Original Article

Predictive equations for estimation of stature in Malaysian elderly people

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Height is an important clinical indicator to derive body mass index (BMI), creatinine height index and also to estimate basal energy expenditure, basal metabolic rate and vital capacity through lung function. However, height measurement in the elderly may impose some difficulties and the reliability is doubtful. Equations estimating height from other anthropometric measures have been developed for Caucasians, but only one study has developed an equation (based on arm span only) for an Asian population. Therefore, a cross sectional study was conducted to develop equations using several anthropometric measurements for estimating stature in Malaysian elderly. A total of 100 adults (aged 30 to 49y) and 100 elderly subjects (aged 60 to 86y) from three major ethnic groups of Malays (52%), Chinese (38.5%) and Indians (9.5%) participated in this study. Anthropometric measurements included body weight, height, arm span, half arm span, demi span and knee height were carried out by trained nutritionists. Inter and intra observer errors and also % Coefficient Variation (%CV) were calculated for each anthropometric measurement. Equations to estimate stature were developed from the anthropometric measurements of arm span, demi span and knee height of adults using linear regression analysis according to sex. Elderly subjects were shorter and lighter compared to their younger counterparts. The %CV of anthropometric measurements in adults and elderly subjects ranged between 5 to 6%, with standing height having the lowest %CV. When the equations derived from adults were applied to elderly subjects, it was found that percentage difference between actual height and the estimated value ranged from 1.0 to 3.3%. However, the percentage difference between estimated height from the equations developed in this study compared to those derived from the equations of other populations ranged between 0.2 to 8.7%. In conclusion, standing height is an ideal technique for estimating the stature of individuals. However, in cases where its measurement is not possible or reliable, such as in elderly subjects, height can be estimated from proxy indicators of stature. In this study arm span showed the highest correlation with standing height, which is in agreement with other studies. It should be borne in mind that equations derived from taller statured populations (e.g. Caucasians) may be less accurate when applied to shorter statured populations.

Key Words: elderly, predictive equation, estimation of stature, height

Introduction

Height is indeed a very important indicator of body size for use in the clinical setting and also for nutrition and health research. Together with body weight, height is an important parameter used to calculate creatinine height index, basal energy expenditure, basal metabolic rate, vital capacity (lung function)[1], estimation of nutrient requirements[2] and calculation of body composition.[3,4] However, there are difficulties in obtaining an accurate measurement of height in elderly subjects. Ageing is associated with several physiological, psychological and biological changes, including body composition, such as an increase in body fat and a decrease in lean body mass and also bone mass.[5] This can lead to changes in body posture and thinning of vertebrae discs which can contribute to a reduction in height[6] or even kyphosis in elderly people with osteoporosis.[4]

It has been reported that height loss among Caucasian populations was 1.2 cm (1/2 inches) for every 20 years after the age of 30.[7] A longitudinal study among rural elderly Malays[8] reported a significant decrement in the mean of height (0.82±2.71cm) after a four year follow up. Therefore, standing height may not be a reliable indicator for stature in elderly subjects. Standing height is also rather difficult to measure in elderly subjects due to several conditions such as infectious diseases, arthritis, paralysis and amputation.[9,10]

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Accepted 19 July 2002

It is also difficult to measure height in bed-bound elderly persons.[11] Even in adult subjects with the above conditions, measuring height is impossible. Long bones were reported to change less with ageing.[12] Efforts have been carried out to develop equations to estimate stature from long bones, such as knee height,[2,4,13,14] arm span [10,15-17] and demi span[18] (Table 1). However, the accuracy of the equations is reduced if used to estimate stature in populations in which the equation has not been derived from.[10] For example, a systematic error occurred when the equation developed for Caucasians[13] was used to estimate stature in Japanese Americans.[19]

With the increase in elderly populations in Malaysia, especially those in the older age group,[20] there is a need to develop equations to estimate stature for use in clinical and community settings, and also in research related to nutrition and health. This study aimed to develop equations for estimation of stature among Malaysian elderly using a proxy indicator of standing height namely arm span, demi span and knee height.[21]

Materials and methods

This is a cross sectional study of 100 adults aged 30 to 49 years and 100 elderly people aged 60 and above. The adult subjects were either out-patients attending a health clinic at Hospital Universiti Kebangsaan Malaysia or staff of the University Kebangsaan Malaysia. The elderly subjects were either residents of old folk institutions in Taiping, Perak and Seremban, Negeri Sembilan or patients attending an elderly health clinic in Sabak Bernam, Selangor. Apart from age, the exclusion criteria for subjects included those with amputated limbs, kyphosis, oedema or dehydration, taking diuretic drugs.

Data were collected by trained nutritionists from September to October 2000. Anthropometric measurements of weight, standing height, arm span, half arm span, demi span and knee height were carried out on both adults and elderly subjects. Weight was measured using a Portable Soehnle Digital weighing scale, according to the standard tech-niques.[22] Standing height was measured using a Portable Leicester Stadiometer, with the subject standing straight with both hands at the side.[22] Arm span was measured as the length between the tip of the middle finger of the right hand to the tip of the middle finger on the left hand, with both hands straight horizontally at 90^0 from the body and subject standing straight against the wall. Half arm span was measured as the length between the sternal notch to the *tip* of middle finger of the left hand[22] and demi span as the length between the sternal notch to the web of the middle finger. These were measured using a metal measuring tape (CMS Weighing Equipment).[18] Knee height was measured using a Knee Height Caliper (CMS Weighing Equipment) in a sitting position.[13]

The inter and intra observer errors were evaluated using subsamples of 30 adults and 30 elderly subjects by observer 1 and observer 2. Each observer took two measurements within the predetermined limits, as shown in Table 2. The Coefficient of Variation (% CV) of each stature indicator was also calculated. Linear regression analysis was carried out to derive predictive equations for estimation of stature with adults height as the dependant variable and arm span, demi span and knee height as independent variables, according to gender. This equation was then used to estimate height amongst elderly subjects. The estimated heights calculated using the equations were compared with the elderly subjects' actual height and also height derived from equations developed in other studies. Data were analysed using SPSS version 9.05.

Table 1. Summary of studies in using long bones as a proxy indicator of stature

Proxy indicator of stature	Subjects	Age Range (y)	Reference
Limbs	White & Black	17 – 99	23
Knee Height	Non-Hispanic, White	65 – 104	13
Demi span	European	20+	18
Arm span	White & black	23 – 28	26
Knee height	White & Black	60 – 80	14
Arm span	Afro-Caribbean, Asian, Caucasian, Oriental	20 – 40	16
Knee height	Mexican American	60	2
Arm span	White	20 – 61	17

Results and Discussion

A total of 100 adults (mean age 42.33 ± 5.78) and 100 elderly subjects (mean age 69.98 ± 6.79) participated in this study, with 52% Malays, 38.5% Chinese and 9.5% Indians. Table 3 presents anthropometric characteristics of the subjects. Elderly men were lighter (P <0.05) and shorter as measured by standing height (P<0.05), arm span (P <0.05) and demi span (P <0.05), as compared to their adult counterparts. A similar trend was noted for female subjects.

The %CV ranged between 3.6 to 6.6 %, of which standing height showed the lowest CV both in adults and elderly subjects, indicating good repeatability and reliability of standing height measurements (Table 4). It appears that %CV in the elderly subjects was slightly higher than those in the adult subjects. Anthropometric measurements among elderly people must be carried out with precision, according to the standard technique, to obtain a lower CV. Nevertheless, the % CV of knee height in the elderly subjects was considered low.

Arm span, demi span and knee height were positively correlated with height (P<0.05 for all parameters) (Table 5). As expected, the correlation coefficient was higher among adults (r = 0.81 to 0.90) compared to elderly subjects (r = 0.67 to 0.78), with arm span showing the highest correlation with height in adults and elderly subjects of both genders.

Table 2. Predetermined limits to accept variations of two measurements of an indicator performed by the same observer

Measurement	Variation limit	Reference
Standing height	1.0 cm	27
Knee height	0.5 cm	27
Weight	0.1 kg	27
Arm span	1.0 cm	22
Half arm span	1.0 cm	22
Demispan	1.0cm	22

Table 3. Anthropometric characteristics of adults and elderly subjects according to sex

Parameters (unit)	Men (n = 96)		Women (n = 104)	
	Adults (n = 49)	Elderly (n = 47)	Adults (n = 51)	Elderly (n = 53)
Weight (kg)	71.4 ± 12.4	60.6 ± 11.0*	61.8 ± 13.3	56.8 ± 14.9
Height (cm)	165.2 ± 6.0	160.4 ± 5.5*	152.9 ± 6.1	148.5 ± 6.4*
Arm span (cm)	172.7 ± 7.5	168.1 ± 7.1*	157.6 ± 6.5	154.6 ± 6.9 *
Half arm span (cm)	85.9 ± 3.7	83.6 ± 3.8*	78.5 ± 3.4	76.9 ± 3.6*
Knee height (cm)	49.8 ± 2.5	49.2 ± 2.2	46.1 ± 2.3	46.3 ± 2.2

*$P<0.05$, significant difference between adults and elderly subjects within the same gender, independent sample t-test

Table 4. Coefficient variation (%CV) for anthropometry measurements in adults and elderly subjects

Parameters (unit)	Adults (n = 100)	Elderly (n = 100)
Standing height (kg)	5.4	5.5
Arm span (cm)	6.2	6.0
Half arm span (cm)	6.2	6.2
Demi span (cm)	6.6	6.4
Knee height (cm)	6.3	5.5

Table 5. Correlation coefficient (r) between standing height and anthro-pometric measurements in adults and elderly subjects ccording to gender

Parameters (unit)	Adults (n = 100)		Elderly (n = 100)	
	Men (n = 49)	Women (n = 51)	Men (n = 47)	Women (n = 53)
Arm span (cm)	0.86*	0.90*	0.78*	0.72*
Half arm span (cm)	0.84*	0.89*	0.77*	0.67*
Demi span (cm)	0.85*	0.83*	0.76*	0.70*
Knee height (cm)	0.81*	0.84*	0.75*	0.70*

*$P<0.05$

These findings are in agreement with earlier studies that reported a higher correlation between height with long bones such as arm span[17] (r = 0.933 between arm span and height of adult subjects). Knee height amongst adult and elderly men showed the lowest correlation. This finding is in agreement with an earlier study among Japanese Americans[19] which demonstrated a rather similar value (r=0.78, $P<0.01$).

Table 6 presents sex specific predictive equations to estimate height from arm span, demi span and knee height derived from adult subjects in this study. The highest r^2 was obtained from the equation developed from arm span. Arm span also showed the lowest SEE value suggesting less measurement error. There was no increment in r^2 value when age was included as an independent variable.

When the equations were used to estimate the height of elderly subjects, it was found that the percentage of difference between the actual standing height and the estimated height (from arm span, demi span and knee height) ranged between 1 to 3%, with arm span being the lowest (Table 7).

Table 8 presents a comparison of estimated height computed from the equations derived in the present study with those calculated using equations developed from other populations. It appears that height estimated from equations derived from other populations tend to overestimate height derived from equations developed in this study, except for knee height. Estimated height from arm span from equations developed for Afro-Carribbean and Asian[16] showed the lowest difference. The regression equations developed for the Afro-Carribeans [Height = 54.9 + (0.66 x Arm span) for men and Height = 66.9 + (0.57 x Arm span) for women][16] and for the Asians [Height = 53.4 + (0.67 x Arm span) for men and Height = 81.0 + (0.48 x Arm span) for women][16] were rather similar to those developed in this study, as shown in Table 6. Whereas, estimated height from arm span from equations developed for Caucasian populations[18] was consistently higher than height estimated from equations developed in this study. The differences may be due to variation in body composition and stature among ethnic groups, i.e. tall versus short statured populations.[23,24]

This study has developed gender specific equations to estimate height from arm span, knee height and demi span for use amongst Malaysian elderly or adults for whom accurate measurement of standing height is not possible.

Table 6. Equations for estimation of standing height according to gender

Gender	Equation	Value of r^2	SEE
Men (n = 49)	H= (0.681 x AS) + 47.56	0.75	3.04
	H= (1.438 x DS) + 51.28	0.72	3.18
	H= (1.924 x KH) + 69.38	0.66	3.51
Women (n = 51)	H= (0.851 x AS) + 18.78	0.81	2.66
	H= (1.549 x DS) + 41.35	0.70	3.41
	H= (2.225 x KH) + 50.25	0.70	3.40

H- Height; AS- arm span; DS-demi span; KH-knee height.

Table 7. Percentage of difference (%) between actual standing height & estimated height in elderly subjects according to gender

Parameters	Elderly men (n = 47)		Elderly women (n = 53)	
	Height (mean ± SD)	% difference[a]	Height (mean ± SD)	% difference
Actual height	160.4 ± 5.5	-	148.5 ± 6.4	-
Estimated height:				
Arm span	162.1 ± 4.9	1.0	150.3 ± 5.8	1.3
Demi span	162.9 ± 5.0	1.6	151.3 ± 5.3	2.0
Knee height	164.0 ± 4.2	2.3	153.2 ± 4.8	3.3

[a]%difference =[(estimated height - actual standing height)/actual standing height] x100

Table 8. A comparison between estimated height among elderly subjects derived from equations developed in the present study and others.

Population of study	Men (n = 47)		Women (n = 53)	
	Estimated height (mean ± SD)	% difference[a]	Estimated height (mean ± SD)	% difference[a]
Arm span				
Present study	165.2 ± 5.1	-	152.9 ± 5.5	-
Afro- Caribbean	168.9 ± 5.0*	2.3	156.7 ± 3.7*	2.6
Asian	169.1 ± 5.1*	2.4	156.7 ± 3.1*	2.5
Caucasian	173.1 ± 5.7*	4.8	160.4 ± 5.2*	4.9
Oriental	170.5 ± 5.6*	3.2	157.5 ± 4.5*	3.0
Demi span				
Present study	165.3 ± 5.1	-	152.9 ± 5.1	-
Caucasian	168.8 ± 4.9*	2.1	157.3 ± 4.4*	2.9
Knee height				
Present study	165.2 ± 4.8	-	152.9 ± 5.1	-
Caucasian	162.6 ± 5.2*	-1.6	163.1 ± 4.4*	6.7
Black	164.0 ± 3.4*	-0.7	149.1 ± 4.5*	-2.4

*P< 0.05, significance difference between mean values of estimated height in the present study and other, independent sample t-test
[a] % difference = [(estimated height from equation of other study – estimated height from equation of the present study) ÷ estimated height from equation of

Acknowledgements
We are grateful to the subjects who participated in this study, Miss Jamie, staff of Klinik Warga Hospital Universiti Kebangsaan Malaysia, Klinik Bagan Terap, Rumah Seri Kenangan Taiping, Rumah Seri Kenangan Seremban and Department of Nutrition and Dietetics, UKM. Special thanks to Cik Nor Zakiah for her statistical advice.

References

1. McPherson JR, Lancaster DR, Carroll JC. Stature change with aging in Black Americans. J Gerontology 1978; 33 (1): 20-25.
2. Chumlea WC, Guo S, Wholihan K, Cockram D, Kuczmarski RJ, Johnson CL. Stature prediction equations for elderly non-Hispanic white, non-Hispanic black and Mexican-American persons developed from NHANES III data. J Am Diet Assoc 1998; 98: 137-142.
3. Hurley RS, Bartlett BJ, Witt DD, Thomas A, Taylor EZ. Comparative evaluation of body composition in medically stable elderly. J Am Diet Assoc 1997; 97: 1105-1109.

4. Roubenoff R, Wilson PWF. Advantage of knee height over height as an index of stature in expression of body composition in adults. Am J Clin Nutr 1993; 57: 609-613.
5. Kuchmarski RJ. Need for body composition information in elderly subjects. Am J Clin Nutr 1989; 50: 1150-1157.
6. Prothro JW , Rosenbloom CA. Physical measurements in an elderly black population: knee height as the dominant indicator of stature. J Gerontology 1993; 48 (1): 15-18.
7. Lehmann AB, Bassey EJ. Longitudinal weight changes over four years and associated health factors in 629 men and women aged over 65. Eur J Clin Nutr 1996; 50: 6 – 11.
8. Suzana S, Artineh, Suriah AR. A 4 year follow up on anthropometric and mortality among rural elderly Malays. Paper Presented at the 15th. Scientific Conference of Nutrition Society of Malaysia. Kuala Lumpur: Nutrition Society of Malaysia, March 2000; 1
9. Bermudez OI, Becker EK, Tucker KL. Development of sex-specific equations for estimating stature of frail elderly Hispanic living in the North Eastern United States. Am J Clin Nutr 1999; 69: 992-998.
10. Cockram DB, Baumgartner RN. Evaluation of accuracy and reliability of calipers for measuring recumbent knee height in elderly people. Am J Clin Nutr 1990; 52: 397-400.
11. Muncie HL, Sobal J, Hoopes JM, Tenney JH, Warren JW. A practical method of estimating stature of bedridden female nursing home patients. J Am Geriatr Soc 1987; 35: 285-289.
12. Mitchell Co, Lipschitz DA. Detection of protein-calorie malnutrition in the elderly. Am J Clin Nutr 1982; 35: 398-406.
13. Chumlea WC, Roche AF, Steinbaugh ML. Estimating stature from knee height for persons 60-90 years of age. J Am Geriatr Soc 1985; 33: 116-120.
14. Chumlea WC, Guo S. Equations for predicting stature in White and Black elderly individuals. J Gerontology 1992; 47 (6): M197-M203.
15. Aggarwal AN, Gupta D, Jindal SK. Interpreting spirometric data: impact of substitution of arm span for standing height in adults from North India. Chest 1999; 115 (2): 557.
16. Reeves SL, Varakamin C, Henry CJK. The relationship between arm span measurement and height with special reference to gender and ethnicity. Eur J Clin Nutr 1996; 50 (6): 398-400.
17. Brown JK, Whittemore KT, Knapp TR. Is arm span an accurate measure of height in young middle-age adults? Clin Nursing Res 2000; 9 (1): 84-94.
18. Bassey EJ. Demi span as a measure of skeletal size. Ann Hum Biol 1986; 13(5): 499-502.
19. Myers SA, Takiguchi S, Yu M. Stature estimated from knee height in elderly Japanese Americans. J Am Geriatr Soc 1994; 42: 157-160.
20. Karim HA. The elderly in Malaysia: demographic trends. Med J Malaysia 1997; 52 (3): 206-212.
21. Ridgard JE. A cross sectional study of the body size and composition and physical activity levels of adult and elderly Malays living in a rural area of West Coast of Malaysia. M Med Sci Thesis. Sheffield, UK: University of Sheffield, 1998.
22. Fidanza F. Anthropometric methodology. In Fidanza F (ed). Nutritional status assessment. London: Chapman & Hall, 1991; 1-6.
23. Bhatnagar DP, Thapar SP, Batish MK. Identification of personal height from the somatometry of the hand in Punjabi males. Forensic Sci Inter 1984; 24: 137-141.
24. Attallah NL, Marshall WA. The estimation of stature from anthropometric and photogrammetric measurements of the limbs. Medical Sci Law 1986; 26 (1): 53-59.
25. Trotter M, Gleser G. The effect of ageing on stature. Am J Phys Anthropometry 1951; 9: 311-324.
26. Steele MF, Chenier TC. Armspan, height and age in black and White women. Ann Hum Biol 1990; 17 (6): 533 – 541.