Mal J Nutr 25(3): 393-403, 2019

Equations to predict height and weight in Asian-Chinese adults

Christiani Jeyakumar Henry[1, 2], **Shalini Ponnalagu**[1] **& Xinyan Bi**[1]

[1]*Clinical Nutrition Research Centre (CNRC), Singapore Institute for Clinical Sciences (SICS), Agency for Science, Technology and Research (A*STAR) and National University Health System, Singapore*; [2]*Department of Biochemistry, Yong Loo Lin School of Medicine, National University of Singapore, Singapore*

ABSTRACT

Introduction: Height and weight measurements are required for the assessment of nutritional status. However, it is difficult to measure these parameters in non-ambulatory persons. Hence, simple predictive equations that estimate these measurements using various anthropometric measurements are necessary. **Methods:** A total of 441 Asian-Chinese adults (174 males, median age = 32.5, IQR: 27.8 years; 267 females, median age = 34.6, IQR: 28.5 years) were used to build height and weight sex-specific prediction equations. An additional 111 Asian-Chinese adults (44 males, median age = 31.1, IQR: 25.0 years; 67 females, median age = 30.6, IQR: 25.6 years) were used to validate the newly developed prediction equations. **Results:** The best predictive model for height included arm length, knee height measurements and age (R^2 = 0.70, standard error of estimate [SEE] = 3.38 for males; R^2 = 0.71, SEE = 3.14 for females). The best weight predictive model included age, arm circumference and waist circumference (R^2 = 0.79, SEE = 4.66 for males; R^2 = 0.78, SEE = 4.38 for females). The new predictive models for height and weight have non-significant prediction biases as compared to the Cereda *et al.* (2010) and Ross equations, respectively. **Conclusion:** Height and weight predictive equations with a higher degree of accuracy have been developed for Asian Chinese adults.

Keywords: Height, weight, prediction equations, anthropometry, simple

INTRODUCTION

Height and weight are significant clinical measures that are necessary to assess the health and nutritional status of an individual (Sah, Kumar & Bhaskar, 2013). Height and weight measurements are used to calculate the body mass index (BMI), which is a rapid and easy method that is widely used to assess the health status of an individual. The BMI is an assessment of body weight and its calculation is beneficial (Hall & Cole, 2006). Based on the BMI, individuals may be categorised as underweight, normal weight, overweight and obese. Furthermore, drug dosages are determined based on the BMI and body surface area calculation which is calculated from height and weight of an individual (Chittawatanarat *et al.*, 2012; Sah *et al.*, 2013).

However, the measurements of height and weight are not always easily obtained especially in those who are

*Corresponding author: Prof. Christiani Jeyakumar Henry
Centre for Translational Medicine, 14 Medical Drive #07-02, MD 6 Building
Yong Loo Lin School of Medicine, Singapore 117599
Phone: +65 6407 0793; Fax: +65 6776 6840; Email: Jeya_Henry@sics.a-star.edu.sg
doi: https://doi.org/10.31246/mjn-2019-0033

not ambulatory and are incapable of upright posture. To date, various indirect methods have been developed to estimate height and weight from measuring body segments. Chumlea *et al.* (1988) were one of the first to develop predictive equations for height and weight estimations using anthropometric measurements in an elderly population. Chumlea's model for predicting height was developed in Hispanic and non-Hispanic Whites, and Blacks, in the United States using knee height. After that, various other models have been developed to predict height and weight using anthropometric measurements in various populations (Agarwal, Zaidi & Agarwal, 2015; Cereda, Bertoli & Battezzati, 2010; Chittawatanarat *et al.*, 2012; Sah *et al.*, 2013).

The generalisation of such equations is questionable as anthropometric measurements are ethnic- and age-specific. For example, Chinese are known to have relatively shorter legs as compared to Caucasians of the same height (Eveleth *et al.*, 1976). As there is no formula to predict height and weight in Asian-Chinese adults, the objective of this study was to 1) develop predictive models for height and weight in Asian-Chinese adults and 2) to compare the predictive performance of the models with two other models.

MATERIALS AND METHODS

Study design and participants

The predictive equations were developed and evaluated for validity using data from a cross-sectional study conducted at the Clinical Nutrition Research Centre (CNRC), Singapore, between June 17, 2014, and October 20, 2017. The inclusion criteria included females who were not pregnant, and males and females without a diagnosis of any major diseases, such as diabetes and hypertension, and not on long-term medication. Athletes and fit individuals were not excluded. Participants were recruited through advertisements that were placed around the National University of Singapore campus, public area, and on the CNRC website. A total of 441 of the enrolled participants (174 males, age range 21-74; 267 females, age range 21-74) were used to develop the predictive equations. An additional 111 (44 males, age range 22-63; 67 females, age range 21-64) who were enrolled under the same study were used to evaluate the validity of the developed prediction equations. The National Healthcare Group Domain Specific Review Board (NHG DSRB, Reference Number: 2013/00783), Singapore, provided ethical approval for the protocols of the cross-sectional study. The trial registration number was ACTRN12614000643673. All participants provided written and informed consent prior to the commencement of the study.

Anthropometric measurements

Anthropometric measurements were taken in a fasting state following standard protocols (Lohman, Roche & Martorell, 1988). As this study was secondary to another primary study in which fasting blood sample was collected, anthropometric measurements were also done in the fasted state. Weight (in kg) was measured to the nearest 0.1 kg in light clothing without footwear using an electronic scale (Seca 763 digital scale, Birmingham, United Kingdom) and height (in cm) was measured using a stadiometer (Seca 763 digital scale, Birmingham, United Kingdom) to the nearest 0.1 cm. Waist circumference (WC) and arm relaxed girth (arm circumference, AC) was measured using a standard non-elastic measuring tape (Lufkin W606PM). WC was taken at the smallest reading above the umbilicus or navel and below the xiphoid process. AC was taken at the level of the midacromiale radiale when the participant assumed a relaxed standing position with the arms hanging by the sides. Tibiale laterale (knee height) was taken as the vertical distance from the tibiale laterale site to the standing height using a segmometer. Foot length was taken as the linear distance between the coronal planes of the Pternion and Akropodion using a caliper scale (Element14, Singapore). All of these measures were done on the right sides of the body.

All anthropometric measurements were done in duplicate. The quality of the measurements was assessed and a third measurement was taken if the deviation between the first two measurements was > 2%. The final measurement value used was the average of the duplicate or triplicate measurements. All measurements were taken by research staff who were trained by one of the principle investigating officers of the study.

Statistical analysis

Sex-specific equations were explored using easily obtainable anthropometric measurements to predict height and weight, separately. Arm length, foot length, knee height and age were explored for predicting height while AC, WC, hip circumference (HC) and age were assessed for predicting weight.

Model selection was done using stepwise regression with the Akaike Information Criterion (AIC) (Shmueli, 2010). The AIC is a measure that is used to compare the fit of related models for a given dataset. The smaller the value of AIC, the better the model fits the data, hence the model with the smallest AIC was chosen as the initial model for predicting height and weight. The initial model was further modified to ensure that the predictive model was simple with easily obtainable measurements. Predictive equations with a maximum of two anthropometric measurements were deemed to be simple. The model with the highest predicted R^2, adjusted R^2 and lowest standard error of estimate (SEE) was chosen as the final predictive model (Table 2A and 2B). The predicted R^2 is a form of cross-validation that indicates the predictive performance of the models in a new dataset that has a different set of participants, which was not included in the model building set. The higher predicted R^2 was one indication of better model performance. The adjusted R^2, as the name suggests, is an adjusted form of R^2 (correlation coefficient of determination), which indicates how well the model fits the data. The higher the value the better the model fit (Ho, 2006).

The predictive performance of the newly chosen predictive models was cross-validated in the independent dataset (N = 111, males = 44, females = 67) and also compared with the performance of the Cereda *et al.* model (Cereda *et al.*, 2010) for height, and the Ross Laboratories model (Melo *et al.*, 2014) for weight. The prediction bias, mean absolute percentage error and root mean squared error (RMSE) values of the chosen prediction models were used to compare the predictive performance of the newly developed models. The prediction bias referred to the mean difference between the observed and predicted values. The smaller the difference the better the (predictive) model predicts. RMSE amplifies errors between the predicted and observed values and helps in determining the predictive performance of the model (Rativa, Fernandes & Roque, 2018). The formula for the RMSE is as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum(observed - predicted)^2}$$

Mean absolute percentage error was calculated using the formula as follows:
Mean absolute percentage error =

$$\left\{\frac{1}{n}\sum\left(\frac{|observed-predicted|}{observed}\right)\right\} \times 100\%$$

The predictive models for both height and weight were also evaluated for bias using the paired sample *t* test and deviation from the line of identity (observed graphically) method. For the latter method, the predicted values (height or weight) were used as the dependent variable and the actual measured values (height or weight) were the independent variable. The Mann-Whitney test was used to test for significant differences in the characteristics of the participants in the model building and validation dataset.

All statistical analyses in this study were done using SPSS version 24 (IBM Corp., Armonk, NY) and Statistical software R (R Studio Inc., Boston, MA). Data were reported as mean±standard deviation (SD) or median and interquartile range where appropriate, and all statistical tests in this study were significant at $p<0.05$.

RESULTS

Table 1 summarizes the characteristics of the participants who were recruited into the study. There were no statistically significant differences in the participant characteristics between the model validation and model building datasets ($p>0.05$). Prediction models for height and weight were developed separately for each sex using this dataset.

The model with the smallest AIC for predicting height included all the variables under consideration, i.e. arm length, knee height, foot length and age. Among them, arm length had the highest standardised coefficient values in linear regression for both sexes. Hence, it was seen to be highly effective in the height-prediction model. Hence, two other models with either knee height or foot (but not both at the same time) were compared while keeping the other variables unchanged. The predicted R^2, adjusted R^2 and SEE of the subsequent models were compared (Table 2A). The

Table 1. Description of the study participants used in model building (n=441) and validation dataset (n=111)

Characteristics†	*Model building dataset*				*Validation dataset*			
	Females (n=267)		*Males (n=174)*		*Females (n=67)*		*Males (n=44)*	
	Median	*Interquartile range*	*Median*	*Interquartile range*	*Median*	*Interquartile range*	*Median*	*Interquartile range*
Age (years)	34.6	28.5	32.5	27.8	30.6	25.6	31.1	25.0
Waist circumference (cm)	69.3	9.9	77.7	11.0	68.5	9.9	80.5	13.7
Height (cm)	159.9	7.8	171.5	8.1	159.0	6.8	170.6	9.7
Arm circumference (cm)	24.8	4.8	28.9	4.8	25.7	4.7	29.5	4.2
Knee height (cm)	40.6	3.9	44.1	4.7	39.7	4.0	44.4	6.3
Foot length (cm)	22.7	1.7	25.0	1.9	22.5	1.9	24.9	1.9
Hip circumference (cm)	91.1	8.0	92.7	8.6	90.4	9.6	94.5	9.1

†There were no significant differences ($p>0.05$) in the characteristics between model building and validation dataset using the Mann-Whitney test.

Table 2A. Details of the model selection process of height for both sexes using the model building dataset (n=441)

Sex	*Models for height*	*Predicted R^2*	*Adjusted R^2*	*SEE*
Males	Arm length, knee height, foot, age	0.69	0.71	3.32
	Arm length, knee height, age†	0.69	0.70	3.38
	Arm length, foot, age	0.66	0.67	3.51
Females	Arm length, knee height, foot, age	0.75	0.76	2.87
	Arm length, knee height, age†	0.70	0.71	3.14
	Arm length, foot, age	0.70	0.71	3.14

†These are the final predictive models that were chosen

model with arm length, knee height and age had the highest predicted R^2, adjusted R^2 and smallest SEE as compared to the initial model that was selected using the AIC procedure in the males (Table 2A). Hence, the height-prediction model for the males included arm length, knee height and age. The model for females showed no significant difference in the performance of the predictive equations with knee height or foot length (Table 2A). As such, the model for males was usable for females as well.

The sex-specific equations that have been developed for predicting height are as follows:

Height (cm) for males =
64.30+[2.19×arm length (in cm)]
+[0.83×knee height (in cm)]
+[0.02×age (in years)]

Height (cm) for females =
67.83+[2.08×arm length (in cm)]
+[0.84×knee height (in cm)]
-[0.06×age (in years)]

The same AIC stepwise regression method was used to develop sex-specific predictive models for weight. The weight-predictive model with the smallest AIC for males included HC, AC and WC measurements, and age. The initial model was further compared with models that either had WC coupled with or without AC instead of HC to obtain a simple predictive model with easily measurable variables (Table 2B).

In males, the model with WC, AC and age was seen to perform similar to the model with HC instead of WC (Table 2B). Hence, the model with WC was chosen as the weight-prediction model for males.

Table 2B. Details of the model selection process of weight for both sexes using the model building dataset (n=441)

Sex	*Models for weight*	*Predicted R^2*	*Adjusted R^2*	*SEE*
Males	Hip circumference, arm circumference, waist circumference, age	0.86	0.87	3.64
	Age, arm circumference, waist circumference†	0.78	0.79	4.66
	Age, arm circumference, hip circumference	0.84	0.84	4.00
Females	Hip circumference, waist circumference, age	0.85	0.86	3.54
	Arm circumference, waist circumference, age†	0.77	0.78	4.38
	Waist circumference, age	0.75	0.76	4.58

†These are the final prediction models that were chosen

Table 3A. Evaluation of the validity of the newly developed prediction equations for height with Cereda *et al.* predictive equations using 111 datasets from 44 males and 67 females

Sex	*Model*	*Prediction bias* (cm)	*Mean absolute percentage error* (%)	*RMSE*† (cm)
Males	Arm length, knee height, age‡	0.00±2.77	1.33±0.92	2.74
	Knee height, age, sex§	-14.38±6.20***	8.36±3.61	15.63
Females	Arm length, knee height, age‡	0.52±3.00	1.51±1.17	3.02
	Knee height, age, sex§	-13.84±4.75***	8.70±2.94	14.62

†RMSE: root mean squared error
‡These are the newly developed equations
§Equations developed by Cereda *et al.* (Cereda *et al.*, 2010)
****p*<0.001

For females, the weight-prediction model with the smallest AIC included both HC and WC along with age. Again models with WC but with or without AC were compared to obtain the model with the highest predicted R^2, adjusted R^2 and low SEE (Table 2B).

The sex-specific equations that have been developed for predicting weight are as follows:

Weight (kg) for males =
-16.75-[0.14×age (in years)]
+[0.69×arm circumference (in cm)]
+[0.89×waist circumference (in cm)]

Weight (kg) for females =
-12.86-[0.15×age (in years)]
+[0.69×arm circumference (in cm)]
+[0.81×waist circumference (in cm)]

The performance of the height- and weight-prediction equations and the various comparative equations are summarised in Table 3A and 3B. Unlike the model by Cereda *et al.* (2010), the prediction bias of the newly developed height-prediction models was not significant for both the sexes. Furthermore, the mean absolute percentage error and RMSE were <2% and <3.0 cm, respectively, for both sexes (Table 3A).

However, the mean absolute percentage error and RMSE of the model by Cereda *et al.* (2010) were about 9% and 16 cm, respectively, for both sexes (Table 3A). Therefore, the newly developed height-prediction models in this study predicted height better than the model by Cereda *et al.* (2010).

As for the weight-prediction models, the newly developed models had non-significant prediction bias with mean absolute percentage error of <7% and RMSE of <5 kg for both sexes (Table 3B). By contrast, the mean absolute percentage error and RMSE were about 16% and 11 kg, respectively, for white people, and, 30% and 17 kg, respectively, for black people when using the Ross Laboratories model (Melo *et al.*, 2014) (Table 3B). Therefore, the newly developed weight-prediction models predicted better than Ross Laboratories model (Melo *et al.*, 2014) for both black and white men and women.

The performance of the height- and weight-prediction models was examined by plotting the predicted versus the actual measured values (Figure 1 and 2). The bold straight lines (line of

Table 3B. Evaluation of the validity of the newly developed prediction equations for weight with Ross's predictive equations using 111 datasets from 44 males and 67 females

Sex	*Model*	*Prediction bias (kg)*	*Mean absolute percentage error (%)*	*RMSE[a] (kg)*
Males	age, arm circumference, waist circumference[b]	-0.25±4.67	5.48±4.23	4.62
	knee height, arm circumference (Ross, white men)[c]	-9.35 ±6.44***	13.36±8.29	11.31
	knee height, arm circumference (Ross, black men)[c]	-12.79±6.32***	17.93±8.49	14.23
Females	arm circumference, waist circumference, age[b]	0.53±4.53	6.46±6.27	4.53
	knee height, arm circumference (Ross, white female)[c]	-8.79±5.32***	16.33±8.97	10.25
	knee height, arm circumference (Ross, black female)[c]	-16.02±5.17***	29.63±9.75	16.82

***P<0.001; [a] RMSE: root mean squared error; [b] The newly developed equations; [c] Equations developed by Ross (Melo *et al.*, 2014).

identity) in Figure 1 and 2 indicate the line of perfect prediction (R^2 = 1). The predicted and observed values for height and weight using the newly developed equations fell on or near the line of identity for both sexes (Figure 1 and 2). However, for the other reference models, the predicted and observed values for height and weight fell below the line of identity. It should be noted that the newly developed height-prediction models slightly overestimate for shorter people and slightly underestimate for taller people (Figure 1 and 2).

DISCUSSION

Height and weight are important anthropometric parameters that need to

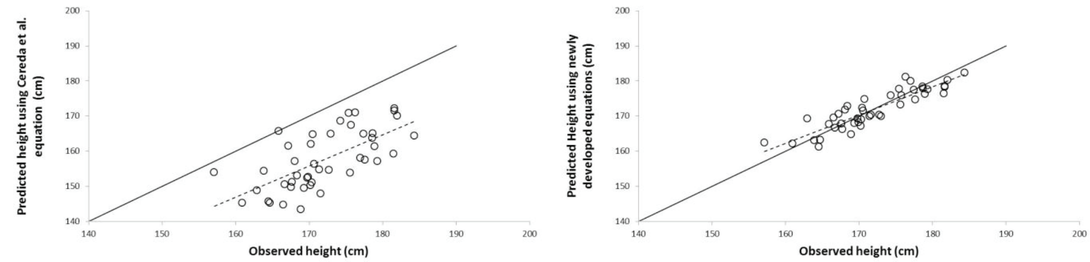

Figure 1A. Line of identity method to compare the bias of the newly developed height-prediction models in males with the Cereda *et al.* model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

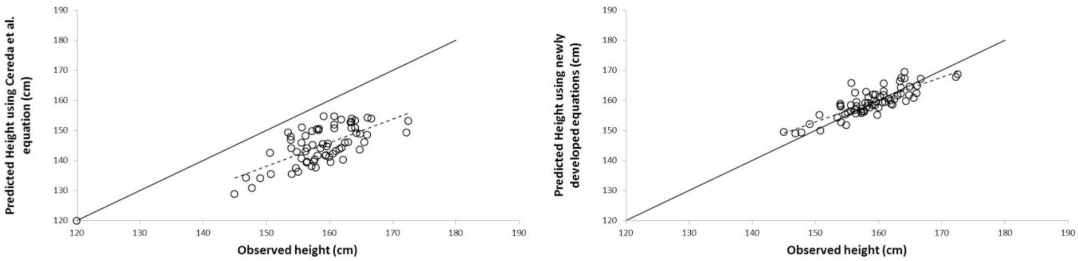

Figure 1B. Line of identity method to compare the bias of the newly developed height-prediction models in females with the Cereda *et al.* model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

be evaluated to determine the nutritional status and drug dosage of an individual. There have been predictive equations that have been developed for various populations because anthropometric measurements are ethnicity- and age-specific (Eveleth *et al.*, 1976). In this study, predictive equations for Asian-Chinese adults were developed. The proposed equations serve to perform screening for over- and under-nutrition in individuals when the direct measurements of height and weight are either impossible or impracticable, i.e. in non-ambulatory people.

Knee height, arm length, foot length and age were the variables that were considered for developing height-prediction model. All the three anthropometric variables that were considered had a linear relationship with height. Knee height is one of the commonest anthropometric variables used as a proxy indicator to standing height, as it is independent of age and does not appear to decrease over time. It can be measured while seated or lying down (Hickson & Frost, 2003). Similarly, foot length was considered as it has been known through the work by Rutishauser (Rutishauser, 1968) that foot length has a strong correlation with the long bones in the body (Patel, Shah & Patel, 2007). As shown in the current study, the model with knee height and arm length had a higher predictive R^2 and lower SEE as compared to a model with foot length. Therefore, knee height, arm length, and age were used to predict height.

HC, AC, WC, and age were the anthropometric variables that were considered for developing the weight-prediction model. All the variables that were considered had a linear relationship with weight. The models with HC, AC, WC, and age had the highest predicted R^2 and lowest SEE for males. However, models with only two anthropometric measurements were considered to be simple and practical. Having to measure multiple anthropometric measurements so as to predict height/weight will not be practical or efficient since it would have defeated the purpose of developing a predictive model as body length could be measured directly instead. Though the models with HC, WC and age had the highest predicted R^2 and smallest SEE for the females, models without HC were compared in both sexes.

As the predictive models are for those who are not able to step on the scale independently, anthropometric measurements that could be obtained with ease from those lying supine are necessary. For this reason, WC was preferred to HC as the former could be obtained by lifting an individual to sit on a wheelchair and obtaining the measurement. Due to this reason,

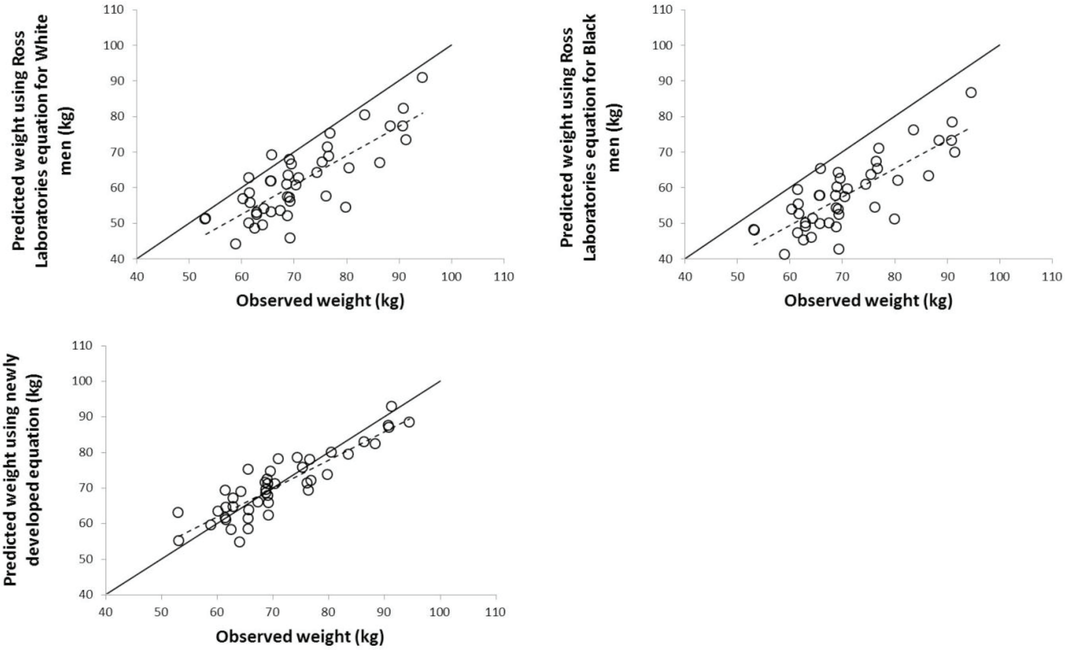

Figure 2A. Line of identity method to compare the bias of the newly developed weight-prediction models in males with the Ross model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

models without HC were developed and compared with each sex.

The predicted R^2 of weight-prediction models with AC, WC and age differed from the models that included HC by 0.08 in males and females. The similarity in performance of models with and without HC but with WC could be attributed to the fact that Asians have a tendency for abdominal adiposity (Lim *et al.*, 2011; Wulan, Westerterp & Plasqui, 2010). Hence, the inclusion of WC and AC was still able to compensate for the exclusion of HC in the model.

Asians have different body morphology compared to Caucasians (Eveleth *et al.*, 1976). Hence, the predictive equations developed in Caucasian populations cannot be generalised to Asians. This has been shown in this study where the height and weight prediction equations by Cereda *et al.* (2010) and the Ross Laboratories model (Melo *et al.*, 2014) respectively, significantly underestimated the height and weight values (p<0.001) for both sexes (Table 3A and 3B). Furthermore, the line of identity in Figures 1 and 2 illustrate that the predicted values using the model by Cereda *et al.* (2010) or Ross Laboratories (Melo *et al.*, 2014) were below the line of perfect prediction (the bold line in Figures 1 and 2); this again illustrates the underestimation made when using these models for predicting height and weight, respectively.

We acknowledge the limitations in this study. The study was done on healthy subjects, so the generalizability of the model in impaired groups such as individuals with extreme skeletal deformities and marked muscle hypotrophy is limited. Secondly, the study was done on Asian-Chinese

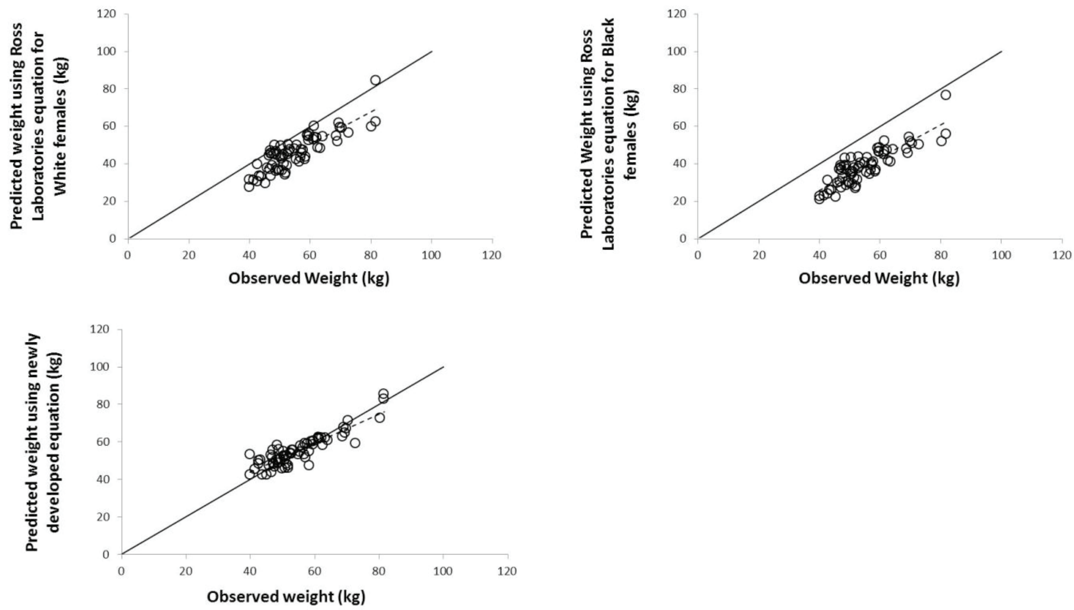

Figure 2B. Line of identity method to compare the bias of the newly developed weight-prediction models in females with the Ross model. This was done using 111 datasets from 44 males and 67 females. The solid black line represents the line of perfect prediction while the dotted line is the best fitted line

living in Singapore. Further research is warranted to validate the applicability of the new equations in a larger number of Chinese adults both living in China and elsewhere. However, the use of a large population to develop the predictive equations is the strength of this study. It should be emphasised that this is the first attempt to predict height and weight in Asian-Chinese adults using anthropometric measurements.

CONCLUSION

Height and weight measurements are necessary for assessing the health status of an individual but they are not easily obtainable in those who are unable to stand erect or remain supine. Hence, equations to predict height and weight that are specific for Asian-Chinese have been developed in this study. The accuracy of the new developed equations to predict height and weight are better than the predictive equations by Cereda *et al.* (2010) and Ross Laboratories model (Melo *et al.*, 2014) respectively.

Acknowledgement

We would like to acknowledge Agnes Tey and Yi Ting Loo for their assistance in data collection. (Prior permission from those mentioned in the acknowledgment has been obtained).

Authors' contributions

CJH, principal investigator, conceptualised and designed the study, interpreted the results, assisted in drafting the manuscript and reviewed the manuscript; SP, performed statistical analysis, interpreted the results, assisted in drafting the manuscript; XB, conducted the study, interpreted the results, assisted in drafting the manuscript and reviewed the manuscript.

Conflict of interest

Authors declare no conflict of interest.

List of abbreviations

AC: arm circumference; AIC: Akaike Information Criterion; HC: hip circumference; RMSE: root mean squared error; WC: waist circumference

References

Agarwal S, Zaidi SHH & Agarwal SK (2015). Correlation of body height by foot length and knee height measurements in population of North India. *Int J Anat Res* 3(3):1225-1229.

Cereda E, Bertoli S & Battezzati A (2010). Height prediction formula for middle-aged (30–55 y) Caucasians. *Nutr* 26(11-12):1075-1081.

Chittawatanarat K, Msc SP, Trakulhoon V, Ungpinitpong W & Patumanond J (2012). Height prediction from anthropometric length parameters in Thai people. *Asia Pac J Clin Nutr* 21(3):347-354.

Chumlea WC, Guo S, Roche A & Steinbaugh M (1988). Prediction of body weight for the nonambulatory elderly from anthropometry. *J Am Diet Assoc* 88(5):564-568.

Eveleth PB, Eveleth PB, Tanner JM & Chang W (1976). *Worldwide variation in human growth* (Vol. 8): Cambridge University Press Archive.

Hall DM & Cole TJ (2006). What use is the BMI? *Arch Dis Child* 91(4):283-286.

Hickson M & Frost G (2003). A comparison of three methods for estimating height in the acutely ill elderly population. *J Hum Nutr Diet* 16(1):13-20.

Ho R (2006). *Handbook of univariate and multivariate data analysis and interpretation with SPSS*: Chapman and Hall/CRC, Boca Raton.

Lim U, Ernst T, Buchthal SD, Latch M, Albright CL, Wilkens LR, Kolonel LN, Murphy SP, Chang L, Novotny R & Marchand LL (2011). Asian women have greater abdominal and visceral adiposity than Caucasian women with similar body mass index. *Nutr & Diabetes* 1(5):e6.

Lohman TG, Roche AF & Martorell R (1988). *Anthropometric standardization reference manual*: Human Kinetics Books, Champaign, Illinois.

Melo APF, de Salles RK, Vieira FGK & Ferreira MG (2014). Methods for estimating body weight and height in hospitalized adults: a comparative analysis. *Rev Bras Cineantropom Desempenho Hum* 16(4):475-484.

Patel S, Shah G & Patel S (2007). Estimation of height from measurements of foot length in Gujarat region. *J Anat Soc India* 56(1):25-27.

Rativa D, Fernandes BJ & Roque A (2018). Height and weight estimation from anthropometric measurements using machine learning regressions. *IEEE J Transl Eng Hlth Med* 6:1-9.

Rutishauser I (1968). Prediction of height from foot length: Use of measurement in field surveys. *Archives of Disease in Childhood* 43(229): 310.

Sah R, Kumar A & Bhaskar R (2013). Body height and its estimation utilizing arm span measurements in population of Birgunj Area of Nepal: an anthropometric study. *J Coll Med Sci-Nepal* 9(4):9-14.

Shmueli G (2010). To explain or to predict? *Stat Sci* 25(3):289-310.

Wulan S, Westerterp K & Plasqui G (2010). Ethnic differences in body composition and the associated metabolic profile: a comparative study between Asians and Caucasians. *Maturitas* 65(4):315-319.