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Prevalence of Obesity, Central Obesity and Relationship between Body Mass Index, Selected Anthropometric Parameters and Body Fat Percentage in a Sri Lankan Female Population

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Abstract: *A cross-sectional study was conducted among female undergraduates residing in the hostels of University of Sri Jayewardenepura, randomly selected using blind draw method to determine the relationship between BMI, selected anthropometric parameters and total body fat percentage (TBF%). All anthropometric measurements were taken in accordance with WHO standards. The TBF% was estimated using a body fat analyzer. Pearson correlations and Chi-square test were performed using SPSS 21. TBF% was significantly associated with BMI, waist circumference, waist to hip ratio and mid upper arm circumference ($p<0.05$) but was not with mid-thigh circumference and waist to thigh ratio. TBF% showed positive correlations with all the anthropometric measurements examined ($p<0.05$). The strongest correlation observed with BMI ($r=0.63$). BMI and some other anthropometric measurements can be utilized as reliable and inexpensive tools for predicting* adiposity *or BF%* in clinical, research, and surveillance settings.

Keywords: Body mass index, Anthropometry, Body fat percentage

1. Introduction

The prevalence of overweight, obesity, and associated metabolic problems are on the rise at an alarming rate worldwide and have become global public health problems [10]. According to the World Health Organization (WHO) in 2014, about 39% of the world's adult population (more than 1.9 billion) were overweight and 13% of adults aged 18 years and over were obese [26]. Overall more women are overweight and obese than men [11]. Overweight and obesity cause comorbidities, severe complications, human deaths as well as social and economic problems in both developing and developed countries [17].

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue. Some examples of anthropometric measures are weight, standing height, recumbent length, skinfold thicknesses, circumferences, limb lengths, and breadths [21]. Several indexes and ratios can be derived from anthropometric measures. Body mass index (BMI) is the most popular, simple index of weight-for-height that is commonly used to classify overweight and obesity in adults [26].

The circumference measures assess subcutaneous and visceral fat tissue. Waist circumference (WC) is an indicator of intra-abdominal fat (visceral fat) that is stored around the organs of the abdomen is referred to as central obesity [22]. Central obesity leads to many disease risks. Mid-upper arm circumference (MUAC) is used to evaluate adult nutritional status that has been found to be particularly effective in determining malnutrition [3].

The ratios derived from circumference measures include waist to hip ratio (WHR) and waist to thigh ratio (WTR). WHR is waist circumference divided by the hip circumference which is a better additional measure of body fat distribution in the abdominal area [20].

Bio-electrical Impedance Analysis (BIA) is one of the methods to measure body fat percentage (BF%). Unlike fat tissues, other tissues containing much water such as muscles, blood vessels, and bones are highly conductive with electricity. The resistance of the fat tissue to the current is termed 'bioelectrical impedance', and is accurately measured by body fat scales. During the measurement, the instrument record whole body impedance from the hands to the feet by applying an extremely weak, safe electric alternating current flux of 0.8 mA at an operating frequency of 50 kHz. Finally, BF% is calculated from the whole body impedance measurement and the pre-entered personal data (age, gender, height and weight) of the corresponding subject [14, 15, 29]. Prediction equations based on BIA have been validated and cross-validated primarily in white populations for all age groups (children, youths, adults and the elderly) but to a limited extent, in Asian, black, and Native American populations [9].

South Asian populations suffer obesity-associated complications at a lower BMI and WC than other ethnic groups [1, 4, 27]. Despite some limitations; anthropometry remains the most practical procedure for monitoring nutritional status and screening individuals at nutritional risk predominantly in developing countries [3, 13]. Some studies have shown, that BMI and BF%, other anthropometric parameters and BF% have an imperfect association [4] and some, in contrast, justify a strong association [23, 25].

In clinical practice, use of BMI and other anthropometric parameters as indicators of obesity and adiposity are easy, inexpensive and require less expertise than laboratory techniques, but their reliability as tools for measuring body fat can be questioned. Hence this study was conducted to determine the prevalence of obesity, central obesity and the relationship between BMI, other selected anthropometric parameters and TBF% in female undergraduates residing in the hostels of the University of Sri Jayewardenepura.

2. Methods

2.1. Subjects

A cross-sectional study was performed among apparently healthy female undergraduates residing in the female hostels of University of Sri Jayewardenepura, Nugegoda, Sri Lanka in 2014 August–December. Female undergraduates with diabetes, hypertension, hyperlipidemia, ischemic heart disease, chronic renal or liver disease, epilepsy, endocrine disease, prolonged inflammatory disease and those who were on medications such as oral hypoglycemic agents, corticosteroids, thyroxine and lipid-lowering therapy, hormone replacement, antiresorptive drugs and pregnant females were excluded.

2.2. Sampling

A simple random sample of 367 apparently healthy female undergraduates who had been in the hostels for more than six months were drawn from the population of female undergraduates residing in the hostels of the university of Sri Jayewardenepura. The participants were randomly selected using blind draw method from those who satisfied the inclusion criteria according to the ratio of students residing in each hostel using the hotel registries.

2.3. Data collection

2.3.1. Study instruments. Data entry sheet was used to record BMI, TBF%, other anthropometric parameters and some demographic data.

2.3.2. Body weight. Body weight was measured to the nearest 0.1 kg using the weighing scale wearing indoor light clothing and no shoes after emptying the urinary bladder. The accuracy of the weighing scale was cross-checked with two other weighing scales at random points while data collection.

2.3.3. Anthropometric measurements. All anthropometric measurements (height, mid-upper arm circumference, mid-thigh circumference, waist circumference and hip circumference) were taken wearing indoor light clothing and no shoes using a stretch-resistant measuring tape to the nearest 0·1 cm inside each individual's room maintaining privacy by one investigator. All anthropometric measurements were taken in accordance with WHO standards and guidelines of the National Health and Nutrition Examination Survey (NHANES) Anthropometry Procedures Manual [16]. The mean value of two measurements was used in the analysis.

Height was recorded using a fixed vertical backboard and an adjustable headpiece with no shoes and no any hair ornaments from the top of the head while stand up straight against the backboard with the heels together and toes apart approximately at a 60º angle while the back of the head, shoulder blades, buttocks, and heels were in contact with the backboard. The head was aligned in the Frankfort horizontal plane.

BMI was calculated as weight in kilograms divided by height squared in meters (kgm^{-2}).

The midpoint between the uppermost edge of the posterior border of the spine extending from the acromion process and the posterior surface of the right arm to the tip of the olecranon process, the bony part of the mid-elbow was marked while stand upright with the right arm bent 90º at the elbow, and the right palm facing up. The MUAC was measured while extending and relaxing the right arm.

MTC was measured around the midpoint between the proximal border of the patella and the muscle tendon in the inguinal crease just below the anterior superior iliac spine of the right thigh (The length was measured and the middle point was marked while sitting. The MTC was measured while standing).

After removing undergarments, WC was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest. (The participant was asked to relax and to have a normal breath and the lowest measure was taken, at the end of normal expiration.)

HC was taken at the widest diameter across the hips (most prominent part of the buttocks) while wearing light clothes.

2.3.4. Total body fat percentage (TBF%). The TBF% was estimated using a commercially available Karada Scan body composition monitor with scale®; Body fat analyzer (Bioelectrical Impedance Analysis) (HBF-362 model, OMRON) according to the instructions provided by the manufacturer. The individuals' personal data (age, gender, height) were entered into the body fat analyzer.

The participant was asked to step onto the measurement platform and to place her feet on the foot electrodes with her weight evenly distributed on the measurement platform, knees and back straight and looking straight ahead and to place both middle fingers along the dents of the grip electrodes and to hold the inner grip electrodes firmly with her thumb and index finger. Then she was asked to press her palms firmly on the grip electrodes and to hold the outer grip electrodes with her ring finger and small finger and to remain still and not to move until her weight measurement was completed. When the "WHOLE BODY" appeared on the display, the participant was asked to raise her arms and extend elbows straight (horizontally) at a 90° angle to her body, parallel to the measurement platform and to hold the display unit in front of her. Body composition measurement was started. When the measurement was completed, she was asked to step off the measurement platform to view the desired measurement results. The TBF % to the nearest 0.1% was recorded.

All measurements were taken during morning hours (0600–1200) and the subjects didn't have any vigorous activity during the preceding 12 hours of the measurement. Inter-observer/operator reliability and precision of impedance measurements in the same subjects under standard condition were monitored.

2.4. Ethical approval

Ethical approval for the study was obtained from the Ethics Review Committee, Faculty of Medical Sciences, University of Sri Jayewardenepura, Sri Lanka. Randomly selected female undergraduates who provided informed written consent were included in the study after providing written and verbal information about the nature of the study, what was expected from the participants, brief description of the research procedure and expected risks and benefits in their native language.

2.5. Statistical analysis

Data analysis was performed using a computer-based statistical package, SPSS for windows version 21.0. The descriptive statistical method was used to describe and summarize the sample characteristics. Correlations were tested by Pearson correlations and associations in subset analysis were performed by Pearson's Chi-square test. A p-value of < 0.05 was considered as significant probability level.

3. Results

3.1. Characteristics of the study sample

Three hundred seventy-three (373) female undergraduates who were residing in five female hostels situated inside the University premises of University of Sri Jayewardenepura participated to the study. Two incomplete data entry sheets, four participants who withdrew in the middle of the procedure were rejected which gave the sample of 367 for analysis.

The study population was in the age group of 20-26 years and the mean age was 22.59 ± 1.57 years. The means of BMI, TBF%, WC, HC, MUAC, MTC, WHR, WTR were respectively, 19.59 ± 3.56 kg/m^2, 28.23 ± 4.71%, 72.43 ± 8.92 cm, 89.50 ± 7.25 cm, 25.27 ± 3.69 cm, 43.64 ± 5.42 cm, 0.81 ± 0.07 and 1.67 ± 0.16.

3.2. Total Body fat percentage (TBF%)

The TBF% distribution among study population is given in Table 1. About 36.8% of females had high TBF% and very high TBF%.

Table 1. Total body fat percentage distribution in the study population

Total body fat %	Percentage
Low TBF% (5% - 19.9%)	4.1 %
Normal TBF% (20.0% - 29.9%)	59.1 %
High TBF% (30.0% - 34.9%)	28.9 %
Very high TBF% (35.0% - 50.0%)	7.9%

3.3. BMI

According to WHO BMI categorization for Caucasians, 41.4% were underweight (<18.5 kg/m^2), 51.0% were normal weight (18.5-24.9 kg/m^2), 6.5% were overweight (25.0-29.9 kg/m^2) and 1.1% were obese (≥30.0 kg/m^2). When BMI was categorized according to WHO BMI categorization for Asians, 41.4% were underweight (<18.5 kg/m^2), 43.1% were normal weight (18.5-22.9 kg/m^2), 7.9% were overweight (23.0-24.9 kg/m^2) and 7.6% were obese (≥25.0 kg/m^2).

3.4. Selected anthropometric parameters

According to the WHO cut-off points for anthropometric parameters, 17.4%, 1.1%, 9.0%, 56.4% and 57.8% of the study population had high-risk levels for WC, MTC, MUAC, WHR, and WTR respectively while 39.0% had under-nutrition level for MUAC (Table 2).

Table 2. Percentages at less risk and high-risk level for selected anthropometric parameters

Anthropometric parameters	%
Waist Circumference	
- at less risk (<80.0 cm)	82.6
- at high risk (>80.1 cm) [5]	17.4
Mid-Upper Arm Circumference	
- under-nutrition (< 24.0 cm)	39.0
- at less risk (24.0cm–30.5 cm)	52.0
- at high risk (>30.5 cm) [13]	9.0
Mid-Thigh Circumference	
- at less risk (≤59.9 cm)	98.9
- at high risk (>60 cm) [8]	1.1
Waist to Hip Ratio (WHR)	
- at less risk (<0.80)	43.6
- at high risk (>0.81) [28]	56.4
Waist to Thigh Ratio (WHR)	
- at low risk (<1.65)	42.2
- at high risk (≥1.65) [16, 18]	57.8

3.5. The association between BMI, other selected anthropometric parameters and TBF%

The association between the TBF% with BMI and anthropometric circumferences and ratios are shown in table 3, table 4 and table 5 respectively.

3.6. The correlation between BMI, other selected anthropometric parameters, and TBF%

The correlation between the TBF% with BMI and other anthropometric parameters are shown in table 6.

BMI	Normal TBF%	High TBF%	P value
BMI Classification for Caucasians			
Underweight	54.3 %	19.3 %	0.000
Normal weight	44.4 %	62.2 %	
Overweight	1.3 %	15.6 %	
Obese	0.0 %	2.9 %	
BMI Classification for Asians			
Underweight	54.3 %	19.3 %	0.000
Normal weight	43.1 %	43.0 %	
Overweight	1.3 %	19.3 %	
Obese	1.3 %	18.6 %	

Table 3. The association between TBF% and BMI

Anthropometric Circumferences	Normal TBF%	High TBF%	P value (χ^2 test)
Mid-Thigh Circumference			
Less risk	99.6 %	97.8 %	0.111
High risk	0.4 %	2.2 %	
Waist Circumference			
Less risk	94.4 %	62.2 %	0.000
High risk	5.6 %	37.8 %	
Mid-Upper Arm Circumference			
Under-nutrition	49.1 %	21.5 %	0.000
Less risk	49.6 %	56.3 %	
High risk	1.3 %	22.2 %	

Table 4. The association between TBF% and anthropometric circumferences

Anthropometric Ratios	Normal BF%	High BF%	P value
Waist to Hip Ratio			
Less risk	52.2 %	28.9 %	0.000
High risk	47.8 %	71.1 %	
Waist to Thigh Ratio			
Less risk	45.3 %	37.0 %	0.124
High risk	54.7 %	63.0 %	

Table 5. The association between TBF% and anthropometric ratios

Variable 1	Variable 2	Pearson correlation (r)	Sig (2 tailed)
WC	TBF %	0.613	0.000
HC		0.613	0.000
MAUC		0.568	0.000
MTC		0.492	0.000
WHR		0.288	0.000
WTR		0.163	0.000
BMI		0.630	0.000

Table 6: The correlation of TBF% with BMI and other selected anthropometric parameters

4. Discussion

Data in the literature on the prevalence of obesity, body fat percentage and other anthropometric parameters in the Sri Lankan population are restricted to few studies, especially among 20-30 years age group.

According to this study done in 367 non-pregnant females in the age group of 20-26 years, the prevalence of overweight and obesity was 15.5% and 41.4% was underweight. Approximately, 17.4% was centrally obese and 36.8% of the population had high

TBF% highlighting that more than half of the population is nutritionally abnormal and other anthropometric parameters also showed high-risk in some of the participants.

The mean waist circumference of our study population was 72.43 cm (SD ±8.92) and 17.4% was at risk level. Mean WHR was 0.81 (SD ±0.067) and 56.4% was at risk level. When WHR has considered more participants were at risk but when only waist circumference is taken into consideration the risk percentage decreased. The percentage in the risk category was highest in WHR and it reduced respectively with WTR, WC, MUAC, and MTC. Thus among anthropometric parameters ratios are better indicators for the prediction of risk.

More than one-third of this young age group was in the risk category for TBF%. This emphasizes that it is crucial to assess this issue and take relevant precautions to prevent future complications such as cardiovascular disorders.

The mean BMI of our study population was 19.59 kg/m^2 (SD ±3.56). The use of universal BMI cut-off points may not be appropriate for the comparison of obesity prevalence between ethnic groups [24]. So we used both WHO cut-off points for Caucasians and Asians. In our study population, 7.6% and 15.5% were overweight and obese according to WHO categorization for Caucasians and WHO categorization for Asians respectively. In WHO categorization for Asians, our study population had given approximately two times more overweight and obese when compared to WHO categorization for Caucasians.

Many kinds of research have been done to find out BMI differences in different ethnic groups and regions of the world. According to Gallagher et al the average female BMI (kg/m^2) for African Americans was 27.1 (SD ±4.3), for Asians it was 23.2 (SD ±3.9) and for Whites, it was 24.5 (SD ±4.5) [7]. According to Elaine C. Rush et al. mean BMI for females were (kg/m^2); European 24·8 (SD ±4·5), Maori 30·0 (SD ±5·9), Pacific 33·1 (SD ±6·3) and Asian Indian 26·3 (SD ±4·6) [24]. Mean BMI of our study sample was lesser than the average Asian values.

According to a research done by Elaine C. Rush et al in 2009, Asians have the highest body fat percentage with the mean of 42·7% (SD ±6·8) when compared to other ethnic groups namely; Europeans (34·0% (SD ±9·1)), Maori (39·5% (SD ±7·4)), Pacific (40·8% (SD ±6·8)). Abdominal fat was the lowest in Europeans and the highest in Asian Indians, while thigh fat was significantly higher in Europeans than the other ethnic groups. But in our study population, the mean body fat percentage was 28.23% (SD ±4.71) and it was lower when compared to all the above. This may be due to differences in the body fat measurement technique (Dual energy X-ray absorptiometry-DXA vs. BIA) and age group.

According to a cross-sectional study done by Wijewardene et al., 2005, in four provinces, namely the Western, North Central, Southern and Uva on 3355 females between the age of 30 and 65 years, the mean BMI and the prevalence of obesity was 23.3 (SD±4.5) kg/m^2 and 36.5% respectively.

According to another research done on 4532 adults aged ≥18 years randomly selected for a national level study on diabetes and cardiovascular disease, the mean BMI and WC were 22.3 (SD±0.2) kg/m^2 and 77.5 (SD±0.5) cm for females, respectively. According to the proposed WHO cut-off points for Asian ethnic group, the percentage of Sri Lankan adults in the overweight, obese and centrally obese categories were 25.2%, 9.2%, and 26.2%, respectively. Based on the cut-offs for Caucasians, these were 16.8%, 3.7% and 10.8% [12].

According to our cross-sectional study, a significant association was observed between BMI-TBF%, WC-TBF%, WHR-TBF% and MUAC-TBF% ($p<0.001$) but there was no significant association was observed between MTC-TBF% and WTR-TBF% ($p>0.05$). TBF% showed positive correlations with all the anthropometric measurements examined (BMI, WC, HC, MAUC, MTC, WHR and WTR). The strongest correlation was with BMI ($r=0.63$, $p<0.001$). Correlations of TBF% with WC, HC, MAUC, MTC, WHR and WTR were 0.613, 0.613, 0.568, 0.492, 0.288 and 0.163, (p<0001 for all) respectively. .

According to a cross-sectional study conducted in Sri Lanka, a significant strong positive correlation was observed between BMI-TBF%, in males ($r=0.75$, $p<0.01$) and in females ($r=0.82$, $p<0.01$) of all ages (TBF% had been estimated by BIA method). Correlations calculated for the three different age groups (young, middle age, elderly) separately, also showed the significance ($p<0.01$). Among 567 of females, 260 females were young with the mean age, BMI and TBF% of 25.9 (SD ±7.2) years, 21.8 (SD ±4.3) kg/m^2 and 28.0 (SD ±6.0) % respectively [23]. Our study further proved this correlation.

According to a cross-sectional, descriptive study among 106 previously healthy, premenopausal women volunteers in southern province Sri Lanka, aged between 30 and 54 years Total Fat Mass (TFM) and Visceral Fat Mass (VFM) determined by DXA, showed positive correlations with all the anthropometric measurements examined (BMI, WC, HC, height adjusted WC, WHR and skin-fold thickness over triceps, infrascapular, and iliac regions). The strongest correlation was with BMI ($r=0.89$ and 0.77 for TFM and VFM respectively, $p<0.001$). Correlations of TFM with WC and HC were 0.72 and 0.87 (p<0001 for all) respectively. WHR showed a poor correlation with TFM ($r=18$, $p=0.09$) [25].

According to a cross-sectional study done in a sample of 488 African American women and 686 white women aged 18 to 69 years, all anthropometric measures used (HC, WC, WHR, and BMI) were highly correlated with the percentage of fat and fat mass measured by DXA [2].

Another similar research had been conducted among 12,044 female UK adults aged 18-99 (99% ≤70) years, with a mean BMI of 25.7 (SD ±5.1) kg/m^2. The relationship between BMI and BF% (measured using BIA) had been found to be curvilinear rather than linear, with a weaker association with lower BMI and had been affected by age [19].

A cross-sectional study among 780 healthy women from Ahvaz, Iran had been conducted to investigate common anthropometric indices in their relationship with body fat content measured by BIA. According to their findings, the strongest correlations had been seen between BF% and BMI, Body adiposity index (BAI) and waist to height ratio (WHtR) ($r > 7.9$ and $p < 0.001$) and they could predict BF% more accurately with relatively good power [6].

According to our study, a considerable number of university students were overweight or obese and higher proportion of hostel students had high TBF%. Since this nutritional abnormality can lead to many disease conditions; dietary interventions, improving awareness and promoting health education on nutrition and regular exercise may be necessary at an early stage for this group of females as they are the future of the country.

5. Conclusion

According to the findings of our study, the prevalence of overweight or obesity and central obesity among the female undergraduates residing in hostels of the University of Sri Jayewardenepura were 15.5% and 17.4% respectively. Approximately one-third of the study population was with the high body fat percentage. A significant association was observed between TBF% with BMI, waist circumference, waist to hip ratio and mid-upper arm circumference ($p<0.001$). A significant correlation was observed between TBF% with BMI, waist circumference, hip circumference, mid-upper arm circumference, mid-thigh circumference, waist to hip ratio and waist to thigh ratio ($p<0.001$). Our findings prove BMI and some other anthropometric measurements can be utilized as reliable tools for predicting BF%/obesity, in a population.

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