International Journal of Community Medicine and Public Health
*Trivedi BJ et al. Int J Community Med Public Health. 2022 Sep;9(9):3522-3529*
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20222218

**Original Research Article**

# Validity of anthropometric measurements for estimation of obesity among geriatric residing in Bhavnagar city Gujarat, Western India

**Bansi Janak Trivedi*, Atul V. Trivedi**

Department of Community Medicine, Government Medical College Bhavnagar, Gujarat, India

**Received:** 16 July 2022
**Revised:** 07 August 2022
**Accepted:** 08 August 2022

***Correspondence:**
Dr. Bansi Janak Trivedi,
E-mail: bansijanaktrivedi@gmail.com



## ABSTRACT

**Background:** Validity of anthropometric measurements has not been adequately evaluated in diverse geriatric population. We determine diagnostic accuracy of body mass index using different anthropometric in assessing the obesity in geriatrics.
**Methods:** This community based cross sectional study was carried out in Bhavnagar city among geriatric people (≥60) residing in 13 different wards of Bhavnagar city during September 2019 to September 2020. Anthropometric data (height, weight, mid upper arm circumference, waist circumference, hip circumference, and skinfold thickness) were measured. Prevalence of obesity measure by different method was compared using kappa coefficient, sensitivity, and specificity.
**Results:** Fair agreement found between waist circumference and BMI for obesity. High sensitivity and low specificity found for BMI measurements at the cut off 30 kg/m$^2$ in comparison of other anthropometric measurements.
**Conclusions:** Body mass index can be used for screening of obesity among geriatrics. however, body mass index should not be used to replace the other anthropometric measurements.

**Keywords:** Anthropometric measurements, Geriatric, Obesity, Validity

## INTRODUCTION

As average life expectancy rises due to continued advancements in living conditions and medical technology, the geriatric population is continuously increasing globally.[1] In India, geriatrics constitute 8.6% of total population.[2] Malnutrition is an important problem in the geriatric age group as nutrition status affects the process of aging and health in geriatrics.[3]

Various changes in body composition occur in aging process which include height, weight and muscular mass loss and an increase in fat mass, including adipose tissue redistribution, with fat accumulation in the trunk and viscera.[4] However, menopause is primarily responsible for changes in fat-free mass, including a postmenopausal reduction in both soft lean tissue mass and bone mass.[5]

Anthropometric measurements are important indicators of nutritional status of an individual. It is non-invasive, inexpensive, and easily applied.[6] One of the objectives for the use of anthropometric measures as described in the World Health Organization (WHO) technical report is to identify individuals and populations at health risk.[7] Body mass index (BMI) and waist circumference (WC) were suggested and widely used to define general obesity and abdominal obesity, respectively.[8-10] Body mass index is a simple, non-invasive, easy, and most commonly method for categorizing individual as underweight, overweight, normal and obese. However, it does not directly measure body fat and fat distribution. Upper arm circumference and thigh circumference are both useful in estimating muscle mass, which could serve as an indicator to detect the lack of nutrition in old age. Skin fold thickness measurement is independent of height and correlates with

body fat. It is less affected by hydration status than weight.

Obesity is defined as an abnormal growth of the adipose tissue because of an enlargement of fat cell (hypertrophic obesity) or an increase in number of fat cells (hyperplasic obesity) or a combination of both.[11] Obesity is major public health issue and associate with many non-communicable diseases. Innovative public health strategies are therefore extremely important for the medical treatment and prevention of obesity.[12,13]

Being overweight or obese increased risk of non-communicable disease such as diabetes and hypertension. This is the first study on the anthropometric measurements among geriatric residing in Bhavnagar city. This study aimed to validate anthropometric measurements by household survey by measuring height, weight, waist circumference, skinfold thickness and mid upper arm circumference.

## METHODS

### *Study design and setting*

We conducted community-based cross-sectional study to determine validity of anthropometric measurement among the geriatrics residing in thirteen wards of Bhavnagar city (Gujarat state, western part of India) having a total population of 0.6 million from September 2019 to September 2020.[14] Total geriatric population in Bhavnagar city is forty-eight thousand (8% of the total population). The literacy rate of the geriatric population residing in urban is 66.[15]

### *Study population*

We included geriatric population (aged ≥60 years) residing in thirteen wards of Bhavnagar city.

Sample size of 260 was calculated using Epi Info software version 7.0 (Centre for Disease Control and Prevention CDC, Atlanta, USA), considering the prevalence (p) of obesity among geriatric residing in Mexico as 62.3%, confidence level as 95%, and allowable error (L) as 10% and non-responder rate as 5%.[16,17] We include subjects were aged 60 years and above (as per nation policy on older person), identified by simple random sampling from an electoral list, who were ambulatory, and who consented to participate in study.[18]

### *Recruitment and Sampling*

Bhavnagar city is comprised of thirteen wards, which are under the jurisdiction of municipal corporation. The electoral roll was identified as base of the study population. Population aged ≥60 years was ascertained from an electoral database from each ward and 20 subjects were identified from each ward by random number table in Open Epi software, thus 260 subjects from 13 wards were selected for the current study. Identified study subjects were approached with help of local health functionaries. If identified study subject did not fulfil the inclusion criteria, refused to give consent, were not present at the time of visit or died, then the next participant was identified with random number.

### *Anthropometric measurements*

All anthropometric measurements were made as per the guidelines of the WHO. All measurements were taken by a principal investigator. BMI, Mid upper arm circumference (MUAC), waist circumference, hip circumference and skin fold thickness measurement use to assess nutrition status.

### *Weight measurement*

Weight was measured using calibrated electronic weighing scale. The study participant had to stand straight with barefoot on the weighing scale. Before each weight measurement it was made sure that scale was set to zero reading to avoid errors.

### *Height measurement*

Height was measured using measuring tape. The measurement of height required a noncompressible flat and even surface which the subject stood. The participant was made to stand barefoot with heels and toes together, legs straight, shoulders relaxed and to look straight ahead at the horizontal plane. To measure the height, the subjects stood upright at the wall without shoes, cap or hair ornaments, and the height was marked at wall.

BMI = weight (kg)/height ($m^2$) as per guidelines of the World Health Organization, under-nutrition was defined as a body mass index (BMI) of less than 18.5 $kg/m^2$, overweight was defined as BMI 25.0-29.9 $kg/m^2$, and obesity as BMI≥30.0 $kg/m^2$.

### *MUAC procedure*

To obtain MUAC a flexible, inelastic measuring tape was used, and the measure was taken in the person's non-dominant arm, just at the mid-point between the acromion and the olecranon, in sitting or standing posture. MUAC indicate both protein and calories reserve. The value obtained was expressed in centimeters. Cut off of MUAC was taken from previous study. Underweight =25.7 cm in male and 24.3 cm in female. Overweight and obesity =28.5 cm in male and 27.5 cm in Female.[19]

### *Waist circumference*

According to the WHO stepwise approach to surveillance (WHO STEPS) protocol for measurement of waist circumference be made at the approximate midpoint between the lower margin of the last palpable rib and the

top of the iliac crest.[20] According to world health organization, the standard cut-off values for abdominal obesity and overweight in adults are WC≥102 cm and ≥94 cm in men, and ≥88 cm and ≥80 cm in women.[20]

### *Hip circumference*

According to WHO protocol Hip circumference measurement was taken around the widest portion of the buttocks.[20] For both measurements, the subjects were stand with feet close together, arms at the side and body weight evenly distributed, and wear little clothing. The study subject was relaxed, and the measurements should be taken at the end of a normal expiration.[20]

### *Skinfold thickness measurement*

Skinfold thickness measurement was taken with Harpenden calliper. Dial graduation of this calliper is 0.20 mm, measuring range 0mm to 80 mm, measuring pressure is 10 gm/mm$^2$ and accuracy is 99% and repeatability is 0.20 mm.[21]

*Triceps:* The measurement of the triceps skinfold was taken at the midpoint of the upper arm. With the elbow bent to 90% the midpoint is located half-way between the acromion process of the scapula and the olecranon process of the ulna. This point was marked. The arm was then extended and allowed to hang loosely by the side. Using the thumb and forefinger, the skinfold is grasped just above the midarm point. The callipers are applied at right angles to the skin at the midarm point and 1 cm in from the surface. The fold should remain held whilst the measurement is taken. Multiple skin-fold sites can be assessed and usually include both limb and trunk sites.

*Biceps:* A vertical pinch mid-biceps at the same level the triceps skinfold was taken.

*Subscapular:* A diagonal fold just below the inferior angle of the scapula.

*Supra-iliac or flank:* A diagonal fold just above the front forward protrusion of the hip bone (just above the iliac crest at the mid axillary line). The sum of measurement should be less than 40 mm in boys and 50 mm in girls.[22]

### *Study variables*

The primary outcome variable was the validity of anthropometric measurements.

### *Ethical considerations*

We have obtained Ethics Committee approval from the IRB (Institutional Review Board), of Government Medical College Bhavnagar for conducting this study. Informed written consent was obtained from study subjects after explaining the nature and purpose of the study in vernacular (Gujarati) language. They were also informed about the potential benefit and expected duration of the study. All information collected during the study was kept confidential. All the participants, who were identified as malnourish as per anthropometric measurements that counselled for adequate intake of food and were given appropriate knowledge regarding nutrition.

### *Statistical analysis*

Simple proportions were calculated for the categorical variables and mean (standard deviation SD) was calculated for continuous variables. Validity assessed by sensitivity and specificity analysis. Contingency tables were used to determine sensitivity and specificity of body mass index, in comparison to the waist circumference, skinfold thickness and mid arm circumference. Agreement of different anthropometric measurement determine by kappa coefficient and results categorized according to the classification of Landis and Koch. kappa coefficients were classified as perfect (κ=0.81-1.00), substantial (κ=0.61-0.80), moderate (κ=0.41-0.60), fair (κ=0.21-0.40), slight (κ=0.01-0.20) and no or poor agreement (κ=0). The kappa coefficient, sensitivity, and specificity were used for comparison of the prevalence of obesity. Receiver operating characteristics (ROC) analysis was done and area under ROC curve (AUC) was assessed. The AUC value can be between 0 and 1, with 0.5 (diagonal line) demonstrating that the anthropometric index has no predictive performance and 1 indicating ideal performance.[23]

## RESULTS

In current study total 260 participants included with 100% response rate (all participants willing to participate in the study). Study found majority of female participants. Mean age of male (n=94) was 67.9±7.5 years and mean age of female (n=166) was 65.72±6.73. Most of (78.08%) study subjects belong to age group between 60 to70 year. Majority (38.08%) of study subjects were educate up to primary level and almost all (95.76%) respondents were Hindu by religion. Majority (80.77%) of study subjects were living with their family. About three fifth study subjects belong to nuclear type of family (Table 1).

Mean±SD weight of study male and female was 64.82±13.75 and 57.96±11.90 respectively. Male were taller than female.

Waist hip ratio-based screening of BMI to estimate obesity, kappa agreement among female was slight (κ=0.131, p=0.087) and among males was fair (κ=0.287, p=0.05) found. Using waist circumference at WC≥102 cm in male and ≥88 cm in women for obesity sensitivity and specificity was 87.5% and 42.85% for male and 88.74% and 26.66% for female respectively.

**Table 1: Socio-demographic variable of geriatrics residing in Bhavnagar city (n=260).**

| Socio demographic factors | Groups | Number | Percentage |
|---|---|---|---|
| **Gender** | Male | 94 | 36.16 |
| | Female | 166 | 63.84 |
| **Age (years)** | 60-70 | 203 | 78.08 |
| | 71-80 | 47 | 18.08 |
| | 81-90 | 7 | 2.69 |
| | 91-100 | 3 | 1.15 |
| **Education** | Illiterate | 65 | 25 |
| | Just literate | 45 | 17.31 |
| | Primary | 99 | 38.08 |
| | Secondary | 48 | 18.46 |
| | Graduate | 2 | 0.77 |
| | Post graduate | 1 | 0.38 |
| **Marital status** | Married | 244 | 93.85 |
| | Unmarried | 0 | 0 |
| | Widow/ widower | 16 | 6.15 |
| **Religion** | Hindu | 249 | 95.76 |
| | Muslim | 11 | 4.24 |
| **Caste** | General | 44 | 16.92 |
| | OBC | 197 | 75.77 |
| | ST | 19 | 7.31 |
| **Living arrangement** | Alone | 15 | 5.77 |
| | With spouse | 35 | 13.46 |
| | With family | 210 | 80.77 |
| **Type of family** | Single | 15 | 5.77 |
| | Nuclear | 148 | 56.92 |
| | Joint | 97 | 37.31 |
| **Occupation** | Home maker | 168 | 64.62 |
| | Retired | 86 | 33.07 |
| | Laborer | 6 | 2.31 |
| **Socio economic status** | Class I | 14 | 5.38 |
| | Class II | 18 | 6.93 |
| | Class III | 66 | 25.38 |
| | Class IV | 97 | 37.31 |
| | Class V | 65 | 25 |

**Table 2: Gender wise description of anthropometric measurement of study subjects (n=260).**

| Anthropometric measurement | Male (n=94) | | Female (n=166) | |
|---|---|---|---|---|
| | Mean±SD | Median | Mean±SD | Median |
| **Age (years)** | 67.90±7.5 | 66 | 65.72±6.73 | 65 |
| **Height** | 158.28±8.17 | 160 | 155.45±7.76 | 150 |
| **Weight** | 64.82±13.75 | 70 | 57.96±11.90 | 58 |
| **BMI** | 25.69±5.40 | 24.82 | 25.42±3.38 | 25 |
| **MUAC** | 25.44±3.51 | 25 | 23.96±4.44 | 22.99 |
| **Waist circumference** | 91.51±11.57 | 91 | 90.87±9.60 | 91 |
| **Hip circumference** | 94.90±9.7 | 96 | 100.10±11.70 | 98 |
| **Waist/hip ratio** | 0.96±0.047 | 0.95 | 0.90±0.058 | 0.91 |
| **Biceps** | 5.31±2.97 | 4.6 | 5.93±3.55 | 4.6 |
| **Triceps** | 8.03±3.45 | 8.6 | 7.74±3.96 | 6.6 |
| **Subscapular** | 8.89±2.79 | 9.1 | 8.70±8.6 | 8.6 |
| **Suprailiac** | 8.94±3.46 | 8.6 | 8.33±3 | 8.2 |
| **Total skinfold thickness** | 31.25±8.17 | 32 | 30.67±9.92 | 29.20 |

In present study 7.5% of normal weight (BMI) female and 10% male had higher waist circumference. This indicates that some non-obese subjects may already have a central fat distribution with a higher risk of non-communicable disease than when BMI cut-off values are used alone.

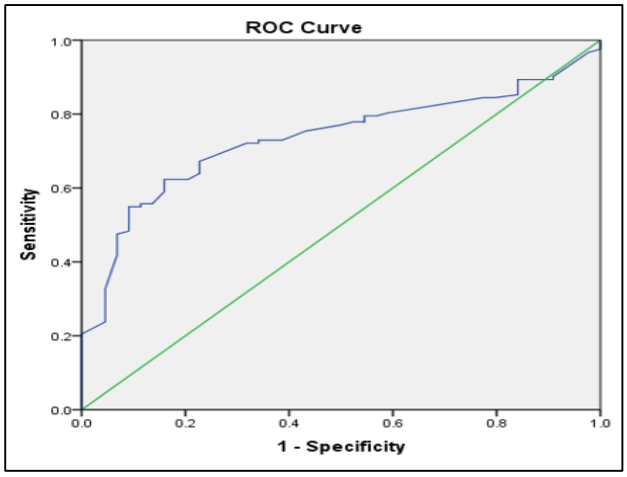


**Figure 1: ROC curve showing ability of BMI in detecting obesity in comparison of waist circumference in females.**

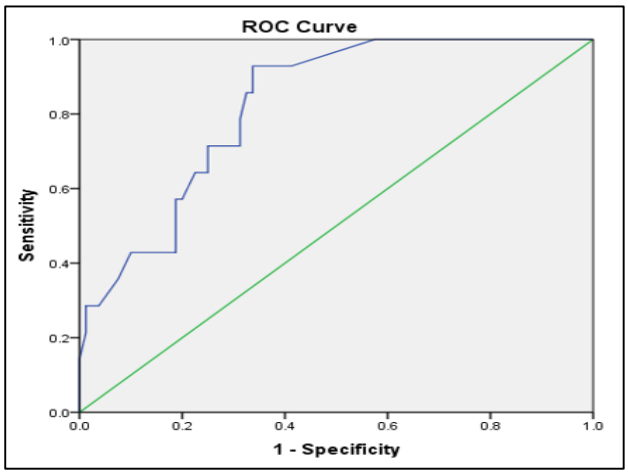


**Figure 2: ROC curve showing ability of BMI in detecting obesity in comparison of waist circumference in males.**

According to present study Skinfold thickness-based screening of BMI to estimate obesity had slight (κ=0.147, p=0.03) and fair (κ=0.154, p=0.104) agreement found in female and male with sensitivity and specificity was 84.88% and 37.5% in male while 88.60% and 37.50% in female at 40 mm and 50 mm cut off point respectively.

MUAC based screening of BMI to estimate obesity, sensitivity and specificity was found to be 91.86% and 74.41% in female and 89.47% and 44.44% in male. Mid upper arm circumference-based screening of BMI to estimate obesity at cut off point 28.50 and 27.50 in male (κ=0.354, p=0.01) and in female (κ=0.21, p=0.01) fair agreements found.

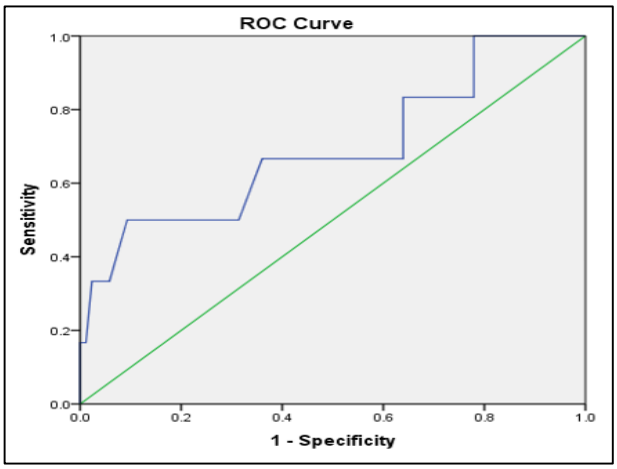


**Figure 3: ROC curve showing ability of BMI in detecting obesity in comparison of skinfold thickness in males.**

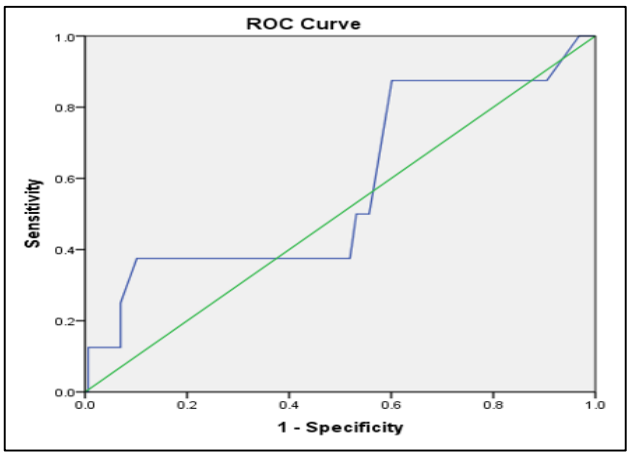


**Figure 4: ROC curve showing ability of BMI in detecting obesity in comparison of skinfold thickness in females.**

ROC curves were made to show the ability of Body mass index in detecting obesity. The ROC curves for men and women separately are shown in Figures 1 to 4. When the cut-off was >30 kg/m$^2$, the area under ROC curve (AUC) was 0.735 (95% CI 0.65-0.81) for detecting obesity in women while in male value was 0.82 (95% CI 0.73-0.92). Whereas in comparison with skinfold thickness AUC was 0.69 (95% CI 0.44 0.93) in male while in female AUC was 0.58 (95% CI 0.36-0.78) found.

## DISCUSSION

This community based cross sectional study attempted to determine validity of anthropometric measurement of detecting obesity among geriatric population residing in Bhavnagar city. Study found high sensitivity (the proportions of obese persons according to other

anthropometric measurements, who are classified as obese according to their body mass index) and low specificity of body mass index for detection of obesity among geriatric residing in Bhavnagar city. By applying kappa statistics slight and fair agreement found between body mass index and waist circumference among male and female for detecting obesity. Slight and fair agreement found between BMI and skinfold thickness for detecting obesity among male and female respectively while fair agreement found between BMI and MUAC for detecting obesity.

Body mass index can't be used as diagnostic purpose because of various reason first, the loss of height with age due to age-related osteoporosis and degenerative disc changes, second, the inconvenience of measuring height in those who may not be able to walk and third the inconvenience of measuring height in stand erect with their eyes at right angles to the ground and finally as people become aged, their fat-to-lean ratio increase.[24]

Present study found high sensitivity (87.5% and 88.74%) and low specificity (42.85% and 26.66%) of BMI in male and female respectively in comparison of waist circumference. Opposite result found by study that showed low sensitivity and moderately high specificity of BMI.[25] According to one systemic review, area under curve (AUROC) analyses indicate that waist to height ratio may be a more useful global clinical screening tool than waist circumference.[26] Another systemic review found high specificity of BMI.[27] Result might be due to body mass index measurements does not differentiate fat mass and muscle mass, so it is not an ideal measurement to detect obesity. It can be use as screening purpose. While another study indicate that BMI is a more sensitive indicator of hypertension in men and waist height ratio and waist circumference are better indicators of diabetes and dyslipidemia. A study found waist circumference is better indicator for cardio vascular risk factor than body mass inex.[10] Another study conducted among Indonesian adults found that low sensitivity in comparison of specificity of BMI for detection of obesity with percentage of body fat as reference in both males and females.[23] Result of their study found opposite result, that BMI can be use as diagnostic purpose. Similar result found by study conducted among Scottish adult reported that estimates of obesity prevalence (BMI>30), based on self-reported height and weight have high sensitivity (83%) and specificity (96%) for men and 89% and 97% for women.[28] Finding of National Health and Nutrition Examination Survey 2001-2006 reported that in comparison of measure BMI sensitivity of self-reported BMI for detection of overweight and obese was 91.4% and 83.3% respectively.[29] Another study found similar result that waist circumference is better indicator for non-communicable disease than BMI.[30]

Current study found high sensitivity and low specificity of BMI in detection of obesity in comparison of mid upper arm circumference. Similar result found by study conducted in Delhi, they have taken as BMI for gold standard and MUAC for screening of detection of overweight.[19] Study conducted in Spain among patients reported high specificity (94.5%) of body mass index in comparison with sensitivity (67.7%).[31] Similar result also found in study conducted in Bangladesh among adult population.[32] It may be because of BMI cannot distinguish among fat mass, lean mass and type of adiposity.

Current study found fair agreement for detecting obesity between BMI and MUAC. While another study conducted in Italy among geriatric in nursing home, reported that agreement was "excellent" between classification of nutrition (low, medium and high risk) status and that obtained using the BMI calculated both by the estimated height and MUAC, with higher values of kappa when the BMI was calculated through the estimated height compared with that obtained using the BMI estimated from MUAC.[33]

Study conducted in Brazil among hospitalized geriatric found that there was good agreement between BMI<22 (kappa=0.44) and mini nutrition assessment for nutrition risk. They found that specificity of calf circumference and arm circumference was 86.1% and 94.4% respectively.[34] One systemic review conclude that bioelectrical impedance, handheld dynamometry and gait speed or a short physical performance battery are the most valid, reliable, and feasible too for muscle mass, strength and performance in older.[35] Study conducted in Sao Paulo among adolescent adult and elderly reported that the agreement between measured and self-reported weight, height and BMI was good and Sensitivity and specificity was 91% and 83% respectively for overweight.[36]

A limitation in the use of skinfolds is that it is only useful for assessment of subcutaneous fat and cannot accurately distinguish between abdominal visceral adipose tissue and saturated adipose tissue. Data on potential confounders such as smoking or other addiction and other lifestyles were not collected, which represents limitation of present study.

## CONCLUSION

High sensitivity and low specificity of BMI suggest that it can be use as screening of obesity. There were slight and fair agreement found between body mass index with other anthropometric measurements. As study conducted in community, we can generalize our result to other geriatric residing in urban domicile.

### *Recommendations*

We reaccommodate BMI can be use as screening of obesity due to high sensitivity and low specificity in geriatric population while MUAC, waist hip ratio and skinfold thickness use as diagnostic purpose. Further study should be carried out to find out better

anthropometric measurement for early detection of non-communicable disease.

*Funding: No funding sources*
*Conflict of interest: None declared*
*Ethical approval: The study was approved by the Institutional Ethics Committee*

## REFERENCES

1. Baek MH, Heo YR. Evaluation of the efficacy of nutritional screening tools to predict malnutrition in the elderly at a geriatric care hospital. Nutr Res Pract. 2015;9(6):637.
2. Government of India. Sample Registration System Statistical Report 2012. Report No. 1 of 2013. New Delhi: Office of the Registrar General and Census Commissioner India, Ministry of Home Affairs, 2013. Available from: https://censusindia.gov.in/nada/index.php/catalog/34788. Accessed on 18 April 2021.
3. Amarya S, Singh K, Sabharwal M. Changes during aging and their association with malnutrition. J Clin Gerontol Geriatr. 2015;6(3):78-84.
4. Kuczmarski RJ. Need for body composition information in elderly subjects. Am J Clin Nutr. 1989;50(5 Suppl):1150-235.
5. Wang Q, Hassager C, Ravn P, Wang S, Christiansen C. Total and regional body-composition changes in early postmenopausal women: age-related or menopause-related? Am J Clin Nutr. 1994;60(6):843-8.
6. Setiati S, Istanti R, Andayani R, Kuswardhani RA, Aryana IG, Putu ID, et al. Cut-off of anthropometry measurement and nutritional status among elderly outpatient in Indonesia: multi-centre study. Acta Med Indones. 2010;42(4):7.
7. WHO Expert Committee on Physical Status: the Use and Interpretation of Anthropometry ( **:1993 (Switzerland ,Geneva** and World Health Organization. ((**1995the use of :Physical status . report of a ,and interpretation of anthropometry World Health .WHO expert committee .Organization**Available from: https://apps.who.int/iris/handle/10665/37003. Accessed on 30 June 2022.
8. Chen CM. Overview of obesity in Mainland China. Obes Rev Off J Int Assoc Study Obes. 2008;9(Suppl 1):14-21.
9. Choo V. WHO reassesses appropriate body-mass index for Asian populations. Lancet. 2002;360(9328):235.
10. Zeng Q, He Y, Dong S, Zhao X, Chen Z, Song Z, et al. Optimal cut-off values of BMI, waist circumference and waist:height ratio for defining obesity in Chinese adults. Br J Nutr. 2014;112(10):1735-1744.
11. Häger A. Adipose tissue cellularity in childhood in relation to the development of obesity. Br Med Bull. 1981;37(3):287-90.
12. Wadden TA, Brownell KD, Foster GD. Obesity: responding to the global epidemic. J Consult Clin Psychol. 2002;70(3):510-25.
13. Swinburn B, Egger G. The runaway weight gain train: too many accelerators, not enough brakes. BMJ. 2004;329(7468):736-9.
14. Registrar General of India. Ministry of Home Affairs. Government of India., 2011. Census of India 2011 - District Census Handbook Bhavnagar: Primary Census Abstract. Government of India, New Delhi. Available at: https://censusindia.gov.in/census.website/. Accessed on 18 April 2021.
15. Population Census 2011, SRS Report 2013- Google Search. Available from: https://www.google.com/search?q=Population+Census+2011%2C+SRS+Report+2013&oq=Population+Census+2011%2C+SRS+Report+2013&aqs=chrome..69i57.1359j0j7&sourceid=chrome&ie=UTF-8 Accessed on 15 August 2021.
16. Epi Info 2000: a database, and statistics program for public health professionals using Windows® 95, 98, NT, and 2000 computers. Available from: https://stacks.cdc.gov/view/cdc/23208. Accessed on 3 July 2021.
17. Sánchez-García S, García-Peña C, Duque-López MX, Juárez-Cedillo T, Cortés-Núñez AR, Reyes-Beaman S. Anthropometric measures and nutritional status in a healthy elderly population. BMC Public Health. 2007;7:2.
18. Ministry of social justice and empowerment. 2018. Social Justice. Available from: HYPERLINK"http://socialjustice.nic.in/"http://socialjustice.nic.in/. Accessed on 3 July 2021.
19. Goswami AK, Kalaivani M, Gupta SK, Nongkynrih B, Pandav CS. Usefulness of Mid-Upper Arm Circumference in Assessment of Nutritional Status of Elderly Persons in Urban India. Int J Med Public Health. 2018;8(1):4.
20. World Health Organization. Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation. World Health Organization; 2011. Available from: http://apps.who.int/iris/bitstream/handle/10665/44583/9789241501491_eng.pdf?sequence=1. Accessed on 3 July 2021.
21. Harpenden Skinfold Caliper- Baty International. Available from: http://www.harpenden-skinfold.com/. Accessed on 9 October 2020.
22. W.P.T. J. Medicine International. 1982;1(15):664.
23. Hastuti J. Anthropometry and body composition of Indonesian adults: an evaluation of body image, eating behaviours, and physical activity. 2013. https://www.semanticscholar.org/paper/Anthropometry-and-body-composition-of-Indonesian-%3A-Hastuti/bcf2bff3623051a9cdf53667c9a9bb50d5e52591. Accessed on 30 June 2022.
24. Wilson MMG, Morley JE. The diagnosis and management of protein energy undernutrition in older persons. Annu Rev Gerontol Geriatr. 1995;15(1):110-42.

25. Batsis JA, Mackenzie TA, Bartels SJ, Sahakyan KR, Somers VK, Lopez-Jimenez F. Diagnostic accuracy of body mass index to identify obesity in older adults: NHANES 1999-2004. Int J Obes. 2016;40(5):761-7.
26. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. Nutr Res Rev. 2010;23(2):247-69.
27. Okorodudu DO, Jumean MF, Montori VM, Romero-Corral A, Somers VK, Erwin PJ, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. Int J Obes 2005. 2010;34(5):791-9.
28. Bolton-Smith C, Woodward M, Tunstall-Pedoe H, Morrison C. Accuracy of the estimated prevalence of obesity from self reported height and weight in an adult Scottish population. J Epidemiol Community Health. 2000;54(2):143-8.
29. Stommel M, Schoenborn CA. Accuracy and usefulness of BMI measures based on self-reported weight and height: findings from the NHANES and NHIS 2001-2006. BMC Public Health. 2009;9:421.
30. Zhu S, Heymsfield SB, Toyoshima H, Wang Z, Pietrobelli A, Heshka S. Race-ethnicity-specific waist circumference cutoffs for identifying cardiovascular disease risk factors. Am J Clin Nutr.
31. Benítez Brito N, Suárez Llanos JP, Fuentes Ferrer M, Oliva García JG, Delgado Brito I, Pereyra-García Castro F, et al. Relationship between mid-upper arm circumference and body mass index in inpatients. PloS One. 2016;11(8):e0160480.
32. Sultana T, Karim MN, Ahmed T, Hossain MI. Assessment of under nutrition of Bangladeshi adults using anthropometry: can body mass index be replaced by mid-upper-arm-circumference? PloS One. 2015;10(4):e0121456.
33. Lorini C, Collini F, Castagnoli M, Di Bari M, Cavallini MC, Zaffarana N, et al. Using alternative or direct anthropometric measurements to assess risk for malnutrition in nursing homes. Nutrition. 2014;30(10):1171-6.
34. Leandro-Merhi VA, De Aquino J, De Camargo J. Agreement between body mass index, calf circumference, arm circumference, habitual energy intake and the MNA in hospitalized elderly. J Nutr Health Aging. 2012;16(2):128-32.
35. Mijnarends DM, Meijers JM, Halfens RJ, ter Borg S, Luiking YC, Verlaan S, et al. Validity and reliability of tools to measure muscle mass, strength, and physical performance in community-dwelling older people: a systematic review. J Am Med Dir Assoc. 2013;14(3):170-8.
36. Carvalho AM, Piovezan LG, Selem SS, de Castro A, Fisberg RM, Marchioni DM. Validation and calibration of self-reported weight and height from individuals in the city of São Paulo. Rev Brasil Epidemiol. 2014;17:735-46.

**Cite this article as:** Trivedi BJ, Trivedi AV. Validity of anthropometric measurements for estimation of obesity among geriatric residing in Bhavnagar city Gujarat, Western India. Int J Community Med Public Health 2022;9:3522-9.