The estimation of body height from ulna length in healthy adults from different ethnic groups

Running headline: Estimating height from ulna length

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Abstract

Background: Assessments of nutritional status frequently incorporate a measure of height in order to evaluate a person's relative thinness or fatness. As height is often difficult to quantify, it may be predicted from alternative anthropometric measurements, including ulna length. Little information is available about the accuracy of these predictions in an ethnically diverse population. The aim of this study was to evaluate published equations for predicting height from ulna length in adults from different ethnic groups.

Method: Ulna length and standing height were measured in a gender stratified sample of 60 Asian, 69 Black and 65 White healthy volunteers aged 21-65 years. Height was predicted from ulna length using the MUST equations and compared against the measured values. Linear regression analysis was used to develop equations to estimate height from ulna length and to explore the relationship between height and ulna length in subgroups.

Results: The mean (SD) age for Asian, Black and White men and women were 31.7 (11.0), 32.0 (10.3), 38.6 (12.5) and 26.2 (5.4), 32.6 (8.9), 35.7 (11.7) years and their mean (SD) height was 170.9 (5.2), 178.1 (7.3), 176.3 (7.7) and 157.7 (4.7), 164.0 (5.9), 163.7 (6.2) cm respectively. Ulna length and measured height were significantly correlated among all subgroups except Asian women (r = 0.11, P=0.57). The mean (SD) difference between predicted and measured height showed significant overestimates for Asian and Black men (4.0 (4.8) and 6.7 (5.3) cm) and Asian and Black women (6.4 (4.9) and 4.4 (4.9) cm) but not for White men and women.

Conclusions: The MUST equations for predicting height from ulna length in healthy

adults should be used with some caution among ethnically diverse populations,

particularly in Asian women.

Introduction

Nutritional screening plays an important role in the identification and prevention of malnutrition in patients in hospitals and the community (Elia, 2003). A large number of screening tools have been proposed to facilitate this and most of them utilise a combination of variables including clinical, dietary, biochemical and anthropometric measurements (Green & Watson, 2005). Anthropometry, the evaluation of body dimensions, is useful because it is an objective measure which allows an approximate evaluation of body stores to be made, for example via body mass index (BMI = weight /height^2). Although BMI is commonly used in nutritional screening, including the Malnutrition Universal Screening Tool (MUST) (Elia, 2003), it requires a measure of height which might be difficult to obtain and / or of questionable accuracy (Kirk *et al.* 2003; Cook *et al.* 2005). As a result, alternative measurements for estimating height are required. Published studies have explored the prediction of height from a range of methods (Hickson & Frost, 2003) including knee height (Han & Lean, 1996; Ritz, 2004), arm span (Brown *et al.* 2000; Mohanty *et al.* 2001; de Lucia *et al.* 2002; Zverev, 2003), demi-span (Bassey, 1986) and ulna length (Cheng *et al.* 1998; Elia, 2003; Gauld *et al.* 2004; Agnihotri *et al.* 2009). The latter has been examined in children (Cheng *et al.* 1998; Gauld *et al.* 2004), young adults aged 18-28 years (Agnihotri *et al.* 2009) and in adults <65 and ≥65 years (Elia, 2003) where the resulting MUST prediction equations have been recommended for predicting height in the absence of actual measurements.

It is well known that anthropometric measurements, including height, can be affected by a variety of factors including racial and ethnic differences (Steele & Chenier, 1990; World Health Organisation, 1995; Launer & Harris, 1996; Reeves *et al.* 1996; Chumlea *et al.* 1998; Cheng *et al.* 1998; Mohanty *et al.* 2001). These differences relate not only to absolute anthropometric measurements, but also to the relationship between

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variables, for example, arm span is approximately equal to height in White adults but greater than height in Black Africans and Asians (Steele & Chenier, 1990; Reeves *et al.* 1996). The equations describing the relationship between ulna length and height have been published but details about how they were derived have not been reported so the ethnicity of the reference population is unknown. An exploration of the applicability of the equations in adults from different ethnic groups is required if prediction equations are to be useful in screening patients from diverse backgrounds. The aim of this study, therefore, was to evaluate the MUST equations for predicting height from ulna length in adults from different ethnic groups.

Methods

Subjects

The subjects were recruited opportunistically from staff and students at London Metropolitan University by inviting those waiting in or passing through the main reception area to participate. Initial inclusion criteria were ability to speak and communicate in English and ability to stand for height and ulna measurement. Subjects with obvious physical disabilities which might influence their height and / or bone length, for example those in a wheel-chair, stooping or walking with a limp, were excluded. The study details were explained and data were subsequently collected from those giving verbal consent. Subjects were asked to provide their date of birth, gender and ethnic background and this was recorded on an anonymous form before their height and ulna length were measured. After all data collection was completed, the records from subjects between the ages of 21 and 65 years were categorised into one of the following groups based on the 2001 UK Census (Office of National Statistics, 2006) and included in the subsequent analysis:

- Asian (Bangladeshi, Indian, Pakistani)
- Black (Black African, Black Caribbean)
- White (English, Irish, Scottish, Welsh)

Measurements

Before collecting data from the study subjects, height and ulna length were measured five times in 12 separate subjects to investigate the reproducibility of the method. On the basis of the results, data were subsequently collected by measuring height once and ulna length three times using a standardised protocol. All measurements were made between 10.30 and 16.30 by a single observer (TT) using the same equipment.

- *Height* - Standing height was measured using a Leicester Height Measure portable stadiometer (Chasmors Limited, London). The stadiometer was placed on a firm, level surface with stabilizers positioned against a wall to ensure rigidity. The subject removed shoes, socks and hats if worn. If they had a hairstyle that would affect the measurements they were asked to adjust it so that an accurate result was obtained. The subject stood on the platform of the stadiometer facing forward with shoulders relaxed, arms hanging freely by the sides, legs straight and close together with the upper back, buttocks and heels in contact with the upright section of the stadiometer. The subject's head was positioned in the Frankfort horizontal plane (Figure 1) by the interviewer and the head plate lowered until it was just brought into contact with the top of the head (Ruston *et al.* 2004). The measurement was performed once and recorded to 0.1 cm.

- *Ulna length* – The forearm was measured using an anthropometric tape (Butterfly, Shanghai, China). If the subject was wearing wristbands, tight jewellery, bracelets or watch that could make the reading inaccurate, they were asked to remove them or change their position. Subjects were asked to bend their left arm and place it across the chest with the fingers pointing to the opposite shoulder (Figure 2). Measurements were taken between the point of the elbow (olecranon process) and the midpoint of the prominent bone of the wrist (styloid process) (Elia, 2003). The procedure was repeated three times, readings were recorded to the nearest 0.5 cm and a mean value was calculated.

Calculation and analysis

Predicted height was calculated from the mean ulna length using the MUST equations for adults aged <65 years (Elia, 2003):

- Men: Predicted height [cm] = 79.2 + (3.60 x ulna length [cm])

- Women: Predicted height [cm] = 95.6 + (2.77 x ulna length [cm])

The difference in age and measurements between subgroups was examined using one-way analysis of variance (ANOVA). Pearson's correlation coefficient and simple linear regression was used to examine the relationship between ulna length and measured height in each subgroup. The difference between measured and predicted height was examined within each subgroup using paired t-tests.

The study protocol was approved by the Research Ethics Committee of London Metropolitan University, 23 August 2007.

Results

The measurement of both height and ulna length was reproducible in men and women with mean coefficient of variations of 0.12 and 0.47 respectively.

Two hundred and eighty subjects agreed to participate and were measured. Data from 86 of them were subsequently excluded from the analysis either because they were aged under 21 years and, therefore, may not have reached adult height (Noppa *et al.* 1980) or because they described their ethnicity as mixed or other than Asian, Black or White. Analyses were subsequently undertaken on the remaining 194 subjects.

Summary statistics for age, measured height and ulna length for the six subgroups are presented in Table 1. There is strong evidence of difference between the means of the ethnic groups for ulna length and height among both men and women (Oneway ANOVA p <0.001 for all four comparisons). Differences in mean age were highly significant among women (Oneway ANOVA p<0.001) and also significantly different among men (Oneway ANOVA p 0.029). The significance (≤0.05) of any paired differences (post hoc Bonferroni correction) are given in Table 1. Asian and Black groups differ in height and ulna length among both men and women; the same is generally true of Asian and White groups with the exception of ulna length among women. Black and White groups differ among men and women with respect to ulna length. Overall, the Asian subgroups contained the youngest, least tall and shortest ulna lengths of the three ethnic groups on the basis of mean values.

In Table 2, the relationship between measured height and ulna length and the difference between mean measured height and predicted height calculated using the MUST

equations has been summarised. There was a moderately strong and significant correlation (r>0.6) between ulna length and measured height among Black and White subgroups for men and women. The relationship was somewhat weaker among Asian men (r=0.43) and among Asian women was very week (r=0.11) and was not significant.

In Figure 3, the distribution of ulna length against height has been plotted separately for each subgroup by gender and ethnicity. The dotted regression line represents the "predicted" relationship according to the relevant MUST equation. The least-squares best-fit regression for each subgroup is shown by the solid line. Any extension of these regression lines beyond the limits of the data distribution must be viewed with caution. There are several features to note. The majority of the values for Asian and Black subgroups fall below the predicted regression. The overall trend for data from the White subgroups is more concordant with the MUST prediction. Among the Black men, there is evidence of a linear distribution of measured height that follows the same slope as data from the MUST equation though typically 5 cm lower across the range of ulna lengths. The data from the Asian subgroups, especially among the women, exhibit a more clustered pattern. These visual patterns are supported by the regression coefficients and the difference between the measured and predicted height in the six subgroups (Table 2).

The predicted mean height for Asian and Black subgroups typically exceeded the measured values by approximately 4 to 6 cm. The mean differences between measured and predicted values for White men and women were much smaller. The slope coefficients for the subgroups were relatively consistent with those used in the MUST equations (3.60 for men and 2.77 for women) with the exception of Asian women where any upward trend in increasing height with ulna length is modest and not significant.

In order to explore further limitations of using ulna length to predict height, the pattern of the difference between predicted height and measured height has been further explored. Since the data comprises of two independent variables and not two indirect measurements of the same variable, conventional "limits of agreement" analysis are not directly applicable. However, the difference for each participant (predicted height minus measured height) can be interpreted as "residuals" using the MUST equation as the baseline for the calculation of these residuals. When plotted against ulna length it is evident that the magnitude of these differences is not unduly affected by variations in ulna length (Figure 4). The mean difference and the 95% "limits of agreement" (SD of difference x 1.96) have been added to indicate that these differences are of considerable magnitude and do not appear to be proportional to ulna length in the subgroups. The limits of agreement are stated in Table 2.

Discussion

This study aimed to evaluate the MUST equations for predicting height from ulna length in healthy adults from different ethnic groups and the results show differences in accuracy, particularly in non-White participants. This raises some concerns about the use of these equations in some groups of the population and, therefore, whether there is a need to develop separate, ethnic-specific equations that would provide more accurate predicted values. In order to address this, there is a need to consider alternative methods of predicting height and the clinical implications of using an inaccurate predicted height value in nutritional screening.

If a value for height cannot be obtained by measurement or calculation using a prediction equation, a self-reported or estimated height might be used. Systematic review of studies examining the accuracy of self-reported height has identified an overall tendency to overestimate true height, probably reflecting societal norms to value tallness (Gorber *et al.* 2007). The studies included examined diverse populations using different methodologies and the degree of disparity between reported and measured values varied considerably. In nutritional screening, if a patient is unable or too ill to self-report their height, this may be estimated by a healthcare professional. However, in a study of 110 patients attending an emergency department, Hendershot *et al.* (2006) reported that only 41% of healthcare professionals were able to estimate patients' height to within 2.54 cm of measured values compared to 53% of patients themselves. This compares favourably with the results from the present study, where height predicted using the MUST equations was within 2.54 cm of individual measured values in only 30%, 15% and 30% of Asian, Black and White men and 17%, 37% and 49% of Asian, Black and White women respectively. Stratton *et al.* (2003) found that using self-reported height and weight in MUST screening of patients with a mean age of 56 ± 15 years and BMI of

27.9 ± 5.7 kg.m^{-2} was unlikely to alter the malnutrition risk category although similar investigations are needed in older patients and those with lower BMI values.

A number of alternative methods for predicting height have been proposed. Regression equations derived from knee height have been most commonly explored in different ethnic groups including non-Hispanic White, non-Hispanic Black and Mexican-American adults aged 60 years and over (Chumlea *et al.* 1998), Korean adults (Hwang *et al.* 2009) and Caucasian adults aged 30-55 years (Cereda et al 2010) all of which have been cross validated. Chumlea *et al.* (1998) did not present data for the differences between height measured and predicted using their equations in a total validation population of approximately 2375 adults but stated that the root mean square error values varied between 3.45 for Mexican-American women and 4.18 for non-Hispanic white women. Hwang *et al.* (2009) reported mean differences between measured and predicted height of less than 1 cm in all validation subgroups (total number 1022) with intraclass correlations between 0.88 (0.83-0.91) for post-menopausal women and 0.92 (0.92-0.94) for men. The differences between height measured and predicted by Cereda *et al.* (2010) was also very small (<1 cm) in a validation population sample of 120 with root mean square error value of 3.2 and 95% confidence intervals of -6.1 and 6.5 cm (combined data for men and women). This range is greater, i.e. less precise, than in any of the groups in the present study although the difference is smaller, i.e. more accurate, than observed in Asian or Black men or women (see Table 2).

The clinical implications of the results from the present study can be explored by extrapolating 'worse case scenarios' in hypothetical screening. We found that ulna length ranged from 23.3 to 26.0 cm. among Asian women and that it was weakly associated with measured height. If we apply this range of ulna lengths to an Asian

woman weighing 50 kg and with a measured height of 157.7 cm (i.e. study mean value from Table 1) her calculated BMI would range between 17.8 and 19.5 instead of the true value of 20.1 kg.m^{-2}, i.e. she would be identified as under nourished when she may not be. However, if an Asian woman with the same measured height and weighing 75 kg was screened using a value for height predicted from the study data, her calculated BMI would range between 26.7 and 29.3 instead of the true value of 30.2 kg.m^{-2}, i.e. she would not be categorised as obese when she actually is. These two opposite hypothetical situations use standard World Health Organization BMI cut off points, which may not be appropriate in an Asian population (World Health Organization, 2004), but illustrate the potential consequences that may arise when inappropriate height prediction equations are used and in this case, how Asian women may be over-diagnosed as under nourished while some who are overweight or obese may not be identified.

No prediction formula derived from regression equations will be able to provide estimates that are 100% accurate and the practicality of the method for collecting data must be weighed against potential inaccuracies. The prediction of height from ulna length offers some advantages over the use of knee height measurement, particularly in bed-bound patients where correct positioning of the leg may be difficult (Cook *et al*. 2005), and it may be more acceptable for the person being measured to bare their fore arm rather than lower leg and foot . An ulna length can be measured using a standard anthropometric tape which is cheaper and more available than an anthropometric calliper that has been used for knee height in some studies (Chumlea *et al.* 1998, Cereda *et al.* 2010).

The participants studied in the present investigation, which has a small sample size compared to other anthropometric validation studies, were recruited from a population

which can be considered as predominantly healthy because they were attending a university to study or work. Clearly, these are neither a representative sample of the whole population or of the people who are most likely to be undergo nutritional screening and this is a significant limitation. As a result, the numerical data from the present study should not be extrapolated and used to 'correct' predicted values of height obtained from the MUST equations in a hospitalised population. However, it is reasonable to conclude that the absence of a significant relationship between ulna length and height observed in the Asian women who participated might be found in other groups of Asian women. As such, further studies are required to develop more accurate equations using ulna length in a non-White population and to explore alternatives to ulna length in Asian women.

In conclusion, the findings from this study indicate that the MUST equations for predicting height from ulna length in adults provide useful estimates of height in White healthy volunteers but overestimate height in Asian and Black healthy volunteers. The absence of a significant relationship between measured height and ulna length raise particular concern about the use of prediction equations in Asian women.

Acknowledgements

References

Agnohotri, A.K., Kachhwaha, S., Jowaheer, V. & Singh, A.P. (2009) Estimating stature from percutaneous length of tibia and ulna in Indo-Mauritian population. *Forensic Sci. Int.* **187,** 109.e1-109.e3.

Bassey, E.J. (1986) Demi-span as a measure of skeletal size. *Ann. Hum. Biol.* **13**, 499-502.

Brown, J.K., Whittemore, K.T. & Knapp, T.R. (2000) Is arm span an accurate measure of height in young and middle-age adults ? *Clin. Nurs. Res.* **9**, 84-94.

Cereda, E., Bertoli, S., Battezzati, A. (2010) Height prediction formula for middle-aged (30-55 y) Caucasians. *Nutrition* **26,** 1075-1081.

Cheng, J.C., Leung, S.S., Chiu, BS., Tse, P.W., Lee, CW., Chan, A.K., Xia, G., Leung, A.K. & Xu, Y.Y. (1998) Can we predict body height form segmental bone length measurements? A study of 3,647 children. *J. Pediatr. Orthop.* **18**, 387-393.

Chumlea, W.C., Guo, S.S., Wholihan, K., Cockram, D., Kuczmarski, R.J. & Johnson, C.L. (1998) Stature prediction equations for elderly non-Hispanic white, non-Hispanic black, and Mexican-American persons developed from NHANES III data. *J. Am. Diet. Assoc.* **98**, 137-142.

Cook, Z., Kirk, S., Lawrenson, S. & Sandford, S. (2005) Use of BMI in the assessment of malnutrition in older subjects: reflecting on practice. *Proc. Nutr. Soc.* **64**, 313-317.

de Lucia E., Lemma, F., Tesfaye, F., Demisse, T. & Ismail., S (2002) The use of armspan measurement to assess the nutritional status of adults in four Ethiopian ethnic groups. *Eur. J. Clin. Nutr.* **56**, 91-95.

Elia, M. (2003) *The 'MUST' Report. Nutritional Screening of Adults: A Multidisciplinary Responsibility. Development and Use of the 'Malnutrition Universal Screening Tool' ('MUST') for adults. Malnutrition Advisory Group (MAG), a Standing Committee of the British Association of Parenteral and Enteral Nutrition (BAPEN).* Redditch: BAPEN.

Gauld, L.M., Kappers, J., Carlin, J.B. & Robertson, C.F. (2004) Height prediction from ulna length. *Dev. Med. Child Neurol.* **46**, 475-480.

Gorber, S.C., Tremblay, M., Moher, D.& Gorber, B. (2007) A comparison of direct vs self-report measures for assessing height, weight and body mass index: a systematic review. *Obes. Rev.* **8,** 307-326.

Green, S.M. & Watson, R. (2005) Nutritional screening / assessment tools for use by nurses: a comprehensive literature review. *J. Adv. Nurs.* **50**, 69-83.

Han, T.S. & Lean, M.E. (1996) Lower leg length as an index of stature in adults. *Int. J. Obes. Relat. Metab. Disord.* **20**, 21-27.

Hendershot, K.M., Robinson, L., Roland, J., Vaziri, K., Rizzo, A.G. & Fakhry, S.M. (2006) Estimating height, weight and body mass index: Implications for research and patient safety. *J. Am. Coll. Surg.* **203,** 887-893.

Hickson, M. & Frost, G. (2003) A comparison of three methods for estimating height in the acutely ill elderly population. *J. Hum. Nutr. Dietet.* **16,** 13-20.

Hwang, I.C., Kim, K.K., Kang, H.C.& Kang, D.R. (2009) Validity of stature-predicted equations using knee height for elderly and mobility impaired persons in Korea. *Epidemiol. Health* **31,** e2009004.

Kirk, S.F.L., Hawke T., Sandford, S., Wilks, Z. & Lawrenson, S. (2003) Are the measures used to calculate BMI accurate and valid for use in older people ? *J. Hum. Nutr. Dietet.* **16**, 366-367.

Launer, L.J. & Harris, T. (1996). Weight, height and body mass index distributions in geographically and ethnically diverse samples of older persons. *Age Ageing.* **25**, 300-306.

Mohanty, S.P., Babu, S.S. & Nair, N.S. (2001). The use of arm span as a predictor of height: A study of South Indian women. *J. Orthop. Surg.* **9**, 19-23.

Noppa, H., Andersson, M., Bengtsson, C., Bruce, A. & Isaksson, B. (1980) Longitudinal studies of anthropometric data and body composition: the population study of women in Goteborg, Sweden. *Am. J. Clin. Nutr.* **33,** 155-162.

Office for National Statistics. (2006) *Census 2001. A guide to comparing 1991 and 2001 Census ethnic group data.* [http://www.statistics.gov.uk/cci/article.asp?id=1471]. Accessed 27 January 2011.

Reeves, S.L., Varakamin, C. & Henry, C.J.K. (1996) The relationship between arm-span measurement and height with special reference to gender and ethnicity. *Eur. J. Clin. Nutr.* **50**, 398-400.

Ritz, P. (2004) Validity of measuring knee-height as an estimate of height in diseased French elderly persons. *J. Nutr. Health Ageing* **8**, 386-388.

Ruston, D., Hoare, J., Henderson, L., Gregory, J., Bates. C.J., Prentice, A., Birch, M., Swan, G. & Farron, M. (2004) *National Diet and Nutrition Survey: adults aged 19 to 64 years. Volume 4: Nutritional status (anthropometry and blood analytes), blood pressure and physical activity.* London: The Stationary Office.

Steele, M.F. & Chenier, T.C. (1990) Arm-span, height, and age in black and white women. *Ann. Hum. Biol.* **17**, 533-541.

Stratton, R.J., Dixon, R., Longmore, D., Stroud, M. & Elia, M. (2003) Effect of recalled weight and height on malnutrition risk. *Clin. Nutr.* **22**(suppl 1), S9-S10.

World Health Organization (1995) *Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee.* World Health Organization Technical Report Series. Geneva. **854**, 1-452.

World Health Organization (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **363**, 157-163.

Zverev, Y.P. (2003) Relationship between arm span and stature in Malawian adults. *Ann. Hum. Biol.* **30**, 739-743.

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Figure 1

Position of head for measuring height using (A) Frankfort plane where lower eye socket is horizontally level with upper ear canal and (B) typical but incorrect position
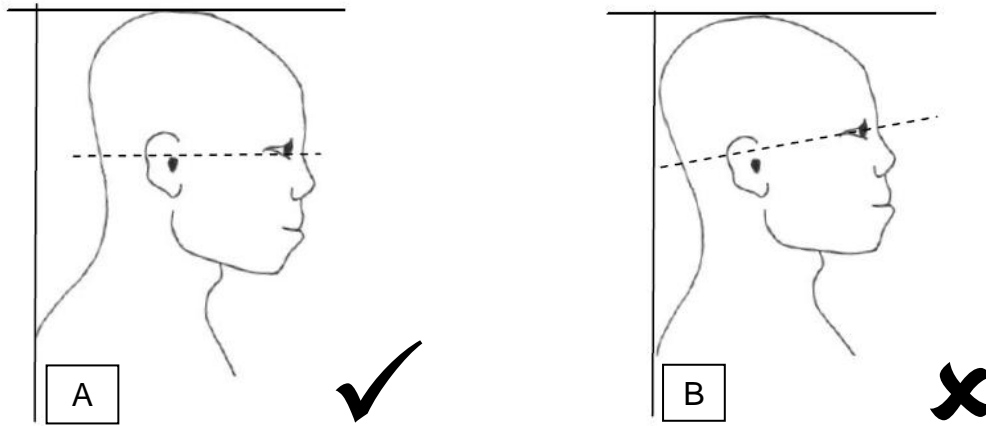
Figure 2

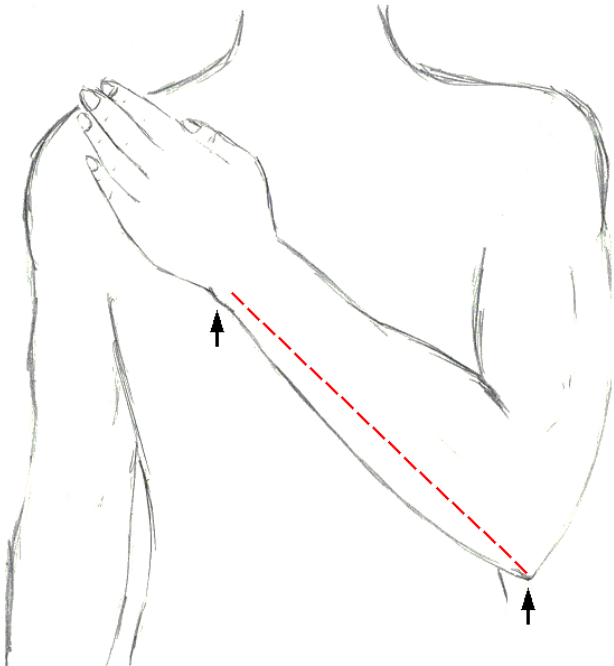The position of the forearm for measuring ulna length

Figure 3

Distribution of measured height against ulna length in 194 participants by sex and ethnicity. The dotted line represents the regression for the relevant MUST equation and the solid line represents the regression for the values from the participants.
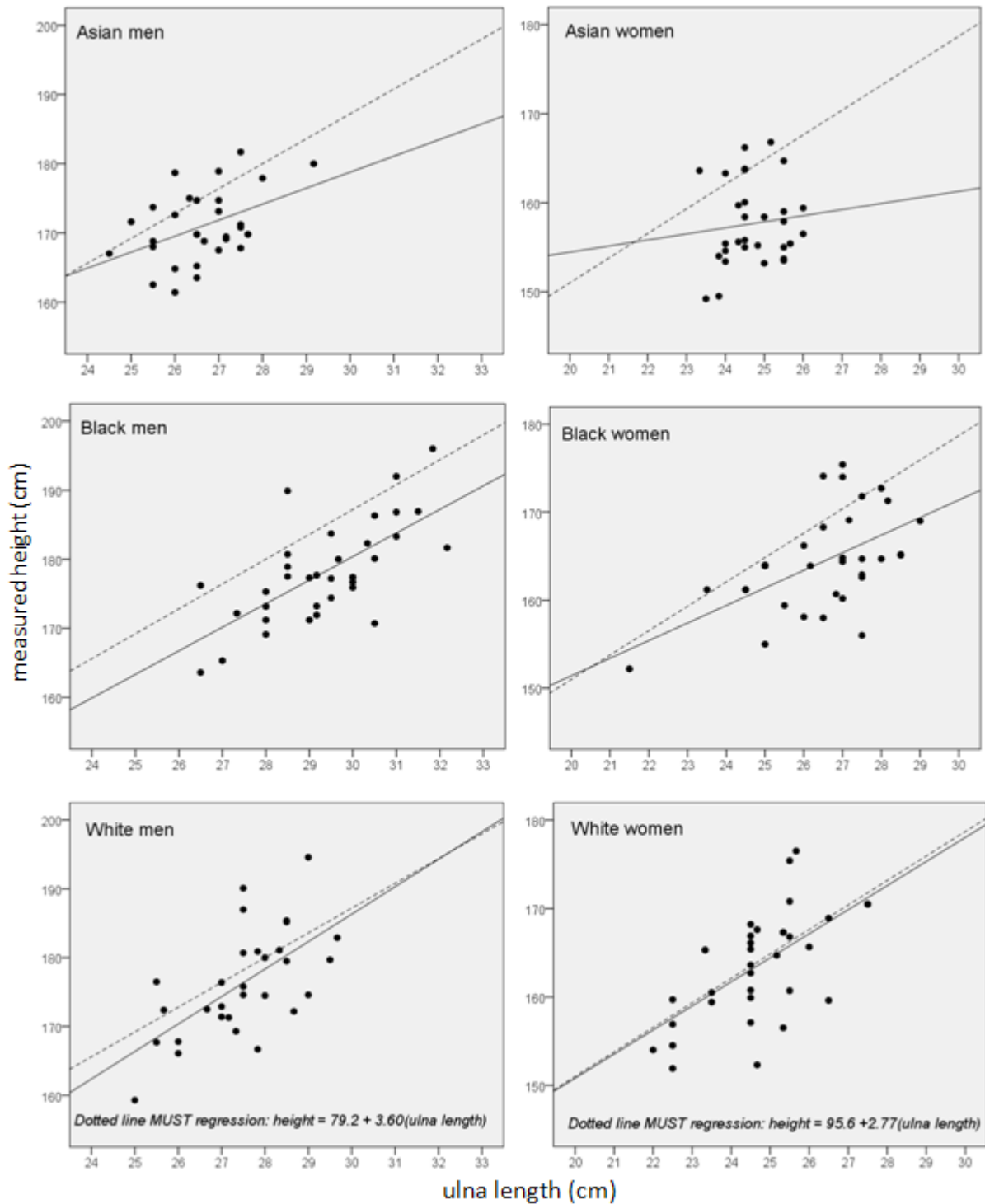

Dotted line MUST regression: height = 79.2 + 3.60(ulna length)

Dotted line MUST regression: height = 95.6 + 2.77(ulna length)

Figure 4

The difference between predicted and measured height plotted against ulna length in 194 participants by sex and ethnicity. The dotted lines represent the mean difference and 95% "limits of agreement" (i.e. ± 1.96 standard deviations).
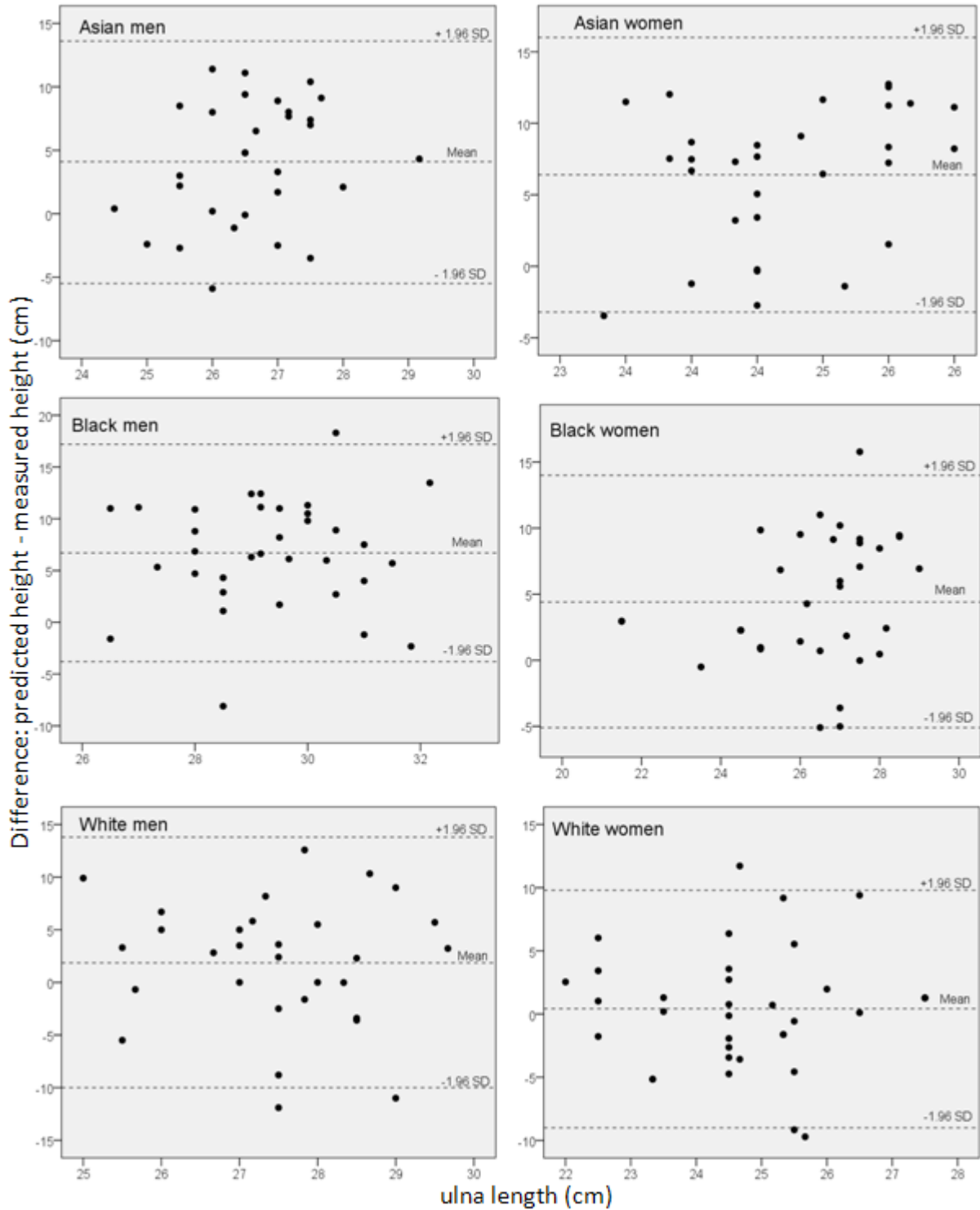
Table 1

Age and measured height and ulna length in 194 subjects by sex and ethnicity

Group	n	Age (years) mean (SD)	range	Measured height (cm) mean (SD)	Ulna length (cm) mean (SD)
Men					
Asian	30	31.7 (11.0)	21-55	170.9 (5.2)	26.6 (1.0)
Black	34	32.0 (10.3)	21-58	178.1 (7.3)	29.3 (1.5)
White	30	38.6 (12.5)	21-62	176.3 (7.7)	27.5 (1.2)
Significance				*AB<0.001; AW=0.009*	*AB<0.001; AW=0.021; BW<0.001*
Women					
Asian	30	26.2 (5.4)	21-45	157.7 (4.7)	24.7 (0.7)
Black	35	32.6 (8.9)	21-57	164.0 (5.9)	26.3 (1.8)
White	35	35.7 (11.7)	21-61	163.7 (6.2)	24.7 (1.4)
Significance		*AB=0.018; AW<0.001*		*AB<0.001; AW<0.001*	*AB<0.001; BW<0.001*

Significance: ANOVA (Bonferroni post hoc test), AB – Asian-Black; AW – Asian-White; BW Black-White.

Table 2

Correlation between measured height and ulna length and difference between measured and predicted height in 194 subjects by sex and

ethnicity

Group	Correlation between measured height and ulna		Regression coefficients		Predicted height (cm)	Difference in height (cm) predicted – measured	
	r	P value	constant a	slope (95% CI) b	mean (SD)	mean (SD)	95% LA
Men							
Asian	0.43	0.017	109.4	2.31 (0.46, 4.17)	175.0 (3.5)	4.06 (4.87)	-5.5, 13.6
Black	0.68	<0.001	77.9	3.42 (2.10, 4.73)	184.8 (5.2)	6.70 (5.33)	-3.8, 17.2
White	0.62	<0.001	66.6	4.00 (2.06, 5.92)	178.2 (4.4)	1.86 (6.07)	-10.0, 13.8
Women							
Asian	0.11	0.570	140.8	0.68 (-1.75, 3.11)	164.0 (2.1)	6.37 (4.90)	-3.2, 16.0
Black	0.61	<0.001	111.5	2.00 (1.07, 2.93)	168.4 (4.9)	4.44 (4.87)	-5.1, 14.0
White	0.63	<0.001	96.3	2.72 (1.54, 3.91)	164.1 (4.0)	0.42 (4.79)	-9.0, 9.8

r – correlation coefficient; CI – confidence intervals; SD – standard deviation; LA – limits of agreement