Australian Journal of Forensic Sciences

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tajf20

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To cite this article: N. R. Loubser, M. A. Bidmos & D. Brits (2024) Assessing the accuracy of the anatomical method for stature estimation in White South African males, Australian Journal of Forensic Sciences, 56:3, 228-241, DOI: 10.1080/00450618.2022.2136242

To link to this article: https://doi.org/10.1080/00450618.2022.2136242

AUSTRALIAN JOURNAL OF FORENSIC SCIENCES
2024, VOL. 56, NO. 3, 228–241
https://doi.org/10.1080/00450618.2022.2136242

Assessing the accuracy of the anatomical method for stature estimation in White South African males

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ABSTRACT

The anatomical method is considered the most accurate stature estimation method, however, research has concluded that the soft-tissue correction factors associated with this method may be sex- and population-specific. Therefore, this study aimed to evaluate the applicability of these soft-tissue correction factors for the estimation of stature in White South African males. Magnetic resonance imaging scans of 30 White South African male volunteers, between 21 and 59 years of age, were used to collect skeletal measurements of bones that contribute to total skeletal height. The soft-tissue correction factors within the literature were subsequently applied to estimate the living stature of each individual. Paired t-tests were used to compare the accuracies of these estimates of living stature to the measured heights of the participants. Living stature was significantly underestimated using the soft-tissue correction factors of Fully (1956; 6.14 cm), Raxter and colleagues (2006; 4.80 cm), and Brits and colleagues (2017; 0.96 cm), and significantly overestimated by Bidmos and Manger (2012; 9.65 cm). Cloete's (2017) equation overestimated stature by 0.65 cm, however, this was not significant. These results suggest population-specific soft-tissue correction factors associated with stature estimation and, therefore, the newly derived stature estimation equations should be used to estimate stature of White South African males.

ARTICLE HISTORY
Received 22 June 2022
Accepted 9 October 2022

KEYWORDS
Forensic anthropology; stature estimation; anatomical method; magnetic resonance imaging; South Africa; population data

Introduction

The anatomical method, also known as Fully's[1] method, is widely accredited as being the most accurate method for the estimation of living stature (LS). This method utilizes the sum total of the lengths of all the bones that contribute towards LS to calculate total skeletal height (TSH), with the further addition of a soft-tissue correction factor to estimate LS[1–7]. Soft-tissue correction factors are added to TSH in order to account for the lack of soft tissue, such as the intervertebral discs, cartilages, etc., which are associated with skeletal remains. This method takes variation in body proportions into consideration making it more accurate than the estimation of LS using regression equations that are formulated using the mathematical method[2,7]. The anatomical method is widely

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considered to be population and sex non-specific[2,7] though other studies have presented contrary results[3–6,8].

King[6] and Bidmos[8] reported that the soft-tissue correction factors proposed by Fully[1] significantly underestimated the stature of modern human populations by 2.4 cm and 4.3 cm, respectively, and concluded that there may be population specificity associated with the soft-tissue correction factors of Fully's[1] method. Raxter and colleagues[2] reported similar underestimations, however, attributed this to vague skeletal measurement descriptions and the inaccurate correction factors proposed by Fully[1]. To improve the accuracy of this method, they clarified measurement definitions and generated a stature estimation equation based on linear regression analysis[2].

Following this research, Bidmos and Manger[3], Brits and colleagues[4], and Cloete[5] assessed the accuracy of Fully's[1] soft-tissue correction factors and Raxter and colleagues'[2] stature estimation equations on South African populations using the skeletal measurements collected from full-body Magnetic Resonance Imaging (MRI) scans. Bidmos and Manger[3] found that these significantly underestimated the stature in Black South African males (BSAM) by 15.8 cm using Fully's[1] method and 14.8 cm using Raxter *et al.*'s[2] method. The authors attributed these differences to possible population-specificity associated with these soft-tissue correction factors and derived a stature estimation equation specifically for the estimation of LS of BSAM[3].

Brits *et al.*[4] found that the correction factors of Fully[1] and the stature estimation equation of Raxter *et al.*[2] significantly underestimated the stature of Black South African females (BSAF) by 7.9 cm and 6.8 cm, respectively, while those by Bidmos and Manger[3] significantly overestimated the LS of their sample by 7.8 cm. Similar results were reported by Cloete[5] with significant underestimations noted for Fully's[1] (7.1 cm) and Raxter and colleagues'[2] (6.1 cm) methods, and a significant overestimation (8.9 cm) using the stature estimation equation of Bidmos and Manger[3]. Interestingly, the equation proposed by Brits and colleagues[4] for the estimation of LS in BSAF overestimated the stature of White South African females (WSAF) by 0.04 cm; however, this was not significant. These results supported the need for population- and sex-specific stature estimation equations which were produced[4,5] using regression analysis, as suggested by Raxter *et al.*[2].

The applicability of the soft-tissue correction factors associated with the anatomical method for the estimation of LS in White South African males (WSAM) is unknown. Therefore, the aim of this study was to assess the accuracy of the soft-tissue correction factors associated with the anatomical method for the estimation of LS of WSAM.

Materials and methods

Participants

Ethical clearance was obtained from the Human Research Ethics Committee – Medical, University of the Witwatersrand (Clearance Certificate No.: M200411) to invite WSAM, between the ages of 20 and 60 years, to undergo full-body MRI scans at the Wits-Donald Gordon Medical Centre, Johannesburg. Similar to the studies by Bidmos and Manger[3] and Brits *et al.*[4], MRI scans were used to negate the effects of secular trends and sampling biases which are often encountered in skeletal collections[9–14].

Stature estimation standards for White South Africans had previously been derived from data on White American[2,15] and European[1,16] population groups. It is, however, well established that White South Africans are osteologically distinct from these groups due to the effects of genetic admixture, geographic distance, and the Founder effect[17], and therefore, require population-specific stature estimation standards. Only individuals 20 years and older were included to ensure that skeletal maturity had been reached, while those over the age of 60 years were excluded to limit the degenerative effects of ageing on stature[18].

WSAM of the public were verbally invited to participate in this study and were informed of the nature, benefits, and risks involved. Interested individuals received an information document and an informed consent sheet to append their signatures, indicating their voluntary participation in this study. As volunteers had to undergo a full-body MRI scan, standard MRI exclusion criteria set forth by the Department of Radiology, Wits-Donald Gordon Medical Centre were explained to each participant and adhered to. This involved excluding volunteers who presented with any metal surgical implants or foreign metal fragments[19]. Individuals presenting with any skeletal pathologies or abnormalities were also excluded and those who were claustrophobic were discouraged from partaking.

Numerous individuals were invited to participate in this study from October 2020 until September 2021, of which 35 volunteers consented to undergo a full-body MRI scan. Unfortunately, five scans had to be excluded from the overall sample due to the presence of sacralization and lumbarization, being too tall for the scanner, or other technical difficulties. Therefore, there was an overall sample of 30 participants in this study. This sample is similar to the overall samples reported by Bidmos and Manger[3] (28 participants), and Brits and colleagues[4] (30 participants) for their studies.

Data collection

The height of each participant was measured, while standing in the anatomical position, by the principal investigator at the Wits-Donald Gordon Medical Centre, using a stadiometer to the nearest 1 mm, following the guidelines suggested by Vallois[20]. Height was measured three times in the morning prior to the scan to negate the effects of diurnal variation on LS[21] and the averages were subsequently used to describe measured LS. Using measured LS also negates the errors affiliated with self-reported stature[22], as well as the limitations of using the cadaveric statures associated with skeletal collections[8].

The participants' MRI scans were taken in the supine position using a 1.5 Tesla Philips Entera MR Scanner, software version 12.1, at the Wits-Donald Gordon Medical Centre. T2-weighted survey scans were collected using 6 mm slice thickness for the coronal sequence from the pelvis to the feet, and 4 mm slice thickness for the sagittal sequence of the head to the pelvis. The multi-stack sequences of the scans were then fused on a working station, where the images were saved as a DICOM (Digital Imaging and Communication in Medicine) file on a disc.

Measurements

The DICOM files were imported into HOROS (version 3.3.6), an open-source DICOM reader, which was used to collect skeletal measurements[23]. Measurements of the bones that

Table 1. The skeletal measurement definitions as described by Raxter *et al.*[2], with the modifications made to take these measurements from MRI scans as proposed by Brits *et al.*[4].

Measurement	Definition
Cranial height (CH) (Figure 1)	measured from the basion to the ectocranium directly opposite the basion[4]
Height of C2 (Figure 1)	measured from the superior margin of the odontoid process to the inferior margin of its anterior body[2]
Height of C3 to L5 (Figure 1)	measured as the maximum height of the vertebra between the superior and inferior margins of the anterolateral aspect of the vertebral bodies, excluding the swellings caused by the pedicles and costal facets[2]
Height of S1 (Figure 1)	measured in the anterior aspect of the sacrum from the sacral promontory to the junction between the 1st and 2nd sacral vertebrae[2]
Physiological femoral length (PFL) (Figure 2 (a2))	measured as the length of the femur from the superior margin of the femoral head to the midpoint of a line drawn between the two distal-most ends of the femoral condyles[4]
Tibial length (TL) (Figure 2 (b2))	measured as the length of the tibia from the most distal point of the medial malleolus to a line drawn parallel to the articular surface of the lateral condyle[4]
Heel height (TC) (Figure 3)	measured as the perpendicular length from the superior aspect of the trochlea of the talus, to a line drawn from the inferior margin of the calcaneal tuberosity to the head of the 5th metatarsal (known as the plane of support[45]). When the head of the 5th metatarsal was not visible in the survey scan, this measurement was taken over multiple slices from the full-body coronal scan, as the perpendicular height from the top of the talus to the plane of support[4]

contribute to stature were collected from these scans according to the definitions by Raxter and colleagues[2], along with modifications proposed by Brits and colleagues[4] for collecting skeletal measurements from MRI scans (Table 1). As per convention, the lower limb bone measurements were taken from the left side[24].

The measurements were summed to calculate the TSH of each participant. Several estimates of LS were calculated using TSH and the soft-tissue correction factors of Fully[1], and the stature estimation equations derived by Raxter and colleagues[2], Bidmos and Manger[3], Brits and colleagues[4], and Cloete[5] denoted as LS_{Fully}, LS_{Raxter}, LS_{Bidmos}, LS_{Brits}, and LS_{Cloete}, respectively.

Data analysis

Intra- and inter-observer repeatability were assessed for the cranial height, the anterior vertebral body heights of C2, C7, T10, L5, and S1[3], the physiological length of the femur, the length of the tibia, and heel height using the technical error of measurement (TEM), the relative technical error of measurement (%TEM), and the coefficient of reliability (R).

Data analysis was completed using IBM Statistical Package for Social Sciences (SPSS: version 26). The data used for the final analysis were assessed for outliers using the Outlier labelling rule[25,26] and tested for normality using the Shapiro–Wilk normality test[27] and the associated histograms. No outliers were identified and the data were found to be normally distributed.

Descriptive statistics, including the minimum, maximum, mean, and standard deviations were calculated for measured LS, TSH, as well as estimated LS_{Fully}, LS_{Raxter}, LS_{Bidmos}, LS_{Brits}, and LS_{Cloete}. Pearson's correlation coefficients were run to analyse the correlation between LS and TSH.

The accuracy of the estimated LS_{Fully}, LS_{Raxter}, LS_{Bidmos}, LS_{Brits}, and LS_{Cloete} compared to the measured LS of the participants were assessed using paired samples t-tests. The

Figure 1. A sagittal MRI scan indicating how the skeletal measurements of the cranium (CH), C2 (axis), and the anterior vertebral body heights of C7, T10, L5, and S1 were collected, as demonstrated by the white lines in the image (scale = 3 cm).

under- and overestimation of each LS estimate compared to the measured LS were also calculated.

A linear regression equation specific for the estimation of LS of WSAM was generated, as per the recommendation of Raxter and colleagues[2], with measured LS as the dependent variable and TSH as the independent variable. An associated standard error of estimate (SEE) value was obtained for this equation, which is considered an indicator of the degree of the accuracy of the equation[15].

Results

Results pertaining to the reproducibility of the measurements used in this study are summarized in Table 2. The TEM and %TEM values for inter-observer repeatability (0.1 cm – 0.3 cm; 0.2–6.3%) were slightly higher than those of the intra-observer repeatability (0.0 cm – 0.3 cm; 0.1–3.2%), whereas the R values for intra-observer repeatability (0.8–1.0) were higher than those for inter-observer repeatability (0.7–1.0). The

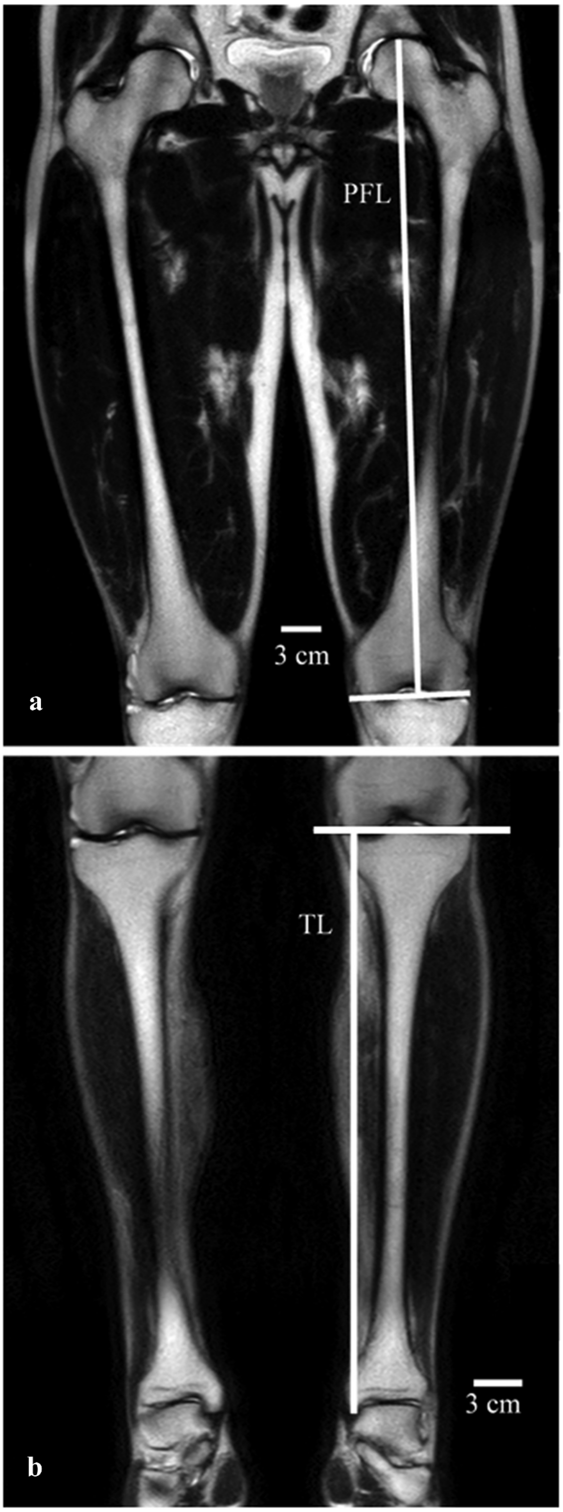

Figure 2. A coronal MRI scan indicating how the A) physiological length of the femur (PFL), and B) tibial length (TL) measurements were collected as demonstrated by the white lines in the images (scale = 3 cm).

Figure 3. A MRI survey scan indicating how the talo-calcaneal (TC) height from the trochlea of the talus to a line that represents the plane of support was collected, as demonstrated by the white lines in the image (Scale = 3 cm).

Table 2. The technical error of measurement (TEM), relative technical error of measurement (%TEM), and coefficient of reliability (R) for intra- and inter-observer repeatability.

	Intra-observer repeatability			Inter-observer repeatability		
	TEM (cm)	%TEM	R	TEM (cm)	%TEM	R
Cranial height	0.1	0.4	1.0	0.2	1.7	0.9
Height of C2	0.0	0.8	1.0	0.2	6.3*	0.7*
Height of C7	0.1	3.2*	0.8	0.1	3.8*	0.7*
Height of T10	0.1	2.1*	0.9	0.1	3.6*	0.9
Height of L5	0.1	1.5	0.9	0.1	2.2*	0.9
Height of S1	0.0	0.8	1.0	0.1	1.7	0.9
Physiological femoral length	0.1	0.1	1.0	0.1	0.2	1.0
Tibial length	0.1	0.2	1.0	0.2	0.6	1.0
Heel height	0.1	1.0	1.0	0.3*	3.4*	0.8

*Values are considered poorly repeatable

measurements that displayed the lowest degree of repeatability were C7, T10 for intra-, and C2, C7, T10, L5, and heel height for inter-observer repeatability, respectively (Table 2).

The volunteer ages ranged between 21 and 59 years old (34.73 ± 9.79 years) with 87% of the sample between the ages of 21 and 42 years (Figure 4).

The average measured LS and TSH for the current sample were 178.05 ± 6.29 cm (164.77–190.10 cm) and 161.18 ± 6.15 cm (148.80–173.60 cm), respectively. The average measured LS was higher than the average estimated LS_{Fully} (171.92 ± 6.56 cm; 158.82–185.13 cm), LS_{Raxter} (173.25 ± 6.36 cm; 160.98–185.88 cm) and LS_{Brits} (177.10 ± 5.51 cm; 166.02–188.25 cm), lower than the average LS_{Bidmos} (187.71 ± 6.38 cm; 174.88–200.61 cm), and very similar to the average LS_{Cloete} (178.70 ± 6.58 cm; 165.48–192.02 cm).

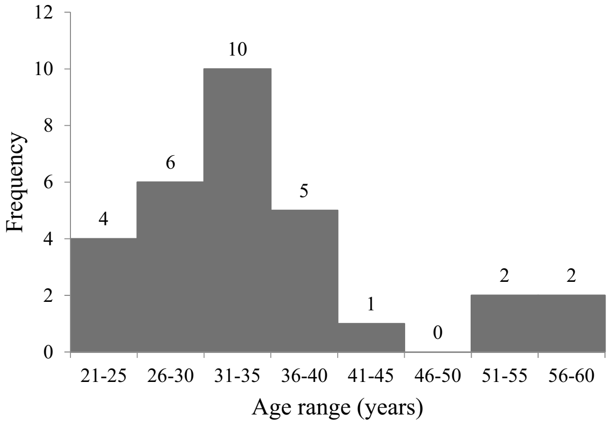

Figure 4. A histogram showing the age distribution of the current sample.

Table 3. Paired t-test results (p-value) of the comparisons between measured LS and the estimates of LS, as well as the minimum, maximum, mean, and standard deviation (SD) of the under- (-) and overestimation (+) of the estimates of LS compared to measured LS.

	p-value	Minimum (cm)	Maximum (cm)	Mean (cm)	SD (cm)
LS_{Fully}	$p = 5.34^{-16}$	−10.35	−1.34	−6.14	2.05
LS_{Raxter}	$p = 1.64^{-14}$	−8.77	−0.81	−4.80	1.83
LS_{Bidmos}	$p = 1.10^{-21}$	5.43	14.65	9.65	1.99
LS_{Brits}	$p = 0.02$	−4.26	4.18	−0.96	2.00
LS_{Cloete}	$p = 0.10$	−3.79	5.62	0.65	2.04

Significance level: $p < 0.05$

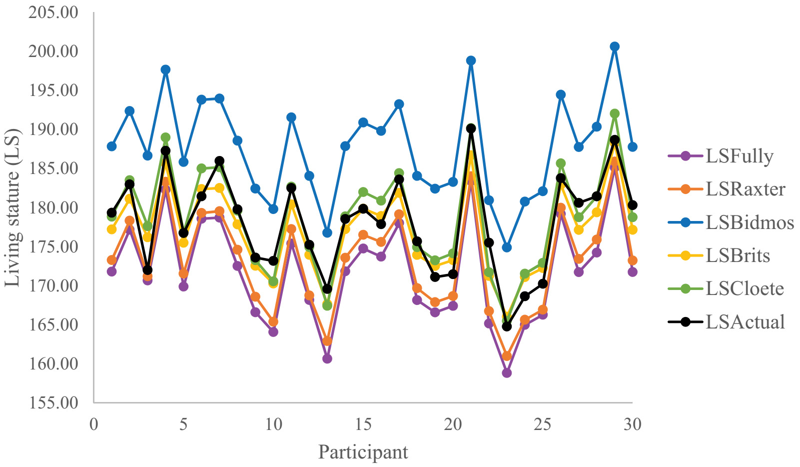

Figure 5. Line graph illustrating the under- and overestimation of measured living stature (LS) indicated by the black line, according to the soft-tissue correction factors proposed by Fully[1] (purple), Raxter *et al.*[2] (Orange), Bidmos and Manger[3] (blue), Brits *et al.*[4] (yellow), and Cloete[5] (green).

Paired t-test

The estimates of LS were compared to the measured LS of the participants using paired samples t-tests. These results, as well as the average under- and overestimation of the LS estimates compared to measured LS are presented in Table 3. All the estimates of LS, besides LS_{Cloete}, differed significantly from measured LS. The LS_{Fully} presented with the greatest underestimation (–6.14 ± 2.05 cm), followed by LS_{Raxter} (–4.80 ± 1.83 cm), and LS_{Brits} (–0.96 ± 1.99 cm). The LS_{Bidmos} significantly overestimated the measured LS of the participants in this study (9.65 ± 1.99 cm) whereas LS_{Cloete} only slightly overestimated LS (0.65 ± 2.04 cm); however, this overestimation was not significant. Figure 5 graphically represents what is presented in Table 3.

New regression equation

Although the overestimation of LS_{Cloete} was not significant, a newly derived stature estimation equation, specific for the estimation of LS for WSAM, was generated to improve the overall accuracy of these LS estimates.

Living stature = 0.948*TSH + 21.77 (SEE = 2.03 cm)

This equation was derived from the relationship between TSH and the measured LS, which is characterized by a strong and significantly ($p < 0.01$) positive correlation ($r = 0.948$). The R^2 value associated with this equation is 0.899, indicating that 89.9% of the variation in measured LS is a result of variation in TSH. Additionally, this equation is associated with a small standard error of estimate (SEE), which indicates a high degree of accuracy when estimating LS using this equation. Using the SEE value, a range of LS estimates were calculated by adding and subtracting one and two SEE values to the estimated LS using the new equation, where 63% of the estimates fell within one SEE (SEE = 2.03 cm) and 97% fell within two SEE values (SEE = 4.06 cm) of measured LS. It is interesting to note that 87% and 100% of the LS_{Cloete} fell within one (SEE = 3.18 cm) and two SEE values (SEE = 6.36 cm), respectively, when compared to the measured LS of the current sample.

Discussion

While skeletal collections are often used to develop the standards and techniques used in forensic anthropology, they are no longer representative of the modern populations from which they are derived due to the effects of secular change[9,10] and sampling biases[11–14]. In addition, the cadaveric statures associated with these collections are often incorrect or missing[8]. In order to address these problems, researchers are now turning to 'virtual anthropology'. Virtual anthropology allows researchers to study the skeletal systems of modern populations through non-invasive means without requiring maceration or dissection of the study samples[19]. MRI was specifically selected for this study because it is a radiographic imaging technique that does not expose research participants to harmful ionizing radiation and is, therefore, one of the safest radiographic imaging techniques to analyse the internal structures of living individuals[19].

The TEM, %TEM, and R were used to assess the intra- and inter-observer repeatability of the measurements in this study. While there is no universally acceptable maximum for

TEM[28], Sierp and Henneberg[29] recommended a maximum of 3 mm for skeletal measurements, while forensic anthropologists recommend an acceptable level of 2 mm[30]. On the other hand, it is widely accepted that %TEM that does not exceed a maximum of 1.5% for intra-observer and 2.0% for inter-observer error to be considered repeatable[31].

As expected, the repeatability of intra-observer error produced a higher degree of reproducibility than inter-observer error. The TEM values for both intra- and inter-observer repeatability did not exceed the maximum acceptable level of 3 mm, while only the inter-observer measurement for the heel height exceeded 2 mm. A few skeletal measurements did, however, exceed the limits recommended by Perini and colleagues[31] for %TEM. The vertebral heights of T10 and L5 exceeded the 1.5% acceptable level for intra-observer error, while the vertebral heights of C2, C7, T10, and L5, as well as heel height, exceeded the 2.0% maximum level stipulated for inter-observer repeatability. It is important to note, however, that these repeatabilities are in agreement with the acceptable levels of < 5% proposed by Uzun and colleagues[32]. The R is an additional measure of the precision of repeated measures that ranges between 0 and 1[33]. Conversely to TEM and %TEM, where smaller values are considered more precise, larger R-values represent a higher degree of reproducibility where values greater than 0.75 are considered sufficiently precise[34]. The only measurements that did not comply with this level were the vertebral heights of C2 and C7 for inter-observer error.

One of the major limitations of this study was that some of the participants were unable to maintain their feet in the anatomical position during their scan, similar to what was noted by Bidmos and Manger[3]. As such, some of the heel height measurements had to be taken over several slices of the MRI scan making consistent landmarks difficult to maintain while these measurements were repeated. Additionally, the vertebral measurements were sometimes obscured by the presence of associated soft tissue making it difficult to clearly identify the landmarks used. It is likely that training in radiographic imaging techniques could improve the reproducibility of these measurements as it is accepted that the degree of imprecision is exaggerated when measurements are taken by inexperienced individuals[33].

The mean measured LS of the WSAM in this sample was 178.05 ± 6.29 cm and is comparable to the mean stature (178.45 ± 6.85 cm) for WSAM in the military as reported by Steyn and Smith[17]. Similarly, these mean statures are comparable to the average statures (178.60 ± 6.55 cm) reported by Myburgh and colleagues[35] for their sample of WSAM soldiers from the South African National Defence Force (SANDF) and therefore the current sample is considered representative of the modern White male population living in South Africa. The average measured LS of the current sample is also comparable to the measured heights of White North American males[36] (178.00 ± 0.39 cm) while being taller than other populations such as Italian[37] (167.00 ± 7.10 cm), Indian[38] (157.95 ± 6.42 cm), Swiss[35] (176.50 ± 0.60 cm), and Black North American[36] (176.40 ± 0.34 cm) males, and shorter than Nigerian[39] (183.44 ± 46.66 cm) and Dutch[35] (180.20 cm) males. WSAM were also significantly ($p < 0.05$) taller than WSAF[5] (166.43 ± 6.46 cm), BSAM[3] (170.79 ± 5.29 cm), and BSAF[4] (159.00 ± 5.30 cm).

The mean TSH (161.18 cm) of the current sample is similar to the skeletal heights reported by Chibba and Bidmos[40] (159.20 cm) and Bidmos[41] (157.65 cm) for WSAM and higher than the skeletal heights reported for WSAF[5] (149.22 cm), BSAM[3] (144.92 cm), and BSAF[4] (141.13 cm). These differences support the consensus that there are both sex and population differences due to the effects that genetic make-up and environmental influences have on various sex and population groups. Additionally, despite Chibba and Bidmos'[40] and Bidmos'[41] results being derived from the skeletons of the Raymond A. Dart Collection of Modern Human Skeletons, these similar skeletal heights support the consensus that the skeletal measurements recorded from MRI scans have similar accuracies to these measurements taken from dry bone[42,43]. Doyle and Wilson[42] reported a 0.01 cm non-significant difference between the skeletal measurements taken from their MRI scans and dry-bone measurements. Similarly, Rathnayaka and colleagues[43] reported a mean difference of 0.02 cm between these two measurement types.

The significant differences expressed between BSAM and BSAF support the consensus that there are sex differences between males and females of the same population. The opposite, however, is observed between WSAM and WSAF, whereby the stature estimation equation developed for the estimation of LS of WSAF can accurately estimate the LS of WSAM. Additionally, the differences expressed between the LS of WSAM and BSA are attributed to the differences in population affinity, however, the same cannot be inferred between BSAF and WSAF. It is likely that the variations observed in the LS of females are not as diverse as those observed in males, similarly noted by Bidmos[8] and Bidmos and Manger[3], as well as being demonstrated by the significant differences expressed between BSAM and WSAM. The consensus that there exists sex- and population-specificities associated with soft tissues are similarly demonstrated in the soft-tissue correction factors used in facial reconstruction[44,45].

The sex- and population-specificity associated with these soft-tissue correction factors confirms the need for a stature estimation equation specifically generated for the estimation of LS for WSAM. Although the stature estimation equation that was derived for the estimation of LS for WSAF did not significantly overestimate the LS of WSAM, a new equation was calculated to improve the accuracy of the estimation of stature of WSAM.

The stature estimation equation specifically generated for WSAM demonstrates a strong, positively linear correlation between measured LS and TSH. This correlation (0.948) is comparable to the correlations between LS and TSH reported for North Americans[2] (0.956), BSAM[3] (0.934), and BSAF[4] (0.942), and was greater than the correlation for WSAF[5] (0.877). Similarly, this correlation was comparable to the correlation (0.960) between the multivariate relationship of the lumbar spine, femur, and tibia and measured LS as reported by Dayal *et al.*[46] for the estimation of LS for WSAM. Additionally, the SEE (2.03 cm) and R^2 (0.899) values attest to the high accuracy associated with this equation and attribute 89.9% of the variation observed in measured LS as being a result of the variation observed in TSH. These results are comparable to the results reported by Raxter *et al.*[2], Dayal *et al.*[46], Bidmos and Manger[3], and Brits *et al.*[4] while being more accurate than the equation generated by Cloete[5].

Furthermore, 97% of the stature estimates made using the new equation fell within two SEE values of the measured LS. Comparatively, 100% of the estimates made using Cloete's[5] equation fell within two SEEs of measured LS, however, it is important to note that Cloete's[5] SEE was also larger than that of the current study and is consequently considered less accurate than the newly derived stature estimation equation for WSAM. The strong correlation, high R^2, and low SEE values attest to the accuracy of the newly derived soft-tissue correction equation and its applicability for the estimation of LS of WSAM.

Conclusion

It is the conclusion of this study that the soft-tissue correction factors associated with the anatomical method are subject to population specificity, and therefore, it is recommended that either the newly derived stature estimation equation or the equation derived by Cloete[5] be used to estimate the living stature of WSAM when using the anatomical method. Future research into the use of the newly proposed equations associated with the anatomical method for the estimation of stature of South African populations will require validation prior to their implementation. Additionally, as South Africa is made up of diverse population groups, future research assessing the accuracy of the anatomical method for the estimation of stature in other population groups is still required.

Acknowledgments

The authors give our utmost gratitude to the volunteers who participated in this study, and to the staff of the Department of Radiology, Dr T.J. Nel Inc., Wits-Donald Gordon Medical Centre: Dr M. Haagensen, Ms E. Bussy, Ms C. Gibbs, and Ms L. Benade. Thank you to Dr A. Spies for her assistance in assessing the inter-observer repeatability of this study. This work is based on research that was financially supported by the National Research Foundation (NRF) – through Thuthuka grants (80655/118149), as well as a Master's scholarship. Any opinions, findings, conclusions, and recommendations that were expressed throughout this study are solely those of the author(s), and therefore, the NRF does not accept liability thereof.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the National Research Foundation [80655, 118149, MSc Master's scholarship].

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