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ASSESSMENT OF OVERWEIGHT AND UNDERWEIGHT OF BANGLADESHI ADULTS USING WAIST-TO-HEIGHT RATIO: A CROSS SECTIONAL ANALYTIC STUDY

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Waist-to-Height-Ratio (WHtR) may be an alternate anthropometric index that can overcome the constraint of Body-Mass-Index (BMI) cut-off values for assessing health-risks. To get suitable cut-off values of WHtR, this study evaluated its use as a substitute to BMI cut-off <18.5 and ≥25 to identify adult undernutrition and overweight respectively. During 2012 a cross-sectional-study was conducted among 650 adult-attendants of the Dhaka-Hospital of icddr,b in Bangladesh. Waist-circumference, height and weight of 260 male and 390 female aged 19-60 years were measured. Sensitivity and specificity of WHtR against BMI<18.5 and BMI ≥ 25 were determined. Significant positive linear correlation was found between WHtR and BMI in males (r = 0.807, p<0.001) and females (r = 0.823, p<0.001). Based on BMI <18.5, area under receiver-operating-characteristic-curve (AUC) for WHtR among males was 0.888; 95% CI 0.850-0.927 and females was 0.889; 95% CI 0.855-0.922, and on BMI ≥25 among males it was 0.936; 95% CI 0.890-0.982 and among females it was 0.955; 95% CI 0.933-0.976. WHtR cut-off <0.44 for male and <0.48 for female to identify undernutrition, and ≥0.51 for male and ≥0.53 for female to identify overweight were chosen separately based on highest corresponding Youden-index. These cut-offs of WHtR intimately make out adult nutritional status as defined by BMI.

Keywords: Body mass index, Waist-to-height ratio, Adult, Undernutrition, Overweight

INTRODUCTION

Nutrition is generally ignored among adults living in developing countries including Bangladesh. Bangladesh is now facing a nutritionally transitional period where over and under nutrition each is happening simultaneously with an increasing rate of non-communicable diseases (Rahman *et al.*, 2006). The most commonly used anthropometric tool in adult population for detecting undernutrition, overweight, and obesity is Body Mass Index (BMI) (Bose, 1996). BMI <18.5 kg/m^2 and ≥25 kg/m^2 respectively indicate undernutrition and overweight/obesity, at the same time predicts various physiological impairments or morbidity of an individual (WHO Expert Committee, 1995). For individual anthropometric measurement and also in nutritional surveys it has been used (Ferro-Luzzi *et al.*, 1992), further it reflects the socioeconomic condition of the people in developing countries (Shetty and James, 1994; Nubé *et al.*, 1998; and Khongsdier, 2002). In certain situations when weight taking is troublesome or weight machine is not available, alternate tool or index is beneficial.

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Waist-to-Height-Ratio (WHtR) is an alternate measure in place of BMI. Ashwell *et al.* (Ashwell and Hsieh, 2005) reported that the ratio was also better than just taking a waist measurement as easy to remember a better cutoff value of <0.5 and it took into account differing height between individuals and ethnic groups. Whilst, BMI is a useful indicator, it does not consider the distribution of fat all around the body (Ashwell *et al.*, 1985; Ashwell, 1994; and Ashwell and Hsieh, 2005). In the absence of suitable weight measuring equipment, waist-circumference may be an option as it requires simply a tape measure rather than weighing scales (Ashwell and Hsieh, 2005); notably in bed ridden patients and many of them can mention/document their height properly as measured previously**.** An inconsistent capability of the BMI to predict disease risk has been evidenced. Because, several studies showed individuals that were overweight or obese based on BMI cut-off values were in fact at reduced mortality compared to the individuals having normal weight, While, only those were severely obese or underweight were found with increased risk (Flegal *et al.*, 2005; Romero-Corral *et al.*, 2006; and Flegal *et al.*, 2007). This study assessed WHtR as an alternative to BMI to identify under nutrition and overweight, and consequently to suggest a suitable cut-off value for the detection of nutritional status among adults.

MATERIALS AND METHODS

The Setting, Subjects and Data Collection

This prospective cross sectional study was carried out during the year 2012 in the Dhaka Hospital of the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b). A total 650 adult-attendants (260 male and 390 female, aged between 19 to 60 years) of the patients who sought treatment at the hospital were enrolled and interviewed. Pregnant women, athletes, and persons with any disability, hormonal disorder or apparent congenital dimorphism were excluded from this study. In each working day from 9 am to 4 pm the first 5 to 6 consecutive eligible attendants of the patients who fulfilled the selection criteria were approached for participating in this study. Verbal consent was obtained from each respondent. Data about age, educational status, occupation, and socio-demographic condition were collected through a pretested questionnaire. Anthropometric measurements were taken using standard and calibrated equipments. Standing height (to nearest 0.1 cm) and weight (to nearest 50 g) were measured using digital height weight scale (TCS-JL18 from JIELI, Zhejiang, China) with standard operating procedures. Standing height was measured without shoe and sock. The person was standing on bare heels while the feet were placed together; occiput (back of the head), back, buttocks, and back of the heels touched the back stick/board, and knee was fully extended. Head was positioned in the Frankfurt horizontal plane. Weight was measured with minimal clothing. A flexible plastic tape (length 60 inch/1.5 m) non-stretch vinyl-coated fiberglass was used to measure Waist-Circumference (WC), accurate up to the nearest 0.1 cm. WC was measured under the cloth at the level mid way between the lowest rib margin and the superior iliac crest on the midaxillary line in a horizontal plane. The subjects stood erect with abdomen relaxed, the arms at the side and feet together and breathing normally. All anthropometric measurements were taken twice and the average was recorded. If the measurements varied by more than 100 g for weight, 0.5 cm for height and 0.2 cm for WC a third measurement was made. In those cases, the average of the nearest two measurements was recorded. BMI was calculated using the standard formula: weight in kg/(height in m)^2. The BMI cut-off point of <18.5 was used to identify adult undernutrition and BMI $\geq$25 was used to identify adult overweight according to World Health Organization (WHO) guideline.

STATISTICAL ANALYSIS

Descriptive statistics were generated for all measurements (weight, height and waist to height ratio), BMI and demographic variables. To assess the linearity of BMI and WHtR, curve estimation was done and correlation analysis between BMI and WHtR was carried out. Receiver Operating Characteristics (ROC) analysis was done and ROC curves for WHtR based on BMI <18.5 for undernutrition and BMI $\geq$25 for overweight (according to WHO guideline) was produced separately for male and female respondents. Area Under ROC Curve (AUC) with its 95% Confidence Intervals (CI) was generated individually for male and female. Sensitivity and 1-specificity coordinate points for each WHtR value was tabulated. Optimal cut-off point was decided by maximizing the sum of sensitivity and specificity using Youden index. The Youden index is a frequently used summary measure of the ROC curve. It both, measures the effectiveness of a diagnostic test and enables the selection of an optimal threshold value (cut-off point) (Fluss *et al.*, 2005). Separate cut-off was generated for underweight and overweight. The analyses were carried out using IBM SPSS statistics version 20 and MedCalc 6.1.

RESULTS

The baseline characteristics of the study population, stratified by sex, are shown in (Table 1). The mean Standard Deviation (SD) age of the male and female participants was 31 (8.1) and 25 (5.9) years respectively and their monthly family income was 8879 (5778) Bangladeshi taka (1 US dollar = 78 taka). Linear model for the relationship between WHtR and BMI was found to be adequate and figure 1 illustrates the linear relationship between WHtR and BMI (WHtR = 0.174 + 0.015 * BMI) and the correlation was highly significant (Pearson correlation coefficient r = 0.802 p<0.001). Stratified by sex, there was a strong significant positive correlation between WHtR and BMI (r = 0.807, p<0.001) for male and (r = 0.823, p<0.001) for female (Figure 1).

The ROC analysis was executed to find the optimal WHtR cut-off for detecting nutritional status. Separate cut-off for men and women were generated. Based on BMI <18.5 the AUC of WHtR for male was 0.888 (95% CI 0.850-0.927) and female was 0.889 (95% CI 0.855-0.922) and based on BMI ≥25 the AUC of WHtR for male was 0.936 (95% CI 0.890-0.982) and female was 0.955 (95% CI 0.933-0.976) (Table 2 and Figure 2). Based on the highest Youden index WHtR value of 0.44 for male and 0.48 for female were found to be the suitable cut-off points for detecting undernutrition and the value 0.51 for male and 0.53 for female were found to be the suitable cut-off points for detecting overweight (Table 3). WHtR cut-off for under-nutrition in male (<0.44) showed a sensitivity of 86.3% and specificity of 73.9%. Corresponding cut-off in female (<0.48) showed a sensitivity of 90.5% and specificity of 70.2%. For over-weight WHtR cutoff in male (≥0.51) showed a sensitivity of 92.9% and specificity of 77.2%. Corresponding cut-off in female (≥0.53) showed a sensitivity of 97% and specificity of 80.8% (Table 3).

Table 1: Anthropometric Characteristic by Sex

Variables	Male (n=260) Mean (SD)	95% CI	Female (n=390) Mean (SD)	95% CI
Age (years)	31.1 (8.1)	30.1 - 32.1	25.4 (5.9)	24.8 – 26.0
Weight (kg)	52.85 (8.95)	51.8 – 53.9	47.27 (9.91)	46.3 – 48.3
Height in (cm)	160.6 (6.2)	159.8 – 161.4	148.8 (5.8)	148.2 -149.4
Body mass index (kg/m^2)	20.49 (3.29)	20.1 – 20.9	21.27 (3.89)	20.9 -21.7
Waist-to-height ratio	0.45 (0.06)	0.4 – 0.5	0.50 (0.07)	0.5 – 0.5

Figure 1: Curve Estimation for Assessing Linear Relationship Between Waist-to-Height Ratio and Body Mass Index (Combined, Upper Panel), and (Male and Female, Lower Panel)

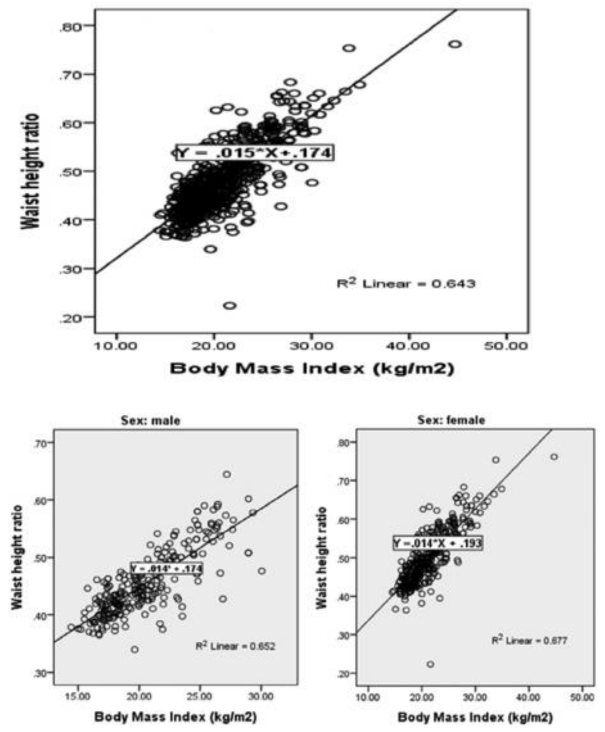

Table 2: Area Under the Receiver Operating Curve (AUC) for Waist-to-Height Ratio Based on Body Mass Index (BMI) < 18.5 and BMI ≥25 for Male and Female Separately

Variable	AUC Mean (Standard Error)	95% CI	p Value
BMI < 18.5			
Male	0.888 (0.020)	0.850 - 0.927	<0.001
Female	0.889 (0.017)	0.855 - 0.922	<0.001
BMI > 25			
Male	0.936 (0.023)	0.890 - 0.982	<0.001
Female	0.955 (0.011)	0.933 - 0.976	<0.001

DISCUSSION

This study has shown a direct correlation between BMI and WHtR, and identified WHtR value ≥0.51 for male and ≥0.53 for female as suitable cut-off points to categorize overweight. These findings favor WHtR as an alternate

Figure 2: ROC Curve of Waist-to-Height Ratio Based on Body Mass Index <18.5 (Underweight, Upper Panel) and BMI $\geq$25 (Overweight, Lower Panel) by Sex

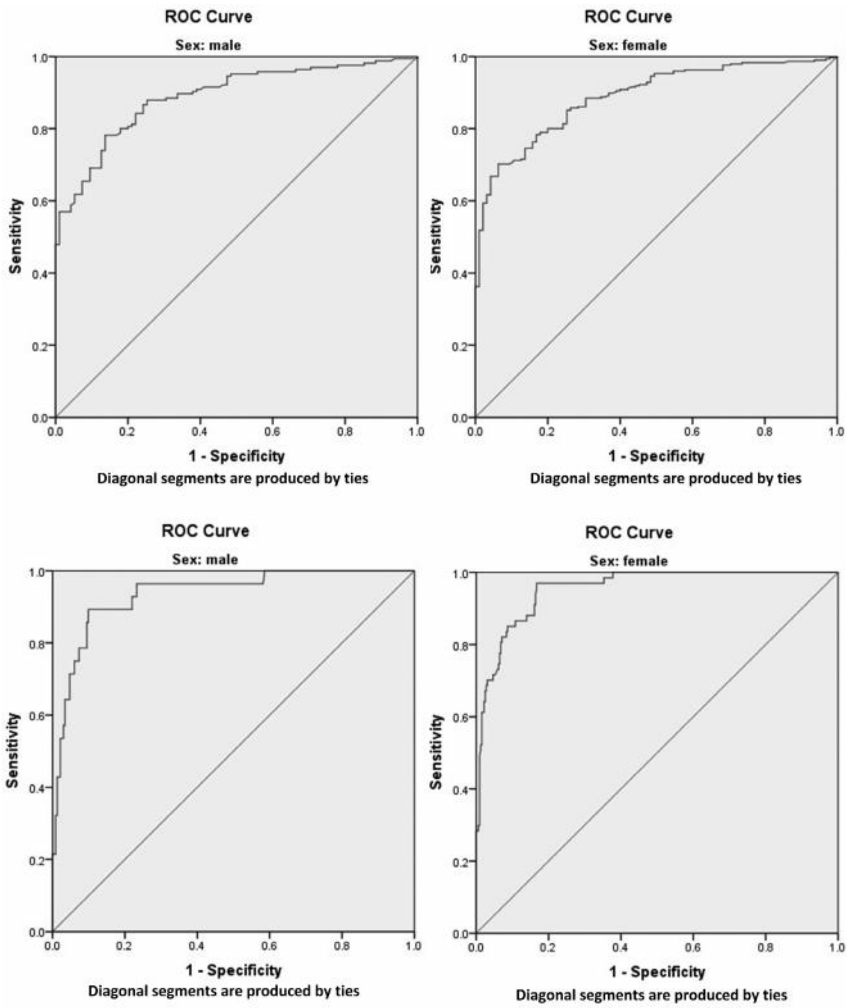

Table 3: Evaluation of Screening Test of Nutritional Status (Body Mass Index (BMI) < 18.5 and BMI > 25) by Waist-to-Height Ratio Based on Highest Youden's Index

	Youden's Index	Cut-Off	Sensitivity	Specificity	Likelihood Ratio for Positive Test	Likelihood Ratio for Negative Test
BMI < 18.5						
Male	0.645	< 0.44	0.863	0.739	3.312	0.185
Female	0.639	< 0.48	0.905	0.702	3.035	1.35
BMI > 25						
Male	0.794	> 0.51	0.929	0.772	4.065	0.093
Female	0.803	> 0.53	0.97	0.808	5.054	0.037

indicator of nutritional status in adult. Although both BMI and WHtR can be used to evaluate nutritional status, WHtR has been mentioned as a superior predictor of cardiovascular risk factors (Park *et al.*, 2009). Others (Ashwell and Lejeune, 1996) also pointed out WHtR as a better measure for women as well as men as a simple index for measuring coronary risk. In the assessment of central obesity and imaging techniques WHtR has shown a robust correlation with central fat (Ashwell *et al.*,1996). WHtR is inexpensive, simple to measure, easy to calculate than BMI, and as an early health notice measurement it is more sensitive (Ashwell and Hsieh, 2005). The WHtR cut-off point may vary among different populations and ethnic groups. For Chinese population, WHtR >0.445 is most favorable for overweight in both boys and girls (Yan *et al.*, 2007). However, insufficient effort has so far been taken to accurately characterize the WHtR cut-off for the population of Indian sub-continent. The lower cut-off proposed from the study by Yan *et al.* is specific for Chinese people since relatively short stature of this population restricts the flexibility towards higher WHtR levels. Compared to the European, even lesser amount of central fat and waist circumferences of Asian adults increase the health risk among them (WHO, 2002). There is robust evidence that, body fat allocation varies across ethnic individual (Bose, 1996). The relationship between general adiposity (as measured by BMI), regional adiposity (measured as body circumferences), MUAC and skin fold thickness, was also varying among different populations (Bose, 2001).

In this study, receiver operating characteristics analysis also determined a WHtR <0.44 as the best cut-off for male under nutrition and a WHtR value of <0.48 for female. Although across ethnic groups, BMI value <18.5 is reminiscent of undernutrition, studies have undoubtedly revealed that body composition measures (e.g., % body fat) and significant ethnic differences in regional adiposity at the similar level of BMI (Deurenberg *et al.*, 1998). Hence, ethno-specific cut-offs for WHtR to identify undernutrition is warranted as well.

The most useful screening method should be pragmatic as well as effective. BMI requires measures of weight and height and need to know some calculation. Sometimes it is not possible to measure weight, mainly in debilitated and immobile patients, because those patients cannot be taken out of their beds to be weighed. Self-measurement and reporting of height is identified to be more satisfactory for the population monitoring (Bolton-Smith *et al.*, 2000). In bedridden patient a supine length measurement could be an alternative of standing height to estimate WHtR. It requires measures of WC and height also. Assessment of WC needs of a simple tape measure instead of consideration weighing machinery. The limitation of this study with the suggested cut-offs is that the data appeared from only one site, which may not comprehensively illustrate the whole population. Therefore, validation studies are required with a bigger and more representative sample.

In conclusion, WHtR is a simple, easy and inexpensive indicator and it correlates intimately with BMI. WHtR comes out to precisely detect adult undernutrition and overweight as identified by BMI. WHtR <0.44 for male and <0.48 for female may be considered as a substitute to BMI cut-off <18.5 to detect adult undernutrition, and WHtR $\geq$0.51 for male and $\geq$0.53 for female may be considered as an substitute to BMI cut-off $\geq$25 to detect adult overweight. After validation studies in larger with more representative sample, it can be recommended as a useful screening tool to identify adult nutritional status.

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ETHICAL CONSIDERATION

Approval for the study was received from the Institutional Review Board (IRB) of the State University of Bangladesh, and permission to take data from the patients' attendants was taken from the Medical Director of the Dhaka Hospital of icddr,b. Prior to data collection Informed verbal consent was taken from each participant. The verbal consent process involved explanation of the research process and what the participant would do if s/he agrees to participate in the study. Documentation of verbal consent was kept by recording a check mark in the questionnaire which was again shown to the participants. Confidentiality was assured and we maintained it.

CONFLICT OF INTEREST

There are no conflicts of interest to declare.

AUTHORS' CONTRIBUTIONS

Conceived and designed the experiments: TS MNK MIH. Performed the experiments: TS MNK MIH. Analyzed the data: TS MNK MIH. Contributed reagents/materials/ analysis tools: TS MNK MIH. Wrote the paper: TS MNK TA MIH.

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