

Agreement between measured height, and height predicted from published equations, in adult South African patients

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Objectives: Estimation equations based on different body segments are commonly used to predict height in patients whose height cannot be directly measured. This study aimed to assess the agreement between measured (reference) height and height predicted from published equations derived from measurement of body segments, in a South African public hospital setting.

Design: A descriptive cross-sectional study was undertaken.

Setting: Medical, surgical, pulmonary, orthopaedic, cardiovascular and general wards at three public hospitals in Bloemfontein.

Subjects: Admitted patients, 20–50 years old; able to stand upright without assistance and without medical conditions or treatments affecting height.

Outcome measures: Stadiometer height, recumbent height, arm span, demi-span, ulna length, knee height, tibia length, fibula length and foot length were measured with standardised techniques. Height, predicted by 12 published equations, was compared with stadiometer height by 95% confidence intervals (CI) and Bland–Altman analysis.

Results: The median stadiometer height of the sample ($n = 141$; 38.3% female; median age 38.8 years, IQR 33.3–44.4 years) was 165.5 cm (males 169.3 cm; females 158.4 cm). Only a set of equations based on knee height and standardised on a large population of adults < 65 years in the United States estimated height without statistically significant deviance from the stadiometer height.

Conclusions: Most standardised equations applied to hospitalised adults in a South African public health setting resulted in height estimations that differed significantly from height. Thus, equations standardised on other populations may not be suitable for the South African population, possibly due to differences in genetic and environmental factors.

Keywords adult, height prediction equations, predicted height, public health, South Africa

Introduction

Height is a fundamental measurement in hospitalised patients. Amongst many other clinical applications, accurate height measurements are required to calculate body mass index (BMI) and ideal bodyweight (IBW), which, in turn, are used in nutritional screening and the calculation of nutritional requirements of patients.^{1,2} International consensus advises that all patients should be screened for nutritional risk on admission,³ and throughout the hospital stay³ so that appropriate dietary intervention based on these screenings can be employed to improve and maintain proper nutritional status.^{3–5} Whereas some patients are admitted with poor nutritional status, others develop disease-related malnutrition during hospitalisation.⁶ Globally, hospital malnutrition is a prevalent phenomenon with devastating consequences for clinical outcomes, including increased length of stay (LOS), longer duration of rehabilitation, increased readmission, increased cost of healthcare and increased mortality.^{6,7}

Body mass index, based on height, is a principal component of all the nutritional-risk screening tools that are recommended by the European Society for Clinical Nutrition and Metabolism (ESPEN), including the Malnutrition Universal Screening Tool (MUST), Mini Nutritional Assessment (MNA) and the Nutritional Risk Screening (NRS2002).⁸ Similarly, BMI is also one of the phenotypic criteria for the diagnosis of adult malnutrition in clinical settings, which was recently developed by the Global Leadership Initiative on Malnutrition (GLIM).³

Accurate measurement of height is, therefore, vital to calculate BMI. However, measurement of height in hospitalised patients is often problematic when patients are unable to stand upright and unassisted. This group of patients includes those connected to lines and monitors, as well as frail, elderly and injured patients. If a patient's height cannot be measured, the patient or a family member is often asked to report the patient's height, or the healthcare professional estimates the patient's height by 'eyeballing'. None of these methods is ideal and studies show that they often result in inaccurate height recording.^{9–12} Recumbent length may also be measured in patients in the supine position, but requires a standardised technique that some authors do not consider practical in the clinical setting.¹³ For example, measurements of recumbent length in the fully supine position may not always be possible due to elevation of a patient's head for clinical reasons, such as preventing aspiration.

Indirect methods for determining height may be used and most commonly involve long-bone measurements that are substituted into height estimation equations. Many such equations have been standardised in populations that differ in age, sex and ethnicity across the world. To date, no equations have been developed specifically for the South African population and only three published studies have investigated the usefulness of some published equations to predict height among South Africans. One study found that a specific set of knee height-based equations satisfactorily predicted height in the elderly recruited from retirement homes in the Western

Cape.¹⁴ The two other studies both focused on equations based on upper body segments in adults in public health settings in the Free State¹ and among healthy young adults in KwaZulu-Natal.¹⁵ Both studies found that upper body-based equations did not accurately predict stadiometer height in these settings. Therefore, evidence is lacking to guide South African healthcare workers on which measurements and equation to use to accurately predict height when direct stadiometer measurement is not possible.

This study aimed to determine the agreement between stadiometer height and self-reported height, height recorded on admission in the participant's medical file, recumbent length and height predicted from 11 published equations chosen to represent the use of different body segments, in the adult populations in a South African public hospital setting.

Methods

Study population and sampling

A descriptive cross-sectional study was conducted in 2016/2017. Ethical approval from the Health Sciences Research Ethics Committee of the University of the Free State (125/2016) and permission from the Free State Department of Health was obtained. The study population comprised patients admitted to Universitas, Pelonomi and National Hospitals in Bloemfontein. The study population was limited to patients admitted to the medical, surgical, pulmonary, orthopaedic, cardiovascular and general wards, as patients in these wards are likely to be able to stand upright without assistance to measure stadiometer height.

An appropriate sample size to do ethnic and gender-specific comparisons of the data was calculated at 500 participants. All patients in the mentioned wards admitted during the time of data collection, who met the inclusion criteria and gave informed consent, were included in the study. Inclusion criteria included age between 20 and 50 years to avoid issues related to long-bone maturation and degeneration, and the ability to stand upright without assistance for all measurements to be taken accurately. Patients were excluded from the study if they were unable to stand upright and unassisted; reported taking medication with known effects on bone development; suffered from peripheral oedema, ascites or anasarca, or were on dialysis (as these fluid compartment overloads could complicate the segmental measurements; had visible curvature of the spine or any injuries or deformities affecting their posture or mobility; or presented with any medical condition (such as contractures, or recent/past bone surgery, or bone injuries/fractures affecting height or long-bone length) that could prevent accurate measurements required for the study.

Data collection

Sociodemographic information, including date of birth, sex and race, was recorded during structured interviews with each participant. As part of the exclusion criteria, medical diagnoses and treatment were recorded from the participants' medical files to ensure that these factors did not influence bone development and growth. Height recorded in the participants' medical file, or the absence thereof, was also noted.

Height (referred to in this study as the stadiometer height), recumbent length, arm span, demi-span, ulna length, knee height, tibia length, fibula length and foot length were

measured by a single qualified dietitian with several years of clinical experience. She practised the techniques required for the different measurements under the supervision of an ISAK-qualified anthropometrist before data collection commenced. Stadiometer height was measured according to the standardised 'stretch' technique¹⁶ using a calibrated, mobile free-standing stadiometer (Seca 213®; Seca GmbH, Hamburg, Germany). Recumbent height,¹⁷ arm span,¹⁶ demi-span,¹⁸ ulna length,¹⁹ tibia length,¹⁶ fibula length²⁰ and foot length²⁰ were measured with a standard, clearly calibrated non-stretchable, steel anthropometric tape (Butterfly, Shanghai, China) according to published, standardised techniques. Knee height was measured with a knee height broad-blade sliding calliper according to the standardised technique.²¹ The same equipment was used for all the measurements and was calibrated daily.

Upon rising in the morning compression of the spine occurs, resulting in the loss of approximately 1% in height.²² The decrease in height occurs rapidly in the first half an hour, and most loss in height occurs in the first two hours of the day.²³ Patients in the specific wards that were included in the study are routinely woken up before 06h00 for observations. All anthropometric measurements were therefore taken between 08h30 and 13h30 according to the stretch stature method to minimise discrepancies linked to diurnal variation.²²

Data analysis

The 11 published equations that were assessed are summarised in Table 1.

The data analysis for this paper was generated using SAS software (SAS Institute Inc., Cary, NC, USA). Categorical data were expressed as frequencies and percentages and numerical data as medians and ranges (interquartile range and range).

Bland-Altman analysis, which is better suited to determine agreement than other methods of comparison such as correlation or regression,²⁹ was used to assess the 95% limits of agreement between height predicted from each published estimate equation, and the stadiometer height. In this analysis, the difference between the stadiometer height and the height estimated by a specific equation was plotted against the mean of the two measurements. The 95% confidence interval for the median difference between predicted and stadiometer heights (paired) was used to assess whether the predicted height, obtained with each equation, differed significantly from the measured stadiometer height.

Due to various unforeseen logistical issues, discussed later, the final sample size comprised 141 participants, and therefore no attempts were made to do gender-specific or ethnic-specific comparisons of the data.

Results

The sample of 141 included 68 (48.2%) participants from Universitas Hospital, 44 (31.2%) participants from Pelonomi Hospital and 29 (20.6%) participants from National Hospital in Bloemfontein. The median age of the participants was 38.8 years (interquartile range [IQR] 10.1 years). The sex and ethnic distribution of the participants are summarised in Table 2. The median reference height measured by stadiometer was

Table 1: Predictive equations to estimate height in the current study

Reference	Population on which the equation was developed	Equation
Demi-span (cm):		
Bassey (1986) ²⁴	125 normal young to middle-aged adults, living in Europe	Males: $(1.40 \times DS) + 57.8$ Females: $(1.35 \times DS) + 60.1$
Hirani <i>et al.</i> (2010) ¹⁸	1 421 normal adults aged 25–45 years, living in England	Males: $65.8 (4.3) + 1.33 (0.05) \times DS$ Females: $64.0 (5.1) + 1.31 (0.07) \times DS$
Ulna length (cm):		
Barbosa (2012) ¹³	Hospitalised adults < 65 years, 432 English, 75 Portuguese; 264 males, 243 females	Males: $84.5 + (3.2 \times UL)$ Females: $92.0 + (2.9 \times UL)$
MUST equations ¹⁹	229 normal adults < 65 years, living in Britain)	Males: $79.2 + (3.60 \times UL)$ Females: $95.6 + (2.77 \times UL)$
Ilayperuma <i>et al.</i> (2010) ²⁵	258 normal young adults 20–23 years, living in Sri Lanka	Males: $97.252 + (2.645 \times UL)$ Females: $68.777 + (3.536 \times UL)$
Knee height (cm):		
Chumlea and Guo (1992) ²⁶	6 672 adults < 65 years, living in the USA	Males: $(2.02 \times KH) - (0.04 \times \text{age}) + 64.19$ Females: $(1.83 \times KH) - (0.24 \times \text{age}) + 84.88$
Chumlea <i>et al.</i> (1994) ²⁷	Normal adults < 60 yrs; 299 black males, 2 177 white males, 402 black females, 2 537 white females, living in the USA	Black males: $73.42 + (179 \times KH)$ White males: $71.85 + (1.88 \times KH)$ Black females: $68.10 + (1.86 \times KH) - (0.06 \times \text{age})$ White females: $70.25 + (1.87 \times KH) - (0.06 \times \text{age})$
Tibia length (cm):		
Banerjee <i>et al.</i> (2015) ²⁸	100 normal adults aged 25–64 years, living in India	Males: $71.361 + 2.575$ (tibia length) For females: $65.344 + 2.691$ (tibia length)
Ahmad <i>et al.</i> (2014) ²⁰	359 medical students, studying in South India	$46.969 + 2.886$ (tibia length)
Fibula length (cm):		
Ahmad <i>et al.</i> (2014) ²⁰	359 medical students, studying in South India	$46.881 + 2.847$ (fibula length)
Foot length (cm)		
Ahmad <i>et al.</i> (2014) ²⁰	359 medical students, studying in South India	$52.255 + 4.519$ (foot length)

DS = demispan, UL = ulna length, KH = knee height.

165.5 cm (males 169.3 cm, IQR 10.4 cm; females 158.4 cm, IQR 10.6 cm).

Only 16 participants (11.3%) had heights recorded in their medical files, and only six participants (4.3%) self-reported their height when asked by the researcher (the rest said that they did not know their height). With these few data points the agreement between stadiometer height and recorded and self-reported height, respectively, could not be determined.

Table 2: Sex and ethnic distribution of participants

Variable	Frequency (n)	Percentage (%)
Sex		
Male	87	61.7
Female	54	38.3
Ethnicity		
Black	119	84.4
Coloured	5	3.6
Asian	5	2.1
White	14	9.9

Table 3 summarises the agreement between stadiometer height and height predicted by equations based on body segments. Stadiometer height (median 165.5 cm; IQR 12.3 cm) differed from recumbent length measured according to the standardised technique (median 166.0 cm, IQR 12.5 cm) by a median value of -0.3 cm (IQR 2.8 cm). In other words, recumbent length overestimated height by a median value of only 0.3 cm. The median difference between stadiometer height and paired recumbent length was statistically significant (95% CI 0.2; 0.5). However, the 95% limits of agreement were -4.0 cm– 1.3 cm (resulting in close clustering of the points around the zero line of perfect agreement in the Bland–Altman plot as indicated in Figure 1). The plot, thus, indicates that recumbent length ranged from underestimating stadiometer height by up to 4 cm to overestimating stadiometer height by up to 1.3 cm. In a 70 kg individual with a stadiometer height of 175 cm (BMI = 22.8 kg/m²), this will result in a predicted BMI that ranges between 22.5 kg/m² and 23.9 kg/m².

As summarised in Table 3 and illustrated by the Bland–Altman plots (Figures 1–5), of the 11 prediction equations that were included, only the set of knee height-based equations by Chumlea *et al.* (1994)²⁷ was able to predict height with no statistically significant difference from the stadiometer height (95%

Table 3: Agreement between stadiometer height (measured by stadiometer) and height predicted by equations based on body segments in cm

Factor	Minimum	Lower quartile	Median	Upper quartile	Maximum	95% Confidence interval for the median difference between stadiometer height and predicted heights (paired)	95% Limits of agreement by Bland Altman analysis
Stadiometer height	144.3	159.2	165.5	171.5	184.1		
Recumbent length	143.9	159.5	166.0	172.0	185.5	[-0.2; -0.5]*	-4.0-1.3
‡Difference	-16.0	-0.8	-0.3	0.2	4.9		
Height predicted by demi-span-based equations (n = 141):							
Bassey (1986) ²⁴	149.9	160.7	166.6	171.4	185.5	[-0.2; -1.5]*	-7.8-9.4
Difference	-11.7	-3.6	-0.8	2.4	12.4		
Hirani <i>et al.</i> (2010) ¹⁸	151.1	161.7	168.7	173.5	187.1	[-1.8; -3.1]*	-9.4-6.9
Difference	-13.7	-5.1	-2.6	0.5	11.4		
Height predicted by ulna length-based equations (n = 141):							
Barbosa <i>et al.</i> (2012) ¹²	156.4	168.6	172.2	176.0	190.4	[-5.6; -7.4]*	-17.8-4.5
Difference	-20.1	-10.3	-6.4	-3.6	7.8		
MUST equations Elia <i>et al.</i> (2011) ¹⁹	157.1	169.6	177.1	181.8	198.4	[-9.6; -11.9]*	-20.4-0.5
Difference	-27.0	-14.6	-11.0	-7.3	3.8		
Illyperuma <i>et al.</i> (2010) ²⁵	147.3	163.2	169.5	172.6	184.8	[-1.1; -3.5]*	-12.7-6.3
Difference	-15.9	-6.3	-2.3	1.3	13.6		
Height predicted by knee height-based equations (n = 141):							
Chumlea and Guo (1992) ²⁶	156.8	164.6	169.3	172.4	188.5	[-4.5; -2.5]*	-13.2-7.0
Difference	-14.3	-7.2	-3.8	-0.5	11.1		
Chumlea <i>et al.</i> (1994) ²⁷	147.9	159.7	165.4	170.6	184.6	[-0.2; 0.9]	-5.8-7.2
Difference	-7.9	-2.0	0.4	2.4	12.5		
Height predicted by tibia length-based equations (n = 141):							
Banerjee <i>et al.</i> (2015) ²⁸	150.4	166.4	171.5	177.5	201.5	[-6.8; -5.1]*	-17.3-4.3
Difference	-46.0	-9.2	-5.7	-3.4	5.8		
Ahmed <i>et al.</i> (2014) ²⁰	138.2	154.2	160.1	165.9	193	[4.4; 6.5]*	-7.9-16.5
Difference	-37.5	2.0	5.8	8.7	18.7		
Height predicted by fibula length-based equation (n = 141)							
Ahmed <i>et al.</i> (2014) ²⁰	144.5	157.4	163.9	167.6	189.8	[1.1; 3.5]*	-6.5-13.0
Difference	-28.0	-1.2	2.5	6.3	18.0		
Height predicted by foot length-based equation (n = 140)							
Ahmad <i>et al.</i> (2014) ²⁰	139.5	157.9	162.7	170.7	187.4	[1.4; 3.6]*	-11.5-14.2
Difference	-14.3	-2.4	2.2	6.2	18.0		

‡Indicates the difference between the predicted height and the paired stadiometer height.

*Indicates that the predicted height differed significantly from the stadiometer height.

CI -0.9; 0.2; 95% limits of agreement: -5.8 cm-7.2 cm). The rest of the equations delivered predicted heights that differed significantly from the stadiometer height (Table 3).

Discussion

Less than 5% of participants in the current study from a population of adult patients admitted to public hospitals in Bloemfontein, South Africa, could self-report their height and only 11.3% had their height recorded in their medical files. Moreover, the study found that among 11 published equations chosen to represent various body segments and standardised on adults < 65 years, only a set of knee height-based equations predicted height that did not statistically differ significantly from stadiometer height.

The fact that so few participant files included height measurements seems to indicate that healthcare practitioners in this setting may not consider height as an important measurement

when assessing a patient. Even though the admission form and prescription chart required measurement of height, while all participants in this study were able to stand unassisted for accurate height measurement, and stadiometers were available in all the wards where participants were recruited, height was recorded in only a small minority of participant files. Conversely, if patients cannot be measured standing upright, healthcare workers may not have the necessary equipment, knowledge or skills needed to measure body segments and apply predictive equations, in which case self-reported height seems like a practical option. The results of the current study, however, confirm the experience of dietitians that most patients in the South African public health setting do not know their height (or weight).

The results also show that recumbent length, although statistically significantly different from stadiometer height, predicted height within very narrow limits of agreement. Based on this, it may be a reasonable alternative to use when actual height

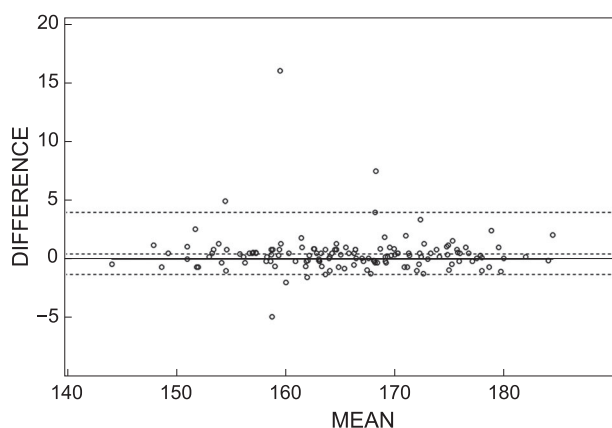


Figure 1: Bland–Altman plot depicting the level of agreement between stadiometer height and recumbent length (x-axis: degrees of freedom; y-axis: the difference between the mean of stadiometer height and recumbent length for each participant).

cannot be measured as it does not require expensive equipment. However, it does require the patient to lie straight and perfectly flat.¹⁷ Many patients who are critically ill are in the semi-Fowler's position due to the effects on haemodynamic parameters³⁰ or attached to various lines, making it difficult to measure recumbent height accurately. In the current study, it was observed that the firmness of the mattress may also affect the measurements.

Even with the right equipment and training, no study to date has identified a reliable method of predicting height in the South African population. The current study found that most published predictive equations yielded predicted heights that were statistically significantly different from stadiometer height in adults in the public hospital setting. Moreover, the difference between stadiometer height and height estimated from most of the applied equations is considered clinically significant as some equations underestimated height by median values of up to 5.8 cm while others overestimated height by median values of as much as 10.9 cm. The 95% limits of agreement, calculated in the Bland–Altman analysis, indicated underestimation of almost 20.4 cm to overestimation of 16.5 cm. Other studies have also found variable accuracy in height prediction equations when applied to different ethnic, age and populations groups than those on which they were standardised.^{13,31,32} Under- and overestimation of height impacts on many applications of the measurement in the clinical setting, amongst others on the calculation of BMI. If the widest range of under- and overestimation indicated by this study (–20.4 cm to +16.5 cm) is considered in the BMI calculation of a 70 kg patient, BMI may be overestimated by up to 4.2 kg/m² and underestimated by up to 3.4 kg/m² depending on the estimation equation applied. This may result in patients being classified in the incorrect BMI categories and their energy requirements being calculated incorrectly.

The current study did, however, identify the knee height-based equations by Chumlea et al.²⁷ as the only set of equations among those applied in the study to predict height that did not differ statistically significantly from stadiometer height. The fact that these equations were standardised on 5 415 normal males and females aged under 60 years (in the United States), and included both black and white ethnicities, may contribute to its higher level of agreement. Other equations applied in this study were typically standardised on much smaller

populations (Table 1). Similarly, Marais et al.¹⁴ also found that knee-height measurements substituted in the equations developed by Chumlea and Guo²⁶ were more closely related to the stadiometer height than arm span in participants aged over 60 years from selected old-age homes in the Western Cape.

On the other hand, published arm-based equations did not accurately predict height in a sample of 900 younger adults in KwaZulu-Natal, and the study concluded that sex- and race-specific equations are needed.¹⁵ This concurs with the findings of van den Berg et al.¹ that the ulna-based MUST equations overestimated height and predicted height that differed statistically significantly from stadiometer height in adult (20–60 years old) patients in a public hospital in the Free State. This raises another possibility, namely that the high prevalence of stunting in the South African setting could play a role in the finding that knee height-based equations deliver better predictions than arm-based equations. The South African Demographic and Health Survey, 2016 indicates that 27.4% of South African children under the age of five are stunted, while the prevalence in the Free State is even higher at 33.5%.³³ As a result of stunting, children do not reach their genetic height potential, which may influence body segment ratios. Some evidence exists that stunting affects the long bones in the lower extremities more than in the upper extremities,^{34–37} which would explain the superiority of age- and sex-appropriate equations based on knee height to predict height in the South African population of patients who represent the lower socioeconomic strata.

The possibility that differences in skeletal proportions, which is commonly attributed to ethnicity, may be more likely to be related to environmental factors is supported by the World Health Organization (WHO) Multicentre Growth Reference Study (MGRS),³⁸ which was designed to develop growth reference standards for infants and children. To obtain reference data, the growth patterns of 8 500 children living in ideal conditions with regard to infant feeding and healthcare in Brazil, Ghana, India, Norway, Oman and the United States were followed. The study aimed to provide the best conditions for growth and development and to limit sources of bias. Subsequently, the MGRS showed that infants and children of different genders and ethnicities from around the world experience similar linear growth when important health and environmental needs are met.³⁸

One problem with knee height measurement is the specialised equipment and skill needed to apply the standardised technique and predictive equations correctly, which may render it impractical for nutritional screening by nursing staff in resource-poor settings.³ Finding the most reliable and practical way of determining height of patients who are unable to stand upright in the South African population may prove to be a very complicated but vitally important focus of future research.

Limitations

Most patients admitted to the relevant public hospitals during the time of data collection did not meet the inclusion criteria due to advanced age and/or not being able to stand upright without assistance for stadiometer measurements. The final sample was therefore smaller than planned with an overrepresentation of men (62%), which may influence the generalisation of the results. However, the sample still represented the South African population with regard to height and ethnicity. The median reference heights for males (169.3 cm) and females (158.4 cm) (18–50 years) measured in this study were in line with the average heights for males (169.1 cm) and females

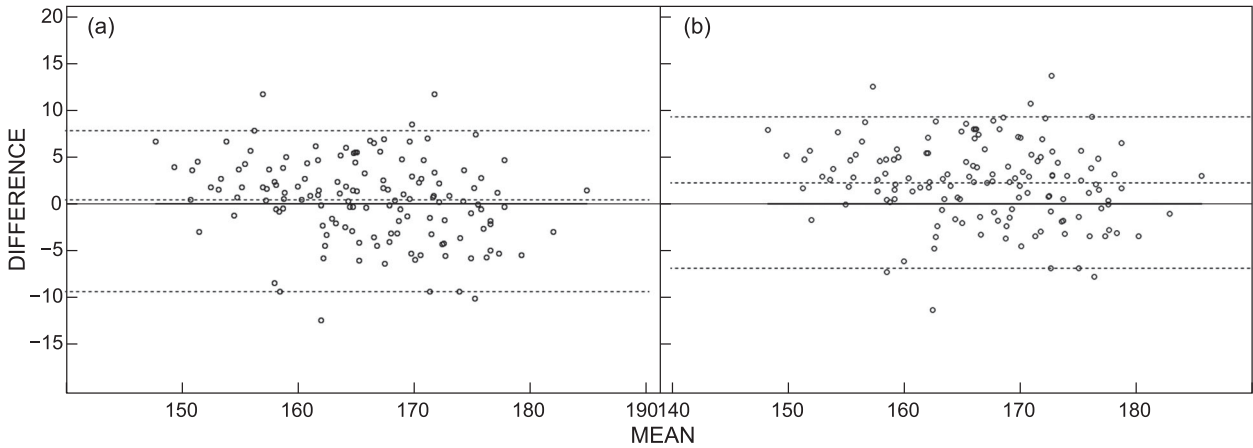


Figure 2: Bland–Altman plots for the equations of Bassey (1986)²⁴ and Hiranie *et al.* (2010)¹⁸ based on demi-span, depicting the levels of agreement between stadiometer height and height predicted from equations based on demi-span (x-axis: degrees of freedom; y-axis: the difference between the mean of stadiometer height and predicted height for each participant).

(158.4 cm) of similar age (15–54 years) reported in the South African National Health and Nutrition Examination Survey (SANHANES-1).³⁹ Similarly, the ethnic distribution of the sample (Black African 84.4%, White 9.9%, Coloured 3.6% and Indian/Asian 2.1%) was roughly in line with the estimated mid-year population statistics reported by STAT SA for 2016 (Black African 80.7%, White 8.1%, Coloured 8.8% and Indian/Asian 2.5%).⁴⁰ In a larger sample it would have been interesting to compare the data across gender and ethnicity.

Another source of bias might have occurred due to some patients staying in bed and others walking around before measurements being taken, which could result in some diurnal variation between patients.

Despite the limitations, the results of the study are still considered meaningful as they provides valuable insight into the reliability of various standardised equations in height estimations that have never before been tested in the South African public health setting.

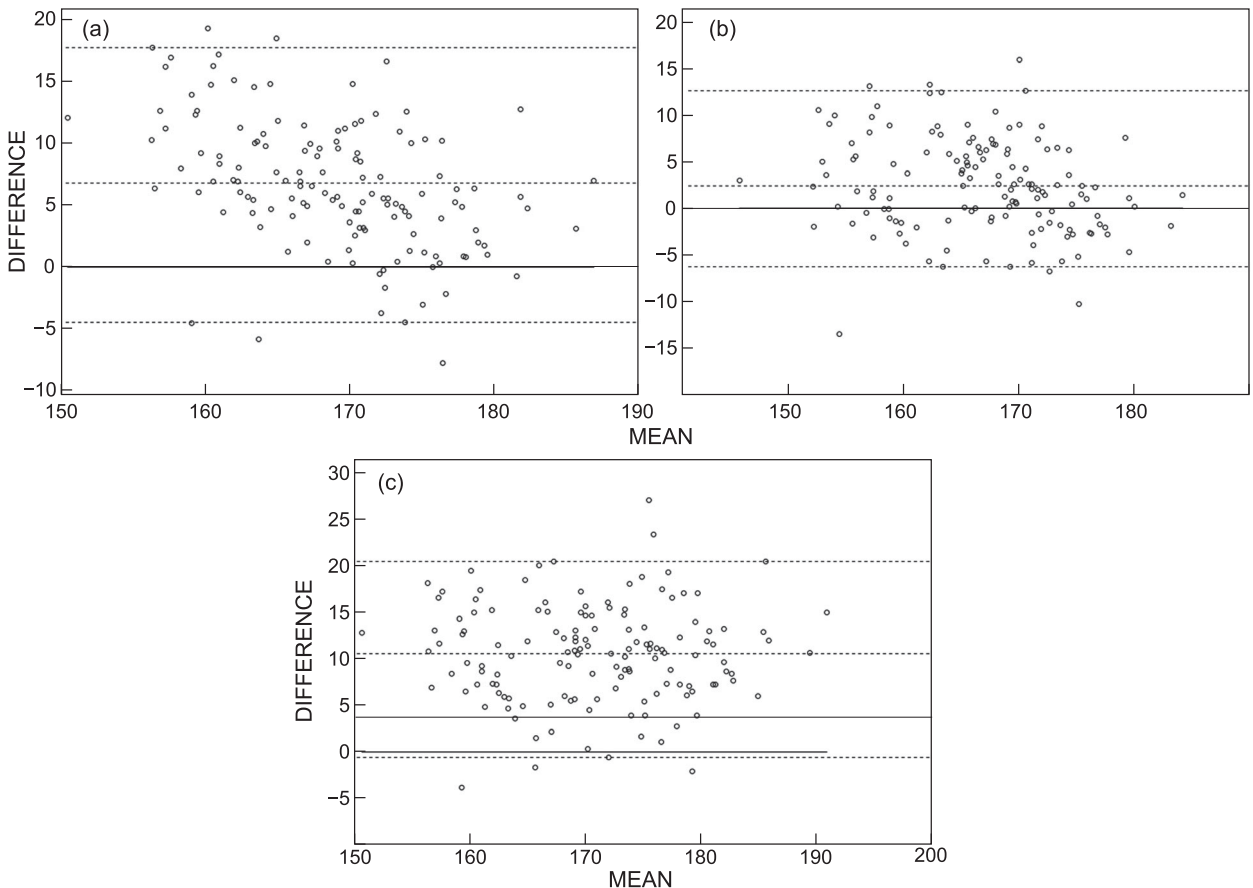


Figure 3: Bland–Altman plots for the equations of Barbosa *et al.* (2012),¹³ Ilayperuma *et al.* (2010)²⁵ and Elia *et al.* (2011)¹⁹ based on ulna length, depicting the levels of agreement between stadiometer height and height predicted from equations based on ulna length (x-axis: degrees of freedom; y-axis: difference between the mean of stadiometer height and predicted height for each participant).

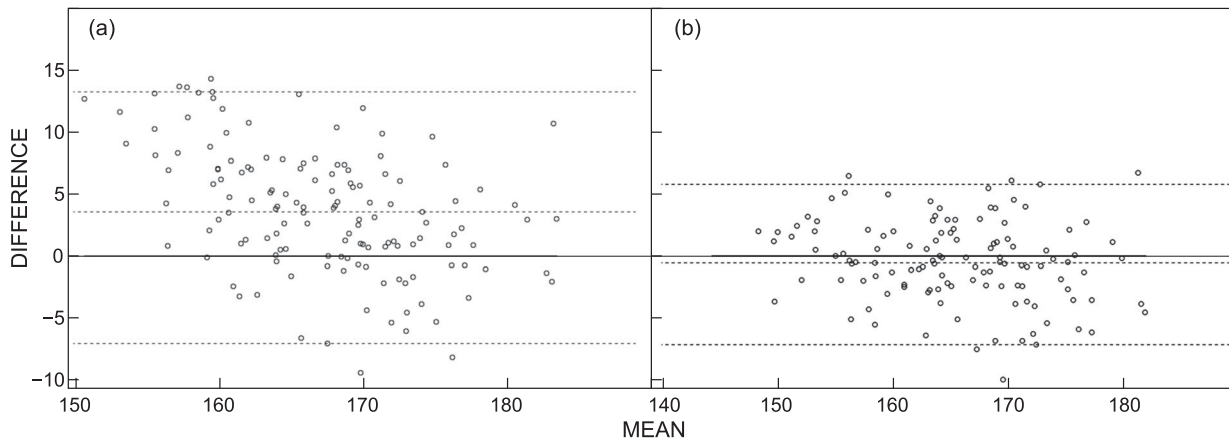


Figure 4: Bland–Altman plots for the equations of Chumlea and Guo (1992)²⁶ and Chumlea *et al.* (1994)²⁷ based on knee height, depicting the levels of agreement between stadiometer height and height predicted from equations based on knee height (x-axis: degrees of freedom; y-axis: difference between the mean of stadiometer height and predicted height for each participant).

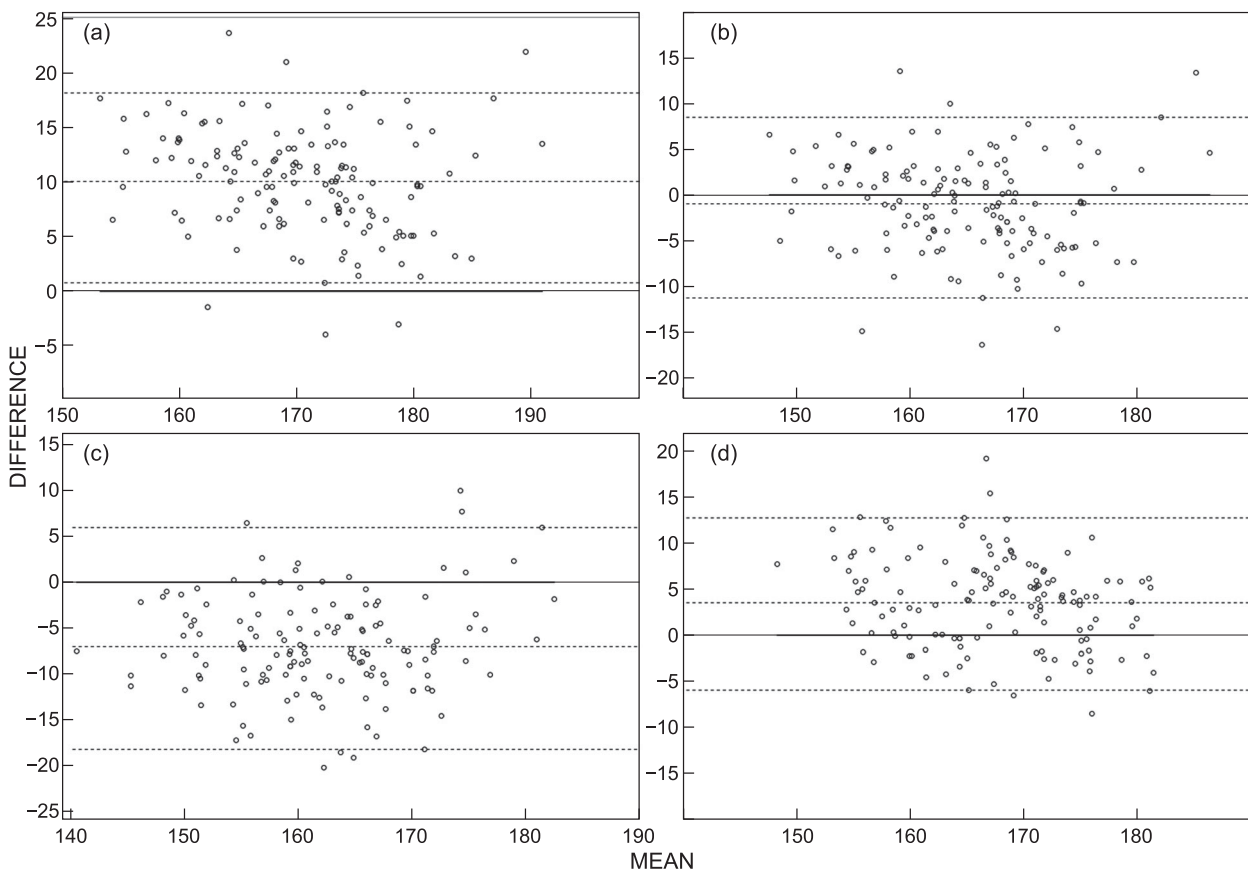


Figure 5: Bland–Altman plots depicting the levels of agreement between stadiometer height and height predicted from equations based on tibia, fibula and foot length (x-axis: degrees of freedom; y-axis: difference between the mean of stadiometer height and predicted height for each participant).

Conclusion and recommendations

Currently, global consensus emphasises that all patients admitted to hospital should be screened for nutritional risk, which requires accurate height measurement to calculate BMI, while accurate height measurements are also required for various other clinically important calculations. The current study identified various obstacles to accurate height recording in the South African public hospital setting, ranging from the fact that patients and their families do not know their height, and admission personnel generally

do not record height on admission in the patients’ medical files, to the fact that no guidelines currently exist on the most reliable measure to use to accurately estimate the height of the many patients who cannot stand upright and unassisted. The importance of obtaining accurate height measurements, especially in screening for malnutrition in hospitalised patients, should not be underestimated. Hospital staff should be educated on the importance of a comprehensive patient assessment, including measuring patients’ height and recording it in the files.

The current study suggests that the set of knee height-based equations of Chumlea et al.²⁷ may be useful for the South African population, but the measurement requires special equipment, knowledge and skill that admission personnel may not have. Based on the current findings, recumbent length, which requires only a measurement tape, may be the most accurate and cost-effective way for admission personnel in resource-poor settings to measure the height of patients who are unable to stand up straight and unassisted. Admission staff, however, need appropriate training in the techniques for height measurements as applicable to different situations. Training could take the form of dietitian-led continuing professional development activities, and should include the development of appropriate and nationally adopted training material for admission staff.

Furthermore, the results raise the possibility that equations, particularly those based on upper body segments that were standardised on non-South African populations, may not be suitable to predict height in the South African population due to environmental factors that impact on the growth of lower body segments, such as the high level of stunting in the country. The short-term solution may be to standardise equations on the South African population, but the high prevalence of stunting in South Africa may mean that this measure may not be applicable to all South Africans. The ultimate solution would involve addressing the high prevalence of stunting in the country by addressing nutrition and lifestyle during pregnancy, and infant and early childhood feeding practices that negatively impact growth, in the context of the environmental enablers and distant political, ideological and economic factors that impact on how South African children survive and thrive.⁴¹

Acknowledgements – The authors acknowledge the participants who made this study possible.

Funding – The study was funded by the South Africa National Research Foundation under Grant 109750.

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Received: 9-05-2020 Accepted: 15-05-2021