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ORIGINAL ARTICLE

Reference values for waist circumference and waist-to-height ratio in Paraguayan children and adolescents

Carolina Bonzi[a], **Teresa Balboa-Castillo**[b,*]

[a] *Magíster en Epidemiología Clínica, Universidad de La Frontera, Temuco, Chile*
[b] *Departamento de Salud Pública, Centro de Investigación EPICYN-CIGES, Facultad de Medicina, Universidad de La Frontera, Temuco, Chile*

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KEYWORDS
Waist circumference;
Waist-to-height ratio;
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Reference values;
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Abstract
Objective: To establish reference values for waist circumference (WC) and waist-to-height ratio (WHR) for Paraguayan children and adolescents aged 7 to 18 years to improve early detection of abdominal obesity.
Methods: We conducted a cross-sectional study using a nationally representative sample of Paraguayan schoolchildren. The analysis included a total of 12 611 students from public, private, and subsidized educational institutions. We determined reference values using smoothed percentiles for WC and WHR using the lambda-mu-sigma (LMS) method, stratified by age and sex.
Results: Of the total sample, 52% of participants were female, 81% resided in urban areas, and 68% were enrolled in the public education system. Regarding nutritional status, 36% had malnutrition due to excess BMI for age, and 25% had abdominal obesity. We generated reference values for WC and WHR by age and sex in the form of tables and reference curves. The WC showed a progressive increase with age in both sexes, with higher values in male participants. At age18 years, the 90th percentile for WC reached values close to the WHO metabolic risk thresholds for adults in both sexes.
Conclusions: This study provides, for the first time, national reference values for CC and WHR for the Paraguayan pediatric population. The generated curves are valuable tools for screening abdominal obesity and can complement nutritional monitoring for the early detection of cardiometabolic risk at an early age.
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* Corresponding author.
E-mail address: teresa.balboa@ufrontera.cl (T. Balboa-Castillo).

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PALABRAS CLAVE
Valores de referencia;
Circunferencia de la cintura;
Relación cintura-estatura;
Obesidad abdominal;
Niño;
Adolescente;
Paraguay

Valores de referencia de circunferencia de cintura e índice cintura-talla en niños y adolescentes paraguayos

Resumen
Objetivo: Establecer valores de referencia de circunferencia de cintura (CC) e índice cintura-talla (ICT) para niños y adolescentes paraguayos de 7 a 18 años, a fin de mejorar la detección temprana de obesidad abdominal.
Métodos: Estudio transversal de una muestra representativa de escolares paraguayos a nivel nacional. Se analizaron 12.611 estudiantes de instituciones educativas públicas, privadas y subvencionadas. Los valores de referencia se calcularon mediante percentiles suavizados de CC e ICT mediante el método Lambda-Mu-Sigma (LMS), estratificados por edad y sexo.
Resultados: De los participantes del estudio, el 52% fueron mujeres, 81% vivía en zona urbana y 68% pertenecía el sistema educacional público. Respecto al estado nutricional, 36% presentó malnutrición por exceso de acuerdo al IMC/edad y 25% presentó obesidad abdominal. Se presentan los valores de referencia de CC y ICT por edad y sexo mediante tablas y curvas de referencia. La CC mostró un incremento progresivo con la edad en ambos sexos, con valores más elevados en varones. A los 18 años, el percentil 90 de CC alcanzó valores cercanos a los umbrales de riesgo metabólico de la OMS para adultos en ambos sexos.
Conclusiones: Este estudio aporta por primera vez valores de referencia nacionales para CC e ICT en población pediátrica paraguaya. Las curvas generadas constituyen herramientas útiles para el cribado de obesidad abdominal y complementa la vigilancia nutricional para la detección oportuna del riesgo cardiometabólico en edades tempranas.
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Introduction

Obesity has become a global public health problem due to its progressively increasing prevalence and the associated comorbidities, placing a significant burden on the health care system.[1] Abdominal or central obesity, defined as excess intra-abdominal fat, is directly associated with metabolic disorders that significantly increase the risk of cardiovascular disease, which is the leading cause of death worldwide.[2]

The body mass index (BMI) is widely used to diagnose obesity in both epidemiological studies and clinical practice. However, its main limitation stems from its inability to accurately distinguish between fat mass and fat-free mass.[3] In this regard, the waist circumference (WC) is now recognized as a simple, inexpensive, and very informative anthropometric measure that should be routinely included in the physical examination. This measure, in addition to providing a more accurate estimate of abdominal fat, has been found to be a better predictor of the risk of cardiovascular disease and mortality than the BMI.[3,4] It is also clinically relevant, as it is a key component in the definition of metabolic syndrome.[3,5] The current evidence supports a correlation to visceral adiposity measured by computed tomography, which further reinforces its clinical and epidemiological utility.[5]

Due to its simplicity, the WC is used on its own or combined with other indicators, such as the waist-to-hip ratio or the waist-to-height ratio (WHtR), to predict cardiometabolic risk.[6]

The World Health Organization (WHO) has proposed WC thresholds to define central obesity in adults.[7] However, there is no global consensus on reference values for children and adolescents, which has led several countries to develop their own.[3,4,8–14] Among the countries in Latin America, Peru, Colombia, and some states in Brazil have developed reference values tailored to their specific population characteristics.[8,9,11] In fact, it is well known that the proportional growth rate and body fat distribution patterns in children and adolescents vary between different populations.[4]

In Paraguay, the Food and Nutrition Surveillance System (SISVAN) reports that one in three school-aged children has excess weight (overweight or obesity).[15] However, there are no national WC reference values to screen for central obesity in the pediatric population.

Having national WC reference values for age and sex would help identify children and adolescents at greater risk of developing obesity-related comorbidities and prioritize preventive interventions. Furthermore, the reference values could serve as an innovative and valuable tool for the epidemiological and clinical monitoring of central obesity in Paraguay.

Given the lack of universal consensus on WC percentiles in the pediatric population and the absence of national standards in Paraguay, we conducted a study with the aim of establishing specific WC and WHtR reference values for Paraguayan children and adolescents aged 7 to 18 years.

Material and methods

Study design and sample

This study is a secondary analysis of data on schoolchildren in Paraguay collected in 2023 by the Food and Nutrition Surveillance System (SISVAN). The SISVAN survey of schoolchildren is an annual nationwide cross-sectional survey that assesses the nutritional status of children and adolescents in Paraguay. Data is collected from individuals selected by multistage probability sampling, with random selection of districts, schools and schoolchildren from the 18 departments of the country.

In our study, we analyzed data for schoolchildren aged 7 to 18 years enrolled in public, private, and subsidized (private ownership with public funding) schools in Paraguay. Although the SISVAN survey includes children aged 5 to 18 years, our analysis was restricted to the subset aged 7 to 18 years, since, according to methodological guidelines, a minimum sample size of 200 to 300 subjects per group (stratified by age and sex) is required to ensure the accuracy of the estimates.[16]

Anthropometric measurements

Weight, height, and WC were measured by health care workers with prior training in nutritional assessment, following the techniques recommended in the Basic Manual on Anthropometric Nutritional Assessment published by the Instituto Nacional de Alimentación y Nutrición (INAN, National Institute of Food and Nutrition).[17] Weight and height were measured with as little clothing as possible, removing shoes and any headwear. The WC was measured with the torso bared, at the midpoint between the iliac crest and the lowest rib, using a measuring tape.[17,18]

Statistical analysis

We excluded incomplete records and children with extreme WC values, defined as a *z* score outside the range of ±4 SDs for age and sex. These values were considered biologically implausible based on the previous scientific literature.[16,19]

The assessment of nutritional status according to the BMI-for-age and height-for-age indicators was performed using the Anthro Plus software from the WHO. The WHtR was calculated as the WC divided by the height. We estimated the prevalence of abdominal obesity defining it as a WHtR of 0.50 or greater. To compare the prevalence of abdominal obesity in male vs female schoolchildren, we used the χ^2 test, considering results with a *p* value of less than 0.05 statistically significant.

We estimated the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles for the WC and the WHtR stratified by age and sex. To this end, we used the Lambda-Mu-Sigma (LMS) method,[20] which can be used to model the change in anthropometric measurements with age by calculating three parameters: Lambda (L), which corrects for the skewness of the distribution; mu (M), the median; and sigma (S), the coefficient of variation. This approach generates smoothed, continuous curves, even in the case of nonlinear distributions. We fitted separate models for boys and girls using the gamlss package for R. The generated reference values are presented the form of tables and curves.

Table 1 Sociodemographic and anthropometric characteristics of the sample.

	n	%
Sex		
Female	6540	51.9
Male	6071	48.1
Setting		
Urban	10 204	80.9
Rural	2407	19.1
Type of school		
Public	8626	68.4
Private	1578	12.5
Subsidized private	2407	19.1
Nutritional status (BMI-for-age)		
Underweight	157	1.2
Risk of underweight	861	6.8
Normal weight	7064	56
Overweight	2777	22
Obesity	1752	13.9
Abdominal obesity (WHtR ≥ 0.50)		
Yes	3198	25.4
No	9413	746

Produced by the authors using data from the 2023 SISVAN survey of schoolchildren.
Abbreviations: BMI, body mass index; WHtR, waist-to-height ratio.

Ethical considerations

The study was approved by the health research ethics committee of the Instituto Nacional de Salud de Paraguay, an independent body with no ties to the research team (ethics committee ruling No. 022/2024). Since the study was based on secondary data from the SISVAN survey, it did not require informed consent. The study was conducted ensuring confidentiality and in adherence to the principles of the Declaration of Helsinki and the international ethical guidelines of The Council for International Organizations of Medical Sciences (CIOMS).

Results

A total of 12 611 Paraguayan children and adolescents aged 7 to 18 years currently enrolled in a public, private, or subsidized school participated in the study. Fifty-two percent were female. Table 1 presents the sociodemographic and anthropometric characteristics of the sample.

According to the cut-off points proposed by the WHO for the BMI-for-age, 56% of participants had an adequate nutritional status, while approximately one in three had excess weight (overweight or obesity).

Furthermore, one in four had abdominal obesity applying a WHtR cutoff of 0.50, a threshold widely used in the sci-

Table 2 Smoothed age- and sex-specific waist circumference percentiles (in cm) for Paraguayan children and adolescents.

Boys and male adolescents

Age	*n*	L	M	S	p5	p10	p25	p50	p75	p90	p95
7	489	0.63	59.28	0.13	47.2	49.8	54.2	59.3	64.5	69.4	72.4
8	542	0.25	61.69	0.14	48.9	51.5	56.2	61.7	67.6	73.3	76.8
9	531	−0.12	64.05	0.14	50.8	53.4	58.2	64.0	70.6	77.1	81.3
10	521	−0.47	66.28	0.15	52.8	55.4	60.2	66.3	73.3	80.7	85.6
11	556	−0.80	68.34	0.15	54.9	57.5	62.2	68.3	75.7	83.6	89.1
12	568	−1.10	70.17	0.14	57.2	59.6	64.2	70.2	77.5	85.6	91.3
13	598	−1.37	71.81	0.13	59.5	61.8	66.1	71.8	78.9	86.9	92.6
14	551	−1.58	73.34	0.12	61.5	63.7	67.8	73.3	80.2	87.9	93.6
15	513	−1.73	74.76	0.12	63.3	65.4	69.4	74.8	81.4	88.9	94.4
16	438	−1.82	76.03	0.11	64.8	66.9	70.8	76.0	82.5	89.8	95.2
17	431	−1.88	77.20	0.11	66.1	68.1	72.0	77.2	83.6	90.9	96.3
18	333	−1.93	78.36	0.11	67.2	69.2	73.2	78.4	84.8	92.2	97.7

Girls and female adolescents

Age	*n*	L	M	S	p5	p10	p25	p50	p75	p90	p95
7	483	0.04	58.49	0.13	47.4	49.6	53.7	58.5	63.7	68.8	72.1
8	530	−0.09	60.69	0.13	48.9	51.3	55.5	60.7	66.4	72.0	75.7
9	602	−0.23	62.97	0.14	50.4	52.9	57.4	63.0	69.2	75.5	79.6
10	568	−0.36	65.24	0.14	52.1	54.6	59.3	65.2	72.0	78.9	83.4
11	584	−0.50	67.30	0.14	53.9	56.5	61.3	67.3	74.3	81.5	86.4
12	580	−0.63	68.95	0.14	55.9	58.4	63.0	69.0	75.8	83.1	87.9
13	661	−0.77	70.10	0.13	57.6	60.0	64.4	70.1	76.7	83.6	88.4
14	618	−0.91	70.93	0.12	59.0	61.3	65.5	70.9	77.2	83.9	88.4
15	571	−1.04	71.68	0.12	60.2	62.4	66.5	71.7	77.8	84.3	88.7
16	530	−1.18	72.38	0.11	61.1	63.3	67.3	72.4	78.4	84.9	89.4
17	506	−1.31	73.00	0.11	61.8	63.9	67.9	73.0	79.1	85.7	90.4
18	307	−1.45	73.53	0.11	62.3	64.4	68.4	73.5	79.8	86.6	91.5

Produced by the authors using data from the 2023 SISVAN survey of schoolchildren.
Abbreviations: L, Box-Cox transformation; M, median; S, coefficient of variation; p, percentile.

entific literature. In the subset with abdominal obesity, 82% also had excess weight based on the BMI-for-age, with 48% classified as obese and 34% as overweight.

The prevalence of abdominal obesity was 25.7% in boys and 25.0% in girls, with no significant differences between the sexes ($P = .336$). However, when we disaggregated the data by age, we found significant differences in some age groups. The prevalence was significantly higher in boys than in girls at ages 11 years (34.7% vs 26.2%; $P = .002$) and 12 years (30.6% vs 24.3%; $P = .016$). In contrast, at age 17, abdominal obesity was more prevalent in female compared to male adolescents (26.5% vs 15.5%; $P < .001$). There were no statistically significant differences in the remaining age groups.

Table 2 and Fig. 1 present the generated age- and sex-specific smoothed WC percentiles for Paraguayan children and adolescents.

The WC was higher in boys and girls across all age groups, with a progressive increase with age observed in both sexes.

Table 3 and Fig. 2 present the generated age- and sex-specific smoothed WHtR percentiles for Paraguayan children and adolescents.

When it came to the WHtR, most percentiles were slightly higher in boys compared to girls from age 8 to age 13 years, although the differences were subtle. Starting at age 14, WHtR values tended to even out between the two sexes, and for some percentiles (p25 to p95), the values were even slightly higher in female adolescents. The median WHtR (p50) remained below the 0.50 threshold at every age and in both sexes.

Discussion

The aim of this study was to establish age- and sex-specific WC reference values for Paraguayan school-aged children and adolescents, using data obtained in the 2023 SISVAN nationally representative survey. We estimated reference values through the calculation of smoothed percentiles (p5, p10, p25, p50, p75, p90, and p95) for WC and WHtR.

Boys and male adolescents had higher WC values compared to girls and female adolescents across all age groups, with a progressive increase with age in both sexes, trends that were similar to those reported in other studies.[9,11,13,19]

The WC values documented in Paraguayan children and adolescents were higher compared to those reported in studies conducted in Peru, Colombia, Brazil, and Venezuela.[8,9,11,21] It is important to note that, although the studies conducted in these countries had large sam-

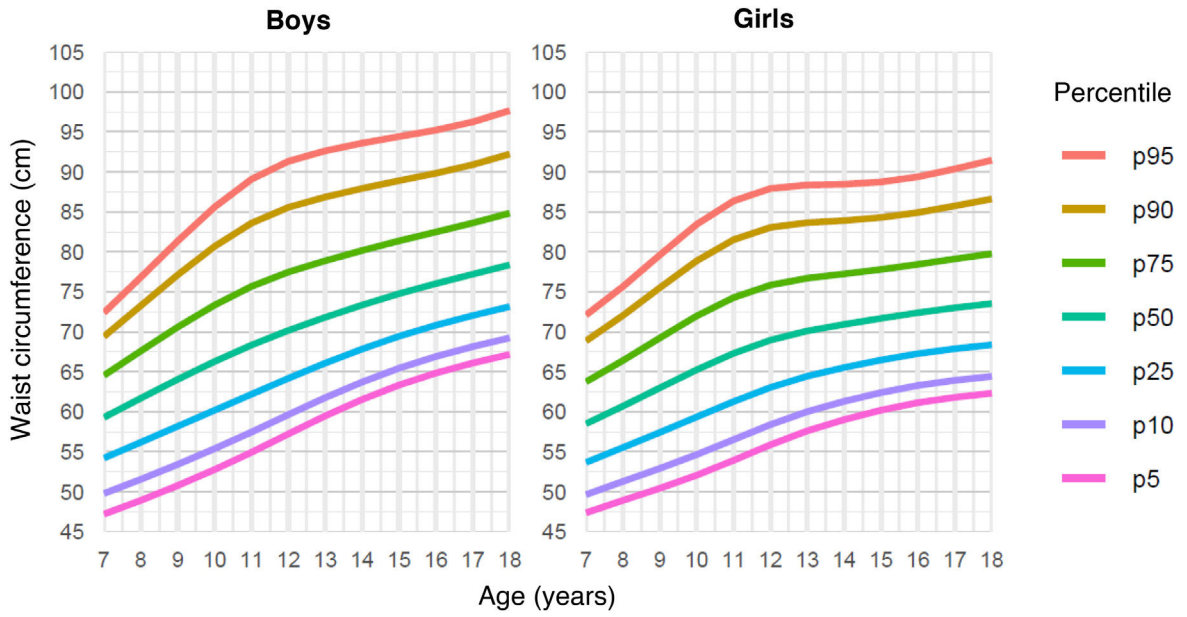

Figure 1 Smoothed age- and sex-specific waist circumference reference percentile curves for Paraguayan children and adolescents.

Table 3 Smoothed age- and sex-specific waist-to-height ratio percentiles for Paraguayan children and adolescents.

Boys and male adolescents

Age	*n*	L	M	S	p5	p10	p25	p50	p75	p90	p95
7	489	0.93	0.48	0.12	0.39	0.41	0.44	0.48	0.52	0.55	0.57
8	542	0.59	0.48	0.12	0.39	0.41	0.44	0.48	0.52	0.56	0.58
9	531	0.24	0.48	0.13	0.39	0.40	0.44	0.48	0.52	0.56	0.59
10	521	−0.11	0.48	0.13	0.39	0.40	0.44	0.48	0.52	0.56	0.59
11	556	−0.45	0.47	0.13	0.39	0.40	0.43	0.47	0.52	0.56	0.59
12	568	−0.80	0.47	0.13	0.38	0.40	0.43	0.47	0.51	0.55	0.59
13	598	−1.14	0.46	0.12	0.38	0.39	0.42	0.46	0.50	0.54	0.57
14	551	−1.49	0.45	0.12	0.38	0.39	0.42	0.45	0.49	0.53	0.56
15	513	−1.84	0.44	0.11	0.38	0.39	0.41	0.44	0.48	0.52	0.56
16	438	−2.18	0.44	0.11	0.38	0.39	0.42	0.44	0.48	0.52	0.55
17	431	−2.53	0.45	0.10	0.39	0.40	0.42	0.45	0.48	0.52	0.56
18	333	−2.87	0.45	0.10	0.40	0.41	0.43	0.45	0.49	0.53	0.57

Girls and female adolescents

Age	*n*	L	M	S	p5	p10	p25	p50	p75	p90	p95
7	483	0.41	0.48	0.12	0.39	0.41	0.44	0.48	0.52	0.55	0.57
8	530	0.23	0.47	0.12	0.39	0.40	0.44	0.47	0.51	0.55	0.58
9	602	0.06	0.47	0.13	0.38	0.40	0.43	0.47	0.51	0.55	0.58
10	568	−0.12	0.46	0.13	0.38	0.39	0.43	0.46	0.51	0.55	0.58
11	584	−0.29	0.46	0.13	0.37	0.39	0.42	0.46	0.50	0.54	0.57
12	580	−0.47	0.45	0.13	0.37	0.39	0.42	0.45	0.50	0.54	0.57
13	661	−0.64	0.45	0.12	0.37	0.39	0.41	0.45	0.49	0.53	0.56
14	618	−0.82	0.45	0.12	0.37	0.39	0.41	0.45	0.49	0.53	0.56
15	571	−0.99	0.45	0.12	0.38	0.39	0.42	0.45	0.49	0.53	0.56
16	530	−1.17	0.45	0.11	0.38	0.40	0.42	0.45	0.49	0.53	0.56
17	506	−1.34	0.46	0.11	0.39	0.40	0.42	0.46	0.49	0.54	0.56
18	307	−1.52	0.46	0.11	0.39	0.40	0.43	0.46	0.50	0.54	0.57

Produced by the authors using data from the 2023 SISVAN survey of schoolchildren.
Abbreviations: L, Box-Cox transformation; M, median; S, coefficient of variation; p, percentile.

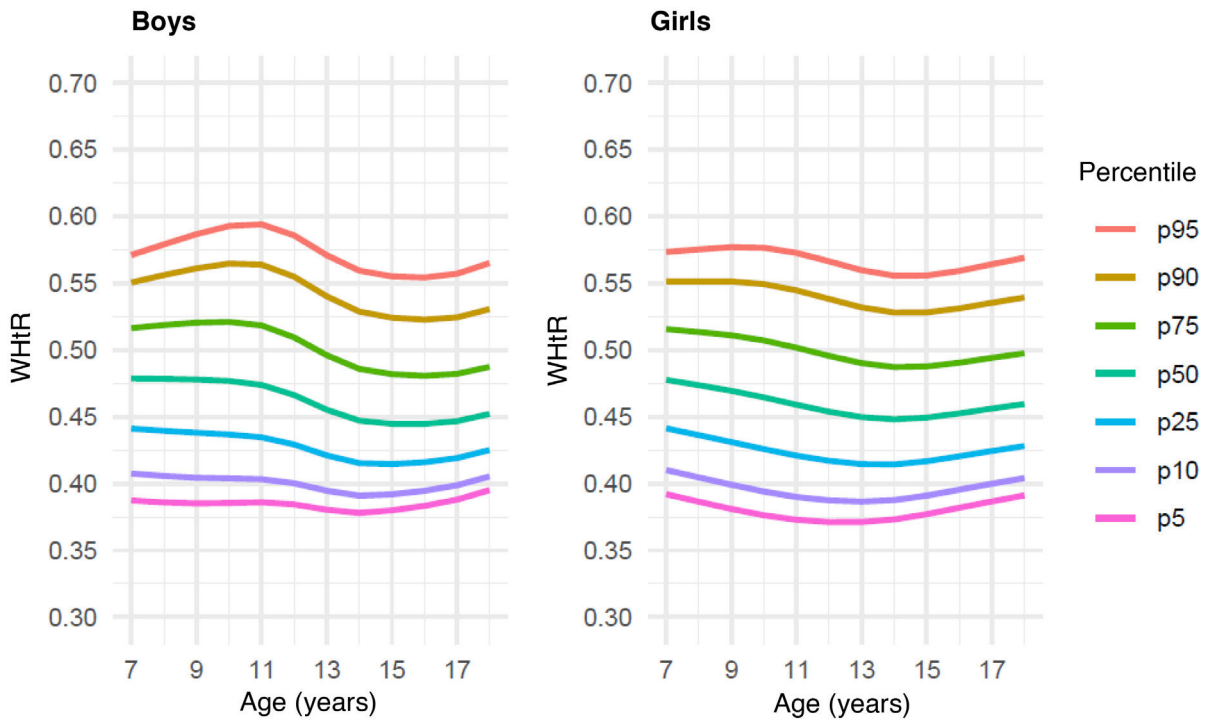

Figure 2 Smoothed age- and sex-specific waist-to-height ratio reference percentile curves for Paraguayan children and adolescents.

ple sizes, none had a nationally representative sample, which limits the generalizability of their results. Furthermore, there were differences in methodology and context that could explain the observed discrepancies. For example, only the studies from Colombia and Peru reported generating smoothed percentile curves with the LMS method, which allows a more direct comparison with our study. However, contrary to our study, the samples in both countries were limited to public schools and, in the case of Colombia, exclusively to children and adolescents of low socioeconomic status, which may have contributed to the lower observed WC values.

On the other hand, WC values in the Paraguayan population were lower than those reported in a study conducted in the Maule region (Chile).[4] This difference could be explained, at least in part, by the composition of the sample: while 19% of the participants in our study came from rural areas, the study in Chile was conducted exclusively in urban settings.

Previous studies have shown that body composition can vary depending on genetic and environmental factors.[21,22] In this regard, the observed differences in abdominal fat (assessed by means of WC values) between the populations of Paraguay and other Latin American countries may result from the interaction of these factors. The variations in WC observed across countries highlight the need for local reference values adapted to the epidemiological and sociocultural context of each region.

In our study, the 90th percentile (p90) values for waist circumference at age 18 years (92.2 cm for men and 86.6 cm for women) were close to the thresholds established by the WHO for adults to determine the risk of metabolic complications ($\geq$ 94 cm indicative of increased risk for men; $\geq$ 88 cm indicative of significantly increased risk for women).[23] This consistency supports the use of the 90th percentile as an adequate threshold for monitoring cardiometabolic risk, which would allow the identification of individuals with clinically significant central adiposity. Furthermore, other authors have proposed the use of the p90 as a practical criterion for detecting abdominal obesity in the pediatric population,[3,5,12,13] as it facilitates a smooth transition to adult diagnostic standards and the implementation of preventive strategies from an early age.

With regard to the WHtR, most percentiles were slightly higher for boys than for girls from ages 8 to 13 years. Starting at age 14, the values became similar in both sexes, and some percentiles were slightly higher in girls (P25 to P95). This trend is consistent with the values reported for Colombian schoolchildren aged 9 to 17 years, with higher WHtR values in boys compared to girls of the same age in the 9-to-13 years range. However, between ages 14 and 17 years, the trend reversed, and girls had higher WHtR values across all percentiles.[11] This difference may be related to sex-based differences in biological maturation. It is well known that girls tend to experience their pubertal growth spurt earlier than boys, which leads to an earlier increase in height.[19,21] Since the WHtR is calculated by dividing the WC by the height, a faster increase in height can cause a temporary decrease in this ratio in women during the early years of puberty. In contrast, boys experience their growth spurt later,[19] which could explain the higher WHtR values at younger ages and the reversal of the trend, with higher values in girls, observed toward the end of adolescence.

The prevalence of abdominal obesity, defined as a WHtR of 0.50 or greater, was 25.4%. Eighty-two percent of participants with abdominal obesity also had excess weight

according to the BMI-for-age, which further supports the usefulness of the WHtR as a complementary diagnostic tool in nutritional surveillance. However, we also identified a group of children with abdominal obesity who did not have excess weight based on the BMI, highlighting the added value of the WHtR in detecting hidden risk.

The prevalence of abdominal obesity, defined as a WHtR of 0.50 or greater, was similar in boys and girls (25.7% vs 25.0%; $P = .336$). However, there were significant differences at specific ages. These findings highlight the importance of using age- and sex-specific reference values for a more accurate assessment of cardiometabolic risk.

Although a WHtR of 0.50 has been proposed internationally as an indicative threshold for cardiometabolic risk in children and adolescents[19,24,25] due to its easy calculation and the clear message it conveys from a public health perspective (''keep the size of your waist to less than half of your height''), the findings of our study suggest that a single threshold may not be the most suitable approach for this population. The reason is that this threshold does not take into account the physiological changes associated with growth and pubertal development. In this context, the use of age- and sex-specific percentiles—such as those generated in our study using the LMS method—offers an alternative for assessing cardiometabolic risk more accurately in Paraguayan children and adolescents.

One of the main limitations of our study is the lack of information on the stage of puberty among the participants, as the SISVAN does not collect data on this variable. Sexual maturation significantly influences the amount and distribution of body fat—abdominal fat in boys and peripheral fat in girls—as well as the weight and height. The variability in the rate of pubertal development among individuals of the same chronological age can complicate nutritional assessment when biological maturity is not taken into account, underscoring the need for caution when interpreting references based solely on age.[21] Furthermore, future research should include clinical indicators (blood pressure, glucose, blood lipids, etc) along with body composition measures in order to validate the proposed cut-off points and percentiles and improve their performance as predictors of cardiovascular risk in children and adolescents. Despite these limitations, this study serves as an essential initial reference for addressing abdominal obesity in the Paraguayan pediatric population.

One of the main strengths of this study is that it constitutes the first national effort to establish age- and sex-specific reference curves for WC and WHtR in the Paraguayan child and adolescent population. These references, developed with data obtained from a nationally representative sample, provide a robust, context-specific, and practical tool for nutritional surveillance, early detection of cardiometabolic risk, and the planning of public health interventions. Having them available makes it possible to overcome the reliance on international standards that may not adequately reflect local anthropometric and epidemiological characteristics. Although these reference values should not be used in isolation as a diagnostic criterion, their application as a complement to a comprehensive clinical and nutritional assessment can be very useful, contributing to timely detection and the planning of preventive interventions from the early stages of life.

This study has been the first to establish WC and WHtR reference values for age and sex in the population of Paraguayan children and adolescents aged 7 to 18 years using data from a nationally representative sample. The curves generated using the LMS method can be useful for the early screening of abdominal obesity and the monitoring of cardiometabolic risk in this population.

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Declaration of competing interest

The authors declare no conflicts of interest.

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