

Neck circumference percentiles and anthropometric and adiposity indicators in Mexican schoolchildren

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ABSTRACT

Introduction. Neck circumference is a useful anthropometric measure for identifying adiposity in children; however, few percentiles are available for school-aged children in northwestern Mexico.

Objectives. To estimate smoothed percentiles of neck circumference by age and sex, and to evaluate their association with anthropometric and adiposity indicators in schoolchildren aged 7 to 12 years in northwestern Mexico.

Population and methods. We conducted a cross-sectional study among 319 schoolchildren aged 7 to 12 years from four elementary schools in Ciudad Obregón, Sonora. Weight, height, neck circumference, waist circumference, triceps skinfold thickness, and body fat percentage (measured by electrical bioimpedance) were measured. We estimated smoothed percentiles using the LMS method.

Results. We included 174 girls and 145 boys. Smoothed percentiles (P10, P25, P50, P75, and P90) were estimated by age and sex. Neck circumference was positively correlated with age-adjusted body mass index (BMI), waist circumference, body fat percentage, and triceps skinfold thickness.

Conclusion. Neck circumference showed a positive association with anthropometric and adiposity indicators, suggesting that it could serve as a complementary anthropometric measure for assessing adiposity in this population.

Keywords: neck; adiposity; childhood obesity; reference values; body mass index.

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INTRODUCTION

Childhood obesity is defined as the excessive accumulation of adipose tissue; its development is multifactorial, and when excess weight persists from childhood into adulthood, the risk of metabolic complications increases.¹⁻³ According to data from the 2026 Global Obesity Atlas, in 2025, 25% of children aged 5 to 19 were obese in 14 countries, and more than 30% had a high body mass index (BMI).⁴ Furthermore, the World Health Organization (WHO) estimated in 2022 that 390 million children and adolescents were overweight, of whom 160 million were obese.⁵

In Mexico, during 2022–2023, the prevalence of overweight and obesity was 36.5% among schoolchildren and 40.4% among adolescents.⁶ In the North Pacific region, where Sonora is located, the National Health and Nutrition Examination Survey 2020–2022 (ENSANUT, by its Spanish acronym) reported prevalence rates of 38.3% among children and 49.1% among adolescents, as well as the highest prevalence of obesity (26.2%) among the country's regions.⁷ BMI is the most commonly used indicator for diagnosing overweight and obesity; however, it does not distinguish between fat mass and lean mass.⁸ Waist circumference is used to assess abdominal adiposity, although there is no consensus on the anatomical site for measurement. In the pediatric population, different reference points have been used, such as the minimum waist circumference, the midpoint between the last rib and the iliac crest, the upper edge of the iliac crest, and the level of the umbilical scar. Although the measurements obtained show similar associations with visceral fat and cardiometabolic risk, their absolute values may vary; therefore, it is essential to specify the protocol used.⁹ Furthermore, waist circumference is correlated with BMI, which limits its usefulness as an independent indicator of cardiometabolic risk.¹⁰ In this context, neck circumference represents a simple, rapid, and low-cost alternative for assessing adiposity, as it has been associated with metabolic abnormalities¹¹ and with the identification of overweight and obesity in schoolchildren.¹² Although Valencia-Sosa et al.¹³ report percentile reference values for Mexican children aged 6 to 11 years, these were obtained from normal-weight schoolchildren in the state of Jalisco; therefore, their data should be extrapolated with caution among schoolchildren in Sonora. Anthropometric measurements may vary depending on the study population's characteristics, as well as the

schoolchildren's age, sex, and nutritional status. Furthermore, regional differences in childhood overweight and obesity have been documented in Mexico, which could reflect variations in body composition and in the sociodemographic and environmental contexts of each region.^{7,13} In this regard, developing smoothed percentiles specific to schoolchildren in Sonora can support a more context-specific and useful assessment for identifying adiposity in this population. Therefore, the present study focused on elementary school students aged 7 to 12 years, a stage at which standardized anthropometric and body composition assessments using electrical bioimpedance are possible, thereby generating reference values applicable to this context.

Consequently, the study aimed to estimate smoothed percentiles of neck circumference by age and sex and evaluate their association with anthropometric indicators and adiposity in schoolchildren aged 7 to 12 years in northwestern Mexico.

POPULATION AND METHODS

We conducted an analytical cross-sectional study between September 2025 and April 2026. The study population consisted of 319 elementary school students in grades 2 through 6, aged 7 to 12, from four urban public elementary schools in Ciudad Obregón, Sonora, Mexico.

We calculated the sample size for a finite population, using the total number of students at the four participating schools as the population, a 95% confidence level, and a 5% margin of error, resulting in a minimum sample size of 239 participants. However, after applying the selection criteria, we included 319 students.

The inclusion criteria were schoolchildren of both sexes, aged 7 to 12 years, enrolled in participating schools, with informed consent from parents or guardians and assent from the children. We excluded those who did not complete the anthropometric or body composition measurements, as well as those with any medical condition or wearing medical devices that prevented evaluation by electrical bioimpedance.

Eighth-semester Bachelor of Science in Nutrition students at the University of Sonora performed the anthropometric and body composition measurements after training in these techniques.

Body weight and body fat percentage were determined using an IronKids® BF-2000 electronic scale (Tanita, Japan), which employs bioelectrical

impedance analysis (BIA), a noninvasive, rapid, and easy-to-use method. The device has a maximum capacity of 150 kg, an accuracy of 100 g, and is designed for use with children aged 5 to 17 years. The manufacturer's built-in algorithm automatically estimated body fat percentage, considering variables such as the participant's age, sex, height, and weight. Measurements were performed following the methodology of the International Society for the Advancement of Kinanthropometry (ISAK).¹⁴

Height was measured using Avanutri 315 portable stadiometers, which have a measurement range of 20-210 cm. Subjects were asked to stand upright and maintain the Frankfurt plane.¹⁴ Using weight and height, age-adjusted BMI was calculated using the WHO's Anthro Plus software, and the z-score was obtained.¹⁵

Waist circumference was measured using a Lufkin metal anthropometric tape (scale from 0 to 200 cm). The child was asked to stand and locate the umbilical scar; the tape was placed around the abdomen without compressing the tissue to take the measurement. The subject was instructed to breathe normally, and the measurement was taken at the end of an exhalation.¹⁶ This anatomical site was chosen because it corresponds to the standardized protocol established for data collection and because it has been previously used in studies of the pediatric population.¹⁷

The triceps skinfold thickness (TST) was measured using the methodology described by ISAK.¹⁴ The measurement was taken using the Slim Guide® Skinfold Caliper, which applies a constant pressure of 10 g/mm², has a measurement range of 80 mm, and an accuracy of ± 1 mm.

Neck circumference was measured with the subject standing upright, with the head positioned in the Frankfurt horizontal plane and facing forward. Using a Lufkin metal anthropometric tape measure with a scale ranging from 0 to 200 cm, we measured along the midline of the neck between the cervical spine and the anterior neck.¹⁸

Statistical analysis

We described categorical variables using absolute and relative frequencies. We assessed the normality of quantitative variables using the Shapiro-Wilk test. Because the variables did not follow a normal distribution, we described them using the median, 25th percentile (P25), 75th

percentile (P75), and interquartile range (IQR). We compared neck circumference between sexes using the Mann-Whitney U test. The association between neck circumference and anthropometric and adiposity indicators was assessed using Spearman's correlation coefficient (ρ). We interpreted correlation strength as follows: negligible (0.00-0.10), weak (0.10-0.39), moderate (0.40-0.69), strong (0.70-0.89), and very strong (0.90-1.00).

We estimated smoothed neck circumference percentiles by age and sex using the LMS method with power-normal regression (xriml) in Stata®. The parameters M (smoothed median) and S (coefficient of variation) were modeled as functions of age using fractional polynomials. Because of the sample size in each age and sex group, we reported the P10, P25, P50, P75, and P90 percentiles, since the extreme percentiles (P3 and P97) may be less stable and accurate in small samples. For presentation, we grouped percentiles by full-year age (7, 8, 9, 10, 11, and 12 years).

Statistical analysis was performed using Stata® version 14 (StataCorp, College Station, TX, USA). A p -value < 0.05 was considered statistically significant.

Ethical considerations

The Institutional Ethics Committee of the Sonora Institute of Technology approved this project on September 22, 2025, under registration number 491. All participants were asked in advance to provide an informed consent form signed by their parent or guardian, in which they agreed to their child's participation in the research; we also requested the minor's informed assent.

The study was conducted in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects¹⁹ and the Nuremberg Code of Medical Ethics.²⁰ The measurements taken posed no risk to schoolchildren. In addition, we considered Articles 28 through 58 of the Regulations of the General Health Law on Health Research²¹ regarding minors.

RESULTS

A total of 319 schoolchildren from the four schools were included, with the following distribution: 44.83% from School 1, 16.93% from School 2, 15.99% from School 3, and 22.26% from School 4; of whom 174 (54.5%) were

girls, and 145 (45.5%) were boys, with a median age of 9 years (IQR: 2.0). The anthropometric characteristics are presented in *Table 1* and *Table 2*. A median BMI/E z-score of 0.09 (IQR: 1.53) was observed, while waist circumference and body fat percentage showed median values of 63 cm (IQR: 17.5) and 21.5% (IQR: 11-4), respectively.

Boys had a significantly larger neck circumference than girls (29.3 cm vs. 27.4 cm, $p < 0.001$). In both sexes, neck circumference showed positive, statistically significant correlations with all anthropometric indicators assessed (*Table 3*).

The strongest correlation was with waist circumference in both girls ($\rho = 0.792$; $p < 0.001$) and boys ($\rho = 0.848$; $p < 0.001$).

Tables 4 and *5* and *Figures 1* and *2* present the age- and sex-specific smoothed neck circumference percentiles for both girls and boys. For girls, the smoothed median increased from 25.87 cm at age 7 to 29.66 cm at age 12, while for boys it increased from 28.02 cm to 31.21 cm over the same age range. Overall, boys had higher neck circumference values across all evaluated percentiles than girls. Similarly, boys exhibited a wider range between the extreme percentiles, particularly starting at age 10.

TABLE 1. Anthropometric characteristics of the schoolchildren included in the study (n = 319)

Variable	Median	P25	P75	IQR
Age (years)	9.0	8.0	10.0	2.0
Height/A (score)	0.09	-0.65	0.88	1.53
BMI/A (score)	0.43	-0.46	1.94	2.4
Waist circumference (cm)	63.0	56.7	74.2	17.5
Body fat (%)	21.5	17.1	28.5	11.4
TST (mm)	12	9	16	7

P25: 25th percentile; P75: 75th percentile; BMI: body mass index; BMI/A: body mass index for age; height/A: height for age; IQR: interquartile range; TST: triceps skinfold thickness.

TABLE 2. Distribution of schoolchildren by sex, age group, and age-specific body mass index categories (z-score) (n = 319)

Variable	Frequency	Percentage (%)
Gender		
Feminine	174	54.55
Masculine	145	45.45
Age (years)		
7-9	194	60.82
10-12	125	39.18
BMI/A (z-score)	Girls n (%)	Boys n (%)
Underweight	7 (4.0)	3 (2.1)
Normal weight	118 (67.8)	75 (51.7)
Overweight + obesity	49 (28.2)	67 (46.2)

BMI/A: body mass index for age.

TABLE 3. Spearman's correlation between neck circumference and anthropometric indicators by sex (n = 319)

Variable	Girls (n = 174) rho	p-value	Boys (n = 145) rho	p-value
BMI/A (z-score)	0.653	<0.001	0.785	<0.001
Waist circumference (cm)	0.792	<0.001	0.848	<0.001
Body fat (%)	0.655	<0.001	0.754	<0.001
Triceps skinfold thickness (mm)	0.469	<0.001	0.567	<0.001

BMI/A: body mass index for age.

DISCUSSION

This study estimated smoothed percentiles for neck circumference by age and sex in schoolchildren aged 7 to 12 years and evaluated their relationship with various anthropometric indicators of adiposity. The main findings show that neck circumference increases with age in girls and boys. It showed a correlation with BMI (z-score) that was moderate in girls ($p = 0.653$) and strong in boys ($p = 0.785$); the correlation with waist circumference was strong in both sexes ($p = 0.792$ and $p = 0.848$, respectively); with body fat percentage, the correlation was moderate in girls ($p = 0.655$) and strong in boys ($p = 0.754$); and with triceps skinfold thickness, the correlation was moderate in girls ($p = 0.469$) and in boys ($p = 0.567$). These results suggest that neck circumference is a complementary anthropometric indicator for assessing overall and central adiposity in schoolchildren. Although it is a simple, quick, noninvasive, and low-cost measurement, it requires training and standardization to correctly identify the anatomical measurement site, especially in schoolchildren with excess adiposity.

The smoothed percentiles obtained by age and sex showed higher neck circumference

values in boys than in girls, consistent with the findings reported by Valencia-Sosa *et al.*¹³ in Mexican schoolchildren aged 6 to 11 years. In that study, median neck circumference ranged from 25.75 to 28.76 cm in boys and 24.60 to 28.25 cm in girls. In comparison, this study observed higher medians, particularly among boys. These differences may be because Valencia-Sosa *et al.* included only schoolchildren of normal weight, whereas this study evaluated a sample without restrictions based on nutritional status.

The larger neck circumference observed in boys is consistent with the findings reported by Valencia-Sosa *et al.* in Mexican schoolchildren and by Katz *et al.* in a Canadian pediatric population, who have noted that boys tend to have higher measurements than girls.^{13,22} This difference may reflect sex differences in physical growth, development, and body composition. In this regard, some participants (schoolchildren aged 10 to 12) are likely in the pubertal stage. During this stage, pubertal changes may influence body fat distribution and the progressive increase in neck circumference.²² Therefore, it is appropriate to present the percentiles stratified by age and sex, as this allows for a more precise

TABLE 4. Smoothed percentile distribution of neck circumference (cm) in schoolgirls aged 7-12 years (n = 174)

Age (years)	n	M	S	P10	P25	P50	P75	P90
7	29	25.87	1.99	23.31	24.53	25.87	27.21	28.43
8	33	26.63	2.33	23.64	25.06	26.63	28.20	29.62
9	35	27.38	2.67	23.96	25.59	27.38	29.18	30.80
10	33	28.14	3.00	24.29	26.12	28.14	30.17	31.99
11	34	28.90	3.34	24.62	26.65	28.90	31.15	33.18
12	10	29.66	3.68	24.94	27.18	29.66	32.13	34.37

M: smoothed median; S: coefficient of variation; P10: 10th percentile; P25: 25th percentile; P50: 50th percentile; P75: 75th percentile; P90: 90th percentile.

Age categories correspond to years lived.

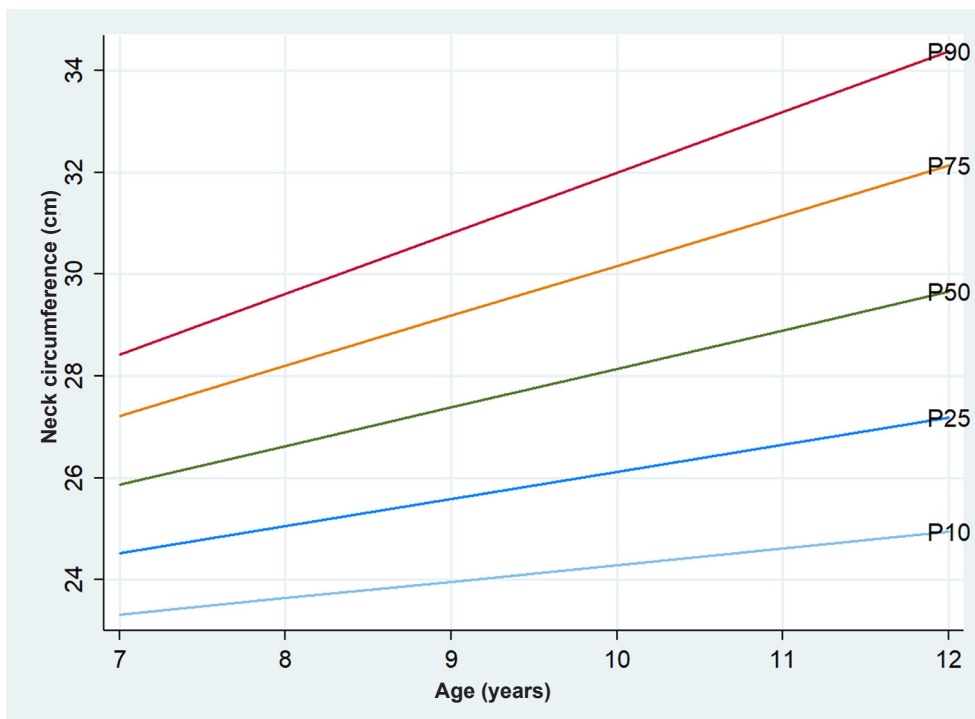
TABLE 5. Smoothed percentile distribution of neck circumference (cm) in school-aged children aged 7-12 years (n = 145)

Age (years)	n	M	S	P10	P25	P50	P75	P90
7	35	28.02	2.25	25.14	26.51	28.02	29.54	30.90
8	21	28.66	2.56	25.39	26.94	28.66	30.38	31.93
9	41	29.30	2.88	25.64	27.37	29.30	31.22	32.96
10	22	29.93	3.18	25.88	27.80	29.93	32.06	33.98
11	21	30.57	3.48	26.13	28.24	30.57	32.90	35.01
12	5	31.21	3.79	26.38	28.67	31.21	33.74	36.03

M: smoothed median; S: coefficient of variation; P10: 10th percentile; P25: 25th percentile; P50: 50th percentile; P75: 75th percentile; P90: 90th percentile.

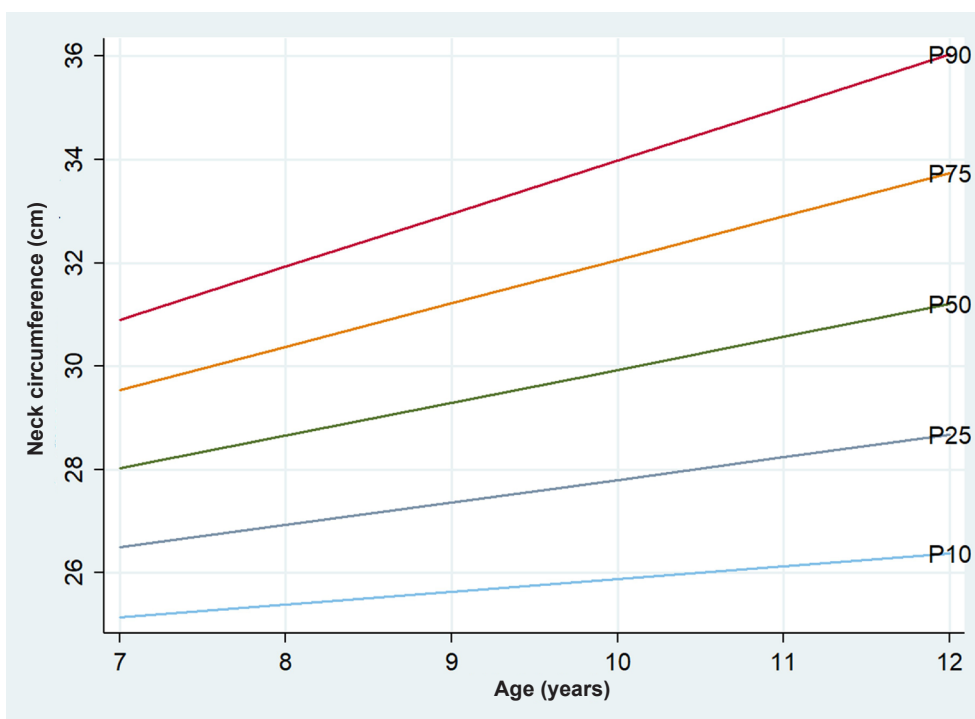
Age categories correspond to years lived.

FIGURE 1. Smoothed percentiles of neck circumference in schoolgirls aged 7-12 years (n = 174)



P10: 10th percentile; P25: 25th percentile; P50: 50th percentile; P75: 75th percentile; P90: 90th percentile.

FIGURE 2. Smoothed percentiles of neck circumference in schoolboys aged 7-12 years (n = 145)



P10: 10th percentile; P25: 25th percentile; P50: 50th percentile; P75: 75th percentile; P90: 90th percentile.

and contextualized interpretation. However, the present study did not assess sexual maturation; therefore, it is not possible to determine the extent to which, or at what level, pubertal development influences differences in neck circumference.

Regarding indicators of adiposity, neck circumference showed the strongest correlations with waist circumference and BMI in both girls and boys. The positive association between neck circumference and waist circumference is consistent with previous studies in Mexican school populations, which suggest that neck circumference may reflect central adiposity or adipose tissue accumulation in the abdominal region.^{11,23} Similarly, Turkay and Kabaran observed a positive, statistically significant relationship between neck circumference, BMI, waist circumference, and body fat in schoolchildren aged 6 to 10 years.¹⁸ It should be noted that in the present study, waist circumference was measured at the level of the umbilical scar, whereas other studies have measured it at the narrowest part of the waist. Although these measurements have shown similar associations with abdominal adiposity and metabolic risk, their values may differ. Therefore, consider the anatomical site and measurement protocol when comparing studies.^{9,17}

The observed correlation between neck circumference and body fat percentage also reinforces the usefulness of this measurement as an adiposity indicator. Romero-Velarde et al. reported that neck circumference was directly associated with body fat percentage—estimated via BIA analysis using a Bodystat 1500MDD II® device—and other adiposity indicators, such as BMI and waist circumference, in children aged 5 to 10 years, particularly those who were overweight or obese.²³ In the present study, the correlation with body fat was higher in boys than in girls, suggesting that the relationship between neck circumference and adiposity may vary by sex. This difference should be interpreted with caution, as children's body composition is influenced by various factors: age, fat distribution, and biological maturation.²⁴

Among the study's strengths is the estimation of smoothed percentiles for neck circumference using the lambda-mu-sigma (LMS) method, a methodology widely used to construct anthropometric references and growth standards. This approach yields more stable and biologically plausible curves by age and sex, in addition to facilitating methodological comparability with

studies conducted in other populations.²⁵

In addition, the authors included a sample of schoolchildren from Sonora and evaluated the relationship between neck circumference and various anthropometric indicators, providing relevant regional information.

However, the study has some limitations. First, its cross-sectional design does not allow the establishment of causal relationships; that is, it is not possible to determine whether the variations result from, or drive, changes in adiposity indicators. Second, the sample consists of schoolchildren from a specific region of Sonora, so the results may not generalize to Mexico's entire child population. Furthermore, the study did not include variables related to sexual maturation and biochemical or metabolic markers, which could help interpret the relationship between waist circumference and neck circumference, adiposity, and cardiometabolic risk. Furthermore, although the evaluators were previously trained on anthropometric techniques, the authors did not formally assess technical measurement error or interobserver agreement. Finally, the sample size by sex and for some age groups—particularly among 12-year-old schoolchildren—could affect the accuracy of the percentile estimates obtained using the LMS method. However, we present sample sizes by age group, and we estimated percentiles using smoothing techniques widely used to construct reference curves.

CONCLUSION

Neck circumference showed moderate to strong correlations with anthropometric and adiposity indicators in schoolchildren aged 7 to 12 years in northwestern Mexico. In addition, we estimated age- and sex-specific smoothed percentiles, which may support anthropometric assessment in this population. ■

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