Observational Study

Medicine®

OPEN

Correlation between body mass index, neck circumference, and waist-hip ratio as indicators of obesity among a cohort of adolescent in Bahrain

A preliminary cross-sectional study

Sayed A. Tantawy, PhD[a,b,*], Dalia M. Kamel, PhD[a,c], Noor Alsayed, PhD[d], Ebrahim Rajab, PhD[e], Walid Kamal Abdelbasset, PhD[f,g]

Abstract

Neck circumference (NC) is an attractive method for determining overweight and obesity in school age children because it is inexpensive and culturally acceptable. However, this technique has not been assessed for its accuracy in school children from countries of the Gulf Cooperation Council, which have high prevalence of overweight and obesity.

The aim of this preliminary study was to investigate the correlation between the body mass index (BMI), NC, and waist-hip ratio and demographic characteristics among 10- to 18-year-old adolescent school children in Bahrain.

BMI was calculated using Center of Disease Control and Prevention Children's BMI Tool for Schools. Data was collected for a total of n = 397 adolescents from 4 different private schools with an average age of 12.91 years; 57.7% were male and 42.3% female.

In this sample of adolescents, 50.1% were either overweight (21.4%) or obese (28.7%). BMI was significantly associated with waist-hip ratio ($P < .01$), gender ($P < .05$), and age ($P < .01$). Multiple linear regressions revealed that NC was significantly associated with age ($P < .001$) and less so with gender ($P = .071$) and BMI was significantly associated with NC ($P < .01$), gender ($P < .01$), and age ($P < .05$). Analysis of the receiver operating characteristic for males and females combined showed fair sensitivity and specificity (Area under the curve (AUC) = 0.707; 95% CI: 0.656, 0.758).

NC is weakly correlated with BMI, and only a fair instrument for identifying overweight/obesity based on receiver operating characteristic curve analysis. Therefore, NC could only be used as an adjunct screening tool for weight status in this sample.

Abbreviations: BMI = body mass index, CDC = Center of Disease Control and Prevention, GCC = Gulf Cooperation Council, HC = hip circumference, NC = neck circumference, ROC = receiver operating characteristic, WC = waist circumference, WHO = World Health Organization, WHR = waist-hip ratio.

Keywords: body mass index, hip circumferences, neck circumference, obesity, waist-hip ratio

Editor: Ediriweera Desapriya.

Our study was performed in accordance with the ethical standards of the Institutional Research Committee and guidelines of Helsinki Declaration 1964.

The authors have no funding and conflicts of interest to disclose.

[a] Department of Physiotherapy, College of Medical and Health Sciences, Ahlia University, Manama, Kingdom of Bahrain, [b] Department of Physiotherapy, Center of Radiation Oncology and Nuclear Medicine, [c] Department of Physiotherapy for Women's Health, Faculty of Physical Therapy, Cairo University, Giza, Egypt, [d] Department of Mathematical Sciences, College of Arts and Science, Ahlia University, [e] School of Medicine, Royal College of Surgeons in Ireland, Adliya, Bahrain, [f] Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Prince Sattam Bin Abdulaziz University, Alkharj, Kingdom of Saudi Arabia, [g] Department of Physical Therapy, Kasr Al-Aini Hospital, Cairo University, Giza, Egypt.

[*] Correspondence: Sayed A. Tantawy, Department of Physiotherapy, College of Medical and Health Sciences, Ahlia University, Manama, Kingdom of Bahrain, P. O. Box 10878, Manama, Bahrain (e-mail: tantawyss@yahoo.com).

How to cite this article: Tantawy SA, Kamel DM, Alsayed N, Rajab E, Abdelbasset WK. Correlation between body mass index, neck circumference, and waist-hip ratio as indicators of obesity among a cohort of adolescent in Bahrain: a preliminary cross sectional study. Medicine 2020;99:17(e19950).

Received: 30 July 2019 / Received in final form: 14 January 2020 / Accepted: 28 February 2020

http://dx.doi.org/10.1097/MD.0000000000019950

1. Introduction

Obesity is a major health problem among children which may result in negative social and emotional consequences as well as increased risk of obesity in adulthood, and related chronic conditions such as cardiovascular disease, diabetes mellitus, hypertension, some cancers, as well as reduced longevity.[1,2] Globally, there has been a ~40 to 60% rise in the prevalence of overweight and obesity amongst children since 1990, and access to energy-dense diets is a key risk factor.[3,4] Additional risk factors include low physical activity, social and cultural factors,[5] as well as lower birth order and lower number of siblings.[6]

In 2013, it was estimated that 23.8% and 22.6%, respectively, of male and female children and adolescents (<20 years old) were overweight or obese.[7] High rates have been reported for countries in the Middle East including the Gulf Cooperation Council (GCC) states (Saudi Arabia, United Arab Emirates, Oman, Qatar, Kuwait, and Bahrain).[4,7] For example, the highest rates for overweight and obesity in the GCC have been reported in Kuwait (25.6% and 34.8% among males, and 20.8% and 20.5% among females).[8] However, a study of 10- to 13-year-old children in Bahrain has shown that these prevalence rates are dependent on the reference standards utilized with the World Health Organization (WHO) standard providing higher rates of overweight and obesity (28.9% and 30.7% for males and

females, respectively) compared to the International Obesity Task Force standard (15.7% and 21.1%).[9] The high prevalence rates of overweight and obesity within the GCC region parallel significant increases in per capita income and wealth, rapid urbanization, and improved living conditions as a result of the booming oil industry over the last 4 decades.[10] However, they are also indicative of future health problems in the population on top of the already large increase in obesity for adults since the 1980s.[11]

People with obesity can be treated appropriately through a combination of lifestyle changes, pharmacological treatments, and bariatric surgery.[12] An important component of this process is screening at an early stage using historically valid, reliable, and inexpensive methods such as waist circumference (WC), body mass index (BMI), or waist-hip ratio (WHR).[13] Furthermore, WC is now widely used to assess central obesity, and BMI is used to determine overweight or obesity.[14] However, both of these methods are not without their limitations for example in cases of abdominal ascites, masses or in athletes.[15–17] More recently, NC has been recognized as tool for assessing overweight and obesity in adults, although its usefulness for screening individuals with central obesity is less clear.[17] Two studies of Saudi adults have demonstrated the NC correlates with WC and BMI, and can be used to screen for overweight and obesity, as well as being culturally acceptable when performed.[18,19] However, 2 recent meta-analyses/systematic reviews have reported that NC has moderate accuracy for identifying overweight and obesity in children and adolescents, although the issues of standardization of measurements and cut-off values by age and gender remain.[20,21]

To date there are a lack of studies regarding the use of NC as a screening tool for overweight and obesity in children from the GCC countries. The aim of this preliminary study was to investigate the relationship between NC, and other indicators of overweight/obesity as well demographic characteristics of adolescent children in Bahrain.

2. Materials and methods

2.1. Participants

Adolescent students in grades 6 to grade 12 (age 10–18 years) were randomly selected from a convenience samples of 4 private schools in Bahrain during January to May 2018. Data were collected following parental consent to participate in the study, and an awareness session for the children about body weight, nutrition, and health lifestyle. This study was ethically approved by the Research Ethics Committee, Ahlia University (reference ARICC-2017/18-RE01).

2.2. Sample size

The total number of school students in grades 6 to 12 was 99,903 in the academic year 2017/2018 (http://www.moe.gov.bh/od_statistics.aspx). Using a 95% confidence level with 5% confidence interval, the sample size needed was 383.

2.3. Data collection

Following the awareness session, students were provided with a demographic questionnaire to complete, and then measurements were conducted by a physiotherapist trained in the techniques, and in a private room. The demographic information collected were gender, age, nationality, birth order, and number of siblings.

2.4. Measurements

Anthropometric measurements were conducted as per Center of Disease Control and Prevention (CDC) guidelines.[22] Height and weight were measured without any heavy clothes and shoes. Height was measured by using a portable stadiometer (Seca 213; Hamburg, Germany) with feet placed together with heels, buttocks, and shoulder blades against the stick and head positioned in the Frankfort horizontal plane. Weight was measured with electronic portable scales (Seca 813; Hamburg).

All circumference measurements were taken using a non-elastic tape (SECA 201, range 0–205 cm, graduation 1.0 mm). WC measurements were taken at midpoint (the narrowest point) between the costal margin and iliac crest, in standing position and at the end of a gentle normal expiration. Hip circumference (HC) was measured at the widest part of the hip at the level of the greater trochanter with the legs close together. WHR was calculated by dividing WC/HC. NC was measured at the level of the mid-cervical spine and mid-anterior neck perpendicular to the long axis of the neck, in standing position with the arms hanging freely and keeping the head aligned in the Frankfort horizontal plane. For males with a laryngeal prominence, NC was measured just below the prominence.

2.5. Statistical analysis

BMI was calculated using CDC Children's BMI Tool for Schools.[23] This tool computes BMI and percentiles for children and adolescents using height and weight measurements, sex, date of birth, and date of measurement. Based on the BMI, children were classified as underweight ($<5^{th}$ percentile), normal (5^{th} to $<85^{th}$ percentile), overweight (85^{th} to $<95^{th}$ percentile), or obese ($\geq 95^{th}$ percentile).[24]

The data was then entered, coded, and analyzed in IBM SPSS Statistics for Windows version 22 (RRID: SCR_002865) (IBM Corp, Armonk, NY). In addition to descriptive statistics, the following Pearson correlations were performed:

(i) BMI with NC and WHR;
(ii) age with BMI, NC, and WHR.

Strength of correlation was determined as per Evans (1996).[25] Multiple linear regression models were performed to test

(i) the effect of demographic and anthropometric characteristics on BMI;
(ii) the effect of demographic and anthropometric characteristics on NC;
(iii) the effect of demographic and anthropometric characteristics on WHR.

Multiple linear regression models were also used to investigate

(i) the relationship between BMI and NC after controlling for demographic and anthropometric characteristics;
(ii) the relationship between BMI and WHR after controlling for demographic and anthropometric characteristics.

Statistical significance was set at a P value of less than .05. Receiver operating characteristic (ROC) curves were used to determine the diagnostic ability of NC to identify overweight and obesity.

Table 1

Weight classification by gender.

Weight classification (BMI)	Males (%)	Females (%)	Proportion of total sample (%)
Underweight	2.2	3.0	2.5
Normal	47.2	47.6	47.4
Overweight	19.2	24.4	21.4
Obese	31.4	25.0	28.7

BMI = body mass index.

3. Results

Data was collected for a total of n = 397 adolescents from 4 different private schools in the Kingdom of Bahrain with an average age of 12.91 years (range 10–18 years); 57.7% were male and 42.3% female. The percentage of Bahraini participants was 89.1%. Based on BMI measurements, 50.1% of all the adolescents were classified as either overweight (21.4%) or obese (28.7%). The percentage of obese boys (31.4%) was higher than the percentage of obese girls (25.0%) as shown in Table 1. However, there was no association between gender and weight classification (X^2 = 2.866, $P = .413$). Overall, there was no difference in the NC of males (33.4 ± 3.3 cm) and females (32.9 ± 4.7 cm) as presented in Table 2.

There was a weak, positive correlation between BMI and NC (r = 0.290, $P = .001$), and a moderate, positive correlation between BMI and WHR (r = 0.532, $P = .001$). There was also a weak, positive correlation between age and BMI (r = 0.164, $P = .001$) and a moderate positive correlation between age and NC (r = 0.419, $P < .001$) as shown in Table 3.

Multiple linear regressions revealed that BMI was significantly associated with age ($P = .002$); also NC was significantly associated with age ($P < .001$) and less so with gender ($P = .071$) and nationality ($P = .061$) as demonstrated in Tables 4 and 5. In addition, WHR was weakly associated with gender ($P = .058$) as shown in Table 6.

The relationship between BMI (dependent variable) and NC (independent variable) was investigated using multiple linear regression models after controlling for gender, age, nationality,

Table 2

Neck circumference by age and gender.

Age (yr)	Neck circumference (cm)	
	Male	Female
10	31.4 ± 0.6 (n = 17)	29.9 ± 0.6 (n = 14)
11	31.5 ± 0.4 (n = 50)	31.1 ± 0.6 (n = 37)
12	32.7 ± 0.5 (n = 46)	32.7 ± 0.7 (n = 32)
13	34.3 ± 0.5 (n = 33)	31.7 ± 0.3 (n = 27)
14	34.5 ± 0.5 (n = 32)	35.6 ± 1.2 (n = 23)
15	35.1 ± 0.6 (15)	33.9 ± 1.0 (n = 12)
16	34.2 ± 0.7 (n = 19)	35.3 ± 1.8 (n = 12)
17	37.2 ± 0.9 (n = 14)	36.3 ± 2.7 (n = 10)
18	38.0 ± 0.5 (n = 2)	–

Data expressed as mean ± SEM.
n = number of participants.

Table 3

Correlations of body mass index and age with neck circumference and waist-hip ratio.

		Neck circumference	Waist-hip ratio
BMI	Correlation	0.290	0.532
	P-value	.001	.001
Age	Correlation	0.419	–0.097
	P-value	.001	.055

Correlation is significant at the 0.01 level.
BMI = body mass index

Table 4

Multiple linear regression of body mass index with demographic characteristics.

Demographic characteristic	Beta	t	*P*-value
Gender	0.066	1.317	.189
Age	0.157	3.056	.002**
Nationality	−0.027	−0.541	.589
Birth order	−0.007	−0.108	.914
Number of siblings	0.049	0.717	.474

** Correlation is statistically significant ($P < .01$).

Table 5

Multiple linear regression of neck circumference with demographic characteristics.

Demographic characteristic	Beta	t	*P*-value
Gender	–0.083	–1.807	.071
Age	0.419	8.906	.000**
Nationality	–0.087	–1.878	.061
Birth order	–0.087	–1.418	.157
Number of siblings	0.029	0.472	.637

** Correlation is statistically significant ($P < .01$).

Table 6

Multiple linear regression of waist-hip ratio with demographic characteristics.

Demographic characteristic	Beta	t	*P*-value
Gender	−0.096	−1.900	.058
Age	−0.040	−0.767	.444
Nationality	−0.009	−0.174	.862
Birth order	0.078	1.156	.248
Number of siblings	−0.102	−1.485	.138

Table 7

Multiple linear regression of body mass index with neck circumference.

Demographic characteristic	Beta	t	*P*-value
Neck circumference	0.620	13.538	.000**
Gender	0.118	2.832	.005**
Age	−0.103	−2.212	.028*
Nationality	0.027	0.634	.526
Birth order	0.047	0.844	.399
Number of siblings	0.031	0.545	.586

Correlation is statistically significant.
* ($P < .05$).
** ($P < .01$).

Table 8

Multiple linear regression of body mass index with waist-hip ratio.

Demographic characteristic	Beta	t	*P*-value
Waist-hip ratio	0.395	8.519	.000**
Gender	0.104	2.248	.025*
Age	0.173	3.657	.000**
Nationality	−0.024	−0.514	.608
Birth order	−0.038	−0.618	.537
Number of siblings	0.089	1.421	.156

Correlation is statistically significant.
* ($P < .05$).
** ($P < .01$).

number of siblings, and birth order. The results showed that BMI was significantly associated with NC ($P < .01$), gender ($P < .01$), and age ($P < .05$) as shown in Table 7.

Finally, the relationship between BMI (dependent variable) and WHR (independent variable) was investigated using multiple linear regression models, after controlling for gender, age, nationality, number of siblings, and birth order. The results showed that BMI was significantly associated with WHR ($P < .01$), gender ($P < .05$), and age ($P < .01$) as presented in Table 8.

Analysis of the ROC curve for males and females combined showed that NC was only a fair instrument for identifying overweight/obesity in the children (AUC = 0.707; 95% CI: 0.656, 0.758) as shown in Figure 1.

4. Discussion

The main aim of this preliminary study was to investigate the relationship between NC and typical anthropometric measurements used to determine weight status of adolescent children in Bahrain. We found a weak positive correlation (r = 0.29) between NC and BMI, and ROC curve analysis suggested that NC was only a fair instrument for identifying overweight/obesity in our sample. In addition, we report that 50.6% of males and 49.4% of females in our sample were overweight and obese based on BMI measurements.

The NC is attractive as a method of screening adults for weight status in GCC countries, because it is cheap and culturally acceptable.[18,19] For the same reasons it is also attractive for screening children; however, data have been lacking. Our results suggest that NC could be used to screen for weight status, but only if combined with other reliable measures of weight status in adolescent children of Bahrain. Previous studies have reported that NC has moderate accuracy for identifying overweight and obesity in children and adolescents.[20,21] However, some studies have questioned the validity of NC for determining obesity and central obesity in children.[26,27] Several expected findings give confidence to our data:

(i) We found a moderate positive correlation between NC and age (r = 0.419),[28] and between BMI and WHR (r = 0.532)[29];

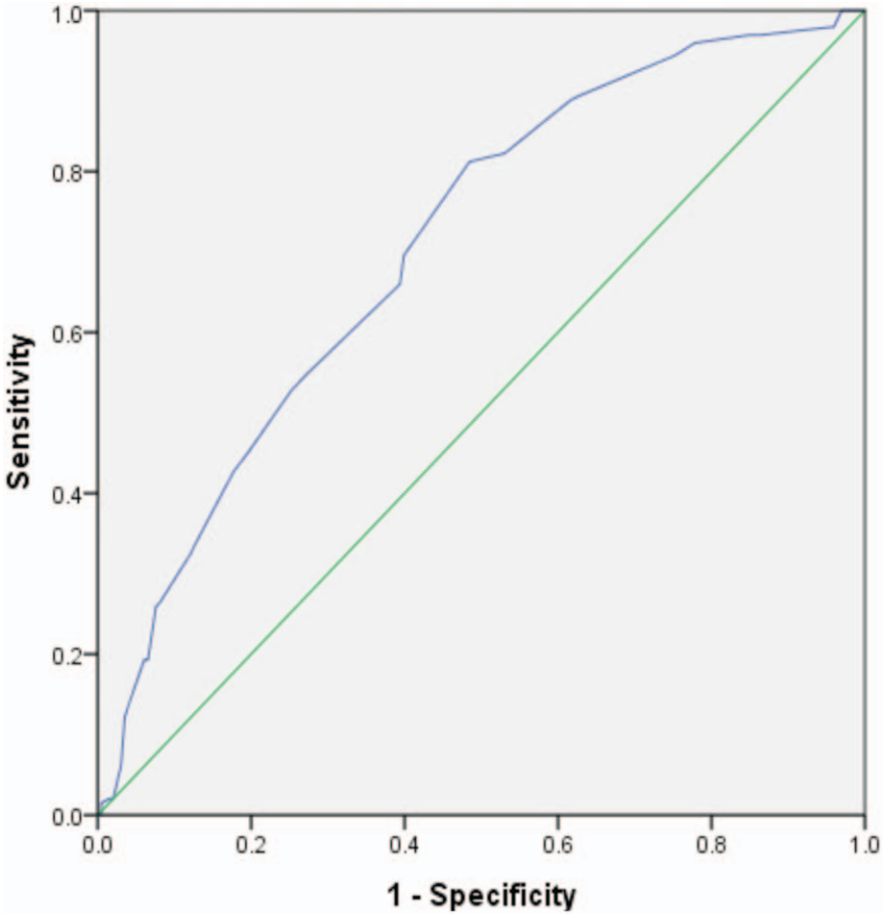

Figure 1. Receiver operating characteristic curves for males and females combined.

(ii) Multiple linear regressions showed BMI was significantly associated with gender ($P < .01$) and age ($P = .002$),[30] as well as NC[21] and WHR ($P < .01$).[31]

In our sample, the ROC curve for males and females combined showed that NC was only a fair instrument for identifying overweight/obesity in children, so we did not proceed to identify cut-off points for overweight and obesity. Our sample size was insufficient to construct ROC curves for males and females separately; this limitation was due to access to schools. Furthermore, half of our sample were overweight or obese, and this unintentional section bias is an important consideration when evaluating NC results.[21] It was beyond the scope of this study to collect data on physical activity or sedentary time; but we recognize that these are important confounders.[32]

To the best of our knowledge this study is the first including anthropometric measurements of adolescent children since the publication of data from national survey on obesity and lifestyle of primary school children in Bahrain (2003–2005).[9] Based on BMI measurements and with reference to CDC (2000) growth charts,[23] we found that overall 50.6% of males and 49.4% of females were overweight and obese. This is higher than Musaiger et al who reported a range of 15.7% to 28.9% and 21.1% to 30.7% for males and females age 10 to 13 years in 2003 to 2005, based on WHO and International Obesity Task Force (IOTF) cut offs.[9] It is important to acknowledge that our sample was drawn from private schools and in that regard may not be representative of the population. However, our results are broadly similar to figures for Kuwait, in the ARABEAT-2 study which focused on adolescents aged 15 to 18 years old.[33] It would suggest that little progress has been made in combating obesity in adolescent children over the last 16 years, and that effects of rapid increases in per capital income and wealth due to early discovery of oil continue to influence dietary habits and lifestyle factors, and remain an on-going public health concern.[10,34]

5. Conclusion

In this preliminary study of adolescent children in Bahrain, we have shown that NC is weakly correlated with BMI, and only a fair instrument for identifying overweight/obesity based on ROC curve analysis. Therefore, NC could only be used as an adjunct screening tool for weight status in this sample. In addition, we found that overall 50.6% of males and 49.4% of females were overweight and obese, and these figures suggest that little progress has been made in combating obesity in adolescent children over the last 16 years.

Acknowledgments

The authors thank all participants who volunteered their time and participated in the study.

Funding for publications costs was provided by RCSI, Bahrain.

Author contributions

Conceptualization: Sayed A Tantawy, Dalia M Kamel, Walid Kamal Abdelbasset.
Data curation: Sayed A Tantawy, Dalia M Kamel, Noor Alsayed.
Formal analysis: Noor Alsayed, Ebrahim Rajab, Walid Kamal Abdelbasset
Funding acquisition: Ebrahim Rajab, Walid Kamal Abdelbasset.
Investigation: Sayed A Tantawy, Dalia M. Kamel, Walid Kamal Abdelbasset.
Methodology: Sayed A Tantawy, Dalia M Kamel, Noor Alsayed.
Project administration: Sayed A Tantawy.
Resources: Walid K Abdelbasset, Ebrahim Rajab.
Software: Dalia M. Kamel, Noor Alsayed.
Validation: Sayed A Tantawy, Walid Kamal Abdelbasset, Ebrahim Rajab.
Visualization: Sayed A Tantawy, Dalia M Kamel.
Writing – original draft: Sayed A Tantawy, Noor Alsayed, Dalia M Kamel, Walid Kamal Abdelbasset.
Writing – review & editing: Sayed A. Tantawy, Dalia M Kamel, Ebrahim Rajab, Walid Kamal Abdelbasset, Noor Alsayed.

References

[1] World Health Organization. *Obesity and overweight*. Fact Sheet No 311. 2015. http://www.who.int/mediacentre/factsheets/fs311/en/. Accessed June 14, 2019.
[2] Karnik S, Kanekar A. Childhood obesity: a global public health crisis. Int J Prev Med 2012;3:1–7.
[3] Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. Int Rev Psychiatry 2012;24:176–88.
[4] Moreno LA, Pigeot I, Ahrens W. Epidemiology of Obesity in Children and Adolescents. Springer Series on Epidemiology and Public Health. vol. 2. New York: Springer-Verlag; 2011.
[5] Sahoo K, Sahoo B, Choudhury AK, et al. Childhood obesity: causes and consequences. J Family Med Prim Care 2015;4:187–92.
[6] Meller FO, Loret de Mola C, Assuncao MCF, et al. Birth order and number of siblings and their association with overweight and obesity: a systematic review and meta-analysis. Nutr Rev 2018;76:117–24.
[7] Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2014;384:766–81.
[8] Farrag NS, Cheskin LJ, Farag MK. A systematic review of childhood obesity in the Middle East and North Africa (MENA) region: prevalence and risk factors meta-analysis. Adv Pediatr Res 2017;4:8doi:10.12715/apr.2017.4.8.
[9] Musaiger AO, Al-Mannai M, Al-Marzog Q. Overweight and obesity among children (10-13 years) in Bahrain: A comparison between two international standards. Pak J Med Sci 2014;30:497–500.
[10] Fund IM. *World Economic Outlook Database*. 2019. https://www.imf.org/external/pubs/ft/weo/2019/01/weodata/index.aspx.
[11] Badran M, Laher I. Obesity in Arabic-speaking countries. J Obes 2011;2011:686430doi: 10.1155/2011/686430.
[12] Garvey WT, Mechanick JI, Brett EM, et al. American Association of Clinical Endocrinologists and American College of Endocrinology comprehensive clinical practice guidelines for medical care of patients with obesity. Endocr Pract 2016;22(Suppl 3):1–203.
[13] Han TS, Sattar N, Lean M. ABC of obesity. Assessment of obesity and its clinical implications. BMJ 2006;333:695–8.
[14] Wakabayashi I. Necessity of both waist circumference and waist-to-height ratio for better evaluation of central obesity. Metab Syndr Relat Disord 2013;11:189–94.
[15] Stabe C, Vasques AC, Lima MM, et al. Neck circumference as a simple tool for identifying the metabolic syndrome and insulin resistance: results from the Brazilian metabolic syndrome study. Clin Endocrinol (Oxf) 2013;78:874–81.
[16] Luo Y, Ma X, Shen Y, et al. Neck circumference as an effective measure for identifying cardio-metabolic syndrome: a comparison with waist circumference. Endocrine 2017;55:822–30.
[17] Pei X, Liu L, Imam MU, et al. Neck circumference may be a valuable tool for screening individuals with obesity: findings from a young Chinese population and a meta-analysis. BMC Public Health 2018;18:529.
[18] Alzeidan R, Fayed A, Hersi AS, et al. Performance of neck circumference to predict obesity and metabolic syndrome among adult Saudis: a cross-sectional study. BMC Obes 2019;6:13.
[19] Alfadhli EM, Sandokji AA, Zahid BN, et al. Neck circumference as a marker of obesity and a predictor of cardiometabolic risk among Saudi subjects. Saudi Med J 2017;38:1219–23.
[20] Ma C, Wang R, Liu Y, et al. Diagnostic performance of neck circumference to identify overweight and obesity as defined by body mass index in children and adolescents: systematic review and meta-analysis. Ann Hum Biol 2017;44:223–9.

[21] Morais AA, Morais UAB, Soares MMS, et al. Neck circumference in adolescents and cardiometabolic risk: a systematic review. Rev Assoc Med Bras 2018;64:54–62.
[22] Centre for Disease Control (CDC) and Prevention. *National Health and Nutrition Examination Survey (NHANES) Anthropometry Procedures Manual*. 2009. http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/BodyMeasures_09.pdf Accessed July 9, 2019.
[23] Centre for Disease Control (CDC) and Prevention: *Division of Nutrition PA, and Obesity, National Center for Chronic Disease Prevention and Health Promotion. Children's BMI Tool for Schools*. 2018. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/tool_for_schools.html. Accessed July 9, 2019.
[24] Nihiser AJ, Lee SM, Wechsler H, et al. Body mass index measurement in schools. J Sch Health 2007;77:651–71.
[25] Evans J. Straightforward Statistics for the Behavior Sciences. Belmont, CA: Brooks/Cole Publishing Co; 1996.
[26] Kim Y, Lee JM, Laurson K, et al. Accuracy of neck circumference in classifying overweight and obese US children. ISRN Obes 2014;2014:781841doi:10.1155/2014/781841.
[27] Hassan NE, Atef A, El-Masry SA, et al. Neck circumference as a predictor of adiposity among healthy and obese children. Open Access Maced J Med Sci 2015;3:558–62.
[28] Katz SL, Vaccani JP, Clarke J, et al. Creation of a reference dataset of neck sizes in children: standardizing a potential new tool for prediction of obesity-associated diseases? BMC Pediatr 2014;14:159.
[29] Moore LM, Fals AM, Jennelle PJ, et al. Analysis of pediatric waist to hip ratio relationship to metabolic syndrome markers. J Pediatr Health Care 2015;29:319–24.
[30] Pietrobelli A, Faith MS, Allison DB, et al. Body mass index as a measure of adiposity among children and adolescents: a validation study. J Pediatr 1998;132:204–10.
[31] World Health Organization. *Waist Circumference and Waist–Hip Ratio: Report of a WHO Expert Consultation*, Geneva, December 8–11, 2008.
[32] Al-Sobayel H, Al Hazza HM, Abahussain NA, et al. Gender differences in leisure-time versus non-leisure-time physical activity among Saudi adolescents. Ann Agric Environ Med 2015;2:344–8.
[33] Musaiger AO, Al-Mannai M, Al-Haifi AR, et al. Prevalence of overweight and obesity among adolescents in eight Arab countries: comparison between two international standards (ARABEAT-2). Nutr Hosp 2016;33:567.
[34] Campbell KJ, Crawford DA, Salmon J, et al. Associations between the home food environment and obesity-promoting eating behaviors in adolescence. Obesity (Silver Spring) 2007;15:719–30.