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Mid-upper arm circumference for identifying adult overweight in large-scale population-based surveys: empirical evaluation using data of the EAT Addis study, Ethiopia

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ABSTRACT

Objectives The present study evaluates body circumferences as a nutrition screening tool for women of reproductive age with children less than 5 years of age to improve the detection of overweight and obesity in a community setting.

Design This study draws data from a community-based cross-sectional study conducted between July–August 2017 and January–February 2018 to account for seasonality in Addis Ababa, Ethiopia.

Setting One hundred and sixteen districts were included in Addis Ababa, Ethiopia.

Participants A total of 4914 women of reproductive age with children less than 5 years of age were participated in this study.

Primary and secondary outcome measures Primary outcome measures included anthropometric indices. There were no secondary outcomes.

Results The optimal cut-off points to identify overweight women of reproductive age were >87.5 cm for waist circumference (WC), >31.7 cm for neck circumference (NC) and >28.0 cm for mid-upper arm circumference (MUAC) based on the highest corresponding Youden index. The area under the receiver operating characteristics curve was 0.92 (95% CI: 0.91 to 0.93) for WC, 0.83 (95% CI: 0.82 to 0.84) for NC and 0.91 (95% CI: 0.89 to 0.92) for MUAC.

Conclusions Our result shows that WC and MUAC are alternative tools to body mass index. Both WC and MUAC are effective in identifying overweight women. We recommend using MUAC in large-scale population-based assessments to identify overweight and obesity in low-income settings as it is logistically simpler and operationally feasible.

Strengths and limitations of this study

- This study used a large sample size covering all districts in a large metropolitan city in Ethiopia, Africa.
- Anthropometric measurements were performed using a standardised measurement protocol, and all the quality controls were considered to enhance data quality.
- This study includes women with children less than 5 years of age. Men and other categories of women were excluded. Thus, the study generalisability is limited.
- Waist circumference cut-offs may overestimate the status of overweight and obesity because only women who reported pregnancy were excluded from the study.
- The health status of the participants was not assessed in our study. Some comorbidities can influence the cut-off points.

INTRODUCTION

Overweight and obesity are public health concerns in low-income settings, and urgent actions are required before the problem compromises the public health system.[1 2] Obesity is a well-documented risk factor for hypertension, cardiovascular disease, diabetes mellitus, reproductive and digestive organ cancers, respiratory problems, osteoarthritis and gynaecological problems.[3] In particular, obesity has been identified to reduce the quality-adjusted of life.[4]

The body mass index (BMI) measures the nutritional status of an individual.[5] The BMI is derived from height and weight measurements, calculated by an individual's weight in kg/m^2. Although measuring height and weight looks straightforward for well-trained health professionals, it is quite complicated in a community setting. Standard equipment is expensive. In addition, accurate measurement requires regular training and standardisation. Moreover, the logistics require carrying the equipment from house to house in a difficult terrain, which can pose a formidable challenge in using BMI to identify overweight and obese individuals in large-scale

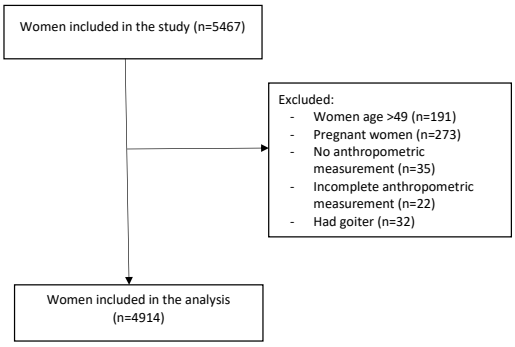

Figure 1 Flowchart of women participated in the analysis.

surveys.[6] Alternative anthropometric assessment methods to measure body (neck, waist and limbs) circumferences using a simple measuring tape can be more pragmatic in low-income settings.[7 8]

Body circumference measurement is also more feasible in low-income settings as they are non-invasive, simple and affordable anthropometric methods. Moreover, the body circumferences do not require any calculation, they are easy to interpret in the field. Thus, using body circumferences is more appropriate for large population-based studies and programmes.[5 9]

Tracking the nutritional status of women of reproductive age becomes necessary as the risks associated with obesity can be serious. Despite conducting many large-scale health-related population surveys at a reasonable frequency, identifying obesity in low-income countries is a nearly impossible task owing to the logistical and technical challenges. Nonetheless, scanty studies have evaluated alternative options for screening overweight and obesity in low-income settings. Moreover, cut-off points for classification of adult nutritional status have not yet been firmly established.[10]

The present study aimed to evaluate body circumferences as a nutrition screening tool for women of reproductive age with children less than 5 years of age. A simple low-cost tool that reasonably identifies overweight and obese women is a useful input for programme to improve the detection of overweight and obesity in a community setting.

Table 1 Characteristics of study participants, Addis Ababa, Ethiopia (n=4914)

Characteristics	n (%)
Age	
15–24	809 (16.5)
25–34	3092 (62.9)
35–44	948 (19.2)
45 and above	65 (1.3)
Education	
Never attended/not finished first grade	603 (12.3)
Grade 1–4	455 (9.3)
Grade 5–8	1489 (30.3)
Grade 9–12	1360 (27.7)
College	1007 (20.5)
Marital status	
Married/living together	4402 (89.6)
Divorced/widowed/separated	430 (8.8)
Never married	82 (1.7)
Women occupation	
Involved in income-earning activity	1302 (26.5)
Not involved in income-earning activity	3612 (73.5)
Overweight and obesity (BMI ≥25 kg/m^2)	1930 (39.3)

BMI, body mass index.

Table 2 Anthropometric characteristics of study participants, Addis Ababa, Ethiopia

Characteristics (n=4914)	Mean (±SD)
Weight	60.8 (12.0)
Height	158.2 (6.1)
MUAC	27.9 (3.8)
Waist	86.5 (12.1)
Neck	31.8 (2.4)
BMI	24.3 (4.7)

BMI, body mass index; MUAC, mid-upper arm circumference.

METHODS

Study design and setting

This study draws data from a community-based cross-sectional study conducted between July–August 2017 and January–February 2018 to account for seasonality in Addis Ababa, Ethiopia. The city of Addis Ababa is divided into 10 subcities, each consisting of 10–15 woredas (the smallest administrative unit in the city). A total of 116 woredas were included in this study. The study participants were women of reproductive age with children under 5 years of age.

Sample size and sampling procedure

The study enrolled 5467 women with children less than 5 years of age across the city of Addis Ababa. This study was part of a larger study (EAT-Addis), and a full description of the sampling procedure is available in a previous publication.[11]

Table 3 Optimal anthropometric cut-off points to screen overweight and obesity in women of reproductive age (n=4914)

Indices	MUAC (cm)	WC (cm)	NC (cm)
Optimal cut-off point	>28.0	>87.5	>31.7
Sensitivity (%)	83.2	87.0	82.3
Specificity (%)	81.2	82.1	70.7
AUC	0.91	0.92	0.84
95% CI	0.89 to 0.92	0.91 to 0.93	0.82 to 0.85
Youden index	0.64	0.69	0.53

AUC, area under the receiver operating characteristics curve; MUAC, mid-upper arm circumference; NC, neck circumference; WC, waist circumference.

Inclusion and exclusion criteria

The inclusion criteria were women aged 15–49 and not pregnant. Exclusion criteria were women with goitre and had incomplete or no anthropometric measurement during the data collection. Therefore, 4914 women who fulfilled the inclusion and exclusion criteria were included in the analysis.

Data collection

The data were collected using a structured and pretested questionnaire, programmed on tablets using the open data kit application. Data were stored on a central server. Interviews were conducted by experienced and trained data collectors and supervisors. The data collectors were standardised for anthropometric measures. The researcher regularly supervised the field data collection.

Measurement

The measured anthropometric indices were body weight, height, mid-upper arm circumference (MUAC), waist circumference (WC) and neck circumference (NC).

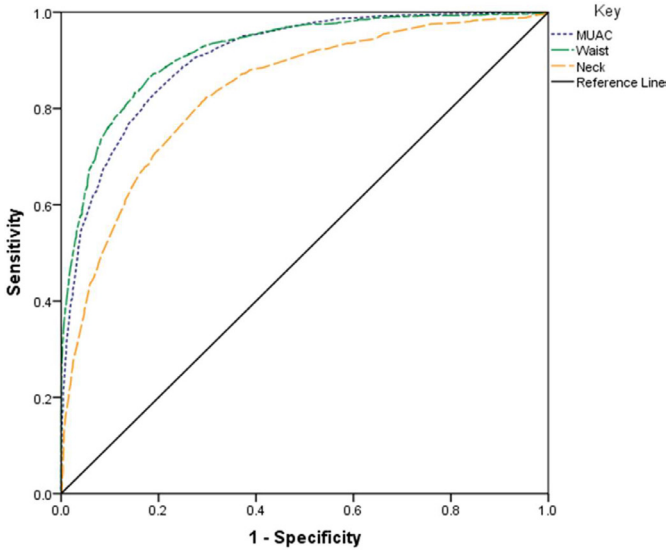

Figure 2 ROC curve showing the performance of different anthropometric measurements in detecting overweight and obesity among women in Addis Ababa, Ethiopia. MUAC, mid-upper arm circumference; ROC, receiver operating characteristics.

Weight and height of the body were measured with light clothing and without shoes. MUAC was taken at the mid-point between the tip of the shoulder and the tip of the elbow. WC measurements were taken from the level umbilicus, using a plastic stretch-resistant tape.[12] The NC was taken at a point midway of the neck, between the mid-cervical spine and mid-anterior neck.[13] While taking these measurements, the mothers were asked to look straight ahead, shoulders down and breathe normally. All circumferences were measured two times, to the nearest 0.1 cm. The average of the two measures was used for the analysis. We used the metric system to measure body circumferences.

Statistical analysis

Data were analysed using SPSS statistical package V.20 and MedCalc statistical software V.19.6.[14] Descriptive statistics were conducted to summarise all measurements in a manageable form. We generated the receiver operating characteristics (ROC) curve to determine the cut-off points. An ROC is a graph where sensitivity is displayed on the Y-axis, and 1–specificity is on the X-axis.[15] ROC analysis was conducted for MUAC, WC and NC based on the BMI cut-off reference for overweight and obesity in women, which is ≥25 kg/m^2. The area under the ROC curve (AUC) was calculated with 95% CIs from the ROC curve. An area of 0.90–1.00 was considered as excellent, 0.80–0.90 as good, 0.70–0.80 as fair, 0.60–0.70 as poor and 0.50–0.60 as fail.[16 17] Youden index (YI) was used to obtain optimal cut-off point to maximising the Youden (*J*) function, which was the difference between true-positive rate and false-positive rate.[15 18] The YI is calculated as follows: (*J*=Sensitivity+Specificity−1).

This study followed STARD (Standards for reporting diagnostic accuracy studies) 2015 guidelines, which included 30 items to guide reporting.[19]

Patient and public involvement

No patient is involved.

RESULTS

A total of 5467 women of reproductive age with children under 5 years of age were identified in the main survey. We

Table 4 Age-specific anthropometric cut-off points to screen overweight or obesity in women of reproductive age, Addis Ababa, Ethiopia (n=4914)

	Overweight by age group in years				Obese by age group in years			
MUAC	15–24	25–34	35–49	15–49	15–24	25–34	35–49	15–49
Cut-off (cm)	>27.0	>28.0	>28.5	>28.0	>28.3	>30.0	>30.9	>30.0
AUC	0.92	0.90	0.89	0.91	0.96	0.92	0.91	0.93
CI	0.89 to 0.94	0.88 to 0.91	0.87 to 0.91	0.89 to 0.92	0.93 to 0.99	0.90 to 0.93	0.89 to 0.93	0.91 to 0.94
Sensitivity (%)	94.8	82.3	81.6	83.2	100	85.7	87.6	87.0
Specificity (%)	75.1	80.1	80.2	81.2	82	83.4	78.0	83.0
YI	0.7	0.62	0.62	0.64	0.82	0.69	0.66	0.7

AUC, area under the ROC curve; MUAC, mid-upper arm circumference; ROC, receiver operating characteristics; YI, Youden Index.

excluded 553 women not fulfilling the inclusion criteria: women age >49 (n=191), pregnant women (n=273), women with goitre (n=32), women anthropometric measured once (n=22) and women for whom anthropometric measurement was not taken (n=35) (figure 1).

A total of 4914 women were available for the analysis. The mean±SD age of the women was 29.4±5.4 years. Sixty-three per cent of women (3092) were within the age group of 25–34 years, 4402 (89.6%) were married and 3856 (78.5%) completed grade 5 and above. Furthermore, 3612 (73.5%) of the women were not involved in income-earning activities. The prevalence of overweight or obese based on BMI ≥25 kg/m^2 was 1930 (39.3%) (table 1).

The mean BMI was 24.3 kg/m^2. The mean MUAC, WC and NC were 27.9 (±3.8) cm, 86.5 (±12.1) cm and 31.8 (±2.4) cm, respectively (table 2).

Optimal cut-off points for each anthropometric index

Based on the YI, the optimal cut-off values for overweight and obese were MUAC >28.0 cm (sensitivity 83.2%, specificity 81.2%), WC >87.5 cm (sensitivity 87.0%, specificity 82.1%) and NC >31.7 cm (sensitivity 82.3%, specificity 70.7%) (table 3).

When we compared the predictability of each anthropometric index using the AUC, the MUAC and WC offer high screening accuracy to predict overweight; both are >0.9 AUC. However, NC was not accurate like others (figure 2).

Simple screening tool from selected anthropometric indices

This study aimed to find an alternative anthropometric index to BMI. We identify MUAC to be an excellent alternative anthropometric tool for BMI in a community setting.

The AUC for MUAC against BMI for overweight was 0.91 (95% CI: 0.89 to 0.92) and for obese 0.93 (95% CI: 0.91 to 0.94). Based on the YI, the optimal MUAC cut-offs to identify overweight and obese were >28.0 cm and >30.0 cm, respectively with high sensitivity and specificity. The age-specific cut-offs across various subpopulations/groups against BMI showed very little variation (table 4).

DISCUSSION

We evaluated the predictive potential of body circumferences to identify overweight and obesity in women of reproductive age in Addis Ababa. Compared with BMI, we found MUAC and WC to be excellent indices with greater than 0.9 AUC, in which NC failed to perform at a similar level. The age-specific cut-offs showed little difference to warrant further considerations. The pros and cons of the two measures are discussed below.

Field survey staff can easily learn the WC measurement procedures. Moreover, the measurement can be done with any non-stretching measuring tape at a minimal cost; it does not require any calculation and interpretation as it is straightforward based on the cut-off. The WC measurement can also be used for self-monitoring of nutritional status; it can also be used by field workers as an alternative tool to detect overweight and obesity as well as an effective tool to measure abdominal obesity and generalised obesity.[20 21] However, it may be challenging to take accurate measurements of individuals with skeletal deformities, intra-abdominal disorders or those with changes in abdominal circumference associated with respiratory movements.[22] Moreover, a lack of consensus regarding the acceptable body location to measure WC poses the problem.[23]

Thus, the MUAC measurement is much easier to handle and suitable for large-scale population-based surveys in low-income countries.[5 24] Moreover, MUAC can be manipulated by personnel with relatively less technical training using simple non-stretching tape as opposed to the standardised height board, weight scales and well-trained personnel with skills to calculate BMI accurately. In addition, MUAC is more useful than BMI in screening women during pregnancy or lactation because the mid-upper circumference is less variable than weight. It is also applicable in patients whose weight and height measurements are difficult.[5 25 26] MUAC is also better suited in communities where measuring the woman's waist is culturally sensitive due to the light closing requirements. Thus, if measurement is not done properly, it can significantly influence its accuracy.[27]

Globally, recognised MUAC cut-offs have not been established to classify nutritional status in adults as many countries have established their MUAC cut-offs to determine the eligibility of the programme.[10 28] Based on our analyses, MUAC >28.0 cm for women with 90.8% accuracy was an optimal cut-off to identify overweight and obesity. The optimal cut-off points for screening should be population-specific, as recommended by most researchers.[20] These cut-off points can be applicable in many low-income countries using population-based anthropometric data that are periodically gathered in large representative population surveys, such as the Demographic Health Surveys. However, the MUAC cut-offs as a detection tool of overweight and obesity among women must be set carefully. A cut-off set with high specificity is important to minimise the number of people applying for services without needing it. This helps to avoid crowding of service centres in low-income settings.[7]

From the results of age-specific analysis, MUAC cut-offs should be in the range of 27.0–28.5 cm, which helps develop a green, yellow and red colour marked tape to facilitate measurement in the field.[29] Since age is difficult to ascertain accurately in low-income countries due to lack of a proper vital event registration system, we propose that a single cut-off >28.0 cm meets the criteria to detect overweight and obese across various age groups in large surveys.

The strength of this study is the large sample size covering all parts of the districts in a large metropolitan city. Anthropometric measurements were performed using a standardised measurement protocol, and all the necessary quality control measures were considered to enhance the quality of the data. However, only women with children less than 5 years of age were involved (other categories of women and men were not involved). WC cut-offs may be overestimating the status of overweight and obesity because only pregnant women were excluded from the study as well as those without health data since comorbidities can influence the cut-off points. These limitations are related to the secondary data. Thus, the generalisability of the study is limited.

CONCLUSION

The result shows that WC and MUAC are the alternative tools to BMI. Both WC and MUAC are effective tools in identifying overweight among women. We recommend using MUAC to identify overweight and obesity for large-scale population-based assessments in low-income settings as it is logistically simpler and operationally feasible.

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Contributors All authors, TS, HYB, KS, AW, E-CE and YB participated in the conception and design of the study. TS, KS, AW and YB conducted data analysis and interpretation. TS drafted the manuscript. All authors revised the manuscript critically for important intellectual content. All authors approved the final version of the manuscript. TS is reponsibele for the overall content of the study as guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study received ethical approval from institutional review boards in Addis Continental Institute of Public Health with the reference number ACIPH/IRB/004/2015 and the University of Gondar with reference number V/P/RCS/05/493/2019. Verbal informed consent was obtained from all participants before taking part in the study.

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