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ORIGINAL ARTICLE

Prevalence of cardiometabolic risk in a national sample of Costa Rican youth using the waist-height anthropometric indicator

Prevalencia de riesgo cardiometabólico en una muestra nacional de jóvenes costarricenses utilizando el indicador antropométrico cintura-estatura

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What do we know about the subject matter of this study?

In recent decades, the prevalence of cardiovascular disease and metabolic syndrome in young people has increased. The WHtR indicator has a better performance than the body mass index to detect cardiometabolic risk factors in children and adolescents at an early stage.

What does this study contribute to what is already known?

This is the first study performed on young Costa Rican students to determine the prevalence of cardiometabolic risk using the WHtR indicator. Its use is suggested as part of the screening tests and to early detect the risk of metabolic syndrome in young people.

Abstract

Central obesity is known as an indicator of cardiometabolic risk, but better anthropometric measures than Body Mass Index (BMI) are needed to detect it. Waist-to-height ratio (WHtR) is an indicator of central adiposity and a strong predictor of cardiometabolic risk. **Objective:** To determine the prevalence of cardiometabolic risk in a representative sample of Costa Rican children and adolescents. **Patients and Method:** Cross-sectional and descriptive study carried out with 2,684 students from 64 educational centers in Costa Rica. Validated questionnaires were applied to the students and their weight, height, and waist circumference were determined. Weight and body fat percentage of the students were determined with a Tanita model SC-331 S (without column). Height was measured with a SECA stadiometer model 217. The abdominal circumference was estimated using a tape mea-

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sure. BMI and WHtR were calculated for each participant. The behavior of the indicator WHtR was analyzed with logistic regression models. All procedures were approved by the Ethics Committee of INCIENSA. **Results:** There was a strong and positive correlation between waist circumference and BMI ($r = 0.748$, $p < 0.001$, 56% of shared variance), and a positive and moderate correlation between WHtR and BMI ($r = 0.611$, $p < 0.01$, 37% of shared variance). **Conclusions:** A third part of the student population of elementary, middle, and high schools (31.8%) is at cardiovascular and metabolic risk.

Introduction

In recent decades, the prevalence of obesity in children has increased alarmingly worldwide, a trend that has led the World Health Organization to promote the goal of halting its further increase by 2025. This epidemic has important consequences for children's health, including an increased risk of developing non-communicable diseases[1]. Some studies report that socioeconomic status may play a difference in the incidence of cardiovascular disease[2,3].

One of the explanations for the consequences of obesity is that adipose tissue increases the rate of expression and/or secretion of adipocytokines[4]. Some of them, such as interferon-γ (IFN-γ), interleukin-6 (IL-6), and tumor necrosis factor α (TNF-α), cause the infiltration of inflammatory immune cells into adipose tissue generating a state of "subclinical inflammation" that can lead to the development of metabolic syndrome (MetS). This syndrome is a group of factors associated with abdominal obesity from childhood that includes high waist circumference (WC), high blood pressure, high glycemia, high triglycerides, or reduced high-density lipoprotein cholesterol[4]. The progression from childhood obesity to adulthood, along with the high probability of developing MetS and the aforementioned comorbidities, makes cardiometabolic risk detection an urgent issue as the time window for prevention may be short.

Obesity in children and adolescents is defined as a body mass index (BMI) higher than the 95th percentile for sex and age[5]. Although this index is easy to calculate, it does not fully reflect adiposity or body composition. On the other hand, abdominal adiposity during adolescence is positively and independently associated with atherosclerosis in adulthood (6) and with insulin resistance[7]. One of the anthropometric measures used to assess adiposity is the waist-to-height ratio (WHtR).

Since 2012, it has been recognized that a WHtR greater than 0.5 represents a risk factor for developing cardiometabolic diseases in adults[8]. A meta-analysis concludes that WHtR has better performance than BMI and WC to measure cardiometabolic risk factors in adults and that WHtR has significantly better detection power than BMI and WC in children and adolescents, except for high triglycerides compared with BMI and high-metabolic risk score compared with WC.

WHtR is a relevant indicator for children and adolescents in terms of measurement and interpretation, which offers advantages in practice and allows rapid identification of young people with cardiometabolic risk factors from an early age[9]. Also, a single fixed cut-off for WHtR has been proposed, stating that a WHtR above 0.5 suggests an increased risk of adverse health outcomes in both children and adults[10].

The main objective of this study was to determine the prevalence of cardiometabolic risk in a representative sample of Costa Rican children and adolescents and in second place to analyze the behavior of WHtR in relation to the socioeconomic level of the study sample.

Patients and Method

Type of study and selection of the population

Descriptive and cross-sectional study. The population consisted of primary school students (cycles I and II) and high school students (cycle III) from public, private, and subsidized educative centers. According to data from the Statistics Department of the Ministry of Public Education, Costa Rica has a student population of about 32% in primary school and 68% in high school, grouped into 4,070 schools and 589 high schools, respectively.

To determine the sample size, the proportion estimation formula was used, with a confidence level of 95% and 3% of error range. The calculation was made considering a maximum variability ($p = 0.5$) and the design effect was estimated at 2. In addition, in order to anticipate possible cases of refusal, the non-response rate was estimated in 15%. Since the educational centers are classified in 27 regional offices, these were considered as strata for the sample distribution, proportional to the enrollment in the respective educational centers.

The random selection of schools and classrooms was carried out using the systematic method. Two groups were randomly selected in each educational center and the questionnaires were applied to 42 students using age (7 to 17 years) as the only inclusion criterion. The exclusion criterion applied was incomplete information from the participant. Finally, 2,684 students were selected from 64 educational centers (40 schools and 24 high schools) in the seven provinces of Costa Rica, a nationally representative sample.

Data collection and measurement techniques

The researchers interviewed students in the first cycle of primary school (n = 395, 14.6%) since many of them did not yet knew how to read and write. Students in the second cycle of primary school and third cycle of high school (n = 2,289, 85.4%) received a previously validated and self-administered questionnaire under the supervision of the professionals to ensure individual responses and clarify doubts during the process.

Socio-demographic data

Sex, age, and socio-economic level of the students were determined according to an index based on the Madrigal's method[11], calculated according to the possession of some specific material goods at home.

Anthropometric measurements

Weight (kg) and body fat were measured barefoot and wearing light clothing (shorts and T-shirt), using bioimpedance analysis with a Tanita scale model SC-331S (without column), which has been recommended for use in children and adolescents[12]. Height (cm) was measured with a free-standing stadiometer SECA model 217 with a wall spacer. BMI was estimated by dividing weight (kg) by height (m^2) and the cut-off criteria were based on sex-specific BMI-for-age growth charts[5]. Waist circumference (WC) was measured in centimeters using an inextensible tape measure placed in the middle between the lower edge of the last rib and the upper edge of the iliac crest, after unforced expiration of the student. The waist-to-height ratio (WHtR) of each participant was calculated by dividing the WC (cm) by height (cm) and considering WHtR > 0.5 as the cut-off point for risk[10]. All height and waist measurements were performed twice for each participant and the average was calculated; a third measurement was performed if there was a difference greater than 0.5 cm. Measurements were performed by standardized professionals.

Statistical analysis

The prevalence of overweight and obesity was calculated from the BMI percentile according to the CDC (Centers for Diseases Control) reference and the cut-off points recommended for children and adolescents, according to age and sex. Overweight was considered when the BMI percentile was between 85th and 95th and obesity when the BMI percentile was equal to or greater than the 95th percentile[5].

The normal distribution of the data was verified using the Kolmogorov-Smirnov test; subsequently, the descriptive statistics of arithmetic mean, standard deviation (SD), and range were calculated. Parametric and nonparametric tests were used according to the normal distribution of the variables. Data defined by more than two categories were tested by ANOVA or Kruskal-Wallis test; Pearson's r or Spearman's r were used for correlation tests. Confidence intervals were established at a 95% confidence level. Homogeneity and Chi-square tests were applied according to age and sex.

The graphical representation of the percentile distribution was performed by adjusting the logarithmic trend line with the equation $y = a\ln(x) + b$, where a and b are regression constants calculated with the least-squares method, x is the age in years and y is the WHtR. Correlation between quantitative variables WC-BMI and BMI-WHtR was analyzed using a correlation matrix to determine the shared variance between variables[13]. The estimation of the logarithmic adjustment lines for percentiles and significance (by sex and percentile) was performed using an Excel spreadsheet and the correlational analysis between the variables (WC-BMI, BMI-WHtR) was estimated using the SPSS 22.0 statistical software[14].

Logistics regression models were used to analyze the behavior of WHtR, considering WHtR as the dependent variable (WHtR > 0.50 = 1, with risk; WHtR ≤ 0.5 = 0, without risk). The method chosen was the reverse one, so the contrast for elimination was based on the probability of the Wald statistic. A value of $p \leq 0.05$ was considered statistically significant.

General and Ethical Procedures

All procedures were performed following the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards. The participants signed the respective consents/assents before taking the measurements and their parents or guardians had to sign the informed consent to participate in the project. The research was approved by the INCIENSA Scientific Ethical Committee (Ordinary Session #27, October 19, 2010; IC-2010-05).

Results

Waist-to-height ratio

The mean age of the study participants was 12.36 years (± 2.56 SD), slightly more than half were female, and 56% were of middle socioeconomic status.

Figure 1 shows the graphical representation of the WHtR percentiles adjusted according to age and sex groups. In general, WHtR values increase with age, with small decreases at some ages in both sexes, perhaps caused by the different number of participants in each of the age groups. The specific results obtained in the distribution of the data determined that in the interval from 7 to 9 years of age, girls show higher significant differences than boys in the 75th, 90th, and 95th percentiles ($p < 0.04$); in the interval from 10 to 12 years, boys show significant differences higher from the 10th to the 95th percentile ($p < 0.02$); in the interval from 13 to 15 years, girls show higher significant differences at the 5th, 10th, 75th, 90th, and 95th percentiles ($p < 0.02$); and in the interval from 16 to 17 years, girls show a higher significant difference at the 75th, 90th, and 95th percentiles ($p < 0.01$).

In girls, mean WHtR values tend to be higher during middle and late adolescence (13 to 17 years of age) compared with the mean WHtR values of boys in those same age groups. In boys younger than 13 years of age (prepubertal), there is a tendency to present higher mean WHtR values than girls of the same age. In fact, there were significant differences in WHtR according to sex in boys aged 9, 11, and 12 years (preadolescence and early adolescence), observing higher values than girls in the same age groups ($p < 0.02$).

For the analysis of WHtR behavior according to socioeconomic level, the middle socioeconomic level was used as baseline ($\bar{x} = 0.48 \pm 0.07$), finding that WHtR is significantly lower in students from families of high socioeconomic level ($\bar{x} = 0.46 \pm 0.0$; $p < 0.001$). No statistical differences were found when comparing the middle socioeconomic level with the lower one ($\bar{x} = 0.47 \pm 0.06$ $p = 0.153$).

The protective effect of the socioeconomic level was corroborated with WHtR analysis by logistic regression, considering WHtR as the dependent variable (1 with risk, 0 without risk) (table 1). The explanatory risk variables associated with WHtR were BMI and fat percentage, and the associated variables protective of WHtR were female sex, age, and socioeconomic level. None of the explanatory variables associated with WHtR showed collinearity problems and this model presented an overall percentage of 82.6% ($p < 0.001$).

Prevalence of overweight, obesity, cardiometabolic risk and correlations between variables

Approximately, 16.3% of the student population was obese and 26.2% was overweight. We found a strong and positive correlation between WC and BMI ($r = 0.748$; $p < 0.001$; 56% shared variance), a positive and moderate correlation between WHtR and BMI ($r = 0.611$; $p < 0.01$; 37% shared variance), and more than one-third (31.8%) of the total population was at cardiometabolic risk ($WHtR > 0.50$).

Figure 2 shows the prevalence of cardiovascular and metabolic risk in the study population according to sex and age groups. The values observed suggest that girls in almost all age groups tend to present higher cardiometabolic risk compared with boys, except in the age groups 9, 11, and 12 years, where the percentage values for boys are higher than for girls. In fact, there was a significant difference at 9 years of age, where the prevalence of cardiovascular and metabolic risk in boys is more than twice that of girls (17.8% vs 37.7%, respectively; $p < 0.021$). No other differences were found.

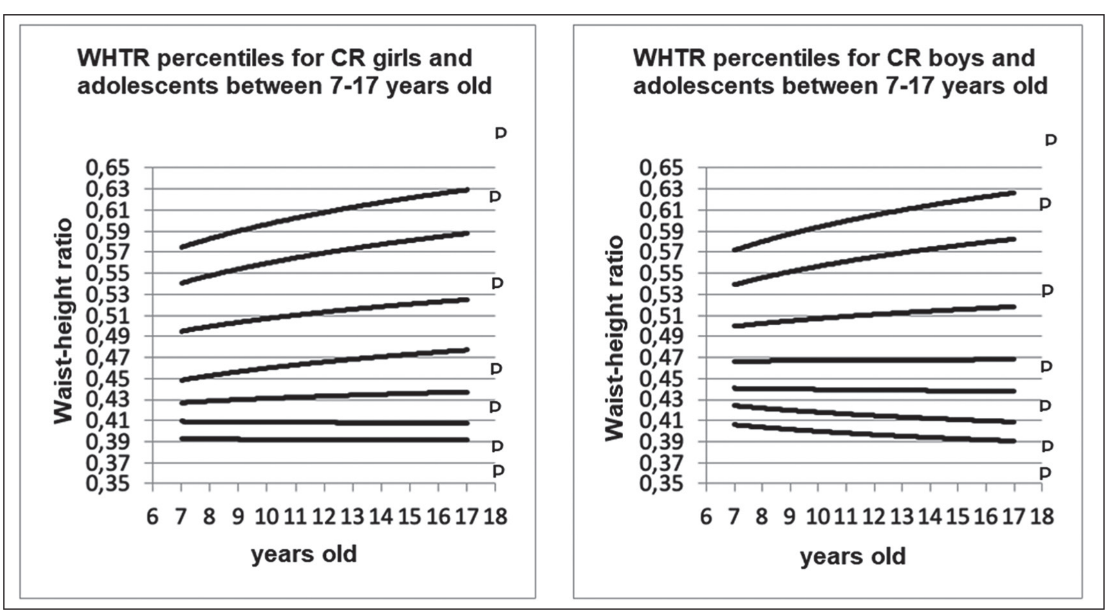

Figure 1. WHtR percentiles for children and adolescents from 7 to 17 years old from Costa Rica.

Discussion

According to the WHtR indicator, one-third of the population studied was at cardiovascular and metabolic risk. However, the cut-off point (WHtR > 0.50) should be considered as "diagnostic" based on empirical and statistical data[15] and, therefore, the results should be interpreted based on existing evidence of other cardiovascular disease risk factors for populations with similar characteristics. In addition, the WC measurement areas used in this study and other investigations should be considered, as well as the morphology of the populations in relation to developmental changes and the level increase in WC as height, visceral and subcutaneous fat increase.

According to a Spanish study[16], the existence of a marked sexual dimorphism, characterized by higher body fat percentage values among girls compared with boys, is due, in part, to sexual maturation processes and neurohormonal factors. In addition, the sexual dimorphism that comes with the differences in body fat can also be explained by the weight gain of females in the years after menarche, resulting in a mean BMI at 17 years of age that is significantly higher than that of the male group.

According to the study by Gonzalez et al.[16], the development pattern could be closely related to the sexual maturation process of the female sex due to the increase in the accumulation of adipose tissue with the onset of adolescence and the beginning of menarche. These physiological processes differentiated by sex suggest that childhood is the most critical period for the diagnosis of obesity and overweight.

Some investigations have used magnetic resonance imaging in anatomical points of the abdominal area[17] indicating that the pattern of fat development implies a redistribution of the volume of adipose tissue from a more peripheral and local model to a more generalized one, especially among women. In this regard, Lee et al.[18] reported that a visceral fat area of 68.57 cm^2 (sensitivity 59.8%, specificity 76.6%; $p = 0.01$) was a metabolic risk factor for children and adolescents aged 10 to 15 years, and regression analysis indicated that the WHtR cut-off point for discriminating that level of risk was 0.54 in boys and 0.61 in girls. In our study, it was observed that a WHtR > 0.5 corresponds to the 71.4

Table 1. Multivariate logistic regression model of variables statistically associated with waist/height ratio (WHtR)

Variables	β	OR	95% CI, for EXP(B)		Standard Error	*p*	Case presentation (%)	
			Lower	Higher			Fraction Etiologic	Preventive Etiologic
BMI (continuous variable)	0.25	1.26	1.23	1.34	0.02	< 0.001	77.8	-
Fat Percentage (continuous variable)	0.12	1.13	1.12	1.16	0.01	< 0.001	88.2	-
Gender (1= Female, 0= Male)	-0.88	0.41	0.32	0.53	0.13	< 0.001	-	58.6
Age in years (continuous variable)	-0.21	0.80	0.78	0.91	0.02	< 0.001	-	19.6
Socio-economic level (continuous variable)	-0.11	0.88	0.80	0.98	0.00	< 0.001	-	11.3

α = -6.176, represents the value of the intersection of the straight line equation, when the independent variables take zero value. BMI: Body Mass Index.

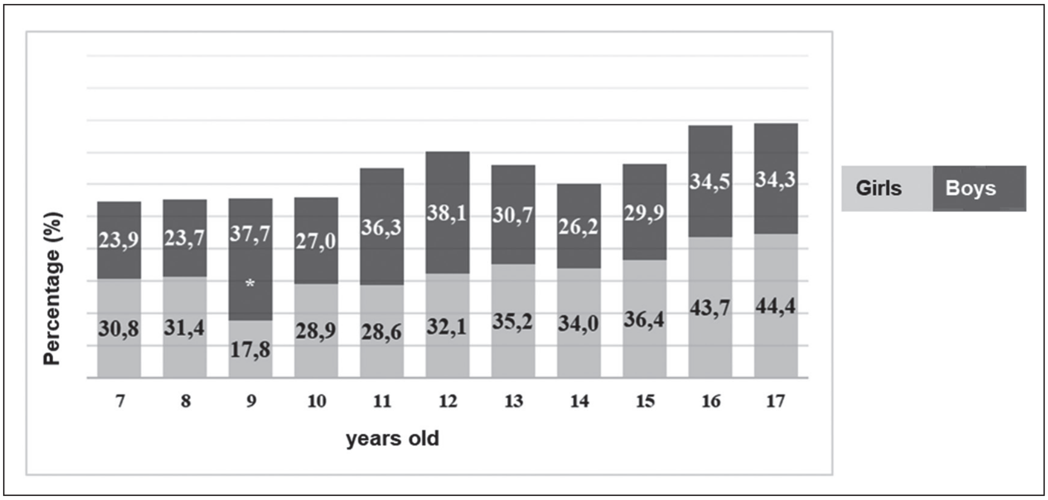

Figure 2. Prevalence of cardiovascular and metabolic risk (WHtR > 0.50) in girls and boys according to age. * 9 years old, $p < 0.05$.

percentile of the female group and the 72.7 percentile of the male group.

A study conducted in Mexico[19] reported an average WHtR of 0.48 for boys and 0.47 for girls aged 6 to 8 years, while a Chilean study[20] found that the average of this indicator for girls and boys aged 5 to 9 years was 0.49. In our study, the average of this indicator for girls aged 7 to 17 years ranged from 0.46 ± 0.04 (lowest at age 9 years) to 0.49 ± 0.08 (highest at age 16 years). For boys aged 7 to 17 years, the average WHtR range was from 0.46 ± 0.4 (lowest at age 7 years) to 0.49 ± 0.06 (highest at age 12 years). However, it should be considered that between the cited studies and this investigation, the WC measurement points, and the age groups examined were different, which could be causing these discrepancies.

When comparing risk levels, the scientific community needs to establish a consensus on WC measurement points since existing studies are heterogeneous regarding measurement techniques and points. These aspects challenge research groups to work with standardized methodologies to perform comparative population analyses. This situation has direct effects on the magnitude of the measurements[21] and the statistical expression of the relationship of risk factors in both children and adults[22].

In Costa Rica, there are no previous studies on the behavior of WHtR in prepubertal boys or girls or middle and late adolescence. The results of this study reveal that children and adolescents with high SES are at a lower risk of cardiovascular disease (according to logistic regression analysis of WHtR) and that, as expected, this risk increased with BMI and fat percentage. The cardiovascular disease risk (according to logistic regression analysis of WHtR) decreased with sex, age, and socioeconomic status. According to Kolle et al, girls from the low socioeconomic status group had a greater increase in WC over the 5-year study period than girls from the high SES group[23]. However, a study in Pakistan found the opposite results, indicating that higher WC values and obesity correlated with higher socioeconomic status and higher parental education[24]. The reason for this discrepancy could be sociocultural.

To our knowledge, this is the first study performed with Costa Rican children and adolescents to determine the prevalence of cardiometabolic risk in these population groups. The detection of this risk in pediatric populations is not routine in the clinical practice, except in specific nutritional situations, such as the presence of obesity and diabetes, in addition to the decrease in the frequency of medical consultations during adolescence that reduces the possibility of early detection of metabolic alterations. The lack of diagnosis, control and treatment of these alterations based on the simple determination of the WHtR indicator could be a factor that hinders the prevention of future undesirable cardiometabolic outcomes.

The findings of this study suggest that WHtR, as a simple and accessible procedure, should be part of the screening for the possible detection of MetS risk from an early age. Therefore, public health authorities could use this anthropometric information and its relationship with more deplorable socioeconomic conditions to suggest effective intervention strategies to reduce WC and WHtR and abdominal obesity-related diseases and their resulting mortality and morbidity. It is necessary to develop a protocol to establish a standardized methodology to measure WC and to use WHtR as a reliable "epidemiological" indicator to detect children and adolescents at cardiometabolic risk, provide follow-up and surveillance from an early age.

Strengths of the study

The sample of this study is broad, probabilistic, and representative for primary schools and high schools in Costa Rica, and the measurements were performed by highly trained and standardized personnel.

Limitations of the study

The design of this study is cross-sectional, so it only allows drawing inferences about associations and not causality. The socioeconomic data were based on self-recording, which may be influenced by social desirability and recall bias. Bioimpedance was used in this study, which is not considered a gold standard method for measuring body composition. Finally, the study population is growing and since their pubertal development was not deeply studied, it is not possible to infer the morphology achieved by the population.

Conclusions

This is the first study carried out in Costa Rica that warns that one-third of the primary school and high school student population (31.8%) is at cardiometabolic risk (WHtR > 0.50). It also provides valid anthropometric data that could be used as a basis for future studies to establish reference values (WHtR percentiles) for Costa Rican children and adolescents.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

Authors state that no economic support has been associated with the present study.

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