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Research Article

Prediction of Standing Height from Arm Span for Calculation of Body Mass Index in Older Adults

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Abstract

Introduction: As age advances, all spine components undergo degenerative changes and the original standing height of the individual diminishes due to loss of vertebral bone, reduced disc spaces and increased laxity of the vertebral support ligaments. Since measuring accurate standing height in older adults is complex, several studies have demonstrated using arm span as an alternative anthropometric measurement to standing height among older adults.

Methods and Objective: A community-based cross sectional study was carried out among 400 (Men: 180; Women: 220) older adults residing in urban municipal corporation of Khammam of Telangana State, India. The objective was to study the correlation between the body mass index (BMI) calculated using both height and arm span among older adults.

Results: The mean height and arm span among men were 164.5 cm (± 6.62) and 175.3 cm (± 7.92), respectively, while it was 149.5 cm (± 5.76) and 158.7 cm (± 8.60), respectively for women. There is a significant ($p < 0.001$) difference between arm span and height in both older men, 10.8 cm ($r = 0.82$) and women, 9.2 cm ($r = 0.68$). Similarly, the body mass index (BMI) derived using both heights and arm span were significantly ($p < 0.001$) different in both genders.

Conclusion: The conventional standing height is not a reliable anthropometric measurement for the assessment of the nutritional status of older adults, and arm span is the best alternative to standing height for calculating body mass index (BMI).

Keywords: *Body Mass Index; Height; Arm Span; Older Adults*

Introduction

As age advances, all the components of the spine undergo degenerative changes. The spine is made up of vertebral bones, discs and muscles. The disc is the cartilage that lies between vertebrae and starts to degenerate with advancing age is called disc degeneration, where the space between the two vertebral bones decreases. Therefore, as the age advances, the original height of the individual diminishes due to loss of vertebral bone, reduced disc spaces and increased laxity of the vertebral support ligaments. The decline in stature and spinal length during old age is ascribed to a reduction in the height of intervertebral discs [1]. Ageing is associated with physiological, psychological and biological changes, particularly with reference to anthropometric parameters [2,3]. Physical activity declines with ageing, and there will be a change in body composition, such as an increase in fat mass and a decrease in lean muscle mass and bone mass [2].

Anthropometric measurements such as weight and height are simple and non-invasive methods vital for assessing an individual's nutritional status [4,5]. Height is also an important parameter for calculating body mass index (BMI), basal energy expenditure, basal metabolic rate, vital capacity [6], nutrient requirements [7], and body composition [8]. Consequently, precise height measurement is crucial for correctly assessing the nutritional status of individuals [9,10]. Height is measured while the subject stands erect on a plain surface without shoes and the head positioned in the Frankfurt horizontal plane. Frankfurt plane is defined when the line joins the inferior margin of the orbit (orbitale), and the tragus of the ear lies in the horizontal plane [11,12]. Accurate anthropometric measurements in older adults might be challenging to obtain because of changes in body composition, posture, mobility, and thinning of vertebrae discs which can contribute to a reduction in height during the ageing process [2,13,14].

Similarly, the height measurement of ageing subjects is difficult and unrealistic owing to their physical handicap, non-ambulation, kyphoscoliosis, lower limb contracture and osteoarthritis of the hip and knees [15,16]. Measuring standing height in older adults with paralysis and amputated lower limbs is also difficult [17]. The use of body mass index (BMI; weight (kg)/height (m^2)), the conventional index to determine adult nutritional status, is limited in the elderly by the measurement of height, which is often unreliable [18,19]. This unreliable BMI in the older age group is because of shrinking inter-vertebral cartilages leading to spinal curvatures like kyphosis and scoliosis [20,21] and postural changes such as bowing of the legs and bent knees due to decreased muscle strength might also lead to inaccurate height measurements [22].

Under these changing circumstances in the older people's stature, measuring the accurate standing height to assess nutritional status is complicated. Therefore, there is a need for an appropriate and alternative body part to estimate the actual height attained during adulthood amongst older people. Several studies demonstrated other skeletal measurements as an alternative to height for assessing the nutritional status in older adults [7,23,24]. Several authors from different countries have estimated stature from different long bones and other body parts. They include upper [25] and lower extremities like the knee height [26-29], foot length [30-33], cephalo-facial measurements [20,30,34,35], sternum [36], iliac spine [37], vertebral length [38] and arm span [3,10,39-41]. Though, several studies have estimated the stature (height) using different body parts, using arm span was the most reliable alternative for estimating height [42]. The alternative measurements for height such as arm-span, knee height and demi-span have been shown to be useful surrogate measures of stature in older people and may be more accurate [43] because the length of long bones in arms and legs does not change with age, unlike vertebral height [44].

Arm span is the horizontal distance between the fingertip of the longest digit on the one hand to the corresponding point; on the other hand, the subject assumes a "crucifix" position with the arms extended laterally [45]. The long bone measurement, arm span, corresponds to the maximum height achieved in early adulthood, is relatively less affected by aging, and does not shrink with ageing [24,45,46], suggesting that it may offer an alternative to height in calculating BMI in older populations [2,19]. However, most studies that looked at the association between arm span and height have focused on Caucasian subjects, and they found that the association between arm span and height differed from race to race [46,47].

Several western studies reported the relationship between arm span and height amongst different age groups and gender, and few studies in India reported this relationship among children and adults. However, such data is not readily available in India for older adults (60 years and above). Hence, keeping it in mind, a community-based study was carried out amongst older people to study the arm span as an alternative to height for calculating body mass index (BMI).

Materials and Methods

A community-based cross-sectional study adopting a stratified random sampling procedure was conducted among the urban geriatric population (60 years and over) of Khammam town in India during 2011-12. A total of 400 older adults (Men: 180; Women: 220) were covered for the study from 12 out of 36 randomly selected urban municipal wards of Khammam town. The number of subjects to be covered from each selected municipal ward was derived based on probability proportional to the size (PPS) of the population of municipal wards.

Anthropometric measurements such as weight, height and arm span were measured using standard equipment and adopting standard procedures. After removing the footwear, the subjects' weight was measured nearest 100 gm with a digital weighing scale (SECA). Height was measured to the nearest 0.1 cm using an anthropometric rod after making the subject stand erect on a flat surface (without footwear) with feet together. The arm span length was measured using SECA non-elastic measuring tape (Seca 201) to the nearest 0.1 cm. The arm span was measured after asking older adults to stand erect with their back to the wall to provide support with both arms extended (with the elbows and wrists extended) at right angles and the palms facing directly forward [19]. The measurement was taken from the tip of the middle finger on one hand to the tip of the middle finger on the other hand. BMI was calculated as weight (kgs) divided by height in meters square [48]. The study was approved by the Principal and Dean, Mamata Medical College, while ethical clearance was obtained from Chairman, Human Ethics Committee, Mamata Medical College, Khammam. Written informed consent was obtained from the participants after explaining the purpose of the study and assuring them confidentiality of the data. Older adults with kyphosis, scoliosis, lower limb contracture, hip and knee joints osteoarthritis, paralysis and amputation were excluded from the study. Non-ambulatory and those older adults not willing to participate were also excluded from the study.

Statistical analysis

Descriptive statistics like mean (± SD) height, weight, arm span and BMI were calculated using Statistical Package for Social Science (SPSS) version: 19.0 [49]. Correlation coefficients were calculated to assess the relationship between height and arm span using Pearson correlation coefficients, and the same was presented as scattered diagrams. Paired t-test was performed to study the mean difference between arm span and height. The McNemar test was used to review the agreement between BMIs calculated using height and arm span. BMI- Arm Span cut-off values equivalent to BMI height were derived using regression analysis, and the area under the curve was estimated by the receiver operating characteristic (ROC) curve for the same. We also calculated sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for both BMIs. The level of significance was considered when $p < 0.05$.

Results

The mean (± SD) age and anthropometric parameters of older adults by gender are presented in table 1. The mean age of men and women was 68.0 (± 6.04) and 67.3 (± 7.23) years, respectively. The mean height and arm span amongst men were 164.5 (± 6.62) cm and 175.3 (± 7.92) cm, respectively, while the corresponding figures for the women were 149.5 (± 5.76) cm and 158.7 (± 8.60) cm, respectively. Significant ($p < 0.001$) differences were observed between the body mass index (BMI) derived using both height and arm span amongst both genders. The relationship and correlation coefficients between arm span and height by gender are presented in table 2. A significant ($p < 0.001$) difference between arm span and height was observed amongst older adults of both genders. The length of the arm span in both genders was significantly ($p < 0.001$) higher than their corresponding standing height, and the difference was relatively higher amongst men (10.8 cm) as compared to women (9.2 cm). The correlation between arm span and height was higher amongst men ($r = 0.82$) as compared to women ($r = 0.68$) (Figure 1 and 3). However, the standing height explaining the per cent of variation for the length of arm span was only 67% for men and 47% for women. Likewise, the BMI derived using the length of arm span was significantly ($p < 0.001$) lower than the BMI derived using standing height in both genders. At the same time, the correlation between BMI-height and BMI-arm span was 0.95 and 0.91 amongst men and women, respectively (Figure 2 and 4). The nutritional status of older adults as per BMI calculated using arm span and height is presented in table 3. The overall prevalence of overweight/obesity (BMI ≥ 25.0) using standing height was 52.1%, while it was only 27.6% when BMI was calculated using arm span ($p < 0.001$). As per BMI-Arm Span, the proportion of chronic energy deficiency (CED) and normal nutritional status was significantly ($p < 0.001$) higher amongst both genders as compared to the BMI- Height. In contrast, the proportion of overweight/obesity was significantly ($p < 0.001$) higher as per the BMI-Height compared to the BMI-Arm span amongst both the genders.

Table 1: *Mean (± SD†) age and anthropometric values of older adults by gender.*

	Men (n = 180)		Women (n=220)	
Particulars	**Mean (± SD)**	**Range**		**Range**
Age (yrs)	68.0 (± 6.04)	60 - 93	67.3 (± 7.23)	60 - 90
Weight (kg)	68.1 (± 13.60)	29.9 - 114.4	58.4 (± 12.65)	27.6 - 95.2
Height (cm)	164.5 (± 6.62)	144.6 - 181.8	149.5 (± 5.76)	132.5 - 168.2
Arm span (cm)	175.3 (± 7.92)	154.4 - 194.2	158.7 (± 8.60)	116.1 - 196.8
BMI*-Height (kg/m^2)	25.1 (± 4.39)	11.8 - 40.2	26.1 (± 5.13)	14.9 - 44.5
BMI*-Arm span (kg/m^2)	22.1 (± 4.00)	11.1 - 36.4	23.2 (± 4.69)	13.5 - 43.3

†SD: Standard Deviation; BMI: Body Mass Index.*

Table 2: *Mean anthropometric values and correlation coefficients by gender.*

Particulars	Arm span	Height	Difference (95%CI)	Pearson Correlation		t-Value	p-value
				r	r 2		
Men							
Length (cm)	175.3	164.5	10.8 (10.1, 11.4)	0.82	0.67	19.03	0.000
BMI* (kg/m^2)	22.1	25.1	-3.0 (2.8, 3.2)	0.95	0.91	42.00	0.000
Women							
Length(cm)	158.7	149.5	9.2 (8.3, 10.0)	0.68	0.47	13.52	0.000
BMI (kg/m^2)	23.2	26.1	-2.9 (2.6, 3.1)	0.91	0.83	33.22	0.000

**BMI=Body Mass Index; p values are for correlations.*

Table 3: *Nutritional status older adults as per BMI* calculated using height and arm span by gender.*

Particulars	n	Nutritional status				Pearson c^2	p-value
		CED†	Normal	Overweight	Obese		
Men							
BMI- Asβ	180	17.8	61.7	16.7	3.9	37.27	0.000
BMI- Ht‡	180	6.1	43.9	38.9	11.1		
Women							
BMI- AS	220	11.4	55.5	25.0	8.2	23.33	0.000
BMI- Ht	220	6.4	39.5	33.6	20.5		
Pooled							
BMI- AS	400	14.3	58.4	21.3	6.3	430.80	0.000
BMI- Ht	400	6.3	41.6	35.8	16.3		

**BMI=Body Mass Index; †CED: Chronic Energy Deficiency; β Arm span: ‡Height.*

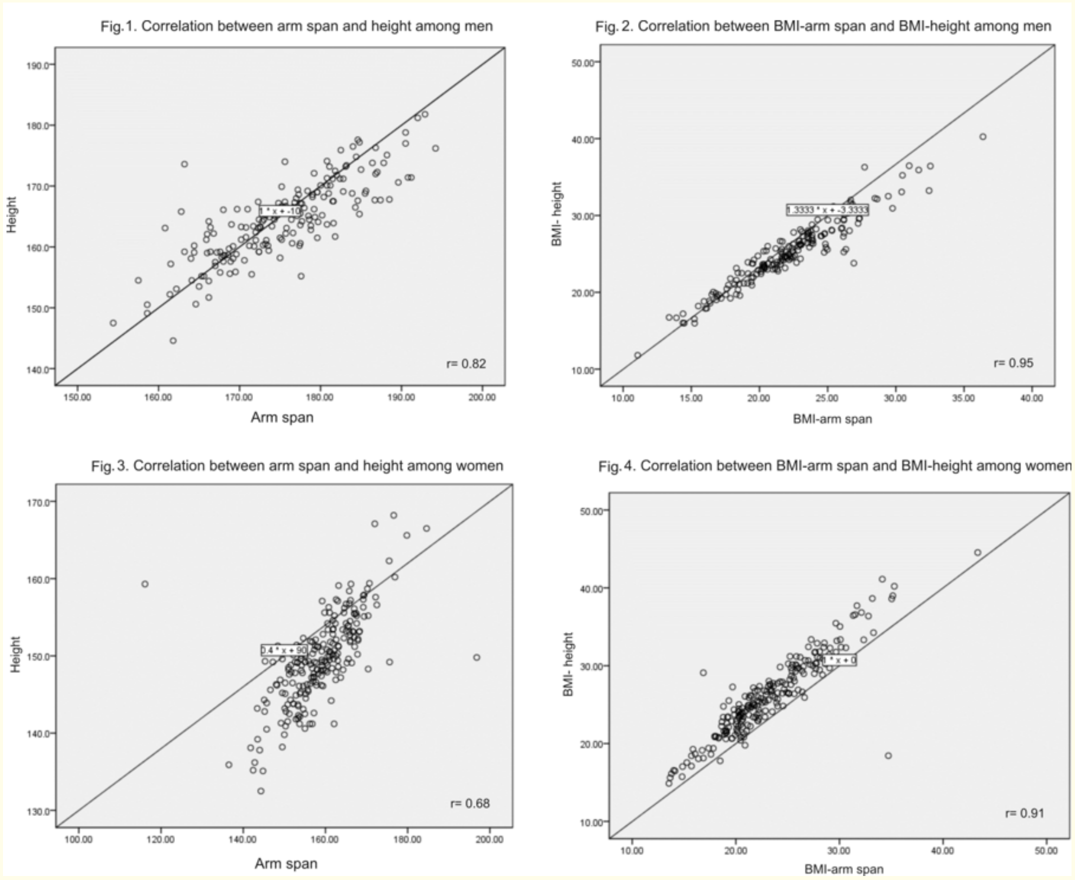


Figure 1-4: *Scattered diagrams show the correlation between arm span, height and BMI-Arm span, and BMI height by gender.*

Figure 1: *The correlation between arm span and height among men was 0.82.*

Figure 2: *The correlation between BMI-arm span and BMI height among men was 0.95.*

Figure 3: *The correlation between arm span and height was among women was 0.68*

Figure 4: *The correlation between BMI-arm span and BMI height among women was 0.91.*

According to the BMI calculated using arm span, 57 older adults had CED. Of them, only 24 (42.1%) subjects were correctly classified as having CED when the BMI was calculated using standing height, while 56.1% of those CED subjects were misclassified as having normal nutritional status. Similarly, of the subjects with normal nutritional status according to BMI-Arm span, only 57.3% were correctly classified as having normal nutritional status, and the rest (42.7%) were misclassified as overweight according to BMI-height. The agreement between BMI-arm span and BMI-height was high only amongst the obese subjects compared to other categories of nutritional status in both the genders (Table 4).

BMI-Arm span cut-off values equivalent to known BMI-height cut-off values were derived using linear regression analysis and are presented in table 5. The corresponding BMI-Arm span cut-off values equivalent to known BMI-height cut-off values such as BMI < 18.5, 25.0 and 30.0 were 16.4, 22.0 and 26.4, respectively. The area under the curve (AUC) through ROC measured the accuracy of these newly

Table 4: Agreement between BMI- arm span and BMI-height by gender.*

BMI-Arm span	BMI-Height				
	N	CED†	Normal	Overweight	Obese
Men					
CED	32	34.4 (11)	65.6 (21)	0.0	0.0
Normal	110	0.0	51.8 (57)	48.2 (53)	0.0
Overweight	30	0.0	3.3 (1)	53.3 (16)	43.3 (13)
Obese	7	0.0	0.0	0.0	100.0 (7)
Pooled	179	6.1 (11)	44.1 (79)	38.5 (69)	11.2 (20)
Women					
CED	25	52.0 (13)	44.0 (11)	4.0 (1)	0.0
Normal	122	0.0	62.3 (76)	37.7 (46)	0.0
Overweight	55	0.0	0.0	49.1 (27)	50.9 (28)
Obese	18	5.6 (1)	0.0	0.0	94.4 (17)
Pooled	220	6.4 (14)	39.5 (87)	33.6 (74)	20.5 (45)
Total					
CED	57	42.1 (24)	56.1 (32)	1.8 (1)	0.0
Normal	232	0.0	57.3 (133)	42.7 (99)	0.0
Overweight	85	0.0	1.2 (1)	50.6 (43)	48.2 (41)
Obese	25	4.0 (1)	0.0	0.0	96.0 (24)
Pooled	399	6.3 (25)	41.6 (166)	35.8 (143)	16.3 (65)

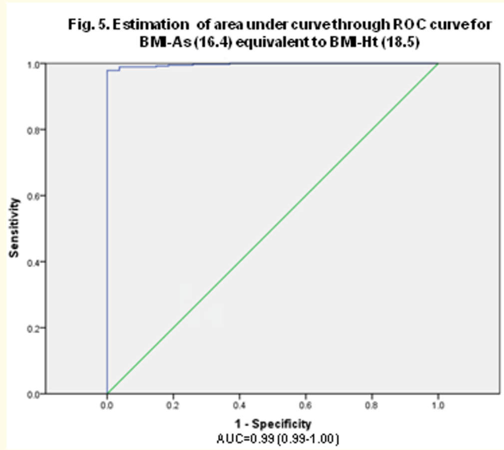
**BMI: Body Mass Index; † CED: Chronic Energy Deficiency.*

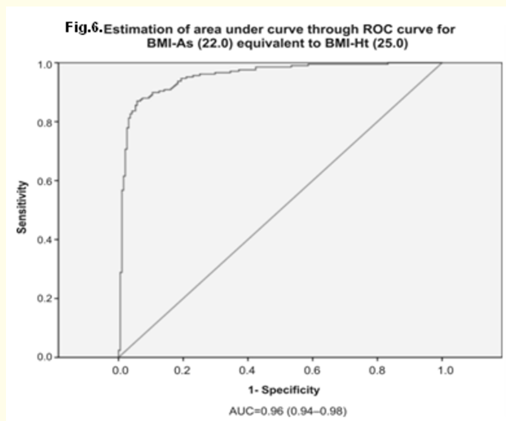
derived BMI-arm span cut-off values. The accuracy of the AUC (95% CI) values of BMI-Arm span cut-off values for BMI height was excellent (Figure 5-7). Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were also calculated between newly derived BMI-Arm span cut-off values and BMI-height cut-off values and presented in table 6. The sensitivity ranged from 0.76 to 0.88 for any BMI category, while the specificity ranged from 0.90 to 0.99.

Table 5: Derivation of BMI-arm span cut-off values equivalent to BMI-height cut-off values.

BMI-Height	BMI-Arm span
18.5	BMI-AS=f* (BMI-Height)
	=0.355+0.868 x BMI
	=0.355+0.868x18.5
	=16.4
25.0	BMI-AS=f (BMI-Height)
	=0.355+0.868xBMI
	=0.355+0.868x 25.0
	=22.0
30.0	BMI-AS=f (BMI-Height)
	=0.355+0.868xBMI
	=0.355+0.868x 30.0
	=26.4

**f= Function of.*





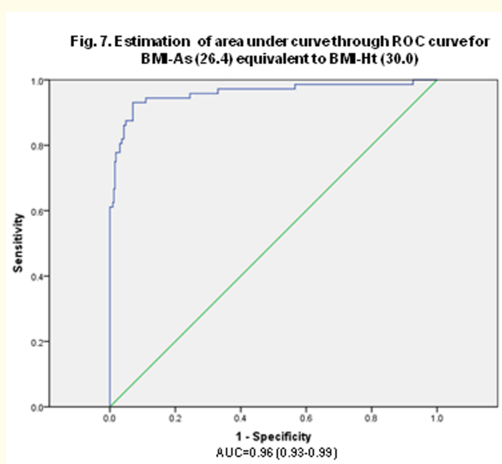


Figure 5-7: *Estimation of the area under the curve (AUC) through the ROC curve for new BMI-arm span cut-off values (16.4, 22.0 and 26.4) equivalent to known BMI height (18.5, 25.0 and 30.0). The accuracy of the AUC (95% CI) values of BMI-arm span cut-off values for BMI-height cut-off values was excellent.*

***Table 6**: Sensitivity, specificity, PPV* and NPV‡ between newly derived BMI-Arm span cut-off values equivalent to BMI-Height cut-off values.*

Nutritional Status	Sensitivity	Specificity	PPV	NPV
CED†	0.88	0.99	0.82	0.99
Normal	0.86	0.90	0.86	0.90
Overweight	0.76	0.90	0.80	0.90
Obese	0.86	0.95	0.78	0.97

**PPV: Positive Predictive Value; ‡NPV: Negative Predictive Value; † CED: Chronic Energy Deficiency.*

Discussion

The relationship between arm span and height and estimation of height from long skeletal bones amongst different age groups and gender were studied by various authors in India. However, such studies were not readily available amongst the geriatric population in India. Our study, perhaps for the first time, studied the relationship between the length of the arm span and standing height amongst the older adults in India. In general, significant ($p < 0.001$) differences were observed between the mean arm span and height as well as in BMIs calculated using both arm span and height amongst older adults of both genders.

The length of the arm span in both genders was significantly ($p < 0.001$) higher than their standing height, and the difference was relatively higher amongst men (10.8 cm) as compared to women (9.2 cm). The difference between arm span and height amongst Malaysian older men (7.7 cm) and women (6.1 cm) was comparable to the present study [50]. However, Kwok., *et al*. [51] reported no difference between the length of the arm span and height amongst Chinese older men (6.4 cm) and women (6.3 cm). While in general, Allen [24] reported the mean difference between arm span and height as 4.7 cm (range -5 to + 17) amongst the elderly. The mean values of arm span and height of older adults in this study are higher compared to their Chinese, Malaysian and Indonesian counterparts [28,50,51]. 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 [28]. Similarly, Kwok and Whitelaw [19] also reported a higher correlation (0.93) between height and arm span amongst older people.

Overestimation of nutritional status is being observed 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 having normal nutritional status and subjects with normal nutritional status as overweight using height to calculate BMI. This could be attributed to a substantial reduction in the standing height amongst older adults.

Several studies have shown that height reduces with advancing age [3,52,53] and that height loss is even more significant after 80 years [54]. Therefore, calculating the nutritional status of aged people using standing height is an unreliable anthropometric measurement. Nishiwaki., *et al*. [55] also opined that inaccurate BMIs lead to substantial numbers of older adults being misclassified as having normal nutritional status or overweight, which can cause significant distortions in data on the impact of underweight and overweight on health outcomes. Siqueira Vde [56] also reported that using the WHO equation (using height) significantly increases the prevalence of overweight, thereby masking the diagnoses of underweight.

As reported by Fatmah, the sensitivity of predicted body height from arm span to assess the nutrition status compared to the actual heigh in elderly males and females is high [28]. Since there was a significant difference in agreement between the different categories of nutritional status as assessed using both height and arm span amongst older adults, we 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.

Assessment of the nutritional status of the ageing population is essential. However, assessing their nutritional status using standing height will lead to misclassifying their nutritional status because of the reduction of height associated with ageing. This would adversely impact the health and nutritional interventions amongst the aged. Therefore, there is a need for alternative anthropometric measurements to height to assess older adults' nutritional status accurately. Since arm length is less affected than the height by the ageing process, it should be considered an alternative to stature when assessing the nutritional assessments of the elderly. Kwok and Whitelaw [19] also reported that arm span is an excellent alternative measurement for height in older people. In the same way, erstwhile studies also reported that arm span is the most reliable anthropometric measurement for predicting the standing height of an individual, and it is a reliable and practical estimate of height in the non-ambulant elderly [3,40].

Conclusion

Therefore, the conventional height is not a reliable anthropometric measurement for the assessment of the nutritional status of older adults because of age-related changes in vertebral bones and posture and loss of muscle tone. Therefore, arm span is the best alternative for the calculation of body mass index (BMI) and thereby accurate assessment of the nutritional status of the ageing population.

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Conflicts of Interest

None.

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