Original Article

Determining the predictive equation for height from ulnar length in the Vietnamese population

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Background and Objectives: Height is an essential measurement in clinical medicine. It allows the calculation of body mass index, ideal body weight, basic energy requirements and tidal volumes. In many patient groups, such as the critically ill, height cannot be measured easily and surrogate anthropometric measures are used. Regression equations estimating height are specific to ethnicity. We aimed to develop the regression equation for Vietnamese men and women to predict height from ulna length and so improve prescription of life-saving treatment in the intensive care units. **Methods and Study Design:** A cross-sectional survey of patients and relatives at the National Hospital for Tropical Diseases was undertaken. Ulna length, standing height and weight were measured. The first two thirds of participants' data, stratified by sex and age, were allocated to a model training group, the subsequent participants entered the validation group. Linear regression equations were calculated for the model group by sex, then applied to the validation group and assessed for precision. Other international equations were also compared. **Results:** 498 males and 496 females were recruited. There was good correlation between ulna length and height in those aged 21-64, r=0.66, $p<0.001$ in males and females. The regression equations were: male: height = 85.61 + (3.16 x ulna length), female: height = 85.80 + (2.97 x ulna length). Equations from other populations were less accurate. **Conclusions:** The regression equations calculated for men and women aged 21-64 showed good correlation and can be used to predict height in those where direct measurement is impossible.

Key Words: height, ulna length, anthropometric, predict, Vietnamese

INTRODUCTION

Basic anthropometric measurements are essential in many areas of medicine. Height is necessary to calculate body mass index (BMI), body surface area and ideal body weight (IBW), which in critical care form the basis for the prescription of life-saving supportive treatments including medications, haemofiltration rates and ventilation parameters.[1] Height is usually measured using a stadiometer, however in severely injured, unconscious or sedated patients this is not possible. Even in those who can comply with standing, measurement of the height of inpatients is rarely performed due to lack of equipment or time.[2] Due to these difficulties the options available to clinicians are to use self-reported measurements, estimated measurements or surrogate measurements. There are obvious problems with self-reporting in critically ill patients and several studies have shown that clinicians' estimations of height and weight are often inaccurate, with errors of greater than 20% of patients' actual measurements occurring frequently.[3,4]

A variety of surrogate markers have been employed to estimate height, such as knee height, leg length, ulna length, hand length and demispan.[5-8] Of these, ulna length is the simplest and most reliable to perform and therefore has been adopted in different health settings for estimating height.[9,10]

In Viet Nam, an emerging economy in South East Asia, there has been a rapid expansion in the number of intensive care units (ICUs) and the ability to care for the critically ill.[11] Despite the growing expertise in many aspects of critical care, most units have no means of weighing patients or reliably measuring their height. Studies have demonstrated that the relationship between surrogate anthropometric measurements and predicted height varies with ethnicity.[12] In particular, measured height in Asian populations does not correlate well with predicted values based on linear regression equations derived from data from a predominantly White-British population.[13,14] The

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Manuscript received 23 March 2016. Initial review completed 07 June 2016. Revision accepted 13 August 2016.
doi: 10.6133/apjcn.012017.01

Vietnamese population remains one of the shortest in the world,[15] suggesting the need for population specific data.

In order to facilitate the deployment of lung protective ventilation strategies in Vietnamese ICUs and aid in accurate prescribing, both of which rely on an estimation of height, we have designed and implemented a study to determine the relationship between ulna length and height in the Vietnamese population.

METHODS

This is an observational cross-sectional survey of adult patients and relatives presenting to the outpatient department of the National Hospital of Tropical Medicine (NHTD), Hanoi between 19th November 2014 and 16th March 2015. Participants were recruited consecutively. Inclusion criteria were: age over 21, written consent, not in need of urgent medical attention, ability to stand, lack of spinal deformity, and lack of upper limb deformity or amputation.

The standard age classifications in adults of those from 21- 64 years and those 65 and above was used.[10,16]

Anthropometric measurements were taken by four trained research nurses. Height was measured using a standardized stadiometer. The study participants removed shoes, hats and hair ornaments and were asked to stand up straight and look straight ahead with their head in the Frankfurt plane. Weight was taken on a standard set of scales, with shoes removed for all participants. Ulna length was measured with standardized tape measures following training to ensure reliability of measurements. Participants were asked to uncover their left forearm and lay their forearm across their chest, touching their right shoulder. Measurements were taken from the olecranon to the mid-point of the styloid process.[10] Ulna lengths of 100 random participants (10% of participants) were measured twice by two separate research nurses who were blinded to each other's results in order to estimate inter-observer error.

Ethical approval (697/QD-NDTW) was granted by the National Hospital of Tropical Diseases (Hanoi) review board October 2014.

Statistical analyses were undertaken using STATA version 13. Data from the first two-thirds of participants recruited, after stratifying for age and sex, were used in a training model group, the subsequent third of the participants were the validation group. Age was summarized as median (range) as non-parametric, other parametric variables were summarized as mean (standard deviation). Anthropometric data between the training and the validation group were compared using unpaired student-t test. Linear regression of height on ulna length was conducted to give sex and age specific prediction equations. Age was categorized as <65 vs ≥65 years in line with the Malnutrition Universal Screening Tool (MUST). The linear regression equations from the training model were applied to the validation groups. This was compared to predictions from available linear regression equations from other Asian populations (i.e. Bengali females 21-65) and the widely used White-British linear regression equation – MUST, defined as:

Bengali:

- Female <65 years: height = 45.89 + 4.39 * ulna length[17]

MUST:

- Male <65 years: height = 79.2 + 3.60 * ulna length
- Female <65 years: height = 95.6 + 2.77 * ulna length[10]

The linear regression equations were then applied to the validation group, by sex. The precision was calculated by calculating the mean bias, (differences between mean predicted heights and mean measured heights). The 95% limit of agreement was calculated following the Bland-Altman method (difference in mean error +/– 1.96*SD). This method was also used to evaluate the precision of international equations (MUST and Bengali) as applied to the validation group.

The inter observer error of ulna measurements was calculated using the relative Technical Error of Measurement (TEM) presented as a percentage. This is in keeping with international standards set by the World Health Organisation.[18] The following equations were used:

Equation 1:

$$\text{Absolute TEM} = \sqrt{\frac{\Sigma d_i^2}{2n}}$$

Where:

Σd2 = the square of the summation of the difference (deviations) between the first and second measurement

i = number of deviations

n = number of participants measured

Equation 2:

$$\text{Relative TEM} = \frac{\text{Absolute TEM}}{\text{VAV}} \times 100$$

Where:

VAV = variable average value (the mean of the mean of the 1st and 2nd measurement taken)[19]

RESULTS

1000 individuals were recruited, 5 were excluded as they were below 21 years and there was incomplete data on 1. The median (mean) age was 36.2 (38.6) years, with 32 patients aged over 65 years (16 men and 16 women). As the recruitment into the over 65 years was so limited, these 32 participants have not been included in further analysis, leaving the final total as 962. Anthropometric measurements by sex and model category are summarized in Table 1.

The correlation coefficient (r) between ulna length and height was 0.66 (p value <0.001) in both males and females. The precision (root mean-squared error) of predictions based on the linear regression model ranged from ±3.82 to ±4.40 cm, see Figure 1 for graphical representation of correlation between ulna length and height by sex. The calculated regression equations for the model training group were:

Male: height (cm) = 85.61 + (3.16 x ulna length)

Female: height (cm) = 85.80 + (2.97 x ulna length)

The mean bias in the validation group was 0.77 cm and 0.71 cm for males and females respectively. In comparison, White-British based data (MUST equation) was less precise and systematically over-estimated the true height with an average bias of 5.59 and 5.80 cm in males and females respectively (Table 2). When the Bengali regression equation was applied to the validation sample, it un-

Table 1. Comparison between age, weight, height, BMI and ulna length in the training model group and the validation group by sex

	Training model	Validation	*p* value
Women			
n	320	160	
Age (median; range)	33.0 (21.0-64.9)	35.2 (21.1-63.1)	0.07
Weight kg(mean; SD)	51.0 (6.4)	51.5 (6.9)	0.42
Height cm (mean; SD)	154.9 (5.1)	154.9 (5.1)	0.92
BMI kg/m^2(mean; SD)	21.3 (2.4)	21.5 (2.6)	0.41
Ulna Length cm (mean; SD)	23.2 (1.1)	23.5 (1.2)	0.02
Men			
n	320	162	
Age (median; range)	38.2 (21.0-64.9)	36.3 (21.1-64.2)	0.19
Weight kg(mean; SD)	61.5 (8.2)	61.8 (8.5)	0.65
Height cm (mean; SD)	165.9 (5.8)	165.5 (5.9)	0.45
BMI kg/m^2(mean; SD)	22.3 (2.6)	22.5 (2.6)	0.33
Ulna Length cm (mean; SD)	25.4 (1.2)	25.5 (1.2)	0.44

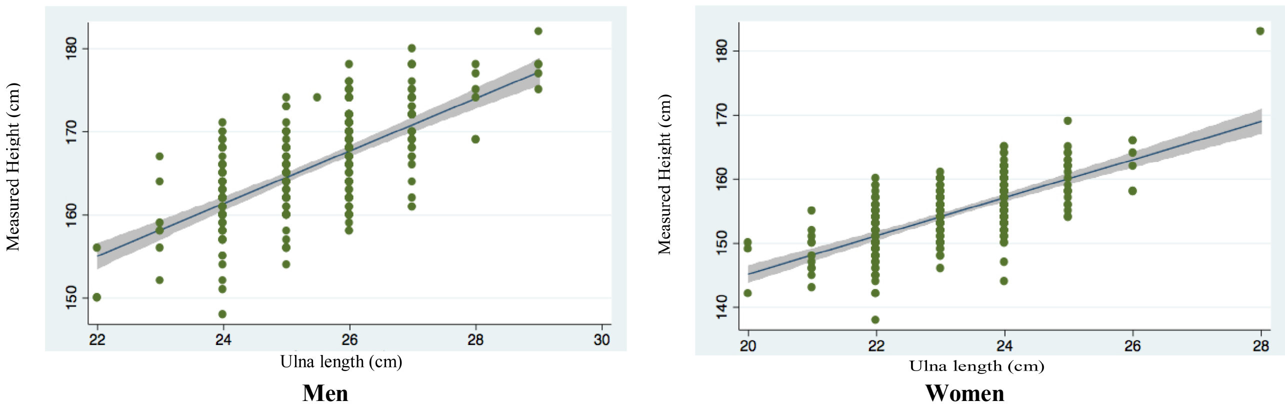

Figure 1. Relationship between height and ulna length by sex. Shaded area indicates 95% CI

der-estimated the true height of females with an average bias of -5.82 cm. See Figure 2 for a graphical representation of the correlation between ulna length and height by sex, with the MUST equation superimposed in males and the MUST and Bengali equation in females.

There was very good consistency in inter-observer measurements of the ulna length for the 107 subjects that were assessed: for 90 subjects, both measurements were identical, 16 differed by 1cm, and only one by 2 cm. The relative TEM was 1.45%.

DISCUSSION

We have shown good correlation between ulna length and height for Vietnamese adults between 21-64 years, both male and female. We have developed an accurate tool to predict height in those where it cannot be measured, as demonstrated by the precision of the model when applied to the validation group. This is in contrast to a previous study that postulated that ulna length and height in Asian women may not correlate well.[13] However this previous study included only 30 females of Asian background, from 3 different nationalities (Indian, Bangladeshi and Pakistani). We have also demonstrated that a commonly used regression equation from the White-British population (MUST) should not be used for the Vietnamese population, as this would lead to over estimation in height and potentially over prescription of medication and excessive ventilation, both of which can cause significant harm.[1] We have also demonstrated that the regression equation from Bengal cannot be applied to the Vietnamese population, as it would lead to under estimation of height. This study has shown that ulna length is a reliable and consistent measurement (TEM 1.45%). As it is rapidly and easily performed, it represents a highly practical clinical tool.

Surrogate anthropometric measurements have been used to estimate height for many years.[7] Data from the White-British population shows good correlation between other white ethnicities but inaccuracies when applied to other groups (Asian or Blacks).[12,20] There are several studies giving regression equations for different Asian nationalities, for example Malaysia, Thailand and China.[14,17,21,22] The average height for males in the Malaysian study was almost exactly the same as measured in this study (165.2 vs 165.8 cm in 21-64 and 160.4 vs 160.4 cm in ≥65) respectively, however Malaysian females were shorter than Vietnamese (152.9 vs 154.9 in 21-64 and 148.5 vs 153.7 cm in ≥65). The data from Thailand found a relatively low value for the correlation coefficient of height and ulna length (≤0.35 in all age and sex groups). It is unclear why this should be the case although environmental, nutritional and genetic factors may well be involved. Even comparing our data with that presented from Bengal, where the average height and ulna length are similar (153.83 cm and 24.46 cm vs 154.9 cm and 23.3 cm), when the linear regression equation developed

Table 2. Correlation between ulna length and height in the training model group and comparison with the validation group and other international equations

	Men	Women
Correlation between measured height and ulna length		
r	0.66	0.66
R^2	0.43	0.44
p value	<0.001	<0.001
Regression intercept		
a	85.61	85.80
95% CI	75.41-95.81	77.19-94.42
p value	<0.001	<0.001
Regression slope		
b	3.16	2.97
95% CI	2.76-3.56	2.60-3.34
p value	<0.001	<0.001
Root mean squared error of predictions (cm)	4.40	3.83
Comparison with validation group		
Mean bias (SD)	0.77 (4.10)	0.71 (3.84)
95% limit of agreement (cm)	-8.80; 7.26	-8.22; 8.77
Comparison with MUST equation		
Mean bias (SD)	5.59 (4.10)	5.80 (3.83)
95% limit of agreement (cm)	-13.62; 2.44	-13.30; 1.70
Comparison with Bengal equation		
Mean bias (SD)	-	-5.82 (4.31)
95% limit of agreement (cm)	-	-14.26; 2.63

Mean bias: mean of predicted height minus mean measured height (cm).

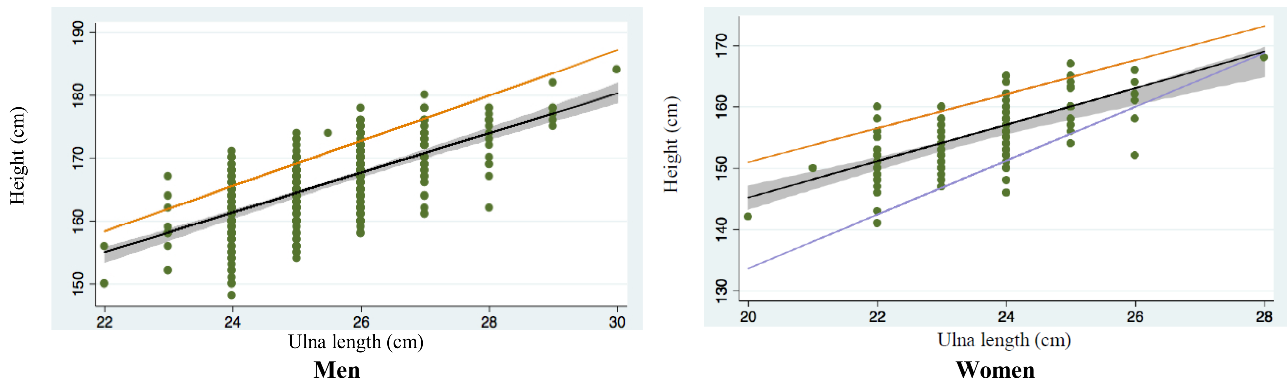

Figure 2. Measured height against ulna length by sex in validation group. Black line shows the model training group applied to the data. Orange line shows the MUST equation applied to the data. Lilac line shows the Bengali equation applied to the data. Shaded area is the 95% CI of the validation group.

from that data is applied to our data the results vary widely (see Figure 2). These studies from within Asia demonstrate that each ethnicity needs a specific equation to allow accurate prediction of height. This has interesting implications for persons of mixed heritage and a further study exploring the accuracy of different predictive equations for these individuals would be very informative.

A limitation of our study was that in the over 65 age group our sample size was too small to give a reliable equation. This was due to the age distribution of participants presenting to the NHTD with most patients or relatives being under 65. We also did not perform intra-observer error measurements for measured height and weight, which would add to the accuracy of the findings. Although the study was performed in only one site, this site receives patients from all of northern Vietnam, both urban and rural and by testing the model on an independent validation sample set we have demonstrated its generalizability. The equation should not be used in those adults with a history of chronic childhood illness, as amongst this group the relationship between ulna length and height may be disrupted, and in those with kyphosis, scoliosis or chest wall deformities.

In conclusion, ulna length is an easy and quick measurement that shows good reliability and can be used to accurately predict height in Vietnamese adults aged 21-65 using the equations presented here. A further study targeting Vietnamese adults aged over 65 years would provide useful further confirmation for that population.

ACKNOWLEDGEMENTS

We would like to thank all participants of the study and the staff of NHTD for making this study possible.

AUTHOR DISCLOSURES

Financial support was supplied by the Wellcome Trust of Great Britain through the major overseas program core grant. There are no conflicts of interest.

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