



Utility of Broca's Index in Assessing Body Mass: Analysis of Anthropometric Measures from a Cross Sectional Study

Jenyz M Mundodan¹, C R Saju², Vidhu M Joshy³

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Author's Affiliation:

¹Assistant Professor, Dept. of Community Medicine, Govt Medical College, Idukki; ²Professor & Head; ³Lecturer in Biostatistics, Dept. of Community Medicine, Amala Institute of Medical Sciences, Thrissur

Correspondence

Dr. C R Saju ²
drsajucr@gmail.com

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ABSTRACT

Introduction: Broca's index is the easiest method to calculate the ideal body weight for height. However, the absence of a defined range limits its utility. This study aims to identify 'normal range' for Broca's index that corresponds to the normal range for BMI and to determine the predictive accuracy for cut-off points thus obtained.

Methods: Anthropometric measurements of adults were taken during a cross sectional survey. BMI and ideal weight as per Broca's Index were calculated for each individual. Broca's Index Ratio was calculated as the ratio of actual weight to the calculated Broca's Index (ideal weight). ROC curves were plotted to identify the best cut off points for Overweight and obesity.

Results: The BMI of the participants ranged from 16.14 to 35.16, with a mean 25.53 kg/m² (SD=2.86). Broca's index ratio had strong correlation with the BMI value (r=0.969). From the ROC curves, Broca's Index ratio against BMI values of 23 and 25 were identified as 0.95 and 1.03. Broca's Index ratio of 1 corresponds to BMI Value 24.01.

Conclusions: Individuals can be advised on their ideal weight (as per Broca's index), with the upper limit being around 5% less than the calculated value.

Key-words: Anthropometric measure, Broca's Index, Body Mass Index, utility

INTRODUCTION

Change in lifestyle and diet has brought in a lot of risk factors for Non Communicable Diseases (NCD). Obesity is one such health problem which has made its inroads into the Indian population. Obesity acts as a major risk factor for most Cardiovascular diseases as well as for Diabetes Mellitus and it increases the all-cause mortality. Obesity has also been identified as a predictor lipid changes as early as adolescence.¹

Accurate assessment of obesity has been a point of concern.² While 'underwater weighing' can be considered as a gold standard to assess total body fat, it is often not practical in most settings. Waist Circumference and Waist-Hip Ratio are good predictors of Cardiovascular diseases, but are often not

acceptable in field surveys.³ Different algorithms for the Ideal body weight (IBW) have been developed based on the general idea that weight is defined by height as a linear function;⁴ these include simpler indices like the Broca's Index, as well as more complex equations.⁵⁻⁸ The complexity of most algorithms makes IBW difficult to calculate; BMI is similarly difficult to calculate without the use of a calculator.⁴

Quetelet Index or Body Mass Index (BMI) has been used routinely to classify obesity and is considered as a Reference standard.^{9,10} There is a U-shaped relationship between BMI and mortality rates, with exponential increases of mortality in adult subjects with high BMI or low BMI.¹¹ Although BMI is the index used most often, it does not reflect obesity in all populations uniformly, and inter-ethnic need to

be taken into account. World Health Organization (WHO) and the International Obesity Task Force recommend the BMI cut-off point of 30 kg/m² for obesity;¹² which was set as 25 kg/m² for the Asian population by WHO Expert Consultation considering the higher risk of type 2 diabetes and cardiovascular disease.¹³ Studies assessing the risk of diabetes in Asian population of US have shown normal cut-off values for BMI was 23 kg/m² for both sexes, with cut-off values for WC as 85 and 80 cm for men and women; the corresponding WHRs were 0.88 and 0.81, respectively.¹⁴

Furthermore, though a simple calculation, studies have shown that the concept and calculation BMI are often not readily understood by layperson.¹⁵⁻¹⁷ Many find it difficult to decipher one's ideal weight from calculation of BMI. This highlights the necessity of a simpler index such as the Broca's Index. Broca's Index is one of the earliest used indices for body weight assessment which gives a single value for ideal body weight; it is fairly easy to understand for lay public.^{18,19} However, it does not give a range for the normal value, the absence of which limits its utility.²⁰ While this method has fallen out of use in scientific discourse, it can be revived for educating the general public on IBW, considering its ease in calculation. This study was conducted to identify 'normal range' for Broca's index that corresponds to the normal range for BMI and to determine the predictive accuracy for cut-off points thus obtained.

METHODS

Anthropometric measurements of adults were taken during cross sectional surveys conducted in a village as part of family surveys in the rural field practice area of Department of Community Medicine of our institution. The survey was conducted over a period of 6 months from May to October 2018 as part of Amala Rural Community Health (ARCH) Programme, the community outreach programme for MBBS students. Consecutive houses were chosen for the study, whereby two wards of the Panchayat were covered. All individuals aged 18 years and above, who were present in the household at the time of visit were taken for the study. Individuals with chronic debilitating diseases were excluded from the study. Houses where one or more of the residents could not be examined were visited within the next 14 days in order to collect the details. Informed written consent was obtained from the participants prior to collecting information and anthropometric assessment.

Along with anthropometric measures such as height, weight, waist circumference and hip circumference, basic socio-demographic details and medical history of the participants were also ob-

tained through a pretested questionnaire. Weight was measured using weighing scales, accurate to 0.1 kg. The scale was kept flat on the floor and the subject was asked to step on it bare feet without holding on to anything, after divesting himself/herself of all heavy objects, including footwear. The weight was recorded to the nearest kilogram. The same set of six weighing scales was used for all the participants and each scale was calibrated at the beginning of data collection. Height was measured using a measuring tape, accurate to 0.1 cm, with the subject standing erect against the wall. Height was recorded to the nearest centimetre. Circumferences were measured using flexible measuring tape, with accuracy of 0.1 cm. Waist circumference (WC) at the level of umbilicus medical and just above the iliac crest laterally, while hip circumference (HC) at the level of greater trochanter of femur laterally, both to the nearest centimetre. Students who were assigned the responsibility of collecting anthropometric data were given a detailed training by the first author at the beginning of each session to ensure internal validity.

Data was analysed using SPSS ver 23. Anthropometric indices such as Quetelet index, Broca's index, Lorentz index and Waist-Hip Ratio were calculated. Individuals were classified based on their BMI according to Asian classification.¹³ Overweight is defined as BMI kg/m² = 23.0-24.99 and obesity as BMI kg/m² ≥ 25.0.

Ideal Body Weight was assessed as Broca's Index, determined as Height (in cm) - 100. Lorentz Index (LI) for males and females were calculated using the formula LI = Height (in cm) - 100 - [Height(in cm) - 150]/2 in women and LI = Height (in cm) - 100 - [Height(in cm) - 150]/4 in men.

For the purpose of comparison with other indices, *Broca's Index Ratio* was calculated as the ratio of actual weight to the calculated Broca's Index (ideal weight); similarly *Lorentz' Index Ratio* was calculated as the ratio of actual weight to the calculated weight as per Lorentz Index. ROC curves were plotted to identify the best cut off points for Broca's index for Overweight and obesity according to Asian Classification of BMI (23 & 25 respectively).

Permission was obtained from the Institutional Ethics Committee prior to commencement. Informed consent was obtained from the participants prior to collection of data. The study involved questions pertaining to socio-demo-graphic variables and assessment of anthropometric measures; there were no invasive procedures involved.

RESULTS

A total of 1791 individuals were included in the study; 52.5% of the participants were females. The

Table 1: Profile of study participants

Variables	Female (n=959)(%)	Male (n=832)(%)	Total
Age (in years)			
<20	42 (4.4)	63 (7.6)	105
21-30	144 (15)	133 (16)	277
31-40	163 (17)	119 (14.3)	282
41-50	217 (22.6)	167 (20.1)	384
51-60	167 (17.4)	174 (20.9)	341
61-70	143 (14.9)	123 (14.8)	266
>70	83 (8.7)	53 (6.4)	136
BMI			
<18.5	75 (7.8)	70 (8.4)	145
18.5 - 22.9	293 (30.6)	299 (35.9)	592
23 - 24.9	169 (17.6)	178 (21.4)	347
25 - 27.49	186 (19.4)	158 (19)	344
>=27.5	236 (24.6)	127 (15.3)	363

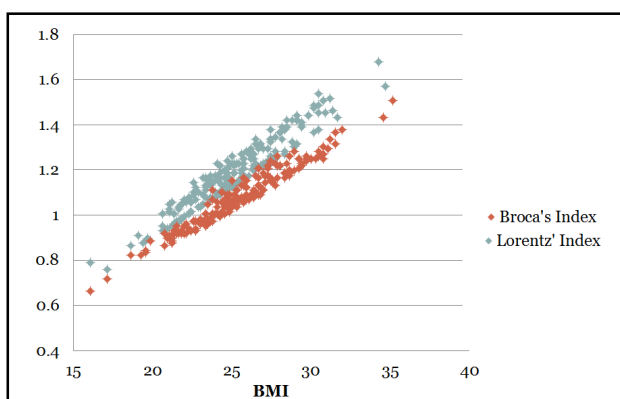
Table 2: Values of Broca’s and Lorentz’ indices at various Cut off points for BMI

BMI	Broca’s Index	Lorentz Index
18.5	0.76	0.81
23	0.95	1.08
25	1.03	1.20
27.5	1.19	1.27
24.01	1.0	

Table 3: Sensitivity and Specificity of the Broca’s Index ratios corresponding to selected BMI cut-off points

BMI	Broca’s Index	Sensitivity	Specificity	Area under Curve
23	0.95	98.5%	99.1%	0.997
25	1.03	96.0%	99.6%	0.997
27.5	1.19			

Figure 1: Correlation of BMI with Broca’s Index and Lorentz’ Index



median age of the participants was 39 years (IQR = 21 years). The BMI of the participants ranged from 16.14 to 35.16, with a mean 25.53 kg/m² (SD=2.86). The mean waist circumference was 85.29 cm (SD=6.44) for males and 89.03 (SD=7.65) for females. The mean Waist-Hip Ratio was 0.83 for females and 1.08 for males. [Table 1] All the four parameters followed normal distribution according to

Kolmogorov-Smirnoff test.

The mean value of the calculated *Broca’s Index Ratio* was 1.079 ± 0.121 [1.081 ± 0.119 in males and 1.075 ± 0.126 in females] and that of *Lorentz Index Ratio* was 1.187 ± 0.147 [1.233 ± 0.140 in males and 1.116 ± 0.126 in female]. A high degree of correlation was seen between *Index ratios* (r=0.875). Both the index ratios individually had strong correlation with BMI value (r=0.969 for Broca’s index, r=0.954 for Lorentz index). When the analysis was restricted to those with Weight Circumference < 90 cm (n=301), correlation was found to be stronger (r=0.993 for Broca’s index, r=0.956 for Lorentz index). [Fig 1]

From the ROC curves plotted for Broca’s Index ratio against BMI values of 23 and 25 were identified as 0.95 and 1.03. It was seen that the value of Broca’s Index ratio of 1 corresponds to BMI Value 24.01. Broca’s Index Ratio corresponding to BMI values of 18.5 and 27.5 were 0.81 and 1.27 respectively.[Table 2] Hence the normal range for Broca’s Index Ratio is 0.81 to 0.95. In other words, the weight of a person should be ideally between 81% to 95% of calculated weight, i.e. Height (cm) – 100.

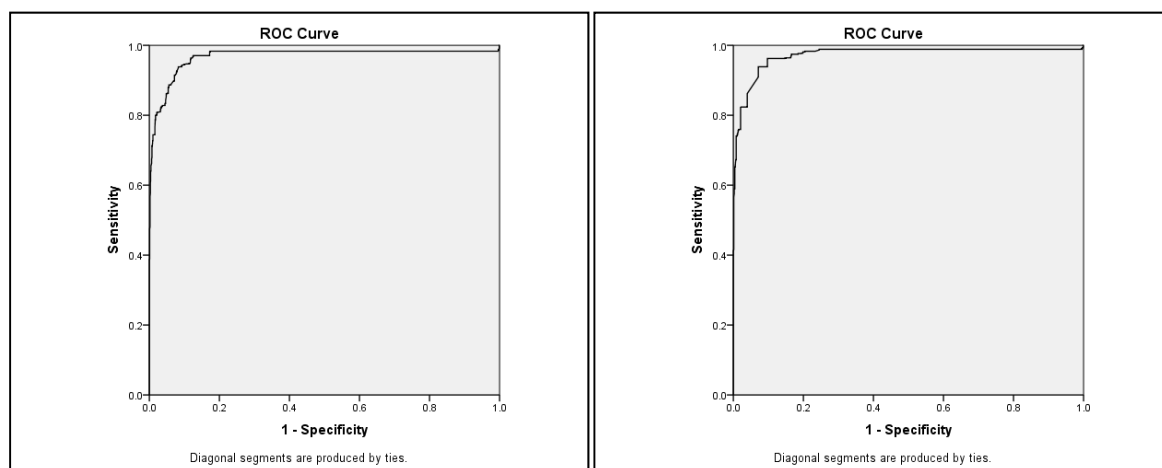
From the ROC curve plotted for the BMI cut off points, it was seen that sensitivity and specificity of the Broca’s Index ratio of 0.95 for BMI 23 were 98.5% and 99.1%, respectively. Similarly, the sensitivity and specificity of Broca’s Index ratio of 1.03 for 25 were 96.0% and 99.6%, respectively. [Figure 2] [Table 3] Hence, Broca’s Index can be considered as a reliable measure for assessing the actual weight against the expected weight, at least at the BMI levels near 23 and 25.

DISCUSSION

This study was aimed at explaining Broca’s Index better with reference to BMI values. The need for this was felt when the authors found it difficult to explain the concept and calculation of BMI to the general public during health education sessions of control of NCD.

While Broca’s Index is not considered a sensitive predictor for the risk of developing Cardiovascular disease, it continues to be one of the simplest indices in assessing obesity. Providing a range for the Broca’s Index, which is easy to calculate, may prove to be a practical option.

A high degree of correlation was seen between Broca’s Index and Lorentz’ Index, which is expected considering the similarity in the formulae. The ratio of actual weight to expected weight as per Broca’s index is mentioned in many studies, though a term for the same was not found in literature; we have used the terms Broca’s Index Ratio and Lorentz’ Index Ratio in this article for ease of understanding.

Figure 2: ROC curves showing Broca's Index Ratio against BMI Cut-off of 23 and 25 respectively**A. BMI < 23****B. BMI < 25**

The Broca's Index ratio for BMI 23 corresponded to 0.95, or in other words the upper limit for ideal weight of a person must be 5% less than the calculated weight (i.e. height in cm - 100). BMI of 25 corresponded to Broca's Index ratio of 1.03. This may be elucidated thus; if the observed weight exceeds the calculated value by 3%, the person may be considered obese. Most important to note is that when the observed weight is equal to the calculated weight, the person falls in the Pre-obese category. (BMI=24.03) as per the current Asian classification of BMI.

A recent study shows strong correlation of Broca's Index with other methods of calculation of ideal body weight. It was seen that Broca's Index compared with Hammond's equation showed a relationship of 95.7%, with Robinson's 96.5% and with the weight calculated from ideal BMI (22.5kg/m²) 99.8%.²¹

As the aim of the study was to assess the validity of Broca's Index with respect to BMI, our study included all adults who were available for Anthropometric measurements. Children were not included as the utility these indices are limited to adults. We analysed the data separately as well as collectively for the cut-off of WHR in order to look into its utility in all groups. A major strength of the study is that it includes a fairly large sample size from the reference population.

CONCLUSION

In summary, the study shows that the weight of a person should ideally be between 81% to 95% of the calculated weight, i.e. Height (in cm) - 100. The calculated weight as per Broca's Index corresponds to BMI Value 24.01. Further, the predicative accuracy of the Broca's Index for BMI is high and hence

can be used in place of the latter, as and when the need arises.

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