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Original Research Article

Neck circumference cut-off points to determine obesity in Chilean preschool children

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ABSTRACT

Background: The prevalence of obesity in Chilean preschoolers is high. Simple methods for the diagnosis in Chilean preschoolers are of public health interest. We determined neck circumference cut-off points as a proxy measure of obesity according to age and sex.
Methods: 597 participants (267 girls) were included. NC, weight, height, and waist circumference were measured. Body mass index scores (BMI z scores) was calculated. Descriptive variables for girls and boys were compared with t-test. Pearson correlations were calculated to examine the relationship of NC with classical anthropometric measures. NC cut-off values (ROC analysis) and Kappa coefficient, were calculated.
Results: NC was positively associated with BMI z score and WC among girls and boys, across age groups (all $p<0.001$). Obese cut-off points of NC for elevated BMI z score were between 25.3~25.9 cm in girls and 26.2 in boys, while those for WC were, 25.7 and 26.3 for 5-year-old girls and boys, respectively. The KC between BMI z score or WC with NC had an agreement strength between poor to moderate (all $p<0.001$).
Conclusions: NC demonstrated to be a reliable indicator for the diagnosis of obesity for Chilean preschoolers. Future studies are needed to validate this finding.

Keywords: Neck circumference, Obesity, Preschooler

INTRODUCTION

Obesity is strongly associated with negative health outcomes, including metabolic syndrome, type-2 diabetes mellitus, cardiovascular disease, and cancer.[1-4] The worldwide prevalence of obesity in preschoolers, according to body mass index z scores (BMI z scores), is high.[5] Previous results also reported the Latin America

and Caribbean region as the global region with the highest prevalence of overweight among children under 5 years of age.[6] In Chile, the prevalence of overweight and obesity in preschoolers is 51.2%.[7] In this context, new strategies for the diagnosis of obesity of Chilean preschoolers are of public health interest.

Traditionally, total and central obesity among children relies on BMI and waist circumference (WC), which has sparked some debate.[8-10] Likewise, neck adipose tissue, an ectopic depot of the upper body, has been associated with cardiometabolic risk (CMR) and inflammatory profile, independent of visceral adipose tissue mass in young people.[11,12] However, findings on neck adipose tissue in the pediatric population are still unknown. Neck circumference (NC) has been associated with adiposity indicators, such as BMI, WC, fat mass index, and/or visceral adipose tissue mass in children and adults.[13,14] Indeed, NC has also been proposed as a useful surrogate tool of estimation of neck adipose tissue and CMR, especially in sedentary young men.[12] Recently, in children and adolescents, NC has also been identified as a potential predictor of early metabolic alterations.[13,15]

At present, NC cut-offs have been used as a novel indicator to screen pediatric obesity in preschoolers, and CMR in children and adolescents.[16,17] Regarding the comparative advantages with other classical anthropometric indicators, NC is characterized by: being an measurement which is easy to determine, not changing throughout the day, not being influenced by abdominal distension, not being altered by inhalation and exhalation, and being a practical assessment that can be easily used during cold weather.[16] Currently, age-related NC cut-offs have been reported in Turkish, and Pakistani preschool children.[18,19] Nevertheless, NC cut-offs for Chilean preschoolers have not been established. Due to the clinical utility of NC of children worldwide, it is useful to have information on studies carried out in several countries, especially in those where prevalence of overweight and obesity has been increasing over the years. In this context, this study aimed to associate NC with anthropometric indicators of total and central fat mass in the pediatric population and to determine NC cut-off points as a proxy measure of obesity in Chilean preschoolers, according to sex and age. This information may be useful to parents, clinical practitioners and teachers, and could redirect obesity screening in public health policies for diagnosing obesity among Chilean preschoolers.

METHODS

Participants

This cross-sectional study included a sample of 597 participants (267 girls) aged 4 to 5 years old**.** Participants were enrolled in the "preschool children: fit, healthy, and smart: PREFITH-CHILE" study (clinical trial registration: NCT 04269135). All assessments were performed in 4 regions, Santiago, Valparaíso, Libertador Bernardo O'Higgins, and Coquimbo from 2018 till 2019. The inclusion criteria were not having neurologic, motor, and hearing alterations or other condition that may limit the practice of regular physical activity, not taking medication that can influence the central nervous system, and understanding the Spanish language**.** This study was approved by the bioethics committee of the nutritional and food institute of the university of Chile. The study protocol and the written informed consent were performed following the Declaration of Helsinki (revision of 2013).

Procedure

Neck circumference; NC was measured using an inextensible metallic tape over the laryngeal prominence and applied perpendicular to the long axis of the neck.[20] During the measurement, the participant was in an anatomical position, standing or sitting with the head in the Frankfort plane and shoulders relaxed. All measurements were made in duplicate, using the mean for the analysis. The error technical measure (ETM) accepted by our laboratory was 1.5%.[21]

Classical anthropometric indicators; body weight (kg) and height (m) were measured using a calibrated digital scale (SECA model 813) and a portable stadiometer brand (SECA model 213) respectively. Participants wore light clothing and no shoes. BMI (kg/m^2) and BMI z-scores were calculated.[22] Waist circumference (WC) was measured in the minimum perimeter, at the end of a normal expiration, the arms relaxed on both sides of the body, at the end of a normal expiration, with the arms relaxed on both sides of the body.[20] WC was measured twice with a metallic tape, and we used the mean value for the analyses. We used the Fernandez et al WC cut-off to define obesity.[23]

Statistical analysis

The present study is based on a secondary analysis of PREFITH-Chile therefore, a specific power calculation was not required for the present study. However, the sample size the original study (considering the 80% of power and error α of 5%) was calculated from results showed by a study about the effects the degree of association of physical fitness with non-invasive risk factors and neuropsychological development in children[24]. The distribution of the main variables was verified using the Shapiro–Wilk test, skewness and kurtosis values, visual check of histograms, Q-Q, and box plots. All the analyses were performed separately for girls and boys by age, given the influence of the interactions of sex/age with BMI and WC on NC (all $p \leq 0.05$). Subject characteristics were reported as the mean and standard deviation, and the descriptive variables for girls and boys were compared with an independent sample t-test (equal variances**).** Pearson correlations were calculated to examine the relationship of NC with classical

anthropometric measures. NC cut-off values were calculated for 4-5 year old children with receiver operating characteristics (ROC) analysis, considering obesity as the dependent variable defined as BMI z scores>2.[22,25] In addition, Cohen's Kappa coefficient was used to determine the agreement between BMI z-scores (as gold standard) or WC, and obesity cut-off points for NC. The agreement strength was based on the following criteria: 0.00-0.20 (poor), 0.21-0.40 (fair), 0.41-0.60 (moderate), 0.61-0.80 (good), 0.81-1.00 (very good).[26,27] All analyses were done using the Statistical Software STATA, version 17.0, and the level of significance was set at ≤0.05.

RESULTS

The main characteristics of NC in Chilean preschoolers aged 4 and 5 years by sex and descriptive characteristics are presented in (Table 1).

No difference in BMI z scores between girls and boys (p=0.0860) was observed. However, boys´ NC was significantly higher than girls´ (25.8±1.6 cm vs. 25.1±1.5 cm, respectively; p<0.001). NC was positively associated (all p<0.001) with all classical anthropometric indicators among girls and boys, across age groups (Table 2).

Pearson correlations of NC with weight were higher in all age and sex groups (r Pearson>0.77). In addition, the association of NC with BMI z score was higher in 5-year-old girls (r Pearson≥0.78). The accuracy of NC to identify high BMI z-score, according to both age and sex is depicted in (Table 3). In girls, obese cut-off points for NC were equal or greater than 25.3 cm for 4-year-old, and 25.9 cm for 5-year-old. In 4- and 5-year-old boys, the cut-off values for obesity were 26.2 cm in both age groups. Obese cut-off points for WC were 25.7 and 26.3 for 5-year-old girls and boys, respectively. In addition, the sensitivity %, specificity %, Youden index, and likelihood ratios for each cut-off point are also shown in (Table 3). The calculated Kappa coefficient between BMI z-score and NC, which ranged from 0.38 to 0.58 and from 0.58 to 0.45 for 4- and 5-year-old girls and boys respectively (all p<0.001) are shown in (Table 4). In addition, the Cohen's Kappa coefficient between NC according to WC was calculated only for 5-year-old. These values were 0.54 and 0.53 for girls and boys respectively (p<0.001).

Table 1: Descriptive characteristics of the study participants.

Variables	All (n=597)		Girls (n=267)		Boys (n=330)		P value
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	5.2	0.5	5.2	0.5	5.2	0.5	0.9173
Weight (kg)	21.1	4.0	20.8	4.0	21.3	3.9	0.1469
Height (cm)	110.6	5.7	109.9	5.7	111.2	5.7	0.0065
BMI z score	1.1	1.2	1.0	1.1	1.2	1.2	0.0860
NC (cm)	25.5	1.6	25.1	1.5	25.8	1.6	≤0.001
WC (cm)	56.1	6.1	56.4	6.1	55.9	6.2	0.3586

Values are means±standard deviation; p for comparisons by sex; (n) is sample size, (p) p value; BMI body mass index; NC neck circumference; WC waist circumference, t test was used to analyse statistical differences according to sex.

Table 2: Association between neck circumference and classic anthropometric variables by age and sex.

Age group	Neck circumference (cm)			
	4-year-old		5-year-old	
All				
Variables	r	n	r	n
Weight (kg)	0.77*	234	0.80*	363
Height (cm)	0.55*	234	0.50*	363
BMI z score	0.68*	234	0.75*	363
WC (cm)	0.69*	234	0.76*	363
Girls				
Weight (kg)	0.74*	103	0.84*	164
Height (cm)	0.56*	103	0.51*	164
BMI z score	0.61*	103	0.78*	164
WC (cm)	0.69*	103	0.79*	164
Boys				
Weight (kg)	0.80*	131	0.79*	199
Height (cm)	0.52*	131	0.48*	199
BMI z score	0.74*	131	0.73*	199
WC (cm)	0.74*	131	0.79*	199

Pearson correlation coefficients were determined to examine the association of neck circumference with weight, height, BMI z score and WC by age and sex; (n)=Sample size; *p≤0.001; BMI=body mass index; WC=waist circumference.

Table 3: Receiver operating curve analysis for neck circumference and waist circumference to determine cut-off points for 4 to -5-year-old girls and boys with obesity according to BMI z-score and WC.

Age (years)	N	AUC (95% CI)	Cut-off (cm)	Sensitivity (%)	Specificity (%)	YI	LR+	LR-
Neck circumference cut-off points according to BMI z score								
Girls								
4	103	0.78 (0.65-0.91)	25.3	84	70	0.54	2.80	-0.20
5	164	0.91 (0.86-0.97)	25.9	83	86	0.69	5.93	0.04
Boys								
4	131	0.88 (0.80-0.96)	26.2	78	88	0.66	6.50	0.11
5	199	0.85 (0.79-0.90)	26.2	82	70	0.53	2.73	-0.17
Neck circumference cut-off points according to BMI z-score								
Girls								
4	-	-	-	-	-	-	-	-
5	164	0.84 (0.83- 0.96)	25.7	95	75	0.70	3.80	0.06
Boys								
4	-	-	-	-	-	-	-	-
5	199	0.85 (0.89-0.97)	26.3	87	81	0.68	4.57	0.16

AUC=area under the curve; CI. BMI=body mass index; Confidence interval; LR+. Positive likelihood ratios (sensitivity/1-specificity); LR-. Negative likelihood ratios (1-sensitivity/specificity); YI. Youden index. WC. Waist circumference.

Table 4: Assessment of level of agreement between obesity according to BMI z-score and waist circumference with neck circumference.

Variables						
Girls						
4-year-old			**5-year-old**			
BMI z-score with NC		**WC with NC**	**BMI z-score with NC**		**WC with NC**	
N with obesity by BMI z score >2	N with obesity by BMI z score >2 and NC >25.3 cm	Without cut-off	N with obesity by BMI z score >2	N with obesity by BMI z score >2 and NC >25.9 cm	N with obesity by WC >61.4 cm	N with obesity by WC >61.4 cm and NC >25.7 cm
19	16		29	24	31	27
Kappa coefficient						
0.38*		-	0.58*		0.54*	
Boys						
4-year-old			**5-year-old**			
BMI z-score with NC		**WC with NC**	**BMI z-score with NC**		**WC with NC**	
N with obesity by BMI z score >2	N with obesity by BMI z score >2 and NC >26.2 cm	Without cut-off	N with obesity by BMI z score >2	N with obesity by BMI z score >2 and NC >26.2 cm	N with obesity by WC >61 cm	N with obesity by WC >61 cm and NC >26.3 cm
23	18	- -	57	47	42	40
Kappa coefficient						
0.58*			0.45*		0.53*	

*P≤0.001. BMI z. Body mass index z-score, N. Sample size, NC. Neck circumference, WC. Waist circumference.

DISCUSSION

This study showed that in a sample of Chilean preschoolers, NC is associated with classical anthropometric indicators, such as BMI z-score and WC, in both girls as boys, with agreement strength between poor to moderate. Our findings suggest that NC could be implemented as an easy, low cost and replicable anthropometric indicator for the clinical obesity diagnosis of Chilean preschoolers. However, future studies are needed to validate this finding. Previous evidence have shown NC as a simple and practical indicator of obesity in children.[18] Specifically in preschoolers, a cross-sectional study showed that in 1766 Turkish children aged 2-6 years old from all socioeconomic levels, NC was statistically associated with BMI≥95th percentile in both sexes.[18] Interestingly, the authors provided NC cut-off values to determine obesity in girls and boys close to our values (girls: 25.8 cm for 4 year old, 25.7 cm for 5 year old; boys: 25.9 cm for 4 year old, 27 cm for 5 year old).

Similarly, another cross-sectional study including 7921 Pakistani children and adolescents aged 5-14 years, showed that NC has a positive correlation (r=0.61, p<0.01) with BMI, even after adjusting by age, sex, and living area, and that approximately 25 and 26 cm are optimal cut-off points to identify 5 year old girls and boys with obesity, respectively.[18,19]

The WC is a double indirect and non-invasive indicator used for diagnosis of central obesity in children and adolescents.[20-28] Several studies in children have shown that NC is significantly associated with WC in school children, and can be used as an inexpensive and simple indicator for central obesity.[29,30] However, only one previous study has explored NC use as a cut-off to detect central obesity. In a cross-sectional study involving 5964 Pakistani children (between 8 and 9 years old), Muhammad Asif et al showed that the NC cut-offs for central obesity diagnosis were 26.54 and 26.56 cm in girls and boys, respectively. However, the lack of studies showing these values only in preschool children does not allow us direct comparisons.

In our study, BMI z score and NC had an agreement strength between poor to moderate (Kappa coefficient) of 0.58, while showing that NC could be an indicator with better sensitivity for 5-year-old girls and 4-year-old boys. It is noteworthy that the Kappa coefficient has not been calculated in other studies involving preschoolers. However, in a study including with 2847 Chinese children aged 7-12 years, Lou et al showed a higher level of Kappa coefficients´ agreement, 0.65 in boys, and 0.63 in girls (p≤0.001). Consequently, the lower sample size and statistical power of our study may explain the results, though more studies are needed to confirm this hypothesis. In addition, we showed for the first time, the Kappa coefficient between NC and WC in 5-year-old preschoolers, with a similar strength agreement between girls and boys. However, the lack of percentile cut-off for central obesity diagnosis for 4-year-old preschoolers does not allow determining the agreement for this age group. Interestingly, for the 5-year-old group, girls showed a better agreement between BMI z score and NC than boys, whose agreement was better for WC and NC. This could be explained by the age-related difference in central and upper body fat distribution by sex, observed as age increases which is closely related to genetic composition and sexual dimorphism, and should be considered in future studies.[12,31-35] Although there are no studies that associate NC with gold standard indicators of total and central fat mass in pediatric population, two studies have shown the association of NC with bio-electrical impedance analysis technique in children and adolescents.[16] In this context, Bammann et al investigated 78 preschool/school children aged 4-10 years, from four different European countries, and showed that NC is not the best predictor of fat mass (unadjusted R^2=0.484).[36] More recently, Coutinho et al showed that in 2794 Brazilian school children 6 to 19 years, from five different schools, NC was strongly correlated with fat percentage.[13]

Despite NC has been associated with higher upper body subcutaneous fat, a deposit of fat that includes neck adipose tissue, described as having an important contribution to the available systemic free fatty acids (more than central fat), and that some studies have shown NC as a good indicator of CMR cluster in children, adolescents and young adults, whether NC is associated with CMR in Chilean preschoolers, is unknown and should be explored in future studies.[11,12,15,17,37-40]

Limitations

Limitations of current study were; considering there is no WC cut-off for 4-year-old children, the level of agreement between NC and WC could not be assessed. In addition, we only included 4 to 5 years old due to the small sample size of 3-year-old children. Nonetheless, determining this indicator in this age group, close to the adiposity rebound, can be seen as a strength of this study.

CONCLUSION

NC is associated with BMI z score and WC, in girls and boys, with agreement strength between poor to moderate. Although the results of this study suggest that NC may be a practical diagnostic tool for obesity in Chilean preschoolers, we recommend that additional studies should test its validity and association with health outcomes. In addition, because the increase in adipose tissue occurs mainly in childhood and adolescence, it would be important to perform longitudinal studies considering this variable and study this association with central obesity and CMR.

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