

# Sewing Tape: A Potential Public Health Tool for Determining BMI in Disadvantaged Populations

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#### Abstract

The prevalence of obesity, a risk factor for non-communicable diseases, is on the increase globally. Body mass index is the most widely used measure of obesity worldwide. Measuring body mass index involves the use of stadiometer, weighing scale, and calculator, or expensive BMI machine. Such instruments may not be available to health professionals in certain areas of the world and so this research asks the question: "Can an ordinary sewing tape measure be used to measure body mass index?"

The aim of this study was to develop a regression equation for calculating body mass index from waist circumference and hip circumference. It used a secondary dataset consisting of 3013 participants of a survey of bank workers across the 36 states of Nigeria and Abuja. The sampling technique was census sampling. The data was collected using a stadiometer, weighing scale, calculator, and BMI machine, and analyzed with SPSS using multiple linear regression.

The participants' mean body mass index was  $26.99\pm4.89$ kg/m<sup>2</sup>, waist circumference  $79.13\pm26.72$ m, and hip circumference  $87.24\pm28.57$ cm. Multiple linear regression showed that both waist circumference and hip circumference were significant predictors of body mass index and correlated in 43.5% of cases. The formula for calculating body mass index from waist and hip circumferences was given as:  $BMI = (WC \times 0.209) - (HC \times 0.132) + 22.009$ .

This formula is a potential handy public health tool for measuring body mass in disadvantaged communities using an ordinary tailoring tape. Further studies should be conducted to improve on the formula.

**Keywords:** Body Mass Index, Waist Circumference, Hip Circumference, Regression Formula, Tape Measure.

### Introduction

According to World Health Organization, over 39% of adults aged 18 years and above, numbering around 1.9 billion, were estimated to be overweight in 2016, and more than 650 million of them (13%) were obese (Zamsad et al., 2019). Globally, about 2.8 million people die yearly of overweight-related and obesity-related disorders (Quinte et al., 2019). Obesity accounts for 31.8% of direct healthcare costs, 68.1% of indirect costs due to reduced or lost productivity, and the cost of medical care for obese people is 32% more than that of people with healthy weight (Yusefzadeh et al., 2019).

Obesity is the accumulation and abnormal distribution of fat in the body causing increased risks of diseases (Merema et al., 2019). It is associated with comorbidities such as hypertension, type 2 diabetes, dyslipidemia, metabolic syndrome, cardiovascular diseases, kidney diseases, hepatic steatosis, cancers, infections, and musculoskeletal disorders (Crane and McGowan, 2019; Eleazu et al., 2019; Morales Camacho et al., 2019).

There are several measures of obesity. These include simple skinfold thickness, waist circumference (WC), hip circumference (HC), waist hip ratio (WHR), body mass index (BMI), underwater weighing (densitometry), bioelectrical impedance, dual-energy x-ray absorptiometry (DEXA), computerized tomography (CT), and magnetic resonance imaging (MRI), and dilution methods (Adab et al. 2018; Blüher, 2019; Fang et al. 2018; Kraak et al., 2019; Li et al., 2019). BMI remains the most acceptable definition and classification of obesity because it defines specific categories of body weight and

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associated risks, and it is used to inform public health policies globally (Heslehurst et al., 2019; Nuttall, 2015).

BMI is calculated as weight (in kilograms) divided by height squared in meters (Siddiqui et al., 2019). It is used to categorize body weight into four main groups: underweight, healthy weight, overweight, and obesity (Garrett et al., 2019). Obesity is sub-divided into three classes: Obesity type 1, type 2, and type 3 (morbid obesity). The corresponding values of BMI for this classification are illustrated in Table 1.

The measurement of BMI requires a stadiometers, weighing scale, calculator, or a BMI machine. These instruments might not be readily available in hard-to-reach socially-disadvantaged populations in developing countries (Wallace et al., 2019; Wilson, 2019). Thus, this research answers the question - Can an ordinary sewing tape be used in measuring BMI?

# Methods

This secondary study used a dataset of 3013 bankers from a cross-sectional survey in 2018 across the 36 states of Nigeria and Abuja. The aim was to develop a regression equation for calculating BMI from WC and HC. The use of this equation would allow healthcare workers in disadvantaged populations to compute BMI using just a measuring tape.

The primary data from a census sample was collected by measuring anthropometric parameters using sewing tape, stadiometers, weighing scales, and Amron BMI machines. Participation in the survey was voluntary. Personal data was deleted for ethical reasons. The anthropometric measurements included weight, height, BMI, WC, and HC. Weight in kg and height in meters were used to compute BMI using a BMI machine and confirmed by the formula: BMI = weight/height<sup>2</sup>.

The primary data in Excel was exported to Statistical Package for Social Sciences (SPSS). The independent variables were WC and HC while the dependent variable was BMI. Both predictor and outcome variables were tested for normal distribution using Shapiro-Wilk, QQ plot, and PP plot of regression standardized residual. A confidence level (CL) of 95% and a level of significance of 0.05 were used for the analysis.

The main weakness of this study was that data was collected from voluntary census where the probabilities of actual participation was unpredictable. However, the findings from this study could open up the need for more research in this direction.

### Results

The weight of the participants ranged from 44kg to 165kg, height from 1.4m to 2.1m, BMI from 14kg/m<sup>2</sup> to 53 kg/m<sup>2</sup>, WC from 24cm to 142cm, and HC from 28cm to 152cm. The mean weight, height, BMI, WC, and HC of the participants were  $78.75 \pm 14.74$ kg,  $1.71 \pm 0.08$ m,  $26.99 \pm 4.89$ kg/m<sup>2</sup>,  $79.13 \pm 26.72$ cm, and  $87.24 \pm 28.57$ cm (Table 2).

Test of normality with Kolmogorov-Smirnov and Shapiro-Wilk (KS/SW) test was statistically significant (p < 0.001) indicating that the variables did not have a normal distribution (Table 3). However, BMI had the same mean, median, and mode of approximately  $27kg/m^2$  suggesting a near perfect normal distribution as depicted in the histogram with normality curve (Figure 1). Field (2013) and Steinskog et al. (2007) maintained that KS/SW tests should be interpreted with caution and a significant test does not invalidate a parametric analysis. Furthermore, test of normality using collinearity diagnostics with PP plots and PP plot of regression standardized residual confirmed that the three variables (WC, HC, and BMI) had some level of normal distribution, showed linear relationships, relative homoscedasticity, and absence of multicollinearity (Figures 2 and 3). Therefore, multiple linear regression was appropriate to generate a regression equation for the calculation of BMI form WC and HC.

The results, according Chin and Marcoulides, 1998 as outlined by Ridzuan et al., 2017, ( $R^2$  values: 0.67-substantial, 0.33-moderate, 0.19-weak) indicated that the model was weak (Ridzuan et al., 2017), but the Durbin-Watson of 1.738 can be considered a relatively good fit (R = .435, R square = .190, Durbin-Watson = 1.738). Durbin-Watson test detects the presence of predicted errors from regression analyses (Das, 2019). According to a rule of thumb for a relatively normal data, Durbin-Watson test statistic values of 1.5 to 2.5 are relatively normal and not a cause for concern (Ho et al., 2019).

Both WC and HC were correlated in 43.5% of cases and the model explained 19% change in the variance of BMI (F (2, 3010) = 352.091, p < .001). However, both WC (t = 16.79, p < .001) and HC (t = -11.381, p < .001) were significant predictors of BMI (Tables 4 and 5).

Therefore, the regression equation for predicting BMI from WC and HC is:

BMI = (WC x 0.209) - (HC x 0.132) + 22.009.

### Discussion

The formula for calculating BMI,  $BMI = weight (kg)/height^2$ , has been criticized by academicians. Professor Nick Trefethen, a mathematician at Oxford University in the United Kingdom, argues that BMI divides the weight by too much in short individuals and by too little in tall counterparts, and therefore, proposes a new formula for BMI as 1.3 x weight (kg)/height (m)<sup>2.5</sup> (De Lorenzo et al., 2019).

Despite increasing varying criticisms for over a century, BMI, devised by Lambert Adolphe Jacques Quetelet, remains the most acceptable and widely used tool for determining abnormal body weight globally (Garcia-Alexander, 2019; Han et al., 2019; Vasyukova, 2019). The prerequisite measurement of weight and height before computing BMI is often cumbersome (Adab et al., 2018). With socially disadvantaged populations, especially in developing countries, these measurements may be impractical and tools for measuring BMI might not be readily available (Ma et a., 2012). These possible circumstances call for the development of less cumbersome and very handy tool for determining BMI.

There is paucity of work done on this topic. Sancar and Tabrizi (2017) confirmed the relative nonavailability of literature in this regard and asserted that studies in this direction should be considered as research of public health importance. Three relevant studies that employed prediction equations using linear regression are discussed below.

Visscher et al. (2006) in Netherlands used various linear regression equations to calculate acceptable BMI values in situations of self-underreporting of weight, height, and BMI. It was observed in the study that participants with high BMI deliberately underreported values. These errors impacted on the computed statistics and analyses and had to be corrected with predicted BMIs. Based on available data, eight different BMI prediction equations were used in the study (Figure 4). Similarly, Morimoto et al., (2007) used regression equations to predict WC from BMI in school-aged children in Japan. They found that there was a significant linear relationship between BMI and WC in each age and sex group and developed sex and age-group specific regression equations for predicting WC from BMI as shown below:

- 9-10-year-old boys: WC = 13.99 + 2.63BMI (r = 0.940, p < 0.001);
- 9-10-year-old girls: WC = 15.09 + 2.61BMI (r = 0.933, p < 0.001);
- 12-13-year-old boys: WC = 23.67 + 2.22BMI (r = 0.880, p < 0.001);
- 12–13-year-old girls: WC = 23.83 + 2.15BMI (r = 0.859, p < 0.001).

In a more detailed study in Turkey, Tabrizi and Sancar (2017) used three different analytical models to predict BMI values from a wide range and combination of independent continuous variables such as age, WC, systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting glucose (FG), high density lipoprotein (HDL), low density lipoprotein, triglycerides (TG), uric acid, and C-reactive protein. The three models used were multiple linear regression, artificial neural networks (ANN), and adaptive neuro-fuzzy inference system (ANFIS). All the three models produced equations with comparable and acceptable values of BMI. When three models were compared, ANFIS appeared the best but the multiple regression model was simple, user-friendly, and would not require expertise in mathematics. The multiple regression model used WC, TG, FG, HDL, SBP, and DBP to produce the BMI prediction equation given below:

BMI = (0.149 x WC) + (0.006 x TG) + (0.072 x FG) - (0.035 x HDL) + (0.043 x SBP) + (0.066 x DBP)

None of these BMI prediction equations tallies with the one from this study ( $BMI = (WC \ge 0.209) - (HC \ge 0.132) + 22.009$ .) but the reviews highlighted the need for further studies in this area with scarcity of literature. Recent study suggests that adding anthropometric measures of obesity to BMI Z Score improves the prediction of cardiometabolic, inflammatory and adipokines profiles in youth (Samouda et al., 2015). However, this study explored simple non-invasive anthropometric measurements of just WC

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and HC using a universally available, culturally acceptable, and widely affordable tool, the measuring or sewing tape.

### Conclusion

This study has achieved its objective of developing a regression formula for calculating BMI from WC and HC using just a measuring tape. The accuracy of this equation needs to be improved upon by further studies. This study was limited by disparity between the results of KS/SW tests and histograms with normality curves, weak goodness of fit for the regression model, the use of voluntary census, and its restriction to the banking sector.

This study has opened up opportunities for future studies. Future research should explore this topic using the probability sampling technique in the general population. The addition of anthropometric measures of adiposity to BMI Z score should be considered using the dataset used in this study. It should be explored further by researchers.

Future research should incorporate age and sex into the regression equations to improve accuracy and reliability. Furthermore, splitting the sample into males and females and computing two equations, and then adjust the equations for age would also improve validity.

Giving the non-availability of medical equipment and the cumbersome nature of BMI measurement, the improvement of this developed equation would go a long way in facilitating the measurement of BMI using just a sewing tape. This tool is potentially a public health tool that is reading available, affordable, handy, and culturally acceptable in socially disadvantaged populations in Nigeria and other developing countries.

### **Figures and tables**

Classification	BMI Score (kg/m <sup>2</sup> )
Underweight	< 18.5
Normal	18.5 - 24.9
Overweight	25.0 - 29.9
Obesity type 1	30.0 - 34.9
Obesity type 2	35.0 - 39.9
Obesity type 3 (morbid obesity)	> 40.0

Table 1. Classification of BMI

Table 2. Descriptive statistics of weight, height, BMI, WC, and HC

	Minimum	Maximum	Mode	Median	Mean	Std. Deviation
Weight (kg)	54.4	116	73	76.4	77.99	12.46
Height (m)	1.56	1.88	1.75	1.74	1.72	0.07
BMI	19.16	38.7	30.50	26.15	26.38	3.93
WC	75	114	92	93.5	93.77	8.82
HC	83	119	103	102	102.12	8.16

Quantitative	Shapiro-Wilk			
Variables	Statistic	df	р	
BMI	.967	3013	<.001	
WC	.867	3013	<.001	
HC	.814	3013	<.001	

Table 3	J. Test	of nor	mality
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Figure 1. Histogram of BMI with normality curve



Figure 2. Collinearity diagnostics with PP plots





Table 4. M	Aultiple I	linear regre	ssion model	summarv a	nd coefficients

	R	Adjusted R	Std. Error of the	Durbin-	Outcom	Predictors
R	Square	Square	Estimate	Watson	e	
.435	.190	.189	4.36370	1.738	BMI	WC and HC

	Unstandardized		Standardized				
	Coefficients		Coefficients			95.% CI for B	
						Lower	Upper
	В	Std. Error	Beta	t	Р	Bound	Bound
Constant	22.009	.255		86.152	.000	21.508	22.510
WC	.209	.012	1.151	16.790	.000	.184	.233
HC	132	.012	780	-11.381	.000	155	109

#### Table 5.: Multiple linear regression coefficients

Figure 4. BMI equations (Visscher et al. 2006)

- BMI =  $0.145 + 0.996 \times$  self-reported BMI +  $0.017 \times$  age
- $BMI = 3.30 + 0.848 \times self$ -reported BMI
- $BMI = 2.60 + 0.87 \times self$ -reported BMI
- $BMI = 2.292 + 0.893 \times self$ -reported BMI
- $BMI = -0.631 + 1.008 \times self$ -reported  $BMI + 0.022 \times age$
- $BMI = 3.21 + 0.830 \times self$ -reported BMI
- $BMI = 5.57 + 0.74 \times self$ -reported BMI
- $BMI = 1.835 + 0.893 \times self$ -reported BMI

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