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Arm span as an alternative to standing height for calculation of body mass index (BMI) amongst older adults

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Abstract

Objectives: Accurate measurement of height is difficult in older adults because of the reduction in height that occurs during the ageing process. Therefore, several western studies have demonstrated the arm span as an alternative anthropometric measurement to height among older adults, as the length of arm span is less affected by aging. The aim of the study was to use arm span as an alternative to standing height for calculation of body mass index (BMI) amongst older adults.

Methodology: 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. 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.

Key Results: The mean (SD) height and arm span among men were 164.5 cm (6.6) and 175.3cm (7.9), respectively, while among women were 149.5cm (5.8) and 158.7cm (8.6). The mean difference between arm span and height was 10.8cm (10.1,11.4)in men and 9.2cm (8.3,10.0) in women (p<0.001). Similarly, significant (p<0.001) differences were observed between the BMIs derived using both height and arm span among both the genders.

Conclusion: The conventional height is not a reliable anthropometric measurement for the assessment of nutritional status of older adults, where the BMI-height model over estimated 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.

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Introduction

Anthropometric measurements such as weight and height provide simple, non-invasive methods for assessing the nutritional status of populations[1] and height is an important measure of body size and for the assessment of nutritional status in children and adults[2]. Height is also an important parameter used to calculate creatinine height index, basal energy expenditure, basal metabolic rate, vital capacity[3], nutrient requirements[4] as well as for the calculation of body composition[5]. Therefore, accurate measurement of height is essential for the assessment of nutritional status of individuals[6,7] as they are at risk of malnutrition[8,9]. Height is measured with the subject standing erect on a plain surface without shoes and the head positioned in Frankfurt horizontal plane. The Frankfurt plane is defined as the line joining the inferior margin of the orbit (orbitale) and the tragus of the ear lies in the horizontal plane[10,11]. Aging is associated with physiological, psychological and biological changes[12]. Similarly, as the physical activity levels declines with aging, there will be a change in body composition such as an increase in fat mass and a decrease in lean muscle and bone masses[12]. Accurate anthropometric measurements in older adults might be difficult to obtain because of changes in body composition, posture, mobility, thinning of intervertebral discs leading to a reduction in height during the aging process[13,14]. Similarly, as the measurement of height amongst some patients of an aging population is difficult and unrealistic because of their physical handicap, inability to ambulate, kyphoscoliosis, lower limb contracture and osteoarthritis of hips and knees[15,16]. Standing height is also difficult to measure in older adults with paralysis and amputated lower limbs[17]. In many older persons, the use of body mass index (BMI; weight (kg)/ height (m^2)), the conventional index that is used to determine adult nutritional status, is limited by the measurement of height, which is often unreliable[18,19]. This unreliable BMI in older age group is because of thinning of the inter-vertebral discs leading to spinal curvature like kyphosis and scoliosis[20,21], and postural changes such as genu valgum and genu varus deformities due to decreased muscle strength[22].

Under these changing circumstances in the stature of the older people, the measurement of accurate standing height for the assessment of nutritional status is difficult. 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[19, 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[7,39-41]. However, 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[42,43] because, the length of long bones in arms and legs do not change with age, unlike vertebral height[44].

Arm span is the horizontal distance between the finger tip of the longest digit on one hand to the corresponding point on the other hand, with the subject assuming a "crucifix" position with the arms extended laterally[45]. The long bone measurement, arm span, corresponds to the maximum height achieved in early adulthood and 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[12,19]. However, most of the 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 [39-43] and few studies in India reported this relationship amongst children and adults. However, such data is not readily available for older adults (age 60 years and over) in India. Hence, keeping in view this objective in mind, a community-based cross-sectional study was carried out amongst older adults with the objective to study the arm span as an alternative to height for calculation of body mass index (BMI).

Materials and Methods

Study design and Participants.

A community based cross-sectional study was carried out adopting a stratified random sampling procedure amongst 400 (Men: 180; Women: 220) urban geriatric members of the population (age 60 years and over) of town of Khammam in India, during July 2011to March 2012.A total of 400 older adults were recruited from 12 out of 36 randomly selected municipal wards of Khammam town. The number of subjects to be covered from each selected municipal ward was derived based on the probability proportional to size (PPS) of population of municipal wards.

Anthropometric measurements

Anthropometric measurements such as weight, height and arm span were measured using standard equipment and adopting standards procedures. Weight of the subjects was measured to the nearest 100 gm with digital weighing scale (SECA) after asking them to remove their footwear. The height was measured to the nearest 0.1cm using an anthropometric rod, once the subject to stand erect on a flat solid surface (without footwear) with feet together. The length of the arm span was measured using SECA non-elastic measuring tape (Seca 201) to the nearest 0.1cm. The arm span was measured after asking older adult individuals 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. The BMI was calculated using the formula of weight (kg) / [height (m)]^2 [48]. The BMI of less than 18.5 kg/m^2 was considered as chronic energy deficiency (CED).

Ethical Clearance and Consent

The study was approved by the Principal & 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, osteoarthritis of both hip and knee joints, paralysis and amputation were excluded from the study. Older adults who were non-ambulatory and unwilling 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]. Pearson's correlation coefficients were used to assess the relationship between height and arm span and represented with scattered plots. Paired t-test was performed to study the mean difference between arm span and height. Bland- Altman plot was done to study the agreement between arm span and standing height. Mantel-Haenszel test was used to study the agreement between BMIs calculated using height and arm span. BMI-arm span cut-off values equivalent to BMI-height were derived using linear regression analysis and area under the curve was estimated by receiver operating characteristic (ROC) curve for the same. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were also calculated for both BMIs. Level of significance was considered when p<0.05.

Results

The mean (SD) age and anthropometric variables of older adults by gender are presented in Table 1.The mean age of men and women was 68.0 (6.0) and 67.3 (7.2) years, respectively, While the mean height and arm span amongst men was 164.5 (6.6) cm and 175.3 (7.9) cm, respectively, and the corresponding figures for the women were 149.5 (5.8) cm and 158.7 (8.6) cm. Similarly, statistically 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 statistically 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) (Fig.1). The correlation between arm span and height was higher amongst men (r = 0.82) as compared to women (r=0.68) (Fig.2&4). However, the standing height explaining the percent of

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

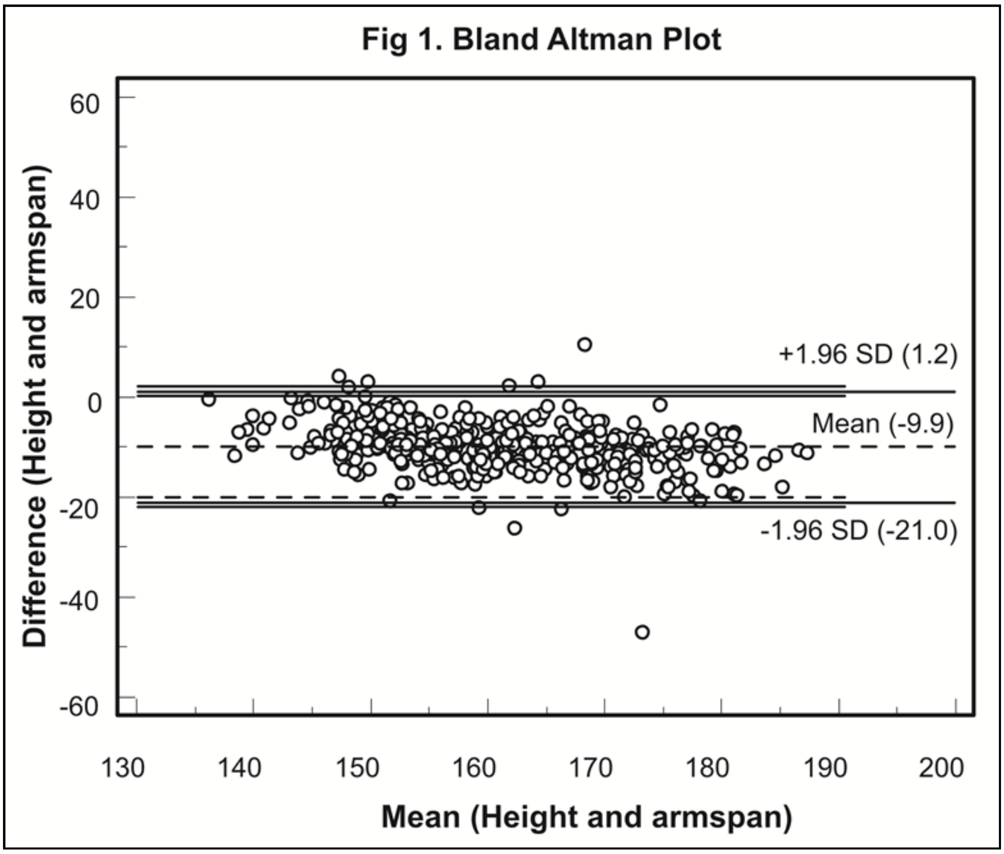
	Men (n=180)		Women (n=220)	
Particulars	Mean(SD)	Range	Mean(SD)	Range
Age (yrs)	68.0(6.0)	60-93	67.3(7.2)	60-90
Weight (kg)	68.1(13.6)	29.9-114.4	58.4(12.6)	27.6-95.2
Height (cm)	164.5(6.6)	144.6-181.8	149.5(5.8)	132.5-168.2
Arm span (cm)	175.3(7.9)	154.4-194.2	158.7(8.6)	116.1-196.8
BMI*-Height (kg/m^2)	25.1(4.4)	11.8-40.2	26.1(5.1)	14.9-44.5
BMI*-Arm span (kg/m^2)	22.1(4.0)	11.1-36.4	23.2(4.7)	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
				r	r 2	
Men						
Length(cm)	175.3	164.5	10.8(10.1,11.4)	0.82	0.67	19.03
BMI*(kg/m^2)	22.1	25.1	-3.0(2.8,3.2)	0.95	0.91	42
Women						
Length(cm)	158.7	149.5	9.2(8.3,10.0)	0.68	0.47	13.52
BMI(kg/m^2)	23.2	26.1	-2.9(2.6,3.1)	0.91	0.83	33.22

*BMI=Body mass index. Note: p-values were statistically significant (<0.001) for length and BMI in both genders, and the given p- values are for correlations.



variation for the length of arm span was only 67% for men and 47% for women. Similarly, the BMI derived using length of arm span was significantly ($p<0.001$) lower as compared to the BMI derived using standing height in both genders. While the correlation between BMI-height and BMI-arm span was 0.95 and 0.91 amongst men and women, respectively (Fig. 3&5). Nutritional status of older adults as per the BMI calculated using both 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 weight was significantly ($p<0.001$) higher amongst both genders as compared to the BMI-height. While, the proportion of overweight and obesity was significantly ($p<0.001$) higher as per the BMI-height compared to the BMI-arm span amongst both the genders.

In general, according to the BMI calculated using arm span, 57 subjects 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% and 1.8% of those CED subjects were misclassified as normal weight and overweight, respectively. Similarly, amongst those subjects with normal weight, only 57.3% subjects were correctly classified as normal weight and rest of the subjects (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 and low amongst the subjects with 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 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 mean values of arm span and height of

Fig.2-5. Scattered diagrams showing correlation between arm span and height & BMI-arm span and BMI-height by gender.

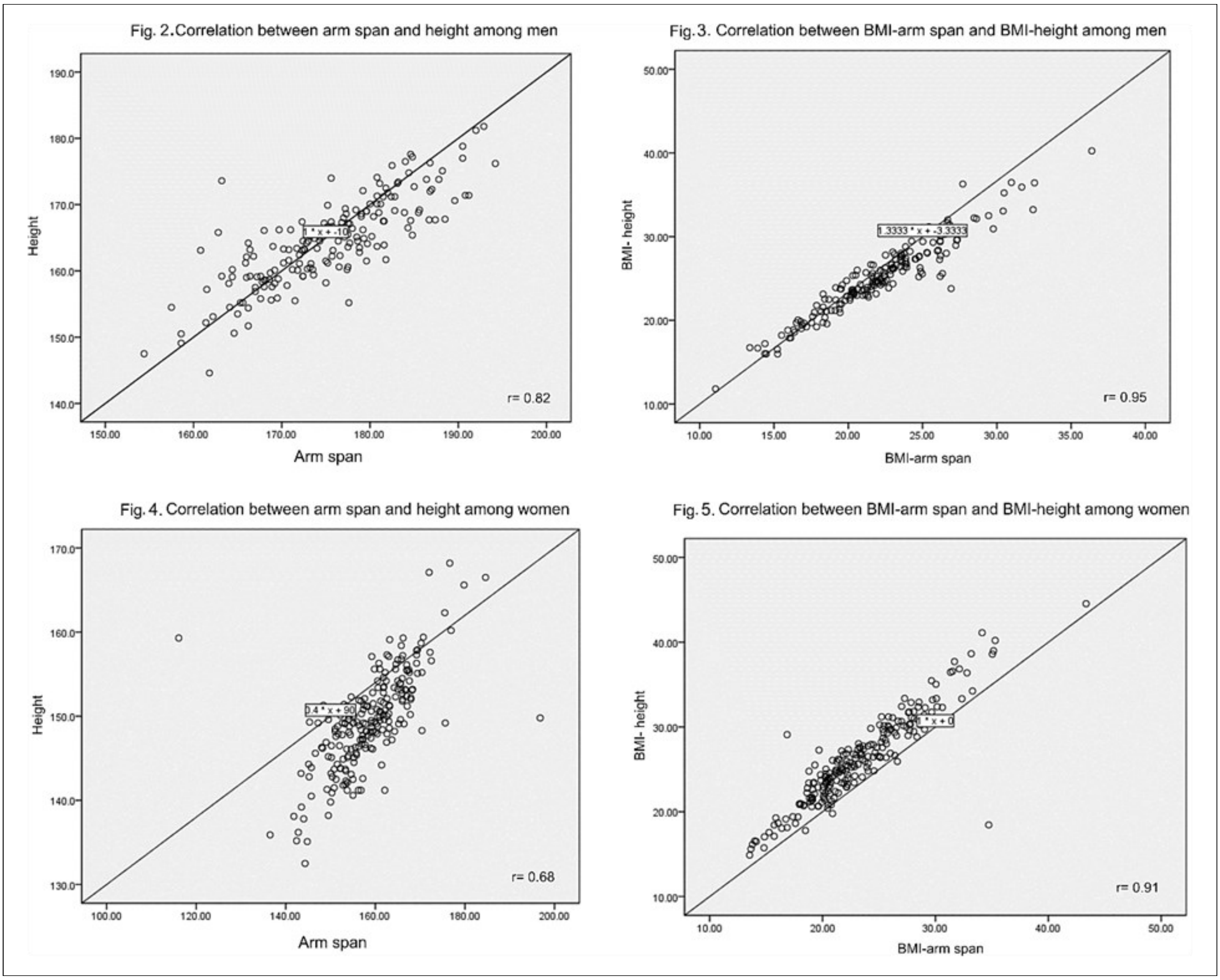


Fig.2.The correlation between arm span and height was among men was 0.82.

Fig.3.The correlation between BMI-arm span and BMI-height among men was 0.95.

Fig.4. The correlation between arm span and height was among women was 0.68

Fig.5. The correlation between BMI-arm span and BMI-height among women was 0.91.

The accuracy of these newly derived BMI-arm span cut-off values were measured by the area under the curve (AUC) through ROC. The accuracy of the AUC (95% CI) values of BMI-arm span cut-off values for BMI-height cut-off values were excellent (Fig.6-8). Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) calculated between newly derived BMI-arm span cut-off values and BMI-height cut-off values are 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.

Discussion

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

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

Particulars	n	Nutritional status				Pearson c2
		CED†	Normal	overweight	obese	
Men						
BMI- Asβ	180	17.8	61.7	16.7	3.9	37.27
BMI- Ht‡	180	6.1	43.9	38.9	11.1	
Women						
BMI- AS	220	11.4	55.5	25	8.2	23.33
BMI- Ht	220	6.4	39.5	33.6	20.5	
Pooled						
BMI- AS	400	14.3	58.4	21.3	6.3	430.8
BMI- Ht	400	6.3	41.6	35.8	16.3	

*BMI=Body mass index; †CED- Chronic energy deficiency; β Arm span:‡Height.

Note:All the p-values were statistically significant (<0.001).

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
Normal	110	0	51.8 (57)	48.2 (53)	0
Overweight	30	0	3.3 (1)	53.3 (16)	43.3 (13)
Obese	7	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
Normal	122	0	62.3 (76)	37.7 (46)	0
Overweight	55	0	0	49.1 (27)	50.9 (28)
Obese	18	5.6 (1)	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
Normal	232	0	57.3(133)	42.7(99)	0
Overweight	85	0	1.2(1)	50.6(43)	48.2(41)
Obese	25	4.0 (1)	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.

The numbers in the parenthesis are number of older subjects.

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	BMI-AS=f (BMI-Height) =0.355+0.868xBMI =0.355+0.868x 25. =0 22
30	BMI-AS=f (BMI-Height) =0.355+0.868xBMI =0.355+0.868x 30.0 =26.4

*f= Function of

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	0.9	0.86	0.9
Overweight	0.76	0.9	0.8	0.9
Obese	0.86	0.95	0.78	0.97

*PPV=Positive predictive value

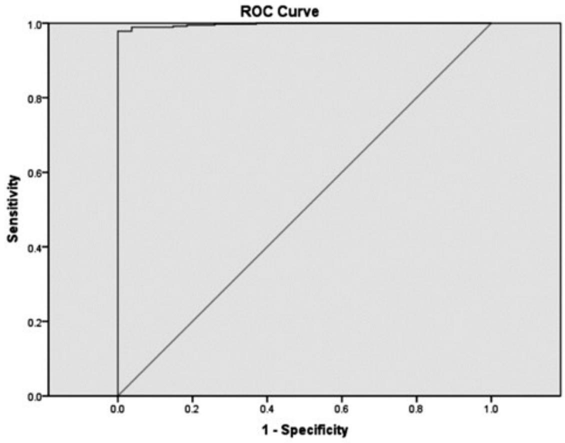
‡NPV= Negative predictive value

† CED=Chronic energy deficiency

were not readily available amongst the geriatric population in India. Our study, is the first of its kind to study the relationship between 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.

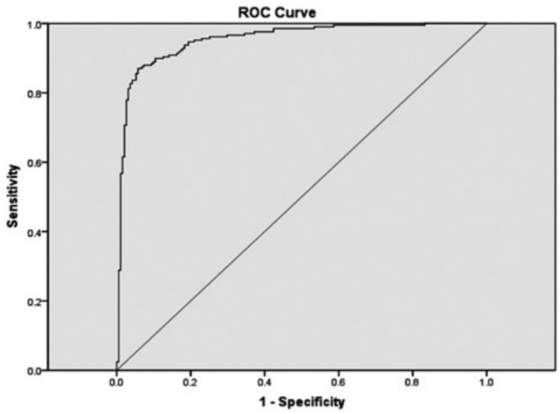
The length of the arm span in both genders was significantly ($p<0.001$) higher than their standing height and the difference was relatively higher amongst men (10.8 cm) as compared to women (9.2 cm). The difference between arm span and height amongst Malaysian elderly men (7.7 cm) and women (6.1cm) was comparable to the present study[50]. However, Kwok et al (2001)reported no difference between the length of the arm span and height amongst Chinese elderly men (6.4cm) and women (6.3cm) [51].While, in general, Allen (1989) reported the mean difference between arm span and height as 4.7 cm (range -5 to + 17) amongst the elderly[24].

Fig 6. Estimation of area under curve through ROC curve for BMI-As (16.4) equivalent to BMI-Ht (18.5)



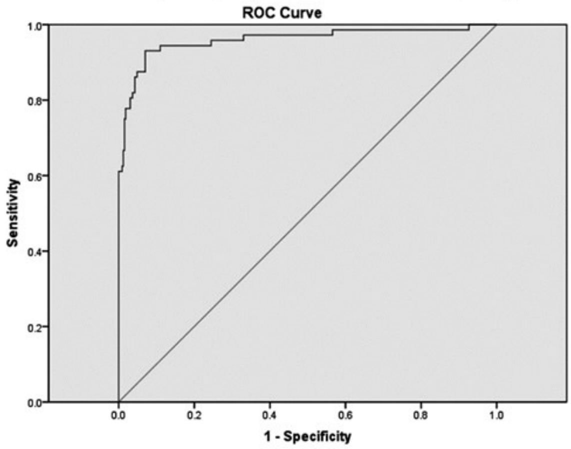
AUC=0.99 (0.99-1.00)

Fig 7. Estimation of area under curve through ROC curve for BMI-As (22.0) equivalent to BMI-Ht (25.0)



AUC=0.96 (0.94-0.98)

Fig 8. Estimation of area under curve through ROC curve for BMI-As (26.4) equivalent to BMI-Ht (30.0)



AUC=0.96 (0.93-0.99)

Fig.6-8. Estimation of area under curve (AUC) through 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 were excellent.

older adults in this study are higher as 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]. The corresponding figures for Bosnia and Herzegovinian adults were 0.876 and 0.887, respectively[52]. Similarly, Kwok and Whitelaw also reported higher correlation (0.93) between height and arm span amongst older people[19].

Over estimation 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 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[53, 54] and that height loss is even greater after 80 years[55]. Therefore, calculation of nutritional status of aged people using standing height is a not reliable anthropometric measurement. Nishiwaki et al[56] 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 Vde[57] also reported that use of the WHO equation (using height) significantly increases the prevalence of overweight, thereby masking the diagnoses of underweight.

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, 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. As reported by Fatmah, 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[28].

Assessment of nutritional status of the status of the aging population older people is very essential. However, the assessment of their nutritional status using standing height will lead to misclassification of their nutritional status, because of reduction of height associated with ageing. This would adversely impact on the health and nutritional interventions amongst the aged. Therefore, 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]. Kwok and Whitelaw[19] also reported that arm span as a good alternative measurement for height in older people. Similarly, other studies also reported that the 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[40,47,59].

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

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