Original Article

Predicting stature from knee height in Chinese elderly subjects

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The main aim of this study was to validate the use of the Caucasian-based knee height equations for predicting stature of Chinese elderly subjects and to compare the predicted height to those estimated by equations derived from elderly subjects of Chinese origin. The study was performed by a survey by measurement of convenience samples. Twenty-one women and 26 men were recruited to validate the use of the Caucasian-based equations. The Chinese-based predictive equations were derived from 164 women and 89 men. The sample included ambulatory elderly subjects of Chinese origin, 60 years of age or older. These subjects were without spinal curvature and able to stand erect. Measurements were taken for height by a standard hospital scale. Calipers was used to measure knee height while the subject was in the sitting position. The measured stature and that predicted by the Caucasian-based equations were significantly different in Chinese elderly women but not in men. New regression models are being developed for the elderly Chinese population in Hong Kong. The relationship between stature, knee height and age appears to be ethnicity- and gender-dependent. While stature of elderly Chinese men can be estimated by either the Caucasian-based or Chinese-based equation, the regression model developed in the present study will better estimate the stature in elderly Chinese women.

Key words: Chinese elders, gender, Hong Kong, knee height, stature, validation.

Introduction

Hospital malnutrition is not uncommon, especially in geriatric patients.[1,2] The monitoring of nutritional status, diagnosis of malnutrition and the delivery of nutritional support often require the knowledge of the patient's stature. For instance, the calculation of body mass index and the estimation of metabolic rate depend on stature as a variable. Such a simple and non-invasive measurement, however, can be difficult to obtain from non-ambulatory patients, as well as those with spinal curvature. Over the years, knee height[3–5] and armspan[4–8] have been introduced as alternative measurements. According to Chumlea *et al.*[3] knee height is superior to armspan in stature estimation. However, the predictive equations were established on Caucasian subjects and there is evidence to suggest that, like armspan and height relationship,[8] knee height-to-stature (KH-S) equations are also ethnic-specific.[9] The objectives of the present study were to validate the use of the Caucasian-based KH-S equations in estimating stature and to develop ethnic-specific regression models for stature estimation in elderly Chinese.

Methods

Potential subjects were approached by the observers and the details of the measurements were given before verbal consent was sought. This procedure was approved by the Ethics Committee at the Haven of Hope Hospital.

Subjects

Subjects were of Chinese origin 60 years of age or older. They were either outpatients of the Ruttonjee Hospital or residents at the Hong Kong Society for the Aged (SAGE) Tsui Lam Hostel for the Elderly. Ailments of the outpatients were not related to disorders of bone, muscle or joints. All hostel residents were in good health. None of the participating subjects had spinal curvature. They were ambulatory and were able to stand erect without any support for height measurement. Twenty-one women and 26 men were initially recruited for the purpose of validating the Caucasian-based equations.[3] Subsequently, the regression models were based on 164 women and 89 men.

Procedure

Height was measured twice in cm by the height bar of a standard hospital scale (Seca, Hamburg, Germany). Subjects were standing straight on the scale without shoes and with

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the head positioned in the Frankfurt horizontal plane. While the subjects were in the sitting position, knee height of their left leg was measured twice, using knee height calipers (Ross Laboratory, OH, USA). The procedure outlined by Chumlea and Guo was followed.[4] Readings were recorded to the nearest 0.1 cm. All data were collected by two observers working independently.

Statistical analyses

The mean of two measurements was used in all calculations. Data are presented as means and standard deviations. Statistical analyses were performed on SPSS for Windows, Version 7.5 (SPSS, Chicago). Stature predicted by the regression equations of Chumlea and Guo was compared to measured height using paired *t*-test. Multiple regression analyses were performed to generate stature predictive equations using age and knee height as independent variables.

Results

The within-observer coefficient of variation (CV) for stature measurement was 0.16 and 0.17% for the two observers. The within-observer CV for knee height measurement was 0.18 and 0.3%, respectively. The between-observer CV for stature and knee height was 0.24 and 0.69%, respectively. The precision of measurement is in general agreement with that reported by Cockram and Baumgartner.[10]

The physical characteristics of our subjects are shown in Table 1. Results of validating the equations from Chumlea are shown in Table 2. A mean difference of 1.7 cm ($P < 0.025$) and 0.2 cm was observed for elderly women and men, respectively.

Regression models derived from the present study are shown in Table 3. In Chinese women, stature could be predicted by knee height and age in a linear regression model with an adjusted r^2 of 0.665 ($P < 0.001$). Knee height is the most important determinant ($t = 17.387$, $P < 0.001$), with a minor, yet significant, contribution from age ($t = 2.839$, $P = 0.005$). In men, knee height ($t = 12.361$, $P < 0.001$) was found to predict stature with an adjusted r^2 of 0.633 ($P < 0.001$). Quadratic and logistic models were also tested but offered no advantage over the linear model. Table 4 shows the results of using the initial 21 women and 26 men to verify the newly established equations for elderly Chinese.

Table 1. Physical characteristics of subjects

	Women	Men
Validation sample		
n	21	26
Age (years)	77.8 ± 6.5 (60–89)	77.3 ± 7.5 (64–92)
Height (cm)	148.1 ± 5.2 (136–156)	159.6 ± 7.2 (144–172)
Knee height (cm)	45.7 ± 1.9 (43–49)	48.4 ± 1.9 (45–52)
Chinese-based regression model		
n	164	89
Age (years)	77.7 ± 6.2 (64–97)	74.3 ± 6.0 (62–88)
Height (cm)	148.9 ± 5.7 (134–161)	161.4 ± 6.6 (142–175)
Knee height (cm)	45.5 ± 1.8 (40–51)	49.1 ± 2.4 (42–56)

Mean ± SD and range (in parenthesis).

Table 2. Validation of equations from Chumlea

	Women	Men
Stature (cm)		
Measured	148.1 ± 5.2	159.6 ± 7.2
Predicted*	149.8 ± 3.6	159.8 ± 4.3
Difference (predicted* – measured)	1.7 ± 3.2†	0.2 ± 4.6

Based on 21 women and 26 men. * The equations of Chumlea *et al.* were 84.88 + (1.83 × knee height) – (0.24 × age) for women and 60.65 + (2.04 × knee height) for men. † $t = 2.435$, $P < 0.025$, by paired *t*-test.

Discussion

Hospital malnutrition is an existing problem. About one-third of the patients in the geriatric ward of a general hospital in Hong Kong were found to be malnourished.[11] As part of the process to implement a more vigorous nutritional status-monitoring scheme, we examined the need to develop ethnic-specific stature predictive equations for non-ambulatory elderly Chinese. Our conclusion is consistent with that of Myers *et al.* in that race-specific models are necessary.[9]

In the validation sample, we found that the Caucasian-based equation significantly overestimated the body height of Chinese women by 1.7 cm (Table 2). This is in general agreement with the results of Myers *et al.* who found the equation to overpredict height of Japanese-American women by a mean of 1.5 cm.[9] The situation is somewhat different for men. While Myers *et al.* found the Chumlea *et al.* equation[3] to underpredict the height of Japanese-American men, the difference between measured and predicted height in the present study was not significant. Reasons for the discrepant results between studies remain to be elucidated, but likely relate to the differences in stature and in trunk-to-leg length among ethnic groups.[12]

Table 3. Equations for estimating stature in Chinese elderly subjects

	Women	Men
Estimate for age	–0.12	—
Estimate for knee height	2.46	2.24
Intercept	46.11	51.16
Adjusted r^2	0.665	0.633
Standard error of estimates	3.28	4.01

Based on 164 women and 89 men. In men, when both age and knee height were entered as independent variables, estimate for age was found to be –0.042 ($P = 0.56$).

Table 4. Validating the Chinese-based knee height to stature regression models

	Women	Men
Stature (cm)		
Predicted* – measured	0.9 ± 3.1	0.1 ± 4.4

Based on the initial 21 women and 26 men.* Predicting equations are 46.11 + (2.46 × knee height) – (0.12 × age) for women and 51.16 + (2.24 × knee height) for men.

Table 5. Impact of knee height and age on the differences in stature predicted by the Caucasian-based and the Chinese-based equations

	Age group Difference (cm) *		
Knee height (cm)	65 years old	75 years old	85 years old
39	6.4	5.2	4.0
41	5.1	3.9	2.7
43	3.9	2.7	1.5
45	2.6	1.4	0.2
47	1.4	0.2	–1.0
49	0.1	–1.1	–2.3
51	–1.2	–2.4	–3.6

* Caucasian-based minus Chinese-based estimated stature.

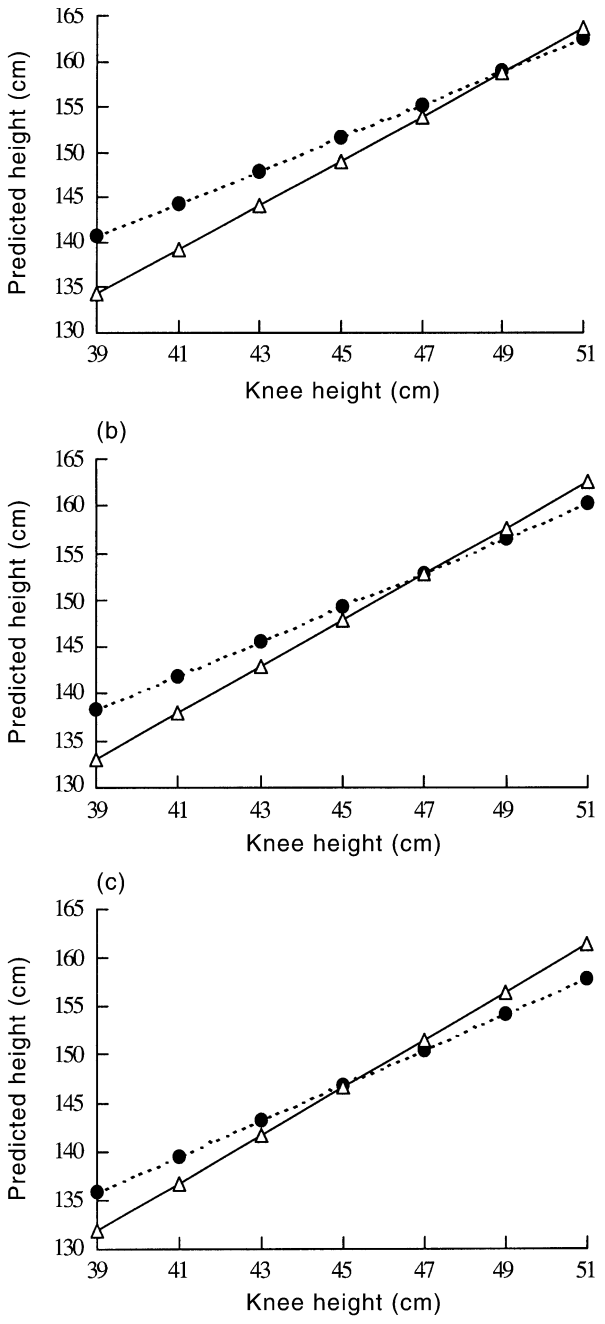

Figure 1. Plots of predicted height against knee height as a function of age in Chinese women. (a) For 65 years old, (b) 75 years old and (c) 85 years old. Predicted height was derived from the Caucasian-based (●) or the Chinese-based equation (Δ).

In women, the Chinese-based regression model gives more precise stature estimation than the Caucasian-based model. We believe that two factors might be important. First, relative to the Caucasian studies,[3,4] the current investigation mainly described women with shorter build. This can be deduced from the knee height data. The mean knee height of the study of Chumlea *et al.*[3] was 49.4 cm, but only 45.5 cm in the present study. In fact, one-third of the 164 women had knee height less than 44.8 cm, the mean minus 2 SD value of the Caucasian database. Since the mean height of our subjects is comparable to that obtained in large-scale surveys on Chinese populations,[13,14] the new equation will be suitable for elderly Chinese women.

The second factor might be an interacting effect of age and ethnicity. Age is a significant predictor for stature in women but not men. As the relationship between these two parameters is negative (Table 3), it highlights the possibility of a differential rate of stature loss with age among ethnic groups. Loss of height is a typical feature of osteoporosis, in which ethnicity is a recognized covariant.[15] Our analyses indicate that in women the magnitude of difference in stature prediction between the Caucasian-based equation and the Chinese-based equation is age-dependent. When predicted stature is plotted against knee height, the intercept of the two prediction lines moves to the left with increase in age (Fig. 1). Depending on the age and knee height, the difference in predicted height could be substantial, especially for those who are under 75 years old and with knee height less than 43 cm (Table 5).

Although our male subjects were also shorter in stature, we found the Caucasian-based equation to be a good predictor of stature of elderly Chinese men. This may be, in part, due to the lack of effect of age on stature in men. In the present study, the age parameter estimate for men was –0.042, which is similar to that reported in Caucasian men (–0.04).[3] Thus, under the current model, knee height becomes the only determinant for stature in men. In contrast to our findings, Myers *et al.* suggested that the Caucasian equation underpredicted height of men of Japanese origin.[9] The discrepancy may, in part, originate from the inclusion of age in their KH-S predictive equation. Their equation was derived from a small sample (n = 16) and age was also not a significant predictor for stature. We have a reservation in including age in the KH-S prediction equation for elderly men.

In summary, the relationship between stature, knee height and age appears to be ethnicity- and gender-dependent. Knee height is highly correlated to stature in both sexes. Age is also a predictor of stature in women, but not men. Non-ambulatory elderly women of Chinese origin should use the ethnic-specific regression equation to predict stature.

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