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Neck Circumference Percentiles of Iranian Children and Adolescents: The Weight Disorders Survey of CASPIAN IV Study

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Abstract

Background: Neck circumference (NC), emerging as a key morphological index for pediatric obesity, is associated with obesity- and overweight-related detrimental conditions in children. In this study, we aimed to provide the age- and sex-specific percentile reference values for neck circumference of the Iranian children and adolescents.
Methods: We used the data gathered through the weight disorders survey of CASPIAN IV study conducted in 2011 - 2012 in Iran, including a total of 21954 Iranian children and adolescents, composed of 10750 girls and 11204 boys, aged 7 - 18 years old. We presented the interval of NC percentile in three age groups of 7 - 10 years, 11 - 14 years, and 15 - 18 years. Finally, age-specific nomograms of NC for both genders in the Iranian and Canadian populations were compared.
Results: The intervals of 90th percentile of NC for boys in the three periods of school age (7 - 10 years), pre-adolescence (11 - 14 years), and adolescence (15 - 18 years) were 24.2 - 30.0 cm, 26.6 - 33.2 cm, and 30.1 - 38.5 cm, respectively. These intervals for girls were 23.7 - 30.1 cm, 26.5 - 33.7 cm, and 28.5 - 36.0 cm, respectively. NC increased with age in both boys and girls and its variability showed an increasing trend with age.
Conclusions: We demonstrated for the first time the NC reference values for the Iranian children and adolescents aged 7 - 18 years old. Considering the significant differences between our national NC references and the values reported from the Canadian population, it seems logical to use these national percentiles not only for epidemiologic studies but also for routine clinical examinations.

Keywords: Neck Circumference, Anthropometric Measures, Obesity, Children and Adolescence

1. Background

Overweight and obesity are known to be associated with various risk factors for later metabolic and cardiovascular disorders, and their prevalence continues to rise among Iranian children and adolescents (1). Therefore, close monitoring in childhood seems to be of utmost importance to prevent long-term complications of the obesity.

The most commonly used criteria for identification of overweight and obesity is the body mass index (BMI). However, the risk of multiple cardiovascular and metabolic disturbances has been found to be correlated with body fat distribution rather than just overweight and obesity (2, 3), and the BMI seems to be deficient in this regard (4-6); thus,

clinical decision-making cannot be solely relied upon this index (7, 8). Accordingly, several anthropometric indices have been proposed to provide further information on the characteristics of subjects including waist circumference (WC), skinfold thickness, and mid-upper arm circumference (MUAC) (9). Of these, WC and MUAC were reported to be useful in detection of central obesity, but measuring WC was found to be challenging, particularly in children (10, 11). Therefore, search for a simple and easily measured index for optimal classification of children continued. In this regard, neck circumference (NC) emerged to be a promising possible alternative indicator for pediatric obesity (12). NC measurements were found to exert some advantages over those traditional indices (12) and it is particularly helpful for prediction of obstructive sleep apnea in children, due to its etiological links with fat distribution in the neck (13, 14). Moreover, since larger sizes of neck have been shown to be associated with pediatric obesity (12, 15, 16), metabolic risk factors (17), cardiovascular diseases (18-20), obstructive sleep apnea (14) and age- and sex-specific reference values of NC might be applicable in prediction of these outcomes.

NC nomograms have been developed for specific populations in Turkey (15), Canada (12), and Europe (21). To date, no valid standard references have been developed for NC measurements of Iranian children and adolescents. This study aimed to develop age- and sex-specific percentile reference values for neck circumference of Iranian children and adolescents. In addition, we aimed to compare the NC values of the Iranian children with the references of the Canadian population.

2. Methods

2.1. Study Population

Data from 21954 Iranian children and adolescents (including 10750 girls and 11204 boys between 7 and 18 years of age) were gathered through a national survey on weight disorders. The survey was conducted in 2011 - 2012 (22, 23) as a complementary of a national school-based surveillance program entitled Childhood and Adolescence Surveillance and PreventIon of Adult Non-communicable disease (CASPIAN-IV survey). Study population and sampling framework were reported in Kelishadi et al. study (23). Briefly, in these surveys, multistage cluster sampling from urban and rural areas of 30 provinces of Iran was performed. Exclusion criteria in these surveys included having a chronic disease, history of chronic medication consumption, and being on a special diet. Participation rate was 90.6%.

The protocols of the present study were approved by research ethics committee of Isfahan and Alborz University of Medical Sciences. Informed consent was obtained from parents of the children or their guardians.

2.2. Measurements

All measurements were recorded by trained physicians using calibrated devices. Detailed description of procedure and measurements were presented in previous article (22). Briefly, the height (cm) without shoes was measured using a stadiometer (SECA Model 207, Hamburg, Germany) while the child standing upright with the heels and back against a vertical scale. The weight was measured without shoes and heavy outer clothing by a balanced scale (SECA Model 710, Germany) that was calibrated daily. A Gulick measuring tape was used to measure NC with an accuracy of 0.1 centimeters (cm) with the most prominent portion of the thyroid cartilage taken as a landmark. WC (cm) was measured at the top of the iliac crest as a landmark. We calculated BMI by dividing weight (kg) by height squared (m^2).

2.3. Statistical Analysis

In order to elicit sex-specific smoothed percentiles for age, the Lambda-Mu-Sigma (LMS) method of Cole and Green was used (24). In this method, three curves are utilized to demonstrate the trend of changes in NCs of the study population. The skewness, the median, and the coefficient of variation are defined as functions of age by the L, M, and S curves, respectively.

Since we included data from the age group of 7 to 18 years, to compare our data with the Canadian study, age-compatible subjects were chosen from our survey including the children and adolescents aged 7 to 17 years old.

The standard curves for NC of Canadian children were presented by Katz et al. in 2014 based on the data gathered from 1913 boys and girls aged 6 to 17 years old through the second cycle of the Canadian health measures survey. Data collection was performed by home visits, the details of which are further described in previous studies (12).

Age- and gender-specific percentiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th) of NC were calculated and the curves were drawn. The goodness-of-fit and the normality of the Z-Scores were examined via Chi square test and de-trended Q-Q plot, respectively. Since 90th and 95th percentiles are considered as the borderline and high values in anthropometric measurements, the results of the present study are mostly reported in these percentiles.

Lambda-Mu-Sigma Chart Maker Pro program (version 2.54, medical research council, Cambridge, UK) was used to develop smoothed age-specific percentiles of NC for both genders. Descriptive statistics were calculated by the STATA (11.0) software and then the percentile curve graphs for these data were plotted.

4. Results

Data gathered from a total of 21954 Iranian children and adolescents (including 10750 girls and 11204 boys aged between 7 and 18 years) through a survey conducted from 2011 to 2012 were analyzed. Table 1 shows the baseline characteristics of the study children and adolescents. NC percentiles by age are presented for both genders in Table 2. Age- and sex-specific NC nomograms are also depicted in Figure 1.

Table 1. Baseline Characteristics of Study Children and Adolescents

	Age Groups[a]		
	7 - 10	11 - 14	15 - 18
Boys			
n (%)	3622 (32.3)	4012 (35.8)	3570 (31.9)
Height (cm)	127.5 (9.3)	148.2 (11.3)	169.6 (9.7)
Weight (kg)	26.6 (7.4)	41.7 (12.6)	61.2 (14.3)
Body mass index ($km/m^{2)}$	16.2 (3.7)	18.7 (4.6)	21.1 (4.3)
Waist circumference (cm)	58.7 (7.3)	68.2 (10.9)	75.7 (10.9)
Hip (cm)	68.6 (7.8)	80.6 (10.9)	90.8 (10.8)
Waist to hip ratio	0.86 (0.08)	0.85 (0.09)	0.84 (0.08)
Waist to height ratio	0.46 (0.05)	0.46 (0.06)	0.45 (0.06)
Neck circumference (cm)	27.5 (2.2)	30.2 (2.8)	34.5 (3.2)
Girls (n, %)			
n (%)	3303 (30.7)	3757 (35.0)	3690 (34.3)
Height (cm)	127.2 (9.6)	149.5 (10.3)	159.5 (7.1)
Weight (kg)	26.4 (7.3)	43.0 (13.1)	54.6 (11.4)
Body mass index (km/m^2)	16.2 (3.5)	19.0 (4.5)	21.4 (4.2)
Waist circumference (cm)	57.7 (7.3)	66.8 (9.4)	72.2 (9.3)
Hip (cm)	68.8 (8.6)	83.1 (10.7)	92.5 (9.7)
Waist to hip ratio	0.84 (0.10)	0.81 (0.08)	0.78 (0.09)
Waist to height ratio	0.45 (0.05)	0.45 (0.06)	0.45 (0.06)
Neck circumference (cm)	27.1 (2.5)	30.2 (2.8)	32.2 (2.7)

[a] Data were presented as mean and standard deviation.

We observed sex-related differences in NC and its growth by age. The differences of NC between boys and girls were at most 4.1 cm for the 90th percentile at the age of 18 years, with boys showing an 11.68% higher NC. However, the 95th percentile of girls aged 9 - 13 years indicated a slightly higher NC than that of boys (0.3 - 0.7 cm).

The maximum annual increase in NC of boys occurred during 14 and 16 years of age (1.4 cm at most for the 95th percentile), while for girls it occurred between 11 and 12 years of age (1 cm at most for the 95th percentile). Moreover, the minimum increase of NC for girls was observed between the ages of 17 and 18 years (0.2 cm) in the 5th percentile. On the contrary, the minimum growth of NC for boys was observed between the ages of 7 and 9 years (0.4 - 0.5 cm) for all the percentiles.

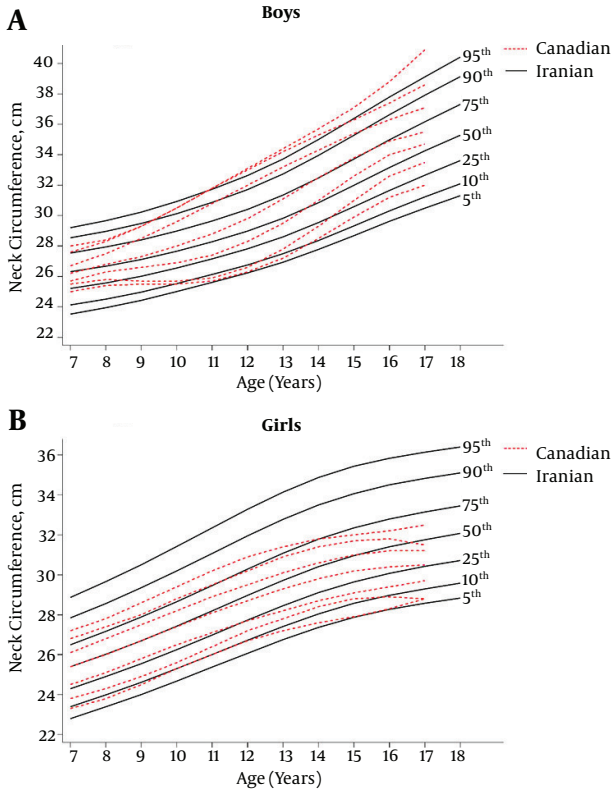

Figure 1. Comparisons of neck circumference percentile curves for Iranian children and adolescents with the Canadian reference data. Centiles are 5th, 20th, 25th, 50th, 75th, 90th, and 95th

The maximum variability (the 95th percentile minus the 5th percentile) of NC was observed at the age of 18 years, and it was at most 9.1 cm and 7.6 cm for boys and girls, respectively. On the other hand, the minimum variability was found at the age of 7, with 5.7 cm and 6.1 cm for boys and girls, respectively.

The NC reference intervals for boys during the three stages of age as school age (7 - 10 years), pre-adolescent (11 - 14 years), and adolescent (15 - 18 years) were 24.2 - 30.0 cm, 26.6 - 33.2 cm, and 30.1 - 38.5 cm, respectively. These intervals for girls were 23.7 - 30.1 cm, 26.5 - 33.7 cm, and 28.5 - 36.0 cm, respectively.

Figure 1 depicts the age-specific nomograms of NC for both genders in the Iranian and Canadian populations

Table 2. Percentile Values of Neck Circumference (cm) by Age and Sex for Iranian Children and Adolescents

Age	Smoothed Percentiles						
	5th	10th	25th	50th	75th	90th	95th
Male							
7	23.5	24.1	25.2	26.3	27.5	28.5	29.2
8	23.9	24.5	25.6	26.7	27.9	29	29.7
9	24.4	25.0	26.0	27.1	28.4	29.5	30.2
10	25.0	25.5	26.6	27.7	29.0	30.1	30.9
11	25.6	26.1	27.2	28.3	29.6	30.9	31.7
12	26.2	26.8	27.8	29.0	30.4	31.7	32.6
13	26.9	27.5	28.6	29.8	31.4	32.7	33.7
14	27.8	28.4	29.5	30.9	32.5	34.0	35.0
15	28.7	29.3	30.6	32.0	33.7	35.3	36.4
16	29.6	30.3	31.7	33.2	35.0	36.6	37.8
17	30.5	31.2	32.7	34.3	36.2	37.9	39.1
18	31.3	32.1	33.6	35.3	37.3	39.2	40.4
Female							
7	22.8	23.4	24.3	25.4	26.5	27.8	28.9
8	23.4	24.0	24.9	26.0	27.2	28.6	29.7
9	24.0	24.6	25.6	26.7	27.9	29.3	30.5
10	24.7	25.3	26.3	27.4	28.7	30.2	31.4
11	25.4	26.0	27.0	28.2	29.5	31.1	32.3
12	26.1	26.7	27.7	29	30.3	32	33.3
13	26.8	27.4	28.5	29.7	31.1	32.8	34.1
14	27.4	28.0	29.1	30.4	31.8	33.5	34.9
15	27.9	28.6	29.6	31.0	32.4	34.1	35.4
16	28.3	29.0	30.1	31.4	32.8	34.5	35.8
17	28.6	29.3	30.4	31.8	33.2	34.8	36.1
18	28.8	29.6	30.7	32.1	33.5	35.1	36.4

next to each other for comparison. Among boys, except ages of 11 and 12 years, the 5th percentile of NC was lower in the Iranian population than the Canadian subjects. The differences are highest at the age of 7; then they decrease to a point that the values are quite equal between the ages of 11 and 12; Finally, the differences again increase until the age of 17. On the other hand, the 95th percentile of NC is higher in Iranian boys up to the age of 11 and after that, the 95th percentile curve of Canadian boys crosses the Iranian curve and diverges up to the age of 17. The differences between the two countries were found to be more prominent in the percentile curves of the girls. The 5th percentile curve of Iranian girls is lower than the Canadian curve for all ages, while the opposite is observed for the 95th percentile curves where they diverge continually with the highest difference at the age of 17.

The maximum NC difference between the two countries was observed in the 95th percentile of girls aged 12 - 17 years old in a way that the NC of Iranian girls is 2.4 - 3.6 cm higher than that of the Canadian girls. On the contrary, in the same age group, the NC of Iranian boys is 0.3 - 0.7 cm lower than that of their Canadian counterparts in the 95th percentile. During 7 - 10 years of age, Iranian boys show 0.4 - 1.2 cm higher NC than Canadian boys for the 95th percentile. Similarly, Iranian girls with 7 - 10 years of age had 1.7 - 2.1 cm higher NC than Canadian girls for the 95th percentile.

5. Discussion

The present study provides the first NC percentile reference values for Iranian children and adolescents aged 7 - 18 years old. This is the first reference curve of NC not only in Iran, but also in Asia and Middle East and North Africa (MENA). We found considerable differences between our national NC reference intervals and the values reported from a Canadian study (12), which necessitates considering the national percentiles not only for epidemiologic studies but also for routine clinical examinations.

In line with previous studies (12, 15, 21), NC increased with age in both genders. Moreover, NC variability showed an increasing trend over age (Figure 1). On the contrary, the curves of different percentiles of NC did not form a plateau in neither of the genders, which is incongruent with the morphological changes observed in Canadian (12) and Turkish girls (15). This plateau is compatible with the puberty pattern in female adolescents (25). However, the European girls (21) did not show this plateau for NC increase, either.

In the standard curves presented for the European population by Nagy et al. (21), the NC values increased constantly with age. Although it seems that puberty affects most anthropometric measurements, NC values in the Iranian and European populations were not affected by puberty, the mechanism of which is not clear.

As presented, for all ages, the 95th percentile of NC in the Iranian girls was higher than that of the Canadian girls, while the Iranian boys showed a slightly lower NC than the Canadian boys from the age of 12 to 17 years. The higher 95th percentile of NC in the Iranian girls is somewhat similar with the results of the Turkish study (15), which might be indicative of the important role of ethnicity, climate, and geographical differences in NC of the people.

The reference values presented in this study could be used by the Iranian physicians to identify children and adolescents with abnormal NC values; considering the significant risks of future cardiovascular and metabolic disorders associated with higher NC (26-29), preventive measures could be taken for these subjects predisposed to the aforementioned conditions. However, further studies are needed to determine the optimal cut-off points for prediction of cardiovascular, pulmonary, and metabolic outcomes.

NC measurements have been proposed by various studies as appropriate markers for screening of overweight and obesity. For instance, in a study by Taheri et al., children aged 7 - 16 years old were evaluated demonstrating that the NC values are significantly correlated with BMI and mid-upper arm circumference (30). As compared to other anthropometric factors used for obesity screening, NC has multiple advantages. First, there is no need for the child to be fully exposed to the crowded clinics for measuring NC. Second, it was shown in the present study that this factor is not affected by physiological changes during growth and development while factors such as BMI and waist circumference are affected by these changes, such as the alterations in the height (31-34). Finally, NC is not affected by pre and postprandial effects (21).

In this study, we faced some limitations, as we could not evaluate the predictive role of NC in obesity-related outcomes. However, the representativeness of the study population, the employed standard methods, and the sufficient sample size included in this study could be mentioned as the strengths of this survey. Moreover, not evaluating children younger than 7 years of age was another limitation that should be addressed by future researchers. Finally, the effects of missing data on the findings should not be neglected; however, the participation rate of 90.6% in the present study minimized these effects.

5.1. Conclusion

The present study aimed to construct NC standard models for the Iranian population. The standards presented by this study could be used to improve the screening and evaluation processes of obesity and overweight status in the field of pediatrics. However, further investigations are required to determine the optimal cut-offs for NCs predicting the adverse outcomes of obesity.

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Footnotes

Authors' Contribution: Mostafa Hosseini, Mostafa Qorbani, Roya Kelishadi, and Neamatollah Ataei designed the study; Mohammad Esmail Motlagh, Hamid Asayesh, Rasool Mohammadi, Mostafa Qorbani, and Roya Kelishadi participated in the acquisition of data; Mostafa Hosseini and Mahmoud Yousefifard analyzed the data; Masoud Baikpour and Arash Abbasi participated in the management of data; Mahmoud Yousefifard and Masoud Baikpour wrote the first draft and revised the manuscript critically; all authors approved the final version of the manuscript to be published and accountable for all aspects of the work.

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