis and these variables would have allowed for more robust adjustments. However, the age variable is strongly related to pubertal changes, and the stratification by age that we performed for WC and W-HtR may have decreased the bias of not adjusting for pubertal development. Further, adjustments for each trunk's skinfolds in the present study allowed for obtaining a more precise independence profile for the evaluated associations, an approach that had not been considered in previous studies.

In conclusion, the findings of this study suggest that abdominal adiposity itself would be a better indicator of cardiometabolic risk in adolescents than abdominal adiposity regarding height. This observation does not support W-HtR as a relevant adiposity marker for cardiovascular and metabolic risks in adolescence.

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Supplementary Material

For supplementary material/s referred to in this article, please visit <http://dx.doi.org/10.1017/S0007114515002275>

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