Development of Demi-span Equations for Predicting Height among the Malaysian Elderly

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ABSTRACT

Introduction: This study aimed to develop demi-span equations for predicting height in the Malaysian elderly and to explore the applicability of previous published demi-span equations derived from adult populations to the elderly. **Methods:** A cross-sectional study was conducted on Malaysian elderly aged 60 years and older. Subjects were residents of eight shelter homes in Peninsular Malaysia; 204 men and 124 women of Malay, Chinese and Indian ethnicity were included. Measurements of weight, height and demi-span were obtained using standard procedures. Statistical analyses were performed using SPSS version 18.0. **Results:** The demi-span equations obtained were as follows: Men: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age) + 4.13; Women: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age). Height predicted from these new equations demonstrated good agreement with measured height and no significant differences were found between the mean values of predicted and measured heights in either gender (*p*>0.05). However, the heights predicted from previous published adult-derived demi-span equations failed to yield good agreement with the measured height of the elderly; significant over-estimation and under-estimation of heights tended to occur (*p*>0.05). **Conclusion:** The new demi-span equations allow prediction of height with sufficient accuracy in the Malaysian elderly. However, further validation on other elderly samples is needed. Also, we recommend caution when using adult-derived demi-span equations to predict height in elderly people.

Keywords: Aged, body height, demi-span, Malaysia

INTRODUCTION

Height is an important determinant of several clinical parameters related to patient care, most of which rely on accurate recording of body weight and height. For example, in nutritional assessment, height is needed to calculate the body mass index (BMI), resting energy expenditure and creatinine height index. Height is also used to determine body surface area for drug dosage adjustment (Sawyer & Ratain, 2001) and to calculate renal clearance (Peters, Henderson & Lui, 2000). In addition, height is necessary for estimating body composition such as fat-free mass (Kyle *et al.*, 2004) and

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for predicting lung volumes (Singh, Singh & Sirisinghe, 1993). However, height measurement in the elderly may be affected by physiological changes in height and body composition that occur with normal ageing. Therefore, measurements of other body segments such as knee height, arm span, demi-span and ulna length have been proposed as alternative methods of predicting height in elderly people because the length of long bones is less affected by ageing (Mitchell & Lipschitz, 1982).

Among these surrogate measures of height, demi-span which is defined as the distance between the midpoint of the sternal notch and the finger roots with the arm outstretched laterally is becoming the preferred alternative measure of height in some nutritional studies for the elderly (Hughes *et al.*, 1995; Chan *et al.*, 2010; Nishiwaki *et al.,* 2011; Lorefält *et al.,* 2011). Demi-span has been used in national-level longitudinal studies (Morgan, 1998; Arai *et al.,* 2010; Gray *et al.,* 2010) and is included in nutrition screening tools such as the Mini Nutritional Assessment (MNA) and the Malnutrition Universal Screening Tool (MUST) to estimate height for BMI calculation when height measurement cannot be obtained (Guigoz, Vellas, & Garry, 1997; Todorovic *et al.,* 2003). The demi-span measurement has been chosen over other proxy measures of height in the Health Survey for England (HSE) and the Scottish Health Survey (SHeS) because it can be easily obtained without causing discomfort or distress (Bromley, Sproston & Shelton, 2005; Craig & Mindell, 2007).

The prediction of height from demi-span has been described by several investigators (Bassey, 1986; Suzana & Ng, 2003; Weinbrenner *et al.,* 2006; Hirani *et al.,* 2010). Currently, the most frequently used demi-span equations to predict height in elderly individuals is extrapolated from those of younger adults, for example the Bassey equations (1986). In Malaysia, Suzana and Ng (2003) also developed demi-span

equations from Malaysian adults aged between 30 and 49 years. However, these adult-derived equations may not be applicable in elderly people, if there has been a significant secular increase in body size (Kwok *et al.*, 2002). Findings from the National Health and Morbidity Survey II (NHMS II) in year 1996 have already reported a secular increase in height among the younger cohort in Malaysia, where the height of the younger generation (20 to 49 years old) is remarkably greater than the older generation (50 to 70 years and above) for all ethnic groups, possibility due to better nutrition brought on by socio-economic development in Malaysia during the last four decades (Lim *et al.,* 2000). In other words, the accuracy of elderly height that is predicted using equations derived from adult populations might be questionable due to the anthropometric differences that have emerged from the secular increase in body sizes. Alternatively, the predictive equations can be derived from elderly people.

Currently, there is no corresponding demi-span equation derived from data for older adults that can be used for elderly people in Malaysia. Further investigations are therefore needed to develop a new set of demi-span equations to predict height in elderly Malaysians. The objectives of this study were to develop demi-span equations for predicting height in elderly Malaysians and to explore the applicability of previous published demi-span equations derived from adult populations to the elderly.

METHODS

This cross-sectional study was conducted at eight shelter homes in Peninsular Malaysia: Perlis, Kedah, Penang, Perak, Kelantan, Malacca, Negeri Sembilan and Johore. A total of 328 elderly individuals were recruited by the purposive sampling method based on the inclusion and exclusion criteria. To be included, the elderly were required to be aged 60 years or older, able to stand erect without

spinal curvature, able to spread left arm perfectly and mentally competent without psychotic disorder. Individuals were excluded if they had conditions that might affect measurement of height, weight, and demi-span, including a plaster cast, a prosthetic, an amputated limb, edema, psychosis, frozen shoulder, kyphosis, bed- or chair-bound. Participants were enrolled in this study after written informed consent was obtained. The study was officially approved by the Malaysian Department of Social Welfare, and ethical approval was obtained from the Human Research Ethics Committee of Universiti Sains Malaysia.

Weight was measured to the nearest 0.1 kilogram (kg) using a calibrated digital scale (Seca 881, Germany). Each participant was weighed while wearing light clothes (with empty pockets) and without shoes. Height was measured to the nearest 0.1 centimeters (cm) using a calibrated body meter (Seca 206, Germany) at the same time of the day (between 9:00 am and 11:00 am) to minimise diurnal variation in height (Coles, Clements & Evans, 1994). Each participant was asked to inhale deeply and stretch to their maximum height while the reading was recorded. Demi-span was measured to the nearest 0.1 centimeters (cm) using a steel measuring tape (Rosscraft, Canada). The participant was asked to stand erect with the back against a wall to provide support. The left arm was stretched out laterally and parallel to the floor at shoulder level, with palms facing forward. The demi-span measurement was taken from the finger root between the middle and ring fingers to the midpoint of the sternal notch (Bassey, 1986). To minimise inter-observer variability, one trained examiner performed all the measurements twice, and an average of two readings was taken.

Statistical analysis was performed using SPSS, version 18.0 (PASW® Statistics 18, SPSS Inc., 2009, Chicago, IL, USA). The level of significance was set as *p*<0.05. Normality of data distribution was evaluated using Kolmogrov-Smirnov test. Descriptive statistics were performed for socio-demographic characteristics and anthropometric measurements. Pearson's correlation coefficient (*r*) was used to examine the association between height, demi-span and age. The relationship between height and demi-span was determined by simple linear regression. To graphically explore the relationship between height and demi-span, separate scatter plots for men and women were created with height plotted on the Y-axis and demi-span plotted on the X-axis. nQuery Advisor® sample size software, version 7.0 (Janet D. Elashoff, 2007, Cork, Ireland) was used to determine the required sample size for equation development. For multiple linear regression analysis, with a significance level (α) of 0.05, 90% power, a total of four predictor variables, and an estimated small effect size ($R^2 = 0.10$), 144 subjects were needed. Stepwise multiple linear regression analysis was conducted to develop equations that could predict height from the included variables. Measured height was the dependent variable, and demi-span, age, gender (man=1 and woman=0) and ethnicity (Malay=1 and non-Malay=0) were the predictive variables. Regression diagnostics that involved residual outlier testing and assumption checking were performed; residual outlier was assessed using Casewise diagnostics in SPSS Regression procedure, whereas assumption checking involved examination of non-multicollinearity, independent error, normality, linearity and homoscedasticity. Calculation of the adjusted R^2 using Stein's formula was used as a method of cross-validation (Stevens, 2009). Stein's formula was given by adjusted $R^2 = 1 -$

$$[\left(\frac{n-1}{n-k-1}\right)\left(\frac{n-2}{n-k-2}\right)\left(\frac{n+1}{n}\right)](1 - R^2)$$

where *n* is the sample size, *k* is the number of predictors and R^2 is the unadjusted value obtained from the SPSS regression output. Stein's formula was used to measure the

shrinkage in predictive power of the equation. The loss of predictive power can be determined by assessing the difference between the calculated adjusted R^2 (Stein's formula) and the observed values of R^2 (SPSS output). A small shrinkage in predictive power suggests that the model has good cross-validity, and vice versa (Field, 2009).

Both equations of Bassey (1986) and Suzana & Ng (2003) were chosen to compare with the new equations developed in this study, with corresponding predicted height referred to as height$_{Bassey}$, height$_{Suzana-Ng}$ and height$_{new}$. Bassey's equations were selected because of i wide use in clinical setting and in nutritional studies since these equations had been included in Mini Nutritional Assessment (MNA) tools to estimate height in the elderly when standing height is impossible to obtain (Guigoz *et al.*, 1997). Suzana & Ng's equations were chosen for comparison in this study because these equations were derived locally to predict height in the Malaysian elderly and the findings might have an impact on the local study. These two equations were chosen for comparison instead of others, such as the equations of Hirani *et al.* (2010) and Weinbrenner *et al.* (2006), because we believed their application in Malaysian elderly will be of greater interest and influence, which will eventually give impact on future local studies.

The method described by Bland & Altman (1986) was used to evaluate the agreement between the different equations, taking measured height (height$_{measured}$) as the standard measurement for comparison against the height predicted by the equations evaluated in this study (height$_{new}$, height$_{Shahar-Ng}$ and height$_{Bassey}$). Bland-Altman analysis was performed to estimate the bias and 95% limits of agreement between the two methods of measurement; bias was calculated by mean differences, and the 95% limits of agreement were calculated by mean difference ± 1.96SD (Bland & Altman, 1986). The Bland–Altman plot was established to visually gauge the degree of agreement between measured and predicted heights; smaller ranges between the upper and lower 95% limits indicated better agreement. Paired *t*-tests were used to assess any significant differences between measured and predicted heights.

RESULTS

The sample consisted of 328 Malaysian elderly, of whom 204 were men (62.2%) and 124 women (37.8%); 167 were Malays (50.9%), followed by 108 Chinese (32.9%) and 53 Indians (16.2%). The mean (SD) age was 71.5 (7.4) years for men and 71.5 (8.1) years for women (age range: 60 – 97 years). For men, mean (SD) height was 159.9 (6.7) cm and mean demi-span was 75.0 (3.8) cm; for women, mean (SD) height was 147.4 (6.9) cm and mean (SD) demi-span was 68.5 (4.3) cm.

Pearson's correlation analyses revealed that there was a strong, positive association between height and demi-span in both genders (*r*=0.759 for men and *r*=0.803 for women). However, age was weakly and negatively associated with height and demi-span in both genders (Table 1) An examination of scatter plots and regression

Table 1. Correlation coefficient of the variables based on gender

| Variables	Correlation coefficient (r)[a]		
	Men (n=204)	Women (n=124)	All (n=328)
Height and demi-span	0.759**	0.803**	0.867**
Height and age	-0.244**	-0.268*	-0.192**
Demi-span and age	-0.139*	-0.185*	-0.127*

[a] Pearson's correlation test
** *p*<0.001 * *p*<0.05

lines revealed a linear relationship between height and demi-span (Figure 1).

Stepwise multiple linear regression analysis revealed that demi-span, gender and age contributed significantly to the prediction of height ($p<0.05$). However, ethnicity did not make a statistically significant contribution to the prediction of height ($p>0.05$) and was therefore removed from the analysis. The equation model to predict height in the sample of the elderly is presented in Table 2. The resulting regression equation was found to be valid for both genders: height (cm) = 67.51 + (1.29 x demi-span) + (4.13 x gender) – (0.12 x age), where demi-span was measured in centimeters, age was measured in years, and gender was coded as '1' for man and '0' for woman. To simplify this equation, we have drawn it up separately for men and women as presented below:

Men: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age) + 4.13

Women: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age)
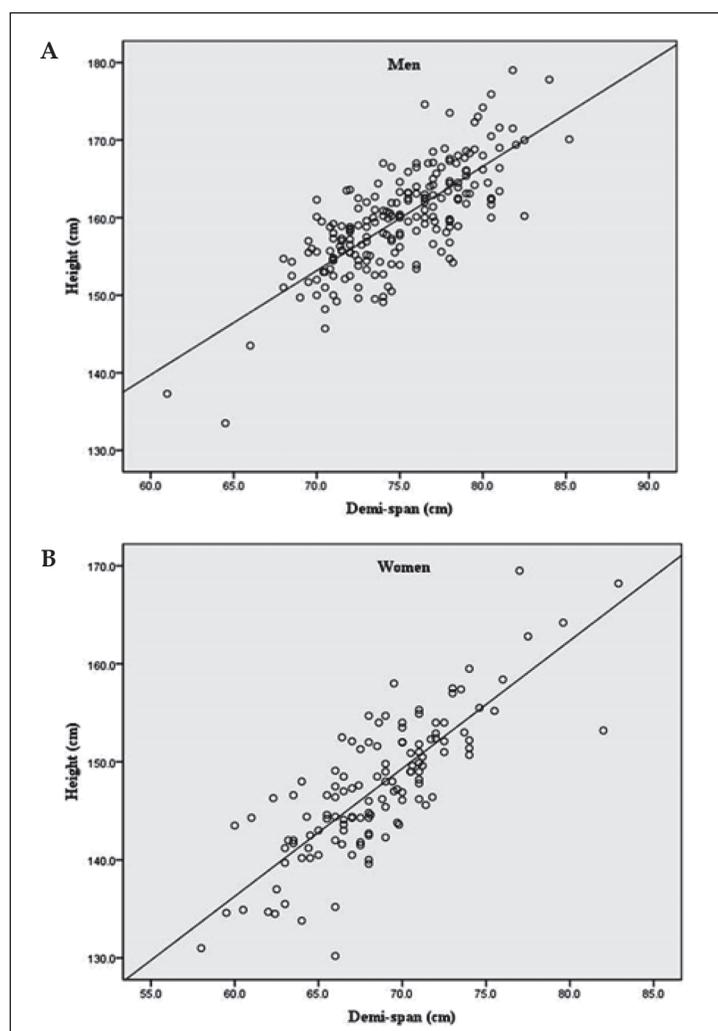
Figure 1. Plots (A) and (B) show linear relationship between height and demi-span in men and women, respectively.

Table 2. Equation model to predict height in the elderly sample

Variables	B	SE	95% confidence interval	P value[a]
Demi-span	1.290	0.059	1.17, 1.41	<0.001
Gender	4.128	0.610	2.93, 5.33	<0.001
Age	-0.119	0.031	-0.18, -0.06	<0.001
(Constant)	67.506	4.922	57.82, 77.19	<0.001

B, non-standardised regression coefficients; *SE*, standard error.
Note: Result of goodness of fit of the model: $R = 0.888$; $R^2 = 0.789$; Adjusted-$R^2 = 0.787$; Standard error of the estimate (SEE) = 4.19 cm.
[a] Stepwise multiple linear regression, significant at $p<0.05$.

Table 3. Bland-Altman analysis showing the differences between measured height (height$_{measured}$) and demi-span predicted height (height$_{new}$, height$_{Suzana-Ng}$ and height$_{Bassey}$)

	Mean (SD)	Mean difference (SD)[a] (measured − predicted)	95% Limits of agreement	P value[b]
Men (n=204)				
Height$_{measured}$	159.9 (6.7)			
Height$_{new}$	159.8 (5.1)	0.02 (4.25)	-8.31, 8.35	0.957
Height$_{Suzana-Ng}$	159.1(5.4)	0.77 (4.37)	-7.80, 9.34	0.013
Height$_{Bassey}$	162.8 (5.3)	-2.90 (4.36)	-11.45, 5.65	<0.001
Women (n=124)				
Height$_{measured}$	147.4 (6.9)			
Height$_{new}$	147.4 (5.8)	0.02 (4.06)	-7.94, 7.98	0.967
Height$_{Suzana-Ng}$	147.5 (6.6)	-0.09 (4.27)	-8.46, 8.28	0.806
Height$_{Bassey}$	152.6 (5.8)	-5.20 (4.14)	-13.31, 2.91	<0.001

[a] The positive and negative values of mean difference denote under-estimation and over-estimation, respectively.
[b] Comparison of methods was assessed by paired *t*-tests.

The new equation provides a bias-free estimation because no violations of the regression assumptions were observed. For cross-validation of the equation, calculation of the adjusted R^2 using Stein's formula was applied by replacing *n* with the sample size (328), *k* with the number of predictors (3) and R^2 with the value of 0.789. The calculated adjusted R^2 (0.785) was very similar to the observed value of R^2 (0.789), indicating only a small shrinkage in the predictive power (0.789 – 0.785 = 0.004, or 0.4%). This small shrinkage suggested that the cross-validity of this equation was very good because it accounted for only 0.4% less variance in the outcome, if the equation was derived from the population rather than a sample. This minor shrinkage (0.4 %) does not cause much loss of predictive power, indicating that this model is generalisable and valid for prediction of height in the elderly.

The results of the Bland-Altman analysis that examined the agreement between measured height (height$_{measured}$) and demi-span predicted height (height$_{new}$, height$_{Suzana-Ng}$ and height$_{Bassey}$) are shown in Table 3. These data are also presented as Bland-Altman plots in Figure 2.

Bland-Altman analysis revealed that the mean differences between height$_{measured}$ and height$_{new}$ were not significant in either gender ($p>0.05$; Table 3). Additionally, the
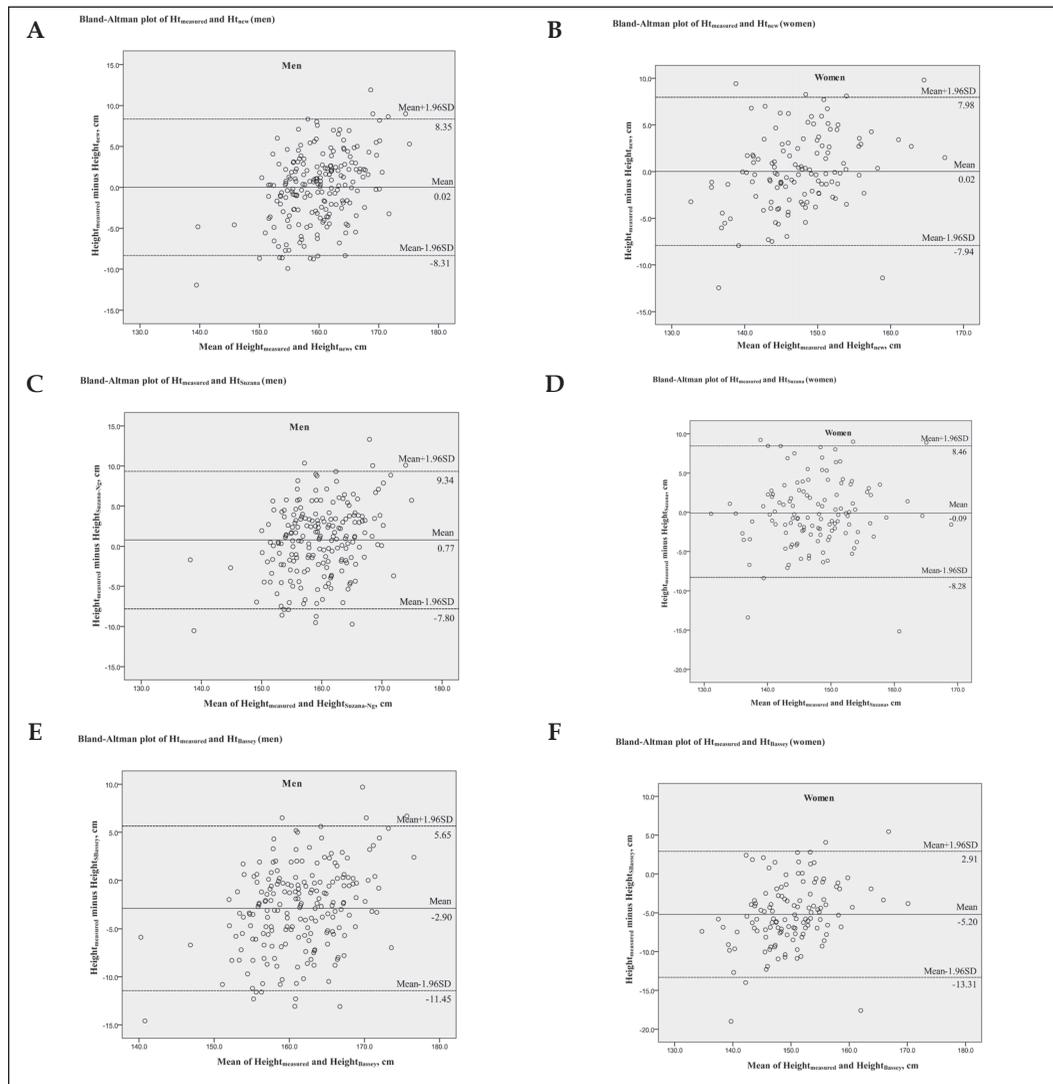
Figure 2. Bland-Altman plots showing (A,B) agreement between height$_{measured}$ and height$_{new}$; (C,D) agreement between height$_{measured}$ and height$_{Suzana-Ng}$; (E,F) agreement between height$_{measured}$ and height$_{Bassey}$.

95% limits of agreement were not wide, ranging between ±8.3 cm in men and ±7.9 cm in women, showing a good agreement between height$_{measured}$ and height$_{new}$ (Figure 2A and 2B). Analysis of the Suzana-Ng equation showed that height$_{measured}$ and height$_{Suzana-Ng}$ did not differ significantly in women (*p*=0.806), but the mean difference was significant in men, where the height calculated using this equation significantly

underestimated measured height by 0.77 cm in men (*p*=0.013; Table 3). According to the Bland-Altman plots (Figures 2C and 2D), the 95% limits of agreement was slightly wide, ranging from -7.80 to 9.34 cm for men and -8.46 to 8.28 cm for women, indicating a fairly poor agreement between height$_{measured}$ and height$_{Suzana-Ng}$. Bland-Altman analysis of Bassey's equation showed that height$_{Bassey}$ significantly overestimated height$_{measured}$ by

2.90 cm in men (p<0.001) and 5.20 cm in women (p<0.001), as displayed in Table 3. In addition, the 95% limits of agreement was relatively wide for both genders, ranging from -11.45 to 5.65 cm for men and -13.31 to 2.91 cm for women, demonstrating a relatively poor agreement between height$_{measured}$ and height$_{Bassey}$ (Figures 2E and 2F).

DISCUSSION

The new demi-span equations were satisfactory in terms of the regression model with a high R^2 (0.789) and an acceptable standard error of estimate (SEE = 4.19cm). The 0.4% minor loss in predictive power showed good statistical representativeness of the new equations, and we can confidently state that the equations derived from our sample are generalisable to the elderly population in Malaysia.

Apart from statistical representativeness, the accuracy of the equations is dependent upon the validity of the elderly sample recruited for the study. Although our elderly sample were institutionalised in shelter homes, they were generally independent because they were staying in the homes mainly due to social rather than medical reasons, such as lack of family and financial support (Visvanathan *et al.,* 2005). Therefore, we hypothesised that our elderly sample would be representative of community-living elderly in terms of anthropometry. Evidence for this is that the mean height of our elderly sample was comparable to that obtained in the Third National Health and Morbidity Survey (NHMS III) (Suzana *et al.,* 2010), in which mean height of our sample to NHMS III was 159.9cm *vs.* 162.0cm for men and 147.4cm *vs.* 149.0cm for women. However, considering the variation that might occur in different ethnic groups (e.g. indigenous or minority groups) and setting (e.g. community and hospital), caution is necessary in extrapolating the data. Further

validation tests would be advisable before the new equations are used in other elderly populations.

Our findings reveal that the new equations formulated in this study appeared to be more reliable than those from adult-derived equations when applied to elderly people. For the Suzana-Ng equations, the discrepant results might be attributed mainly to difference in age groups and anthropometric characteristics among the population used to formulate the equations. For instance, adult subjects involved in their study had a mean age of 42.3 years and had a mean height of 165.2 cm for men and 152.9 cm for women. These values were greater than our mean values of height (159.9 cm for men and 147.4 cm for women) in an elderly cohort with a mean age of 71.5 years. The Suzana-Ng's equations significantly underestimated height by 0.77cm in elderly men (p=0.013). Among women, however, no significant differences were found between the measured and predicted heights (p=0.806). The reason for this phenomenon is not clear, but it is possible that the inclusion of a majority of overweight female subjects (mean BMI=26.4 kg/m^2) in Suzana & Ng's study (2003) may have reduced the accuracy of height measurements. Some investigators have hypothesised that excess weight leads to progressive narrowing of intervertebral disc spaces (Cereda, Bertoli & Battezzati, 2010) and causes loss of height in adult women, hence, giving artifactual results in our study that significant bias between height$_{Suzana-Ng}$ and measured height did not exist. However, this hypothesis has yet to be proven and requires further investigation.

Bassey's equations significantly overestimated the height of elderly individuals in our study (men: 2.90cm; women: 5.20cm; p<0.001). These variations can be explained in part by the different age groups and ethnic populations used in formulating these equations. Bassey's equations were generated from European adults, with a

mean age of 34-35 years. Men and women had mean heights of 177 cm and 165 cm, respectively, and demi-span values of 85.1 cm and 77.6 cm, respectively. These values were markedly greater than our mean values of height (159.9 cm and 147.4 cm for men and women, respectively) and demi-span (75.0 cm and 68.5 cm for men and women, respectively). These findings also highlight that equations derived from other ethnic populations may have an unavoidable bias. Malaysians are shorter than Europeans and may have different body proportions; Pheasant (2003) reported that Asians are shorter than Caucasians because Asians have relatively short legs compared to Caucasians.

The implication of our findings relate to the ability to predict height in elderly individuals by using demi-span equations. Information on predicted height is of potential use since it is the major component of BMI calculation, and is of clinical importance in the determination of nutritional status in the elderly, particularly those who are non-ambulatory and kyphosis that prelude measurement of standing height. Our new demi-span equations may be practical for use in combination with the nutritional screening tool in predicting BMI among the elderly in Malaysia.

Our study has some limitations. The first limitation is its generalisability to the population because only residents from shelter homes were included. However, we made efforts to obtain a more diverse geographic sample by visiting eight shelter homes located in different states in Peninsular Malaysia. In fact, the mean height of our elderly sample was comparable to that obtained in large-scale surveys on the Malaysian population (Suzana *et al.*, 2010), which allowed us to infer that the institutionalised elderly might not differ from community-living elderly in terms of anthropometry. Still, a larger study that includes a more general population sample

would be useful to determine if better equations should be developed, or if this new equation is widely applicable.

An additional limitation is that elderly individuals aged 90 years and older were not adequately represented because only 3 participants were in this age category. As a result, our equations are not recommended for use in elderly persons aged 90 years and older. Future studies should include age limits in sample selection, because there often occurs kyphosis and frozen shoulder in the oldest-old groups (aged 80 and above) that might affect the accuracy of anthropometric measurements.

Another limitation is that the applicability of our new demi-span equations is restricted to elderly people in Malaysia. The use of this equation is strongly discouraged in non-elderly adults and in populations outside Malaysia. As for use in Malaysia, this equation is only applicable to the elderly from the Malay, Chinese and Indian ethnic groups. The appropriateness of this new equation for other ethnic minorities or native Malaysian groups (*Orang Asli*) needs to be confirmed by future studies.

This study is also limited in statistical validation, as we only cross-validated equations using Stein's formula and used Bland-Altman analysis to quantify the agreement between the measured and predicted heights. No external validation was done. Therefore, caution is needed in using the new demi-span equations in different ethnic groups (e.g. indigenous or minority groups) and settings (e.g. community and hospital). There is a need for validation tests on other elderly samples in future studies.

CONCLUSION

New demi-span equations for predicting height in Malaysian elderly are introduced in this study. The adult-derived demi-span equations by Suzana & Ng (2003) and

Bassey (1986) may not be specific for elderly individuals. Therefore, to predict height in the elderly, we recommend using our new equations. It is important to recognise that both Suzana-Ng's and Bassey's equations have made important scientific contributions to clinical practice. We are not questioning the validity of these equations; alternatively, we encourage re-analysing their precision in the geriatrics context due to the anthropometric differences that may exist between the adult and elderly populations. Therefore, further validation tests on other elderly populations are warranted.

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