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Regression equations for stature reconstruction from the lower limb bones of contemporary White South Africans

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ABSTRACT

In 2008, Dayal and colleagues generated regression equations to estimate the total skeletal height (TSH) of White South Africans. However, the validity of these equations has been questioned. The magnetic resonance imaging scanograms of 74 White South African adults were used to assess the reliability of these equations. The physiological lengths of the femur (FEPL) and tibia (TPL) were measured from these scans and input into the appropriate equations by Dayal and colleagues to calculate TSH_D. Paired t-tests, mean differences (MD), and mean absolute differences (MAD) were used to compare TSH_D with the measured TSH (TSH_{Meas}) taken directly from the scanograms and ELS were compared with the measured stature (LSM) taken of participants prior to their scans. Although there were no significant differences between TSH_{Meas} and TSH_D for males and TSH_{Meas} and TSH_D(TPL) for females, all ELS_L were significantly different to LSM, and the ELS_C using the FEPL were significantly different to LSM. These significant differences and associated large MD and MAD conclude that the equations by Dayal and colleagues are no longer valid. New stature estimation equations were derived for the estimation of stature of White South Africans, characterized by strong correlations and low SEEs.

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Living stature; stature estimation; forensic anthropology; MRI scanogram; White South Africans; lower limb bones

Introduction

Stature reconstruction from bones presented for forensic analysis is an essential part of the process of establishing the biological profile of an individual(s). In the presence of a complete skeleton with intact bones, the anatomical method, which was first described by Fully[1] and revised by Raxter *et al.*[2], is preferred because it provides an accurate estimate of stature[3,4]. In addition, its application is universal and is not dependent on population group or sex[2,5,6]. It requires taking a suite of measurements from various bones of the skeleton that constitute stature including the skull, vertebrae, long bones of the lower limb and the articulated height of the talus and calcaneus[1,2,6–11]. Consequently, its major drawback is that it is not only a very tedious process but also time consuming[5]. Since intact bones and complete skeletons are not usually available in many forensic cases, an alternative method, known as the mathematical method, is often used.

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İşcan and Steyn[12] reported that Karl Pearson in 1899 introduced the mathematical method for the estimation of stature. This method is based on a statistical theorem known as regression analysis, which involves the formulation of equations from bone measurements of the skeleton. This method can be applied to both intact and fragmentary bones and it is less time-consuming and tedious compared with the anatomical method. Unlike the anatomical method, which is universally applicable, the mathematical method is population and sex-specific. It therefore requires the formulation of equations for the estimation of stature for different population groups, sexes and at appropriate intervals in order to account for secular changes[13,14]. Consequently, studies have been published on the estimation of stature from measurements of intact long bones of upper and lower limbs in different parts of the world[12]. Similar efforts have been made at the formulation of regression equations from measurements of fragments of long bones[15–17] and other bones of the skeleton in cases when long bones are not available for forensic analysis[18,19].

In South Africa, a country with one of the highest crime rates in the world, researchers have also developed regression equations for estimation of stature from measurements of various bones of the skeleton including the skull[20,21], the sacrum[22] and bones of the foot[8,23]. In 1983, Lundy[24] developed population- and sex-specific regression equations for the estimation of stature in Black South Africans. He[24] used the hybrid method of stature reconstruction whereby the anatomical method was used in the calculation of the total skeletal height. Thereafter, the mathematical method was used in the development of regression equations for the estimation of skeletal height from the maximum lengths of the humerus, radius, ulna, femur, tibia and fibula. In 1987, Lundy and Feldesman[7] revised these equations due to some computer software errors. Since Lundy and Feldesman's[7] regression equations are both population- and sex-specific, Dayal *et al.*[9] conducted a similar study using long bones of upper and lower limbs of White South Africans. They[9] also developed standards that could be used for the estimation of stature of White South Africans from individual and combinations of measurements of the humerus, radius, ulna, femur, tibia and fibula.

The validity of the regression equations developed by Lundy and Feldesman[7] and Dayal *et al.*[9] on any contemporary South African population group has been questioned because the sources of data for these studies are skeletal collections. Some researchers have argued that skeletal elements in many skeletal collections are not representative of the contemporary populations from which they were obtained, since they contain an over-representation of the elderly population group and individuals from lower socio-economic status[25–29]. The effect of secular trends on populations is another factor that has rendered these skeletal collections unrepresentative of their respective contemporary population groups[30,31].

Recently, Bidmos and Brits[32] tested the validity of Lundy and Feldesman's[7] equations on contemporary Black South Africans using data obtained from MRI scanograms. They[32] demonstrated the non-validity of these[7] equations and consequently derived new regression equations for the estimation of living stature from individual measurement of the femur and tibia and a combination of these measurements. Since there has not been any attempt to test the validity of Dayal *et al.*[9] equations on any South African population group, it is, therefore, the aim of this study to investigate the validity of these equations on a sample of contemporary White South Africans using data collected from MRI scanograms and to formulate new equations, if necessary.

Subjects and methods

Ethics approval (M2111174) was obtained from the Human Research Ethics Committee – Medical of the University of the Witwatersrand, Johannesburg, South Africa, to access data used in two previous studies that evaluated population-specificity of soft tissue correction factors in stature reconstruction using the anatomical method[33,34]. The skeletal measurements for the White South African females were collected by M Cloete[33] during 2017 and that of the White males by N Loubser[34] between 2020 and 2021 as part of their MSc research, which forms part of a bigger project related to stature estimation in South African populations. The demographics of the participants and the details of data acquisition were described in these studies[33,34]. In both studies, data were collected from invited participants and volunteers who are White South African males and females between the ages of 20 and 60 years. The age distribution of the samples is provided in Table 1.

Living stature of each participant was measured (LSM) using a stadiometer on the morning of the day of the MRI scan in both studies[33,34] in order to mitigate against documented loss of stature during the day[35,36].

A full body MRI scan of each participant in a supine position was performed at Wits-Donald Gordon Medical Centre in Johannesburg, South Africa. The scanned images were then transferred to a DVD from which a suite of measurements as described by Raxter *et al.*[2], with some modifications as proposed by Bidmos and Manger[10] and Brits *et al.*[11], were taken on each scanogram using the freely available software, OsiriX[37] and HOROS (version 3.3.6). These measurements include cranial height, height of C2 to S1, bicondylar lengths of the femur, condylar malleolar length of the tibia, and the talocalcaneal height. The sum total of these measurements is known as the total skeletal height (TSH_{Meas}). Two of these measurements, namely the bicondylar length of the femur (FBC) and condylar malleolar length of the tibia (TCM), defined below, have been described and illustrated in previous studies;[11,32] and were used in the assessment of the validity of the Dayal *et al.* [9] lower limb stature estimation equations.

(1) Bicondylar length of the femur (FBC): The length of the femur measured from the most proximal point of the femoral head to the midpoint of a line drawn between the distal femoral condyles[11,32–34].
(2) Condylar malleolar length of the tibia (TCM): The vertical length of the tibia measured from the distal projection of the medial malleolus to a line drawn parallel to the articular surface of the lateral condyle[11,32–34].

Table 1. Age (years) distribution of White South African male and female participants.

Age range	Males	Females
21–25	4	26
26–30	6	6
31–35	10	1
36–40	5	2
41–45	1	2
46–50	0	3
51–55	2	2
56–60	2	2
Total	30	44

Each individual measurement, i.e. FBC and TCM and a combination of both, was substituted into the appropriate stature estimation equations formulated by Dayal *et al.*[9] to estimate total skeletal height (TSH_D), as per the equations below:

Males

$$\text{Total skeletal height} = 2.30 \times \text{FBC} + 51.17 \pm 2.64$$

$$\text{Total skeletal height} = 2.49 \times \text{TCM} + 62.92 \pm 3.16$$

$$\text{Total skeletal height} = 1.27 \times \}(\text{FBC} + \text{TCM}) + 50.67 \pm 2.49$$

Females

$$\text{Total skeletal height} = 2.64 \times \text{FBC} + 34.69 \pm 2.40$$

$$\text{Total skeletal height} = 2.86 \times \text{TCM} + 47.52 \pm 2.59$$

$$\text{Total skeletal height} = 1.44 \times (\text{FBC} + \text{TCM}) + 35.42 \pm 2.13$$

The accuracy of the regression equations derived by Dayal *et al.*[9] for the estimation of stature of White South Africans using FBC, TCM and a combination of both measurements was assessed. For each subject, TSH_D was calculated from (i) FBC, (ii) TCM and (iii) a combination of FBC and TCM using the appropriate regression equations of Dayal *et al.*[9]. The estimated total skeletal height using Dayal *et al.*[9] equations (TSH_D) was compared with the measured total skeletal height from the MRI scanograms (TSH_{Meas}) reported by Cloete[33] and Loubser[34] for White South African females and males respectively, using a paired t-test. The correlation between TSH_{Meas} and TSH_D was calculated. In addition, an estimate of living stature was calculated for each subject using the soft tissue conversion equation of Cloete[33] and Loubser[34] for females (ELS_C) and males (ELS_L) respectively. The soft tissue regression equations for conversion of TSH to ELS by Cloete[33] and Loubser[34] are provided below:

$$ELS_C = 1.07 \times \text{TSH} + 6.24\ (\text{SEE} = 3.18\text{cm})$$

$$ELS_L = 0.948 \times \text{TSH} + 21.77\ (\text{SEE} = 2.03\text{cm})$$

A comparison of the mean between LSM and each of ELS_C and ELS_L was performed. In addition to this comparison of means, three other criteria, namely mean difference (MD), mean absolute deviation (MAD), and percentage in range at one standard error of estimate (SEE) and two SEE were also explored. This is defined as the number of times that the LSM falls within the estimated stature range that was calculated using one and two SEE. This number is then expressed as a percentage of the sample size[38]. Regression analyses were subsequently performed separately for males and females initially and then for combined male and female data for the estimation of living stature from FBC, TCM and a combination of both measurements. From these analyses, the unstandardized coefficients and constants were obtained in addition to the correlation coefficient (r), correlation of determination (r^2) and standard error of estimate (SEE).

Results

The ages of subjects in the female sample ranged between 20 and 60 years, with a mean of 30 years (SD ±11.6). Males also had a similar age range, between 22 and 59 years, with a mean age of 35 years (SD ±10.0). The majority of male (83.3%) and female (79.5%) subjects fell within the 20 and 40 years age bracket (Table 1). There is no statistically significant difference between the mean ages of both sexes (Table 2). The means and standard deviations for LSM, TSH_{Meas}, FBC, and TCM are also shown in Table 2. Males showed statistically significant higher mean values for all measured variables compared with females (Table 2).

Measured values of FBC, TCM and the combined measurement of FBC and TCM were substituted into the appropriate sex-specific regression equations of Dayal *et al.*[9] to estimate TSH_D. A comparison of TSH_{Meas} with TSH_D was made using a paired t-test following confirmation of normal distribution of the data set using the Shapiro-Wilk test of normality. There was no statistically significant difference between TSH_{Meas} and TSH_D using Dayal *et al.*'s[9] equations for FBC, TCM and the sum of both parameters in males. In females, the equations for FBC and a combination of FBC and TCM showed a statistically significant difference between TSH_{Meas} and TSH_D. These results indicate that regression equations previously derived for skeletal height estimation by Dayal *et al.*'s[9] equations using FBC, TCM and a combination of these measurements are valid for White South African males but not for White South African females (Table 3). A strong to very strong correlation was also obtained between TSH_{Meas} and TSH_D in both males (range = 0.91–0.93) and females (range = 0.89–0.92). A statistically significant difference was observed between the mean values of LSM and ELS_L in males, following the application of a soft tissue correction factor proposed by Loubser[34], for both the individual and combination of FBC and TCM (Table 3). However, in females, a statistically significant difference was

Table 2. Descriptive statistics of the sample age (years), height (cm) and bone measurements (cm). [AQ]

	Male			Females				
Variables	*n*	Mean	Std. Dev	*n*	Mean	Std. Dev	t-statistic	p-value
Age	30	34.7	10.0	44	30.0	11.6	−4.700	0.075
LSM	30	178.1	6.3	44	166.4	6.5	−7.620	<0.0001
TSH_{Meas}	30	161.2	6.2	44	149.2	5.3	−8.893	<0.0001
FBC	30	47.8	2.2	44	44.5	2.3	−6.276	<0.0001
TCM	30	39.2	2.5	44	36.2	2.1	−5.703	<0.0001

Table 3. Comparison of measured skeletal height and skeletal height using Dayal et al.'s [9] equations, as well as measured living stature (LSM) and living stature estimates (ELS) using Loubser's [34] and Cloete's [33] equations for White South African males and females, respectively.

	Males					Females				
Variables	Correlation	MD	MAD	*t*	p-value	Correlation	MD	MAD	*t*	p-value
TSH_{Meas} & TSH_D (FBC)	0.91	0.00	1.75	0.00	1.00	0.89	−3.06	3.36	2.54	**0.01**
TSH_{Meas} & TSH_D (TCM)	0.92	0.64	1.99	−0.41	0.69	0.89	−1.71	2.53	1.40	0.16
TSH_{Meas} & TSH_D (FBC+TCM)	0.93	0.00	1.57	0.00	1.00	0.92	−2.41	2.80	1.97	**0.05**
LSM & ELS (FBC)	0.85	3.49	4.08	−2.43	**0.02**	0.86	−2.80	3.32	2.04	**0.04**
LSM & ELS (TCM)	0.87	4.09	4.45	−2.62	**0.01**	0.83	−1.30	3.07	0.94	0.35
LSM & ELS (FBC+TCM)	0.88	3.46	4.03	−2.28	**0.03**	0.87	−2.10	2.98	1.50	0.15

observed only for the equation for FBC (Table 3). A strong correlation was obtained between LSM and ELS_L in males (range = 0.85–0.88) and ELS_C in females (range = 0.83–0.87) (Table 3).

The MD for females (−1.3 to −2.8 cm) is lower than that obtained for males (3.5 to 4.1 cm) (Table 4). The negative value of MD in females indicates a tendency for overestimation of LS using Dayal *et al.*'s[9] equations in combination with Cloete[33] and a soft tissue correction factor, whereas the positive values obtained in males indicate a tendency for underestimation of LS (Table 4). While the magnitude of MD in females is considered slight, it is more noticeable in males (Table 4). The MAD in females ranged between 3.0 and 3.3 cm while it is between 4.0 and 4.4 cm (Table 4). This is considered a more precise measure of accuracy as it is the mean of the absolute difference[38]. The percentage in range, which is another measure of the utility of Dayal *et al.'s*[9] equations following the application of Cloete[33] and Loubser[34] soft tissue correction factors for females (ELS_C) and males (ELS_L) respectively, is as shown in Table 4. The LSM fell within one SEE of the range of ELS_C in 59 to 64% in females. A lower percentage in the range of 23 to 27% was obtained in males (Table 4). Higher accuracies of 80 to 93% and 43 to 57% were obtained in females and males for correct bracketing of the LSM within two SEE of the ELS respectively.

New sex-specific and generic (pooled) regression equations for the direct estimation of living stature were calculated from FBC, TCM and the sum of both parameters for White South Africans (Table 5). The correlation between LSM and ELS_C in females (0.83–0.87) was strong and statistically significant ($p < 0.001$) as shown in Table 5. A similar result was obtained between LSM and ELS_L in males (0.85–0.88). However, a higher correlation (0.89–0.92) was obtained for the generic equations (Table 5). In the female sample, the sum of FBC and TCM displayed the highest correlation with LSM ($r = 0.87$, $r^2 = 0.76$) while the weakest correlation was obtained for the regression equation generated for TCM ($r = 0.83$, $r^2 = 0.69$). The SEE for the equations generated for females ranged between 3.29 and 3.70 cm (Table 5). In the male sample, a combination of FBC and TCM presented the strongest correlation ($r = 0.88$, $r^2 = 0.77$) with LSM while the SEE ranged between 3.12 and 3.29 cm. For the generic equations, the correlation between LSM and each of FBC and TCM were 0.85 ($r^2 = 0.72$) and 0.87 (0.76) respectively. The SEE ranged between 3.47 cm (for a combination of FBC and TCM) and 3.87 cm (for TCM) (Table 5).

Table 4. Comparison of measured living stature with estimated living stature using Dayal et al's[9] equation and sex-specific soft tissue correction factor*.

			% in range	
Equations	MD	MAD	1 SEE	2 SEE
Female				
2.64×FBC+34.69	**-2.8	3.3	59.1	79.5
2.86×TCM+47.52	−1.3	3.1	63.6	86.4
1.44×(FBC+TCM)+35.42	−2.1	3.0	59.1	93.2
Male				
2.30×FBC+51.17	3.5	4.1	26.7	56.7
2.49×TCM+62.92	4.1	4.4	23.3	43.3
1.27×(FBC+TCM)+50.67	3.5	4.0	23.3	56.7

MD = Mean difference
MAD = Mean absolute deviation
SEE = Standard error of estimate
*Soft tissue factor of Cloete[33] for females and Loubser[34] for males
**Negative values indicate a tendency of overestimation by the soft tissue correction factor, while positive values indicate a tendency of underestimation

Table 5. New equations for stature estimation (cm) in White South Africans, correlation and standard error of estimate.

Equations	Correlation	F-statistic	p-value	SEE	% in range	
					1 SEE	2 SEE
Female						
2.50 (FBC) + 54.94	0.86	121.82	<0.001	3.35	72.7	95.5
2.56 (TCM) + 73.97	0.83	92.38	<0.001	3.70	72.7	95.5
1.76 (FBC) + 0.88 (TCM) + 56.23	0.87	64.66	<0.001	3.29	77.3	95.5
Male						
2.47 (FBC) + 59.80	0.85	71.85	<0.001	3.39	70.0	96.7
2.25 (TCM) + 89.79	0.87	89.96	<0.001	3.12	66.7	100.0
0.72 (FBC) + 1.65 (TCM) + 78.70	0.88	45.25	<0.001	3.13	73.3	100.0
Generic						
2.86 (FBC) + 40.05	0.91	347.32	<0.001	3.59	64.9	96.0
2.85 (TCM) + 64.586	0.89	288.07	<0.001	3.87	67.6	96.0
1.87 (FBC) + 1.07 (TCM) + 45.48	0.92	188.65	<0.001	3.47	64.9	94.6

SEE = Standard error of estimate
*Significant correlation at $p < 0.05$

Discussion and conclusion

To circumvent the challenges associated with using skeletons available in skeletal collections for research, anthropologists have sought alternative methods to conduct research on modern living populations and have turned to virtual anthropology[39]. Virtual anthropology affords researchers the opportunity to study the osteology of living individuals, through non-invasive means[40–42]. While MRI scanograms are not the preferred imaging modality to study osseous material[42,43], they were specifically selected for this study as they did not expose participants to harmful ionizing radiation[42–45]. Additionally, the skeletal measurements which have been recorded from MRI scans have produced similar accuracies to those measurements taken from dry bone[46,47].

The current regression equations employed for the estimation of living stature of White South Africans were derived by Dayal and colleagues[9] who used Raxter *et al*.'s[2] anatomical method to estimate the living stature of their skeletal sample. It has, however, been shown that the soft-tissue regression equations generated by Raxter and colleagues[2] significantly underestimates the stature of modern South Africans[10,11,33,34], and therefore, the regression equations for the estimation of living stature by Dayal and colleagues[9] is questionable. The use of LSM in the current study avoids these problems and allows for the direct regression of various skeletal measurements to actual living stature.

The average LS of the male and female samples of the current study are comparable to the reported heights of White South African military personnel[48] and are, therefore, considered representative of modern White South Africans. These individuals were also shown to be taller, on average, than Black and White North Americans[49], Black South Africans[32], as well as Japanese males (168.1 ± 6.0 cm) and females (153.4 ± 7.1 cm)[50].

The average FBC and TCM measurements differed significantly between the sexes. These measurements were also slightly larger than those stipulated by Dayal and colleagues[9] for the White South African male and female skeletons housed in the Raymond A. Dart Collection of Modern Human Skeletons. The differences in the bone measurements also suggest positive secular trends in White South Africans. Additionally, the FBCs of the current samples are larger than that reported for Black South Africans[32], Korean individuals[51], as well as Black and White North American individuals[13]. The TCM measurements were larger than those reported for Koreans[51] while the male and female TCM measurements were larger and shorter than those reported for Black South Africans[32], respectively. These differences reiterate the necessity for population and sex-specific regression equations for the estimation of living stature.

Although the TSH_D for the male sample were not significantly different from TSH_{Meas} and TSH_D is considered valid when estimating the LS of White South African males, the MD and MAD variables are high. The MD values are exaggerated when analysing the absolute values of these differences, due to the fact that TSH_D either overestimated or underestimated TSH_{Meas} to a degree where the negative and positive values were counteracted. The MAD emphasizes the differences between TSH_D and TSH_{Meas}. Additionally, it can be concluded that the MAD between TSH_D and TSH_{Meas} attributed to the significant differences between ELS_L and ELS_M for the male sample. The validity of these equations should, therefore, be reconsidered. The TSH_{Meas} for the female sample differed significantly from $TSH_{D(FBC)}$ and $TSH_{D(FBC+TCM)}$ and, therefore, these equations by Dayal *et al.*[9] are not valid when estimating the stature of White South African females. Similar to the results for the male sample, although only the $ELS_{C(FBC)}$ was significantly different from LSM, the MD and MAD values are considered high and, therefore, it is concluded that the equations by Dayal and colleagues[9] are invalid when estimating the LS of White South Africans.

Additionally, the percentage of the LSM that fell within the range of one SEE and two SEE values of ELS_L and ELS_C were calculated for males and females, respectively (Table 4). It is evident from these results that a large percentage of LSM did not fall within one or two SEE values of ELS, particularly for the male sample of this current study. The SEE of a regression equation indicates the accuracy of that equation, where smaller SEE values indicate a more accurate estimation[36]. As such, it is unsurprising that females presented with a higher percentage than males as the SEE of the female equation (3.18 cm) is larger than the male equation (2.03 cm) and will, therefore, present with a wider range.

New sex-specific and generic regression equations for the estimation of LS were calculated from FBC, TCM, and the combined FBC and TCM and all the regression equations produced showed very strong, significant ($p < 0.05$) positive correlations with LSM (Table 5). The combined FBC and TCM equations consistently produced the highest correlation with LSM. The correlations between the FBC were similar between the male and female sample of the current study. The tibia, however, produced a higher correlation with LSM than the femur in the male sample, while the opposite is observed for the female and generic regression equations, where the correlation between the femur and LSM was more similar to the correlation between LSM and the combined FBC and TCM equation. The correlation between each of the femur, tibia and a combination of femur and tibia with LS of males and females in the current study was stronger than that reported in previous studies, as shown in Table 6 while a weaker correlation was observed for other studies. The association of the femur, tibia and a combination of the two measurements with LS for the generic equations consistently produced strong correlations, which outperformed the previously outlined studies, except for those outlined by Dayal and colleagues[9]. These correlations, however, do support the viewpoint that the lower limb long bones produce the strongest associations with stature because these bones directly contribute to the overall height of an individual[52].

Table 6. Comparison of standard errors of estimate (SEE) for the present study and previous studies by different authors.

		Femur		Tibia	
Authors and date	Population	*r*	SEE	*r*	SEE
Males					
Trotter & Gleser, 1952[13]	White Americans (military)	0.87	3.27	–	–
Trotter & Gleser, 1952[13]	Black Americans (military)	0.77	3.93	–	–
Lundy & Feldesman, 1987[7]	Black South African	0.90	2.78	0.869	2.78
Muñoz et al., 2001[54]	Spanish	0.85	–	0.876	–
Dayal et al., 2008[9]	White South African	0.92	2.64	0.88	3.16
Lee et al., 2014[55]	Korean (max femur length)	0.86	3.21	–	–
Chiba et al., 2018[56]	Japanese	–	3.81	–	–
Bidmos & Brits, 2020[32]	Black South African	0.88	2.58	0.878	2.58
Current study	White South African	0.85	3.39	0.87	3.12
Females					
Trotter & Gleser, 1952[13]	White Americans (Terry)	0.85	3.78	–	–
Lundy & Feldesman 1987[7]	Black South African	0.90	2.789	0.873	3.056
Muñoz et al., 2001[54]	Spanish	0.85	–	0.812	–
Dayal et al., 2008[9]	White South African	0.93	2.4	0.91	2.59
Lee et al., 2016[55]	Korean (max femur length)	0.89	3.47		
Chiba et al., 2018[56]	Japanese	–	3.61	–	–
Bidmos & Brits, 2020[32]	Black South African	0.88	2.56	0.792	3.28
Current study	White South African	0.86	3.35	0.83	3.7

The SEE value for the femoral equation of the female sample was smaller than that of the male sample, while the opposite is observed for the tibial and combined regression equations (Table 5). Although the SEE values of the generic equations were consistently larger than the sex-specific equations, indicating a slightly less accurate result, it is more accurate to use a generic equation to estimate the LS of unknown skeletal remains than to apply the equation of the incorrect demographics to the skeletal remains[38]. Furthermore, although these standard error of estimates are deemed acceptable for stature estimation, it is important to note that errors in the estimates of the stature will increase for shorter and taller individuals[53]. The most accurate regression equations for the estimation of living stature of White South African males would be the TCM equation and the equation of the combined FBC and TCM for females and the generic equations. Additionally, a higher percentage of the LSM fell within one and two SEE values of the ELS when using the new regression equation than ELS_C and ELS_L. These results further support that the newly derived regression equation more accurately estimates LS of White South Africans.

In conclusion, newly derived sex-specific and generic regression equations for the estimation of living stature of White South African males and females have been generated using the bicondylar length of the femur and the condylar malleolar length of the tibial, as well as the combination of the two. These equations provide accurate estimates of living stature directly calculated from skeletal measurements, and therefore, do not require the addition of soft-tissue correction factors. A major limiting factor of this current study was the costs associated with the collection of full-body MRI scanograms resulting in a regrettably small sample size, along with the difficulties associated with trying to recruit participants. Future research into the derivation of regression equations will be greatly improved with an increased sample size, as well as a standardization of how to record skeletal measurements from MRI scanograms.

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