Long-bone Measurement for Height Estimation in Thai Adult Subjects

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Abstract

Four hundred medical inpatients admitted to Chulalongkorn University Hospital between February 1994 and January 1995 were recruited in a study which aimed to compare a number of long-bone measurements, in both the erect and supine position, with height and to reveal clinical appropriateness of long-bone measurements for predicting height and BMI in the Thai adult population. Armspan in both supine and erect positions, halfspan in both supine and erect position, and knee-to-floor height correlated best with height. The armspan and halfspan were shown to be reliable as a direct estimate for height in Thai adult subjects. The BMIs calculated from the armspan or 2 x halfspan differed slightly from the BMI of height and were appropriate for nutritional assessment in clinical practice. For frail patients whose armspan and halfspan was not able to be measured, the knee-to-floor height is an alternative long-bone measurement for height prediction.

Height is an essential variable for calculating body mass index (BMI) which has been widely used for nutritional assessment[1-5]. Unfortunately, the use of BMI is limited by measurement of height in many immobile and kyphoscoliosis patients. This limitation is not uncommon in the elderly which makes nutritional assessment more difficult. Armspan and many long-bone lengths have been investigated for height estimation[6-13] and various height-predicted formulas or nomograms have been reported. However, the previous studies paid more attention to statistical significance of height prediction than to clinical significance of BMI estimation which is a desirable index calculated from weight and height. The present study aimed to compare a number of long-bone measurements in both the erect and supine position with height and to reveal clinical appropriateness of long-bone measurements for height and BMI prediction in the Thai adult population.

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SUBJECTS AND METHOD

Four hundred medical inpatients admitted to Chulalongkorn University Hospital between February 1994 and January 1995 were studied. The subjects were able to ambulate without difficulty and were willing to participate in the study. Individuals with clinical evidence of kyphoscoliosis or edema from whatever cause were excluded. The weight and height of all subjects were measured using the same instrument. Length of long-bones was measured using a flexible tape on which a scale had been calibrated with a scale of the height-measuring instrument. All measurements were collected by a single observer (SM).

Measurement technique of height and other anthropological indices described in the reports of Haboubi(11) and Kwok(12) were used in this study. Height was read to the nearest millimeter while the subject stood upright against a wall with their head positioned in the Frankfurt plane. Armspan in the erect position (ASS) was measured with the subject standing erect with back against the wall and arms outstretched at right angles to the body with palms facing forward. The measurement was taken from fingertip to fingertip, passing in front of the clavicles. Arm span in the supine position (ASL) was measured with the subject lying on one pillow in bed and arms outstretched at right angles to the body with palms facing upward. The measurement was taken from fingertip to fingertip, passing in front of the clavicles. Left halfspan in the erect (HAL) and supine (HAS) positions were taken from the center of the sternal notch in the midline to the fingertip of the left hand while the subject was in the position of arm span measurement. Total arm length was taken from the tip of the acromial process to the end of the styloid process of the ulna on the left arm in both the erect position with arm hanging down (TAS) and the supine position while lying on one pillow (TAL). Upper-arm length was taken from the tip of the acromial process to the olecranon on the left arm in both the erect position with arm hanging down (UAS) and the supine position while lying on one pillow (UAL). Forearm length was taken from the olecranon to the styloid process of the ulna on the left arm in both the erect position with arm hanging down (FAS) and the supine position while lying on one pillow (FAL). The tibial length (TL) was taken from the proximal medial border of the tibia to the medial maleolus in the sitting position. The knee-to-floor height (KF) was taken from the anterior surface of the thigh to the floor with ankle and knee each flexed at a 90 degree angle in the sitting position. The reading of long-bone measurements was taken to the nearest millimeter. Body mass index (BMI) of height was defined as weight/height^2 (kg/m^2). Body mass index of predicted heights were defined as weight/(predicted height^2).

The correlation coefficients (r) between anthropometric indices were analysed. Multiple regression analysis was used to measure the relationship between height, age and each of the measured long-bone lengths in male and female subjects. Height-predicting formulas of long-bone length were obtained from the multiple regression models. Predicted heights of each long-bone lengths were calculated from these formulas. Conventional estimation of height by the armspan and the halfspan x 2 were also considered. BMI of these predicted heights were calculated. Mean, standard deviation and 95 per cent confident interval of the difference between BMI of height and the predicted BMIs were computed. Correlation coefficients (r) between BMI of height and BMIs of various predicted heights were obtained. Student *t* tests were used to compare the mean and standard deviations of different groups. SPSS programme was used for statistical analysis.

RESULTS

Mean age and its standard deviation (SD) of the 400 subjects recruited in the study were 48.3 and 15.7 years respectively. The minimum and maximum age were 15 and 79 respectively. One hundred and seven subjects (26.8%) were male of which their mean age (SD) was 50.2 (15.2) years. Two hundred and ninety three subjects (73.3%) were female of which their mean age (SD) was 47.6 (15.9) years. Thirty per cent of the subjects were aged 60 and over. Mean (SD) of height and various long-bone lengths by sex and age are shown in Table 1. Good correlation between height and most of the long-bone lengths was demonstrated (Table 2). The long-bone lengths which had good correlation coefficient (7 or more) in both male and female subjects were the ASL, ASS, HAL, HAS and KF. These 5 long-bone lengths were selected for further analysis. Correlation between height and other anthropometric indices in men was better than that in women. Better cor-

Table 1. Mean (standard deviation) of height and various long-bone lengths by sex and age*.

	All	Sex		Age group	
	subjects (N = 400)	Men (N = 107)	Women (N = 293)	Young subjects (N = 280)	Elderly subjects (N = 120)
Height (cm)	160.5 (6.7)	167.0 (6.6)	158.2 (5.0)	160.5 (6.8)	160.6 (6.6)
ASL (cm)	163.0 (8.1)	171.2 (8.0)	160.0 (5.6)	162.8 (8.1)	163.3 (7.9)
ASS (cm)	161.1 (8.1)	169.3 (7.9)	158.1 (5.8)	160.9 (8.1)	161.4 (8.0)
HAL (cm)	81.5 (4.2)	85.6 (4.1)	80.0 (3.0)	81.5 (4.1)	81.6 (4.3)
HAS (cm)	80.8 (4.1)	84.8 (4.2)	79.4 (3.0)	80.8 (4.2)	81.0 (4.0)
TAL (cm)	54.7 (3.6)	57.4 (3.2)	53.7 (3.2)	54.6 (3.7)	54.9 (3.3)
TAS (cm)	55.8 (3.4)	58.4 (3.3)	54.8 (2.9)	55.6 (3.4)	56.2 (3.3)
UAL (cm)	29.6 (2.4)	31.2 (2.2)	29.1 (2.2)	29.5 (2.3)	29.9 (2.5)
UAS (cm)	30.8 (2.5)	32.1 (2.5)	30.4 (2.3)	30.7 (2.5)	31.2 (2.3)
FAL (cm)	25.7 (1.7)	27.0 (1.8)	25.3 (1.3)	25.7 (1.7)	25.8 (1.6)
FAS (cm)	25.9 (1.7)	27.2 (1.7)	25.4 (1.3)	25.8 (1.7)	26.0 (1.6)
TL (cm)	41.3 (3.3)	43.0 (3.4)	40.6 (3.1)	41.2 (3.4)	41.5 (3.3)
KF (cm)	48.5 (2.5)	50.5 (2.7)	47.8 (2.0)	48.6 (2.5)	48.5 (2.6)

*Detail of abbreviated names - see text

Table 2. Correlation between height and long-bone length in all subjects and by sex and age.

	Correlation with height				
	All subjects	Men	Women	Age 15-59 years	Age 60 years and over
ASL	0.8841*	0.8592*	0.7947*	0.8897*	0.8715*
ASS	0.8848*	0.8673*	0.7921*	0.8931*	0.8656*
HAL	0.8472*	0.8449*	0.7175*	0.8788*	0.7767*
HAS	0.8653*	0.8385*	0.7706*	0.8639*	0.8701*
TAL	0.7280*	0.7739*	0.5854*	0.7105*	0.7809*
TAS	0.7186*	0.6428*	0.6109*	0.7142	0.7363*
UAL	0.5953*	0.5607*	0.4536*	0.6464*	0.4873*
UAS	0.5045*	0.3438*	0.4641*	0.5104*	0.4983*
FAL	0.6585*	0.5600*	0.5260*	0.6302*	0.7294*
FAS	0.7221*	0.6687*	0.5950*	0.7084*	0.7597*
TL	0.5116*	0.4166*	0.4351*	0.4986*	0.5462*
KF	0.8273*	0.8304*	0.7295*	0.8466*	0.7863*

* $p < 0.001$

Table 3. Height-predicted formulas by using long-bone length of male and female subjects which were obtained from multiple regression analysis.

Long-bone measurement	Men	Women
ASL	0.7 [ASL] + 46.38	0.71 [ASL] + 44.77
ASS	0.72 [ASS] + 44.32	0.69 [ASL] + 49.01
HAL	1.34 [HAL] + 52.29	1.18 [HAL] + 63.74
HAS	1.3 [HAS] + 56.69	1.28 [HAS] + 56.49
KF	2.01 [KF] + 65.16	1.81 [KF] + 71.61

Table 4. Mean, standard deviation (SD) and 95% confidence interval (95% CI) of the differences between body mass index calculated from height and body mass index calculated from various long-bone lengths*.

	All subjects			Men			Women		
Differences of BMIs	Mean	(SD)	95% CI	Mean	(SD)	95% CI	Mean	(SD)	95% CI
BMI(HT)-BMI(ASL)**	0.58	(0.9)	(0.48) - (0.67)	0.9	(0.9)	(0.71) - (1.08)	0.46	(0.9)	(0.36) - (0.56)
BMI(HT)-BMI(ASS)**	0.09	(1)	(-0.01) - (0.18)	0.47	(1)	(0.28) - (0.66)	-0.06	(1)	(-0.17) - (0.05)
BMI(HT)-BMI(2HAL)***	0.58	(1.2)	(0.46) - (0.71)	0.9	(1)	(0.71) - (1.1)	0.47	(1.3)	(0.32) - (0.62)
BMI(HT)-BMI(2HAS)***	0.25	(1.1)	(0.14) - (0.35)	0.54	(1.1)	(0.33) - (0.75)	0.14	(1)	(0.02) - (0.26)
BMI(HT)-BMI(f-ASL)****	-0.06	(0.82)	(-0.14) - (0.02)	-0.23	(0.8)	(-0.39) - (-0.08)	0.0	(0.8)	(0.09) - (0.09)
BMI(HT)-BMI(f-ASS)***	-0.08	(0.8)	(-0.16) - (0.00)	-0.28	(0.8)	(-0.44) - (-0.13)	-0.01	(0.8)	(-0.1) - (0.09)
BMI(HT)-BMI(f-HAL)**	0.15	(1)	(-0.25) - (0.06)	-0.56	(0.8)	(-0.72) - (-0.4)	-0.0	(1)	(-0.12) - (0.11)
BMI(HT)-BMI(f-HAS)**	-0.13	(0.9)	(-0.22) - (-0.04)	-0.48	(0.9)	(-0.64) - (-0.31)	-0.0	(0.85)	(-0.1) - (0.09)
BMI(HT)-BMI(f-KF)**	-0.24	(1)	(-0.34) - (-0.15)	-0.95	(0.9)	(-1.12) - (-0.78)	0.01	(0.92)	(-0.09) - (0.12)

* Detail of abbreviated names - see text

** Statistical significance for sex difference ($p < 0.000$); no statistical significance between young and elderly subjects

*** Statistical significance for sex difference ($p < 0.005$); no statistical significance between young and elderly subjects

**** Statistical significance for sex difference ($p = 0.01$); no statistical significance between young and elderly subjects relation between height and other anthropometric indices of young subjects, compared to those of the elderly subjects, was also demonstrated (Table 2). Height-predicted formulas of selected long-bone lengths in male and female subgroups were obtained from multiple regression analysis (Table 3). Age was not an independent variable of height and not recruited in these formulas.

Predicted height derived from formulas of the ASL, ASS, HAL HAS and KF were used for computing BMI. Abbreviated names were used including BMI(f-ASL), BMI(f-ASS), BMI(f-HAL), BMI(f-HAS) and BMI(f-KF) for the BMI calculated by the predicted height of the ASL, ASS, HAL, HAS and KF respectively. The ASL and ASS were directly used as estimated height of the subjects and abbreviated names of the BMI calculated from these estimated heights used in this report were BMI(ASL) and BMI(ASS) respectively. Twice the HAL and HAS were also used as estimated heights and the BMI calculated from these height estimations were computed. Abbreviated names for them were BMI(2HAL) and BMI(2HAS) respectively. Abbreviated name for BMI of height was BMI(HT).

The differences between the BMI calculated from height and the BMIs calculated from long-bone lengths were computed. Mean, standard deviation and 95 per cent confident interval of the BMI-differences are shown in Table 4. Almost all 95 per cent confident intervals of the BMI-differences were within the range of the -1 to 1 kg/m^2 in both men and women subgroups. There was a statistically significant difference between the BMI-differences of male and those of female subjects. However, no statistically significant difference between the BMI-differences of young and those of aged subjects. Correlation coefficients of correlation between the BMI(HT) and those of selected long-bone lengths were excellent (Table 5).

Table 5. Correlation between body mass index calculated from height and body mass index calculated from various long-bone length* in all subjects.

	Correlation coefficient
BMI(ASL)	0.9552**
BMI(ASS)	0.9547**
BMI(2HAL)	0.9241**
BMI(2HAS)	0.9443**
BMI(f-ASL)	0.9652**
BMI(f-ASS)	0.9649**
BMI(f-HAL)	0.9501**
BMI(f-HAS)	0.9592**
BMI(f-KF)	0.9442**

* Detail of abbreviated names - see text
** $p < 0.001$

DISCUSSION

This study demonstrated that only the ASL, ASS, HAL, HAS and KF have good correlation with height in both male and female subjects. Both armspans measured in supine and erect positions had the best correlation with height and confirmed that armspan approximates to height at maturity(14,15). Correlation in men and young subjects was better than that in women and elderly subjects. The differences between correlation coefficients in men and women were considerably wider than the differences between correlation coefficients in young and elderly subjects. Thus, we decided to perform a multiple regression analysis in men and women separately. We also considered only the ASL, ASS, HAL, HAS and KF in further analysis.

Age was not included in the multiple regression models suggesting that age was not an independent factor of height in this population. A probable explanation is that subjects in this study were relatively young whose height reduction was not significant. Because it takes a 20-year period or more for a significant secular reduction of height in humans(16,17), association between age and height might be obscured in a relatively young population. Similar results were shown in other studies(12,18). In the present study, subjects with clinical evidence of kyphoscoliosis were not included (most of them were aged 70 years or more). Because the objective of this study was to determine the clinically appropriate long-bone measurements for height and BMI prediction in Thai adult subjects, it was reasonable that pathological confounders of height were excluded.

Because height is an essential variable for calculating body mass index (BMI) which has been widely used for nutritional assessment, effect on BMI should be of the most concern in evaluating clinical appropriateness of any predicted height. For this reason, difference between the BMI(HT) and the predicted BMIs from various long-bone measurements were considered. It was clearly shown in this study that the differences between the BMI(HT) and the other predicted BMIs were rather small and was not clinically significant for using these predicted BMI instead of the BMI(HT) in nutritional assessment. It also suggested that there was no clinical advantage in using the formulas from the multiple regression model over the simple use of armspan or 2 x halfspan. Therefore, estimated height directly from the ASL, ASS, HAL and HAS are practical in clinical practice. However, it has been shown that the KF is more feasible for measuring than the armspan in frail elderly patients(19). Thus, the KF and its formula for predicting height would be an alternative method in frail subjects. Excellent correlation between the predicted BMI and the BMI(HT) was demonstrated in this study and confirmed the clinical value of using these long-bone lengths for predicting height in clinical practice.

In conclusion, the armspan and halfspan are reliable estimates for height in Thai adult subjects. There is no need to use any formula or nomogram. The BMIs calculated from the armspan or halfspan correlate well with the BMI of height and are appropriate for nutritional assessment in clinical practice. For frail patients whose armspan and halfspan are not able to be measured, the knee-to-floor height is an alternative long-bone measurement for height prediction.

SUMMARY

Four hundred medical inpatients admitted to Chulalongkorn University Hospital between February 1994 and January 1995 were recruited in a study which aimed to compare a number of long-bone measurements, in both the erect and supine position, with height and to reveal clinical appropriateness of long-bone measurements for predicting height and BMI in the Thai adult population. Armspan in both supine and erect positions, halfspan in both supine and erect positions, and knee-to-floor height correlated best with height. The armspan and halfspan were shown to be reliable as a direct estimate for height in Thai adult subjects. The BMIs calculated from the armspan or 2 x halfspan differed slightly from the BMI of height and were appropriate for nutritional assessment in clinical practice. For frail patients whose armspan and halfspan are not able to be measured, the knee-to-floor height is an alternative long-bone measurement for height prediction.

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REFERENCES

1. Abernathy RP, Black DR. Healthy body weights: an alternative perspective. Am J Clin Nutr 1996; 63(suppl): 448S-51S.
2. Keys A, Findaza F, Karvonen MJ, Kimura N, Taylor HL. Indices of relative weight and obesity. J Chr Dis 1972; 25: 329-43.
3. Garrow JS. Indices of adiposity. Nutr Abstr Rev 1983; 53: 697-708.
4. Simopoulos AP. Characteristics of obesity: an overview. Ann NY Acad Sci 1987; 409: 4-13.
5. Report of a WHO Study Group. Diet, nutrition, and the prevention of chronic disease. WHO Tech Rep Ser 797. Geneva: WHO, 1990.
6. Buri PS, Hathirat S, Suvachittanont O, Watthanakasetr S. Weight-height indices in Thai adults. Siriraj Hosp Gaz 1985; 37: 693-700.
7. Steel MF, Chenier TC. Arm span, height, and age in Black and White women. Ann Hum Biol 1990; 17: 533-41.
8. Jarzem PF, Gledhill RB. Predicting height from arm measurements. J Pediatr Orthop 1993; 13: 761-5.
9. Chumlea WC, Roche AF, Steinbaugh ML. Estimating stature from knee height for persons 60 to 90 years of age. J Am Geriatr Soc 1985; 33: 116-20.
10. Mitchell CO, Lipschitz DA. Arm length measurement as an alternative to height in nutritional assessment of the elderly. J Parenter Enter Nutr 1982; 6: 226-9.
11. Haboubi NY, Hudson PR, Pathy MS. Measurement of height in the elderly. J Am Geriatr Soc 1990; 38: 1008-10.
12. Kwok T, Whitelaw MN. The use of armapan in nutritional assessment of the elderly. J Am Geriatr Soc 1991; 39: 492-6.

13. Piette F, Queruel D, Jean A, et al. Estimation chez le sujet age de la taille maximale atteinte au cours de la vie. Rev Geriatr 1990; 15: 69-72.
14. Harris JA, Jackson CM, Paterson DG, Scammon RE. The Measurement of Man. Minnesota: University Press 1930: 82.
15. Brown OT, Wigzell FW. The significance of span as a clinical measurement. In: Anderson WF, Issacs B, eds. Current Achievements in Geriatrics. London: Cassell Press, 1964: 246-51.
16. van Leer EM, van Noord PA, Seidell JC. Components of adult height and height loss. Secular trend and effects of aging in women in the DOM project. Ann Epidemiol 1992; 2: 611-5.
17. Mc Pherson JR, Lancaster DR, Carroll JC. Stature change with aging in Black Americans. J Gerontol 1978; 33: 20-5.
18. Allen SC. The relation between height, armspan, and forced expiratory volume in elderly women. Age Ageing 1989; 18: 113-6.
19. Berkhout AM, Cools HJ, Mulder JD. Measurement or estimation of body length in older nursing home patients. Tijdschr Gerontol Geriatr 1989; 20: 211-4.

การวัดความยาวกระดูกเพื่อประมาณความสูงของประชากรผู้ใหญ่ไทย

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ผู้ป่วยในแผนกอายุรศาสตร์ของโรงพยาบาลจุฬาลงกรณ์จำนวน 400 คนได้เข้าร่วมการศึกษาที่มีจุดมุ่งหมายเปรียบเทียบค่าที่ได้จากการวัดความยาวกระดูกในตำแหน่งต่าง ๆ ทั้งท่านอนและท่ายืนกับความสูงเพื่อค้นหาความเหมาะสมของการใช้ค่าความยาวกระดูกในการทำนายความสูงของประชากรผู้ใหญ่ไทย จากการศึกษาพบว่าค่า armspan ทั้งในท่านอนและยืน ค่า halfspan ทั้งในท่านอนและยืน และค่า knee-to-floor height มีความสัมพันธ์กับความสูงดีที่สุด ยังพบว่าค่า armspan และ halfspan ที่ใช้ประมาณความสูงโดยตรงโดยไม่ใช้การคำนวนจากสมการเฉพาะมีความน่าเชื่อถือสูง นอกจากนี้ค่า body mass index ที่คำนวนจากค่า armspan หรือ 2 เท่าของค่า halfspan มีความแตกต่างเพียงเล็กน้อยจากค่า body mass index ที่คำนวนจากความสูง สำหรับผู้ป่วยที่ทุพพลภาพมากที่ไม่สามารถวัดความสูงและไม่สามารถวัดค่า armspan หรือ halfspam ได้การวัดค่า knee-to-floor height สามารถใช้ทดแทนในการประมาณความสูง

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