Use Of Arm-span In Nutritional Assessment Of Elderly And Non-ambulatory Individuals Of Tribal Area Of Central India

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Background: The use of body mass index (BMI) in the elderly is limited by the measurement of height which is often unreliable. Arm-span approximates to height at maturity. As stature varies with age owing to spinal deformities like kyphosis, scoliosis or alterations in shape of vertebral discs, it is necessary to estimate true height, which can be done by establishing the relationship between arm-span and height as an effective surrogate measure to calculate BMI. Objective: To evaluate the use of arm-span as an alternative to standing height for calculation of BMI amongst older individuals. Study design: The study is an observational cross-sectional study carried out among 400 geriatric populations attending tertiary care teaching institute of tribal area of central India. BMI based on height (BMI-Ht) and BMI based on arm-span (BMI-As) were calculated and compared using regression equations. Result: The mean arm-span (164.99 in men and 153.65 in women) was seen to be more than the mean height (160.87 in men and 151.22 in women) in both genders. There was a strong correlation between height and arm-span in both the genders. The BMI-As (18.336 in men and 19.282 in women) was lower than the BMI-Ht (19.247 in men and 19.922 in women) in both the genders. As per BMI arm-span, the proportion of malnutrition was higher as compared to BMI-height. Conclusion: Arm-span could be a better alternative to height in calculating BMI and so the nutritional status, assessing pulmonary function, body surface area for drug dosage, renal clearance, and other purposes.

Keywords: Arm-span, BMI, BMI-Ht, BMI-As, Elderly

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INTRODUCTION
Obtaining accurate height estimate is important for calculating nutritional status using body mass index (BMI), basal energy expenditure, basal metabolic rate, pulmonary function, vital capacity, determining body surface area for drug dosages, nutrient requirements and renal clearance, creatinine height index, and other patient care issues. However, measuring height can be difficult for older individuals, who cannot stand, or who have various physical anomalies such as spasticity, contractures, fractures, amputations, scoliosis, kyphosis, paralysis, or osteoporosis. Standing height is also difficult to obtain in hospitalized and bedridden patients. Investigators have assessed the validity of arm-span, demi-span, half arm-span, knee-height, foot length as potential height estimates for use in these groups in lieu of standing height. Arm-span could be a better alternative instead of height in calculating BMI and so the nutritional status. Poor nutritional status is common among the elderly, and is associated with increased morbidity and mortality. Yet, until recently, there has been little research on the nutritional status of the elderly. Ageing is accompanied by changes in the body composition and stature. Functional decline is a reality for the elderly. Using height in calculating BMI could be inappropriate because of height loss with ageing due to compression of vertebrae, thinning of vertebral disc, kyphosis, genu valgum and varus deformities due to decreased muscle strength and osteoporosis; and so, inability to stand erect or steadily due to pain. It might be that by using height in calculating BMI, the prevalence of chronic energy deficiency in elderly is underestimated. Arm-span is relatively independent of ageing because the length of long bones i.e. those in arms and legs, do not change with age, unlike vertebral height and spine length; and is highly related to the height of an individual. Therefore, to predict the prevalence of undernutrition in elderly it may be more reliable to use arm-span. Most of the studies that looked at the association between arm-span and height have focused on Caucasian subjects. Some studies in India from Darjeeling (West Bengal) and Karnataka have reported on the relationship between arm-span and height. However, these were carried out in younger people. In India, there are limited published data in elderly persons to study this relationship.

AIMS AND OBJECTIVES:
1. To evaluate the use of arm span as a proxy for height in the assessment of nutritional status of elderly using body mass index (BMI).
2. To find the correlation between the arm span and standing height.

METHODOLOGY:
1. Study design: This is an observational cross-sectional study carried out in 400 men and women above 50 years attending tertiary care teaching institute of tribal area of central India.
2. Study setting: The out-patient and in-patient departments of Kunwar Tilak Singh (KTS) Government hospital and Medical College.
3. Study population: All men and women attending out-patient and in-patient departments of tertiary care teaching hospital (KTS), Gondia, Maharashtra, India, above 50 years of age.
   a) Inclusion criteria: All men and women above 50 years, non-ambulatory individuals, those with hemiparesis, paraparesis, patients with lower limb deformities like kyphoscoliosis, valgus and varus deformity of lower limbs, club foot, poliomyelitis.
   b) Exclusion criteria: All young and adult individuals less than 50 years, children, pregnant women, significant edema, metabolic diseases, cancers, muscular pathology, abnormally short individuals with congenital disorders like Turner’s syndrome, Achondroplasia; abnormally long individuals like Marfan’s syndrome, Klinefelter’s syndrome; individuals with upper limb deformities like cubitus valgus or varus, orthopedic conditions like joint stiffness, elbow joint...
contractures, any pathological condition of upper limb; individuals who refused to give written consent were excluded from the study.

4. **Sample size:** It was calculated using 95% confidence interval, as 400, amongst which 225 were men and 175 were women.

5. **Data collection:** Data was collected in the period of two months from 1st May to 30th June, 2018. In our study, a predesigned pretested questionnaire was used. Face to face interview was taken to ask the relevant information. In case, the participant is unable to answer, the accompanying person was interviewed.

6. **Sampling procedure:** We evaluated 10 patients every day from our tertiary care hospital in the period of two months.

7. **Materials used:** Digital weighing machine was used to calculate weight in kilograms. Stadiometer was used to calculate standing height in centimeters with the participant standing without footwear against the scale, upright, looking straight ahead at Frankfurt’s plane. Calibrated steel tape was used to calculate height in non-ambulatory individuals and the arm-span in all the study subjects in centimeters. Arm-span was measured with participants standing against the wall, looking straight eye level, with arms abducted at 90° at shoulder level and palms’ facing forwards; then the flexible steel tape was extended from the tip of the middle finger of one hand straight across the chest to the tip of the middle finger of the other hand.

8. **Data analysis:** Descriptive statistics like mean (SD) of weight, height, arm-span, and BMI were calculated by gender wise distribution. BMI based on height was calculated for both genders and defined as BMI-Ht=weight/height² (kg/m²). BMI based on arm span was calculated and defined as BMI-As=weight/armspan² (kg/m²). Confidentiality was strictly adhered to and identification number rather than names were used during the analysis. Comparison was done using regression equations. Correlation were tested between height and arm-span and the BMI-As and BMI-Ht using Pearson’s product moment correlation coefficient(r). Linear regression analysis was performed to estimate the change of height with one unit change of arm-span; as well as to correlate BMI-Ht and BMI-As. Using BMI, nutritional status of individuals was assessed and categorization was done as malnourished, normal, overweight and obese. An agreement was established between BMI-Ht and BMI-As. We established cut-off values for arm-span and tested its accuracy, as height has established standard cut-off values; but as arm-span shows significant difference with height and its cut-off values are not established to categorize the nutritional status with respect to BMI-As.

9. **Ethical consideration:**
The study is an observational cross-sectional study community-based study carried out in tribal area of central India. Prior approval of institutional ethics committee was taken. The study population included men and women above 50 years and non-ambulatory individuals attending tertiary care teaching institute of tribal area of central India. A total of 400 population by taking minimum 50% prevalence sample size was calculated. Written informed consent was taken from all the participants and they were informed about their voluntary participation. The study period was two months between 1st May 2018 to 30th September 2018. The study is focused on relationship between height and arm-span. The relationship is not affected by socio-economic and related factors.

**IMPLICATIONS:** The study will investigate the relationship between height and arm span in elderly and non-ambulatory elderly individuals. The feasibility of arm-span measurement in immobile elderly individuals will be studied as proxy measure to standing height. It will be helpful in assessing the nutritional status in elderly and non-ambulatory individuals.
**RESULTS:** A total of 400 elderly persons participated in the study, amongst which 225 (56.25%) were men and 175 (43.75%) were women. The mean and standard deviation of anthropometric variables of individuals by gender are presented in Table 1. The mean age of men and women was 61.26 (9.347) and 59.14 (8.733) years respectively. The mean height and arm-span amongst men were 160.87 (7.873) and 164.99 (9.233) respectively while the mean height and arm-span amongst women were 151.22 (7.134) and 153.65 (7.907) respectively. This shows that the mean arm-span was significantly more than the mean height in both the genders. Men had a higher mean arm-span and height as compared to women. Similarly, the mean BMI-Height was 19.247 (3.311) in men and 19.922 (3.726) in women; and the mean BMI-Arm-span was 18.336 (3.289) in men and 19.282 (3.640) in women. Statistically significant differences were observed between the body mass index (BMI) derived using height and arm-span amongst both genders. BMI derived using arm-span was lower than the BMI derived using height in both the genders.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Men (n=225)</th>
<th>Women (n=175)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age in yrs</td>
<td>61.26</td>
<td>9.347</td>
</tr>
<tr>
<td>WT (kg)</td>
<td>49.85</td>
<td>9.519</td>
</tr>
<tr>
<td>HT (cm)</td>
<td>160.87</td>
<td>7.873</td>
</tr>
<tr>
<td>Arm Span(cm)</td>
<td>164.99</td>
<td>9.233</td>
</tr>
<tr>
<td>BMI-ht (kg/m²)</td>
<td>19.247</td>
<td>3.311</td>
</tr>
<tr>
<td>BMI-as (kg/m²)</td>
<td>18.336</td>
<td>3.289</td>
</tr>
</tbody>
</table>

There was a strong correlation between arm-span and height when analyzed by gender (p<0.001). Regression analysis was done for men and women separately and variance (R-square) was calculated. R-square indicates the proportion of variability in height which can be explained by arm-span. It was seen that R-square was higher in men than in women. For every unit of increase of arm-span in men, there was 0.876 cm significant increase in height (p<0.001). In women, height increased significantly by 0.848 cm per 1 cm increase in arm-span (p<0.001) - Table 2.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Arm-span</th>
<th>Height</th>
<th>Difference(95%CI)</th>
<th>Pearson Correlation(r)</th>
<th>t value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length(cm)</td>
<td>164.99</td>
<td>160.87</td>
<td>4.12</td>
<td>0.876</td>
<td>13.861</td>
</tr>
<tr>
<td>BMI(kg/m²)</td>
<td>18.336</td>
<td>19.247</td>
<td>-0.911</td>
<td>0.955</td>
<td>13.848</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length(cm)</td>
<td>153.65</td>
<td>151.12</td>
<td>2.53</td>
<td>0.848</td>
<td>8.075</td>
</tr>
<tr>
<td>BMI(kg/m²)</td>
<td>19.282</td>
<td>19.922</td>
<td>-0.64</td>
<td>0.960</td>
<td>7.944</td>
</tr>
</tbody>
</table>

*p<0.001 for all variables.*
The present study has shown that there was strong correlation between arm-span and height among both men and women. \( r^2 \) for men was 0.768 and for women, \( r^2 \) was 0.719. A linear relationship is seen between the two variables: arm span-height and BMI-arm span – BMI-height.

**Graph 1. Showing linear relationship between height and arm span in men**

**Graph 2. Showing linear relationship between BMI-Ht and BMI-As in men**
Graph 3. Showing linear relationship between height and armspan in women

![Graph 3](image)

Graph 4. Showing linear relationship between BMI-Ht and BMI-As in women

![Graph 4](image)

Graph 1: The correlation(r) between arm-span and height among men was 0.876.
Graph 2: The correlation(r) between BMI-arm span and BMI-height among men was 0.955.
Graph 3: The correlation(r) between arm-span and height among women was 0.848.
Graph 4: The correlation(r) between BMI-arm span and BMI-height among women was 0.960.
The BMI derived using length of arm-span was significantly (p<0.001) lower than the BMI derived using height in both the genders. While the correlation between BMI-height and BMI-arm span was 0.955 and 0.960 amongst men and women respectively. The nutritional status of older adults as per the BMI calculated using both arm-span and height is presented in Table.3. The categorization of individuals according to nutritional status was done as: Malnourished, Normal, Overweight and Obese as per WHO standards. When categorized using BMI-arm span, the proportion of malnutrition was higher as compared to BMI-height. While the proportion of overweight and obese was higher when categorized using BMI-height as compared to BMI-arm span.

Table: 3. Nutritional Status of elderly as per BMI calculated using both height and arm-span

<table>
<thead>
<tr>
<th>Particulars</th>
<th>No.</th>
<th>Malnourished</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obese</th>
<th>Pearson c²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-As</td>
<td>225</td>
<td>58.2</td>
<td>37.8</td>
<td>4</td>
<td>0</td>
<td>299.443</td>
</tr>
<tr>
<td>BMI-Ht</td>
<td>225</td>
<td>48.2</td>
<td>46.8</td>
<td>4.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-As</td>
<td>175</td>
<td>44.8</td>
<td>47.7</td>
<td>7.5</td>
<td>0</td>
<td>274.682</td>
</tr>
<tr>
<td>BMI-Ht</td>
<td>175</td>
<td>41.4</td>
<td>50.6</td>
<td>7.5</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Pooled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI-As</td>
<td>400</td>
<td>52.4</td>
<td>42.1</td>
<td>5.5</td>
<td>0</td>
<td>572.993</td>
</tr>
<tr>
<td>BMI-Ht</td>
<td>400</td>
<td>45.2</td>
<td>48.5</td>
<td>5.8</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

The agreement between the BMI-arm span and BMI-height was established as presented in Table.4. The agreement between the BMI-arm span and BMI-height was high among the normal subjects than with other categories, with measure of agreement Kappa being 0.818 which is significant statistically (p<0.001).

Table: 4. Agreement between BMI-Arm span and BMI-Height by gender

<table>
<thead>
<tr>
<th>BMI-Arm span</th>
<th>BMI-Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Men</td>
<td></td>
</tr>
<tr>
<td>Malnourished</td>
<td>131</td>
</tr>
<tr>
<td>Normal</td>
<td>83</td>
</tr>
<tr>
<td>Overweight</td>
<td>08</td>
</tr>
<tr>
<td>Obese</td>
<td>00</td>
</tr>
<tr>
<td>Pooled</td>
<td>222</td>
</tr>
<tr>
<td>Women</td>
<td></td>
</tr>
<tr>
<td>Malnourished</td>
<td>78</td>
</tr>
<tr>
<td>Normal</td>
<td>83</td>
</tr>
<tr>
<td>Overweight</td>
<td>13</td>
</tr>
<tr>
<td>Obese</td>
<td>00</td>
</tr>
<tr>
<td>Pooled</td>
<td>174</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Malnourished</td>
<td>209</td>
</tr>
</tbody>
</table>
The cut-off values for BMI-height are already established to categorize the individuals according to their nutritional status; but as we have observed the differences in lengths of arm-span and height, more so in elderly when compared with other studies carried in younger population, we derived BMI-arm span cut-off values equivalent to BMI-height cut-off values using linear regression as presented in Table 5.

**Table 5. Derivation of BMI-Arm-span cut-off values equivalent to BMI-Height cut-off values**

<table>
<thead>
<tr>
<th>BMI-Height</th>
<th>BMI-Arm-span</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.5</td>
<td>BMI-As = 0.234 + 0.947 * (BMI-Ht) = 0.234 + 0.947 * 18.5 = 17.75</td>
</tr>
<tr>
<td>25</td>
<td>BMI-As = 0.234 + 0.947 * (BMI-Ht) = 0.234 + 0.947 * 25 = 23.909</td>
</tr>
<tr>
<td>30</td>
<td>BMI-As = 0.234 + 0.947 * (BMI-Ht) = 0.234 + 0.947 * 30 = 28.644</td>
</tr>
</tbody>
</table>

The cut-off values for BMI-Arm span thus obtained were 17.75 for malnourished, 23.909 for normal and 28.644 for overweight. The accuracy of these cut-off values was tested using ROC curves presented in Fig.1 to 3.

**Fig. 1. Estimation of area under curve (AUC) through ROC curve for BMI-As (17.75) equivalent to BMI-Ht(18.5)**

The area under curve (AUC) in Fig.1 is 91.8%, which means the accuracy is 91.8%.
Fig. 2. Estimation of area under curve (AUC) through ROC curve for BMI-As(23.909) equivalent to BMI-Ht(25)

The area under curve (AUC) in Fig. 2 is 82.6%, which means the accuracy is 82.6%.

Fig. 3. Estimation of area under curve (AUC) through ROC curve for BMI-As(28.644) equivalent to BMI-Ht(30)

The area under curve (AUC) in Fig. 3 is 75%, which means the accuracy is 75%.

DISCUSSION:
Kwok T et al. in 1991 studied the relationship between height and arm-span in 101 elderly men and women. A comparison of BMI by height and arm-span was made. The correlation between height and arm-span was 0.93. The mean difference between BMI-Ht and BMI-As was 1.79 (SD 1.11); so concluded that arm-spans is a reliable and practical estimate of height in the non-ambulant elderly. B Rabe et al., in a study “Body mass index of the elderly derived from height and from arm-span” undertook a study on
69 elderly (36 women and 33 men) aged 60-69 years in Indonesia. The inter-relationships of height and arm-span were examined. The correlation coefficient for the regression of the two measures were $r=0.83$ and $r=0.81$ ($p<0.001$) for women and men respectively. Substituting the arm-span term in the denominator to compose a Body Mass using Arm-span (BMA) Index, they observed for this population a 32% increase in estimates for Chronic Energy Deficiency (CED) for women and 24% increase in estimates of CED for men. Corresponding estimates for obesity rates declined by 45% and 81% respectively. de Lucia E et al\textsuperscript{9} in 2002, studied a total of 1706 Ethiopians i.e. 884 males and 822 females aged 18-50 years from four different ethnic groups. BMI using height and arm-span were calculated and compared. BMI-Ht (0.83-0.9) and BMI-As (0.89-0.97) were highly correlated in the ethnic groups. They concluded that arm-span can be used as a proxy for height to estimate BMI, but the two measures varies considerably with ethnicity and sex. Dr. N Arlappa et al\textsuperscript{10} in 2011-12 discussed that the conventional height is not a reliable anthropometric measurement for the assessment of nutritional status of older adults, where the BMI-height model overestimated the nutritional status of older adults compared to the BMI-arm span model. Therefore, arm span is the best alternative to height for calculation of body mass index (BMI) in older adults. A community-based cross sectional study was carried out during 2011-12 among 400 (Men: 180; Women: 220) urban geriatric population (age 60-years and over) of the town of Khammam in Telangana, India. Weight, height and arm-span were measured with standard procedures. Nutritional status of older adults was calculated by body mass index (BMI) classification using both height and arm-span. Height data were obtained for 141 wheelchair users by Froehlich-Grobe et al\textsuperscript{5}. Height estimates included asking for self-report and measuring recumbent length, knee height, and arm-span. Findings indicated that the four measures yielded significantly different height estimates and BMI values for both men and women. For both sexes, arm-span resulted in the longest estimate and measured recumbent length the shortest, with the reverse pattern for BMI values. The common variance estimates were outstanding for recumbent length (92%) and knee height (>83%) and very good for self-report (>75%), while the common variance for arm-span was poor (<42%). In a study “Relationship between height and arm-span of elderly persons in an urban colony of New Delhi” by Anil Kumar Goswami et al\textsuperscript{7}, a community based cross-sectional study was conducted on 711 elderly (298 men and 431 women). Arm-span and height of persons 60 years and above were measured. The mean arm-span (160+/-.11.3cm) of the participants was more than the mean height (152+/-.9.1cm). Men had higher mean arm-span and height as compared to women. There was a strong correlation between arm-span and height when analyzed by gender ($p<0.001$). The overall regression coefficient was 0.73 for men which indicate that for every unit of increase in arm-span, there was 0.73cm significant increase in height. In women, height increased significantly by 0.70cm per 1cm increase in arm-span. They concluded that there was strong association between arm-span and height among both men and women. V Hirani and J Mindell\textsuperscript{11} examined differences between measured height and demi-span equivalent height (DEH) among people aged≥65 and investigated the impact on body mass index (BMI) of using DEH. The height measurement was lower than the DEH from age group 70–74 years onwards in men and in each age group in women. The prevalence of underweight was lower when using measured height than when using DEH in women aged ≥65, particularly in those aged 80 years and over. The prevalence of overweight and obesity was higher using measured height than DEH in women aged ≥65. They confirmed in a large nationally representative sample that demi-span measurement may be a useful estimate of stature in people (particularly women) aged ≥65 for BMI calculations. In a study “Relationship between arm-span and height among elderly persons in a rural area of Ballabgarh, Haryana, India, by Jamir L et al\textsuperscript{12}, a total of 528 elderly persons (237 men and 291 women) enumerated in the three randomly selected villages. The mean arm-span (164.4+/-.11.1cm) of the elderly participants was higher than the mean height (156+/-.9.1cm). Males had a higher mean arm-span (173.6+/-.7.6cm) and height (163+/-.6.8cm) as
compared to females (arm-span 156.8+/−6.9cm; height 150.1+/−5.6cm). Arm-span was consistently more than height in all age groups with an average difference in mean arm-span and height of 8-9cm. Arm-span correlated well with height in all age groups; whereas for every 1cm increase in arm-span, there was 0.69cm increase in height, keeping gender constant. Hence, they concluded that arm-span is a good predictor of height among elderly persons. However, their study findings may be limited to rural settings. In a study “The relationships between height and arm-span, mid-upper arm and waist circumferences and sum of four skin folds in Ellisras rural children aged 8-18 years” by KD Moyenki and MM Sekhotha13, they undertook study at 22 schools randomly selected within Ellisras area, Limpopo Province, South Africa. The sample population comprised 1769 children (911 boys, 858 girls) aged 8-18 years. Mean height (137.6 to 162.2cm) was found to be higher than arm-span (125.7 to 157.4cm) throughout all age groups for Ellisras rural boys and girls with difference ranging from 4 to 11.5 cm. Height and arm-span showed a highly significant (p < 0.001) relationship with correlation coefficient ranging from 0.74 to 0.91 in both boys and girls throughout the age range. They concluded that arm-span was a significant predictor of height in all the age groups for both boys and girls. Melo et al14 compared the values obtained through methods directed to height and body weight estimates in relation to measurements taken from hospitalized adult. Study participants were 142 adults of both genders. Anthropometric measurements of body weight, height, knee height, arm length, span, demi-span, recumbent height, calf, arm and abdominal circumferences and subscapular skin fold thickness were taken. The estimated height by the formula that utilizes the variable knee height among men was the only measurement which did not represent significant differences. Other methodologies for estimating body weight and height presented significant differences, which suggest that new studies using other methodologies are necessary. Hickson and Frost15 found moderate correlation between direct height measurements and other methods for estimating height: half arm-span (r = 0.87; p < 0.01) and knee height (r = 0.89; p < 0.01). One of the most prominent physiological changes of the aging process is found in body composition, such as diminution in height16. The process, which is different in men and women, begins around the age of 40, with a height reduction of 2 to 3cm per decade increasing progressively with age17,18. Physiological changes and illness characteristics associated with aging are important factors among the possible causes of height reduction, including: flattening of the vertebras, reduction in intervertebral disc thickness, dorsal kyphosis, scoliosis, bowing of the legs, and flattening of the plantar arch18. However, when used alone, this index is deemed to have limited effectiveness as a good indicator of nutritional status in the elderly because it does not reflect body fat redistribution and excludes height reduction16,19. Reduction in height may lead to an overestimation of BMI, with consequent overestimation of overweight and underestimation of underweight. The possible impact of height on BMI indicates that there is a need to develop alternative ways of estimating height among elderly who were bedridden, confined to wheelchairs, and unable to stand for benchmarking20. Improving estimations of height allows for a more accurate definition of BMI. Several alternative methods for estimating height are mentioned in the literature, such as measurements of arm-span21,22, half arm-span23,24 and knee height25. The present study was aimed at assessing the relationship between height and arm span of elderly. Older people are becoming an increasingly important proportion of the population of developing countries, yet little information exists on their nutritional status26. The use of alternative measurements of stature such as arm span were easier to obtain in older people and may be more accurate than standing height measurement. Inaccurate height measurements can lead to discrepancies in BMI. Height may underestimate the prevalence of underweight and overestimate the prevalence of overweight11. Several studies have shown that height reduces with advancing age18,19 and height loss is even greater after 80 years. Arm length is less affected than the height by the ageing process, so it should be considered as an
alternative to stature when assessing the nutritional status of elderly. In the present study, the mean height and arm span amongst men were 160.87(7.873) and 164.99(9.233) respectively while the mean height and arm span amongst women were 151.22(7.134) and 153.65(7.907) respectively. This shows that the mean arm span was significantly more than the mean height in both the genders. Men had a higher mean arm span and height as compared to women. Similarly, the mean BMI-Height was 19.247(3.311) in men and 19.922(3.726) in women; and the mean BMI-Arm span was 18.336(3.289) in men and 19.282(3.640) in women. Statistically significant differences were observed between the body mass index (BMI) derived using height and arm span amongst both genders. BMI derived using arm-span was lower than the BMI derived using height in both the genders. Goswami et al. in his study observed that the mean arm span was more than the mean height in all age groups. This was true for both men and women. A study from rural Haryana reported that the mean arm span (164.4 ± 11.1 cm) was higher than the mean height (156.1 ± 9.1 cm). Arm span was found to be consistently more than height in all the age groups, with an average difference in the mean arm span and height of 8–9 cm. Similar findings were also reported from studies by Chilima and Ismail. KD Monyeki et al. recorded longer mean height than arm span among Ellisras rural children. Similar results were reported by Lucia et al. for the four ethnic groups Oromo, Ambara, Tigre and Somali in Ethiopia. Furthermore, Yabanci et al. reported shorter arm span compared with height among Turkish children aged 7–14 years. The results of the present study exhibit different trends from earlier reports. In Malawian children and Indian children arm span was found to be higher than height. The relationship between arm span and height as well as estimation of height from long skeletal bones amongst different age groups and gender was studied by different authors in India. However, such studies were not readily available amongst the geriatric population in India. Arlappa N observed the correlation coefficients between arm span and height were higher amongst men (r = 0.82) compared to women (r=0.68) and the corresponding figures reported by Fatmah (2010) for the elderly in Indonesia were 0.79 for men and 0.84 for women. The corresponding figures for Bosnia and Herzegovinian adults were 0.876 and 0.887, respectively. Similarly, Kwok
and Whitelaw also reported higher correlation (0.93) between height and arm span among older people. Goswami et al study findings from regression analysis showed age and gender wise variations in height that could be predicted by arm span. Similar findings were also seen from a previous study among rural elderly population in Haryana. The overall regression coefficient in study by Goswami et al for men indicated that for every unit of increase in arm span of men, there was a 0.73 cm significant increase in height. This was similar to the findings from the rural study.

In women, height increased significantly by 0.70 cm per 1 cm increase in arm span in this study which is also similar with that seen from the rural population. This indicates that irrespective of the difference in population groups, whether urban or rural, the rate of change of arm span and height is constant which is an important finding of the study. Monyeki et al found a significant strong correlation was recorded between height and arm span, waist circumference, MUAC (mid upper arm circumference) and sum of four skin folds in the present study among boys and girls. Similar trends were reported among Turkish children aged 7–14 years for height, arm span and MUAC. In other studies, too, height and arm span were reported to be strongly correlated.

B Rabe found that the high correlation between height and arm span of 0.83 for females and 0.81 for males, found in the sample of Indonesian elderly, confirmed that arm span approximates the same rank-ordering of a population as height. The nutritional status of older adults as per the BMI calculated using both arm span and height is presented in Table 3. The categorization of individuals according to nutritional status was done as: Malnourished, Normal, Overweight and Obese as per WHO standards. When categorized using BMI-arm span, the proportion of malnutrition was higher as compared to BMI-height. While the proportion of overweight and obese was higher when categorized using BMI-height as compared to BMI-arm span. Arllappa observed that there was over estimation of nutritional status amongst the older adults when BMI was calculated using height, where the prevalence of overweight/obesity (BMI ≥ 25.0) using standing height was 52.1% as against the only 27.6%, using arm span (p<0.001). Similarly, a higher proportion of older adults with CED were misclassified as normal weight and normal weight subjects as overweight using height to calculate BMI. This could be attributed to substantial reduction in the standing height amongst the older adults. Several studies have shown that height reduces with advancing age and that height loss is even greater after 80 years. Therefore, calculation of nutritional status of aged people using standing height is not reliable anthropometric measurement. Nishiwaki et al also opined that inaccurate BMIs lead to substantial numbers of older adults being misclassified as normal weight or overweight, which can cause significant distortions in data on the impact of underweight and overweight on health outcomes. Siqueira V de also reported that use of the WHO equation (using height) significantly increases the prevalence of overweight, thereby masking the diagnoses of underweight. B Rabe in his study observed that according to the classification system of James et al, about one-third of the examined female and male subjects had CED whereas a little less than one-third of the elderly were obese. The total percentage of the female population in some stage of chronic energy deficiency would rise from 32 to 47% if arm span is, indeed, a more valid representation of the biologically relevant length of an older, shortened individual. Estimates of obesity of any grade, on the other hand falls from 31 to 17% in this gender. For men, the proxy use of arm span raises the overall apparent CED prevalence from 33 to 42%, while lowering that of obesity from 21 to 3%.

The agreement between the BMI-arm span and BMI-height was high (Table 4) among the normal subjects than with other categories, with measure of agreement Kappa being 0.818 which is significant statistically (p<0.001). The cut-off values for BMI-height are already established to categorize the individuals according to their nutritional status; but as we have observed the differences in lengths of arm-span and height, more so in elderly when compared with other studies carried in younger population, we derived BMI-arm-span cut-off values equivalent to BMI-height cut-off values using linear regression. The area under curve
(AOC) in Fig.1 is 91.8%, which means the accuracy is 91.8%. The area under curve (AOC) in Fig.2 is 82.6%, which means the accuracy is 82.6%. The area under curve (AOC) in Fig.3 is 75%, which means the accuracy is 75%. Similar study was carried out by Arlappa N\textsuperscript{10} who observed that since there was a significant difference in agreement between the different categories of nutritional status assessed using both height and arm span amongst older adults, they derived the BMI-Arm span cut-off values equivalent to known BMI-height cut-off values using regression analysis. The sensitivity between BMI-arm span cut-off values and BMI-height cut-off values ranged from 0.76 to 0.88 for any BMI category, while the specificity ranged from 0.90 to 0.99. As reported by Fatmah\textsuperscript{12}, the sensitivity of predicted body height from arm span to assess the nutrition status compared to the normal nutrition in elderly male and female is high\textsuperscript{28}. Froehlich et al\textsuperscript{12} commented in their study that by obtaining an accurate height estimate for individuals with severe mobility impairments who use wheelchairs is challenging, as the impairment typically precludes people from standing for measurement with a stadiometer. Further, having an accurate estimate is important for use in equations related to patient care such as determining appropriate drug dosages, assessing pulmonary function, and measuring BMI. Evidence supports arm span as a reasonably accurate height estimate for ambulatory young and middle-aged\textsuperscript{41,42} and ambulatory older adults\textsuperscript{8}. Although arm span estimates a person’s maximum achievable height, several factors may affect the estimate for those with mobility impairment. People with early onset disability likely never achieved their “maximal” height, in part due to lack of weight bearing on the long leg bones. Also, those with more severe mobility impairment may have physical anomalies, such as joint contractures that restrict full body extension or bone demineralization that contribute to discrepancies between arm span and body length. Monyeki\textsuperscript{13} et al’s findings of the Ellisras do not differ with other investigations worldwide. In Montenegrins the use of arm span was very effective to determine the height of female and male communities in the surrounding areas, even though it may differ in ethnic and racial groups\textsuperscript{42,43}. In all of the estimations of body height from various anthropometric measurements, it is important to emphasize that arm span has been the most reliable indicator for predicting the body height of an individual\textsuperscript{44}. Arm span can be a reliable method used to measure height for disabled, old-aged and deformed individuals\textsuperscript{54,15}

WEAKNESS: The more study sample should be included for comprehensive study. Whether obesity is because of fat distribution or muscle distribution cannot be commented; hence some alternative to weight should also be assessed, as that of waist-hip ratio.

STRENGTH: The measurement tools and calibration were accurate.

CONCLUSION: Due to the anthropometric changes that take place with increasing age, there is a progressive loss of height. Arm span could be used instead of height, as an alternative measurement in nutritional studies in elderly persons. As arm span, as an anthropometric measure, remains unchanged over time, it could be used instead of height, as an alternative index to the conventional body mass index. There is a need of alternative anthropometric measurement to height for the accurate assessment of nutritional status amongst older adults. Since arm length is less affected than the height by the aging process, it should be considered as an alternative to stature when assessing the nutritional assessments of the elderly 6, 58. In India, many of the elderly are at an increased risk of malnutrition, be it underweight or obesity. Therefore, emphasis should be laid on developing proper methods for measuring basic indicators of nutrition.

RECOMMENDATION: More studies should be undertaken with regard to nutritional status of elderly to find alternative indices for both height and weight, as both seem to be unreliable with increasing age.

SUMMARY: The use of body mass index (BMI) in the elderly is limited by the measurement of height which is often unreliable. Arm span approximates to height at maturity. It may, therefore, be an alternative to height in calculating BMI and so also the nutritional status. The study is an observational cross-sectional study carried out among 400 geriatric population attending tertiary care teaching institute of tribal area of central India. Weight, Height and Arm-span were
calculated as per standard techniques; height and arm-span compared; BMI based on height (BMI-Ht) and BMI based on arm-span (BMI-As) were calculated and compared using regression equations. The mean arm-span (164.99 in men and 153.65 in women) was seen to be more than the mean height (160.87 in men and 151.22 in women) in both genders. There was a strong correlation between height and arm-span in both the genders. The BMI-As (18.336 in men and 19.282 in women) was lower than the BMI-Ht (19.247 in men and 19.922 in women) in both the genders. As per BMI-arm-span, the proportion of malnutrition was higher as compared to BMI-height. Therefore, arm-span could be a better alternative to standing height in calculating body mass index for assessing nutritional status and for other clinical implications in elderly and non-ambulatory individuals.

REFERENCES:


