Calcaneal Measurement in Estimation of Stature of South African Blacks

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ABSTRACT Stature (height) is an important factor in establishing the identity of a person in the living as well as in the skeletonized state. When stature is estimated from the bones of the limbs, regression equations, which estimate the ratios of the lengths of bones to the height of the individual, are generated. The majority of bones that were used previously were the long bones. The calcaneus was used for estimating stature only in American whites and blacks (Holland [1995] Am. J. Phys. Anthropol. *96:*315–320). The regression equations that he generated were found to be useful for stature estimation in these population groups. Since the calcaneus has not been used for the same purpose in South Africa, the aim of this study was to derive regression equations that will allow this bone to be used for stature estimation in South African blacks. In total, 116 complete skeletons (60 males and 56 females) were selected from the Raymond A. Dart Collection of Human Skeletons, School of Anatomical Sciences, University of the Witwatersrand (Johannesburg, South Africa). The skeletal heights of these sets of skeletons were calculated using the anatomical method of Fully ([1956] Ann. Med. Leg. *35:*266–273). Nine parameters of the calcaneus were measured and matched against skeletal heights, using univariate and multivariate regression methods. Regression equations were obtained for estimation of the stature of the South African black population from the calcaneus. The standard error of estimate that was obtained with univariate regression analysis was higher than the corresponding values using multivariate regression analysis. In both cases, the standard errors of estimate compared well with the values obtained for fragmentary long bones by previous authors. Am J Phys Anthropol 126:335–342, 2005. © 2004 Wiley-Liss, Inc.

Stature is an important factor that complements other data such as age, sex, and race in the identification of an individual from skeletal remains. Many researchers have suggested and used different methods for estimating living stature from the skeleton. The two methods that are widely in use for stature estimation are the anatomical and mathematical methods.

Lundy (1983) reported that Dwight first introduced the anatomical method in 1894, which was later improved upon by Fully (1956), who measured appropriate dimensions of the skull, vertebrae, femur, tibia, talus, and calcaneus. The sum total of these measurements gave the total skeletal height (TSH). In order to account for the thickness of the scalp, intervertebral discs, and soft tissue of the sole of the foot, he also devised a correction index. For a skeletal height of 153.5 cm or less, 10.0 cm were added; between 153.6–165.4 cm, 10.5 cm were added; and for skeletal heights of 165.5 cm and above, 11.5 cm were added. The resultant height after the addition of the correction index gave an estimate of the living stature (ELS).

In the anatomical method, age related loss in stature is also corrected for (Trotter and Gleser, 1951; Hertzog et al., 1969; Galloway, 1988; Cline et al., 1989). Trotter and Gleser (1951) recommended that for individuals above 30 years of age, 0.06 cm per year above the age of 30 years should be subtracted from the estimated living stature. The presumption made in the course of formulating this correction factor is that a decrease in stature starts at the age of 30 years and it is the same in both sexes. However, Galloway (1988) disagreed with this notion, and published a new formula that proposed 45 years of age as the onset for age-related decrease in stature. He also suggested that 0.16 cm per year above the age of 45 should be subtracted from the estimated living stature. Giles (1991) published a table of estimates that should compensate for age-related decrease in stature for individuals aged between

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46–85 years. His study not only suggested that the use of the correction factor proposed by Galloway (1988) overestimated stature loss, but also showed a sex difference in this factor. However, there is uncertainty as regards the general use of these correction factors for populations other than American whites.

The advantage of the anatomical method is that it gives a more reliable estimate of stature, since it takes into account the components that constitute stature (Lundy, 1985; Formicola, 1993; Formicola and Franceschi, 1996). However, it can be time-consuming and complicated (Lundy, 1988a). Since all the bones that constitute stature are not always available in forensic cases for stature estimation, the anatomical method is not universally applicable.

The mathematical method involves the derivation of equations which show linear relationships between the length of bones and stature. Long bones such as the humerus, radius, ulna, femur, tibia, and fibula were extensively used for this purpose (Trotter and Gleser, 1952a,b, 1958; Lundy, 1983). Since long bones are often recovered in various states of fragmentation in forensic and archaeological practice, the development and use of other methods become necessary.

Measurements from fragmentary femora, tibiae, and humeri (Steele and McKern, 1969; Simmons et al., 1990), the lower end of the femur and the upper end of the radius (Mysorekar et al., 1980), and parts of the ulna and tibia (Mysorekar et al., 1984) have been used to derive regression equations for stature estimation. The length of the metacarpal bones (Meadows and Jantz, 1992) as well as the length and breadth of the hand (Saxena, 1984) have also been used in the estimation of adult stature. Though little work has been done using osteometric criteria of individual bones of the foot, stature estimations from the length of the metatarsals (Byers et al., 1989), footprints, and shoe prints (Giles and Vallandigham, 1991) have been documented. The standard error of estimate obtained from the use of these methods is high compared with the use of intact long bones, and therefore will reduce the accuracy of the estimation. Small compact bones have a greater chance of being recovered intact in forensic and archaeological cases than long bones. One such bone is the calcaneus.

The calcaneus is the largest tarsal bone in the skeleton of man, and is able to withstand high tensile forces (Hall and Shereff, 1993). It has six surfaces: superior, plantar, medial, lateral, anterior, and posterior surfaces. On the superior surface is an oval dorsal articular facet for articulation with the body of the talus. Located anterior to this facet are the anterior and middle facets. These two facets can sometimes combine to form an anteromedial facet. The variation in the number of articular facets of the calcaneus was shown to exhibit racial differences (Bunning and Barnett, 1965; Bidmos, 2002).

Although certain measurements showed the calcaneus to be sexually dimorphic in American whites and blacks (Steele, 1976), Central Europeans (Riepert et al., 1996), Italians (Introna et al., 1997), and South African whites (Bidmos and Asala, 2003), the usefulness of these measurements in stature estimation has not been fully documented. Holland (1995) used two measurements on the calcaneus and one on the talus to obtain regression equations for stature estimation among American whites and blacks. These were: maximum length of the calcaneus (MAXL), posterior length of the calcaneus (PCAL), and maximum length of the talus (MTAL). Holland (1995), echoing other notable anthropologists (Stevenson, 1929; Trotter and Gleser, 1952a,b; Lundy, 1983), cautioned that the applicability of any equations derived should be limited to the populations from which they were originally derived.

Since similar equations are yet to be formulated for any population in South Africa, it was the aim of this preliminary study to investigate the usefulness of the calcaneus in stature estimation, and to derive regression equations for South African blacks of both sexes.

MATERIALS AND METHODS

Two samples were used in this study. Sample A consisted of 116 complete skeletons of South African blacks (60 males, 56 females) whose documented age at death ranged from 22–75 years; they were selected using a table of random numbers. These skeletal remains were obtained from the Raymond A. Dart Collection of Human Skeletons housed in the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg, South Africa. Skeletons with obvious pathologies such as fusion of the vertebrae, evidence of fractures, broken edges, excessive osteophytic lipping, and loss of bone density were excluded. The data collected from this sample were used in the formulation of regression equations. Sample B (independent sample) consisted of 14 (8 males, 6 females) complete skeletons obtained from the Raymond A Dart and Pretoria Collections. This sample did not include any of the skeletons that were used in the derivation of the regression equations. This sample served to test the reliability of the derived regression equations.

The method of Fully (1956) of stature estimation was used in the present study, because the reliability of documented stature in the Raymond A. Dart Collection of Human Skeletons has been questioned (Lundy, 1983). As a result, each selected sample was checked for completeness by searching for the presence of the skull with the calvaria, cervical vertebra C2 to lumbar vertebra L5, sacrum, left femur, left tibia, left talus, and left calcaneus. In cases where the left femur and tibia were absent or had obvious pathologies, their right counterparts were used. In the case of a skeleton with an extra vertebra, the anterior body height of the extra vertebra was included in obtaining TSH because previous authors

(Shore, 1930; De Beer Kaufman, 1974; Lundy, 1988b) advised this inclusion.

Measurement of total skeletal height

TSH was obtained from the following measurements:

1. Basibregmatic height of the skull (BBH), using a spreading caliper;
2. Anterior body height of vertebra C2 (including the odontoid process) to L5, using a digital vernier caliper;
3. Bicondylar (physiological) length of the femur (FEML), using an osteometric board;
4. Condylomalleolar length of the tibia (TIBL), using an osteometric board; and
5. Articulated talocalcaneal height (TCH), using an osteometric board.

Calcaneal measurements

On each calcaneus, nine parameters were measured. These were maximum length (MAXL), load arm length (LAL), minimum breadth (MINB), body height (BH), maximum height (MAXH), middle breadth (MIDB), dorsal articular facet length (DAFL), dorsal articular facet breadth (DAFB), and cuboidal facet height (CFH). All measurements followed the definitions by Martin and Knußman (1988), with the exception of MINB, BH, and MAXH, which were redefined as follows:

1. Minimum breadth: Linear distance between the medial and lateral surfaces of the superior part of the body of the calcaneus.
2. Body height: Linear distance between the superior and inferior surfaces of the body of the calcaneus taken in the coronal plane at the midpoint between the most posterior point of the dorsal articular facet and the most anterior point of the calcaneal tuberosity.
3. Maximum height: Maximum distance between the most superior and most inferior points on the calcaneal tuberosity.

The left calcanei were used in the present study, because a preliminary comparison of measurements taken from paired calcanei revealed no statistically significant side differences ($P < 0.05$). However, the right calcaneus was used whenever the left calcaneus was not available or was morphologically unsuitable.

The basibregmatic height of the skull, anterior body height of C2 to S1, bicondylar length of the femur, condylomalleolar length of the tibia, talocalcaneal height, and all calcaneal measurements were tested for reliability, using the concordance correlation coefficient of reproducibility (Lin, 1989).

The data were entered separately for males and females into a Microsoft Excel spreadsheet and analyzed using the Statistical Product and Service Solutions (SPSS, 1998) program. Descriptive statistics including means, standard deviations, and variances were obtained for each of the calcaneal measurements. Normality of distribution of data for both sexes was verified by comparing the histograms of each variable with the normal distribution curve. Scatterplot diagrams showing the relationship between each of the calcaneal measurements and TSH were obtained for both sexes.

TABLE 1. Table of concordance correlation coefficients of reproducibility (Pc)[1]

Variables	Pc	Variables	Pc
BBH	0.991	LAL	0.915
C2	0.995	MINB	0.948
L5	0.986	BH	0.985
S1	0.934	MAXH	0.960
FEML	0.998	MIDB	0.962
TIBL	0.990	DAFL	0.971
TCH	0.935	DAFB	0.927
MAXL	0.938	CFH	0.928

[1] **BBH,** basibregmatic height; **C2,** anterior body height of axis; **L5,** anterior body height of fifth lumbar vertebra; **S1,** anterior body height of first sacral vertebra; **FEML,** physiological length of femur; **TIBL,** condylomalleolar length of tibia; **TCH,** articulated height of talus and calcaneus; **MAXL,** maximum length of calcaneus; **LAL,** load arm length of calcaneus; **MINB,** minimum breadth; **BH,** body height; **MAXH,** maximum height; **MIDB,** middle breadth; **DAFL,** dorsal articular facet length; **DAFB,** dorsal articular facet breadth; **CFH,** cuboidal facet height.

Simple regression analysis, in which individual variables of the calcaneus were regressed against TSH to obtain regression equations, was performed. Multiple regression analysis, in which various combinations of these variables were regressed against TSH, was also done. From these analyses, the correlation coefficient (r), standard error of the estimate (SEE), and standardized and unstandardized coefficients were obtained.

RESULTS

Repeatability

The range of values of concordance correlation coefficients of reproducibility obtained for each of the measurements tested for repeatability (Table 1) fell within the internationally accepted standard range of between 0.90–0.99, as suggested by Cameron (1984). This shows that the measuring technique used in this study was satisfactory.

Descriptive statistics

The means and standard deviations of the measurements are presented in Table 2. Males showed significantly ($P < 0.05$) higher mean values for all measurements compared with females, as indicated by the *F-statistic*. The mean ages for males and females were 30 and 35 years, respectively.

Regression analyses

Males (univariate). All measurements showed significant positive correlation with TSH except CFH (Table 3). The range of values was between 0.27–0.47. The highest correlation was shown by

TABLE 2. Descriptive statistics of calcaneus of South African blacks

	Males			Females				
Variables	N	Mean	SD	N	Mean	SD	F-statistic	*P* value
MAXL	59	79.71	3.99	56	73.38	4.61	62.18	0.000
LAL	60	46.18	3.36	56	41.65	3.36	52.65	0.000
MINB	58	25.48	3.17	56	21.18	2.65	61.53	0.000
BH	60	37.18	2.86	56	33.69	2.83	43.57	0.000
MAXH	60	43.71	2.86	55	40.36	2.94	38.34	0.000
MIDB	59	42.61	2.56	55	39.00	2.62	55.37	0.000
DAFL	60	30.12	1.85	54	27.42	2.24	49.60	0.000
DAFB	60	23.11	1.85	53	20.61	1.60	58.30	0.000
CFH	54	23.91	1.94	53	20.73	1.79	77.67	0.000

TABLE 3. Equations for stature estimation (in cm), correlation, and standard error of estimate from individual variables of calcaneus[1]

					Accuracy	
Equations	Correlation	F-statistics	*P*-value	SEE	1 SEE	2 SEE
Male						
1.07(MIDB) + 105.67	0.47	16.04	0.000*	5.22	87.5	100.0
0.63(MAXL) + 100.87	0.43	13.01	0.001*	5.34	87.5	100.0
0.75(MAXH) + 118.67	0.37	9.05	0.004*	5.47	87.5	100.0
0.75(BH) + 123.63	0.37	9.01	0.004*	5.47	87.5	100.0
1.15(DAFB) + 124.80	0.37	8.98	0.004*	5.47	25.0	100.0
0.96(DAFL) + 122.48	0.31	5.94	0.018*	5.60	87.5	100.0
0.50(LAL) + 128.47	0.29	5.18	0.027*	5.63	62.5	100.0
0.51(MINB) + 138.53	0.27	4.46	0.039*	5.73	75.0	87.5
Female						
1.76(DAFL) + 94.48	0.65	37.40	0.000*	4.69	50.0	83.3
0.82(MAXL) + 82.49	0.61	31.40	0.000*	4.98	50.0	83.3
1.16(MIDB) + 97.24	0.50	17.90	0.000*	5.30	33.0	100.0
1.17(MINB) + 117.46	0.50	18.21	0.000*	5.41	66.7	83.3
1.08(BH) + 105.81	0.50	17.53	0.000*	5.44	50.0	100.0
1.03(MAXH) + 100.97	0.48	16.04	0.000*	5.54	16.7	100.0
1.54(DAFB) + 110.72	0.39	9.31	0.004*	5.69	50.0	100.0
0.64(LAL) + 115.80	0.35	7.27	0.009*	5.88	50.0	100.0

[1] SEE, standard error of estimate.
* Significant correlation at $P < 0.05$.

MIDB, while the other variables are arranged in descending order of correlation. The standard error of the estimate for each equation as presented in Table 3 ranged from 5.22–5.73 cm. The unstandardized coefficients and intercepts obtained from the analyses are used in obtaining regression equations for stature estimation. The total skeletal height is the sum of the products of the unstandardized coefficient and the magnitude of the corresponding variable (in mm) and intercept (Table 3). In order to obtain a range for skeletal height, the standard error of the estimate was also added to or subtracted from the final estimate. For example, an individual with MAXL of 80 mm would have a skeletal height of:

$$\mathrm{TSH} = [(0.63 \times \mathrm{MAXL}) + 100.87] \pm 5.34 \text{ cm} = (0.63 \times 80 + 100.87) \pm 5.34 \text{ cm} = 151.27 \pm 5.34 \text{ cm}.$$

Addition of a soft-tissue factor of 10.0 cm for a skeletal height of 153.5 cm and less, as suggested by Fully (1956), gives a living stature estimate of:

$$\mathrm{ELS} = 161.27 \pm 5.34 = 155.93 \text{ cm} - 166.61 \text{ cm}.$$

This means that the living stature of the individual to whom the calcaneus belonged ranged between 155.9 and 166.6 cm.

Males (multivariate). Different combinations of measurements that best estimate skeletal height are shown in Table 4 in increasing order of standard error of the estimate and decreasing order of correlation. The correlation coefficients obtained from these combinations (0.52–0.60) are higher compared to those obtained from the use of individual variables. Also, the standard errors of the estimate for these combinations (4.9–5.11 cm) are lower compared with those obtained from the use of individual variables. Therefore, they probably provide better estimates of stature.

Females (univariate). Again, the CFH did not show significant correlation with stature when individual variables were analyzed. The range of values obtained for the correlation coefficient (0.35–0.65) was higher than that obtained for males (Table 3). The regression equation for each variable was derived in the same way as mentioned above for male samples. These equations are arranged in increasing magnitude of standard error of the estimate (4.69–5.88 cm).

TABLE 4. Equations for stature estimation (in cm), correlation, and standard error of estimate from combinations of variables of calcaneus

Equations	Correlation	SEE	Accuracy	
			1 SEE	2 SEE
Male				
1 0.38(MAXL) + 0.35(MAXH) + 0.59(MIDB) + 0.56(DAFB) + 68.17	0.60	4.90	62.5	100.0
2 0.44(MAXL) + 0.37(MAXH) + 0.69(MIDB) + 70.86	0.58	4.95	87.5	100.0
3 0.46(MAXL) + 0.85(MIDB) + 78.37	0.55	5.00	100.0	100.0
4 0.55(MAXL) + 0.59(MAXH) + 81.91	0.52	5.11	87.5	100.0
Female				
1 0.69(MAXL) − 0.67(LAL) + 0.37(BH) + 1.27(DAFL) + 72.24	0.77	4.01	33.0	100.0
2 0.81(MAXL) − 0.73(LAL) + 1.41(DAFL) + 75.22	0.76	4.07	33.0	83.3
3 0.30(MAXL) + 0.51(MAXH) + 1.16(DAFL) + 68.11	0.74	4.26	16.7	100.0
4 0.71(MAXH) + 1.43(DAFL) + 74.88	0.72	4.35	16.7	83.3

TABLE 5. Comparison of standard errors of estimate for present study and previous studies by different authors

Investigator	Variables	SEE
Lundy and Feldesman (1987)	Humerus, radius, ulna, femur, tibia, fibula, and lumbar spine	1.8–5.3
Trotter and Gleser (1952a)	Humerus, radius, ulna, femur, tibia, and fibula	3.0–5.1
Present study	Calcaneus	4.0–5.9
Byers et al. (1989)	Metatarsals	4.0–7.6
Holland (1995)	Calcaneus	4.1–6.3
Meadows and Jantz (1992)	Metacarpals	5.1–5.7
Simmons et al. (1990)	Fragmentary femora	5.5–7.2

Females (multivariate). The combinations of variables that best estimate stature are shown in Table 4. The correlation coefficients obtained (0.72–0.77) from these combinations were higher than those obtained from the use of individual variables. These standard errors of the estimate were also lower (4.01–4.35 cm).

Independent sample

Tables 3 and 4 show the results of the accuracy of stature estimation using regression equations at 1 and 2 standard errors of the estimate (SEE). The estimated living stature fell within 1 SEE in 25–80% of cases in males, while the accuracy was higher at 2 SEE (87.5–100%). Females, however, showed lower percentage accuracy, as the living stature estimates fell within 1 SEE in 16.7–66.7% of cases and within 2 SEE in 83.3–100% of cases.

DISCUSSION

Previous authors showed that osteometric differences exist between different populations (Trotter and Gleser, 1958; Lundy, 1983; Holland, 1995; Steyn and Iscan, 1997; King et al., 1998), and suggested that standards derived for a specific population should not be used for other populations. Although the calcaneus has been used for stature estimation in American whites and blacks (Holland, 1995), it is being used in South Africa for the first time. In the present study, nine calcaneal measurements as well as different combinations of these measurements were used for the purpose of obtaining regression equations for stature estimation.

The reliability of stature estimation from bones using regression equations is given by the SEE. Trotter and Gleser (1958, p. 115) reported that in 1953, Keen defined the standard error of estimate as "a measure of expected accuracy of a stature estimate of an individual who belongs to the same population from which the equation was derived." Although males showed higher mean values for all variables than females (Table 2), lower SEE were observed in females compared to their male counterparts (Tables 3 and 4). The reason for this is unclear.

The standard errors of estimates for individual variables that showed significant correlation with TSH in both sexes ranged from 4.69–5.88 cm. This range is lower than the 4.69–6.25 cm obtained by Holland (1995). MAXL and MIDB consistently fall within the best three variables in each group, and can be used for stature estimation.

Certain combinations of variables showed lower SEE (4.01–5.11) than individual variables. When these variables are measurable on the calcaneus, they should be used for stature estimation, as they yield higher accuracy than individual variables. The range for SEE from the present study compared well with that obtained from the use of other bones, and seems to be more accurate than the use of fragments of long bones (Table 5). However, it is less accurate in estimating stature compared to intact long bones.

The significant correlation of some individual variables of the calcaneus, as well as combinations of these variables with TSH, proves the usefulness of the calcaneus in stature estimation among South African blacks. The regression equations for these population groups are presented for the first time in Tables 3 and 4. The low correlation observed between TSH and some calcaneal measurements in this study is due to the fact that the actual contribution of the calcaneus towards stature is small.

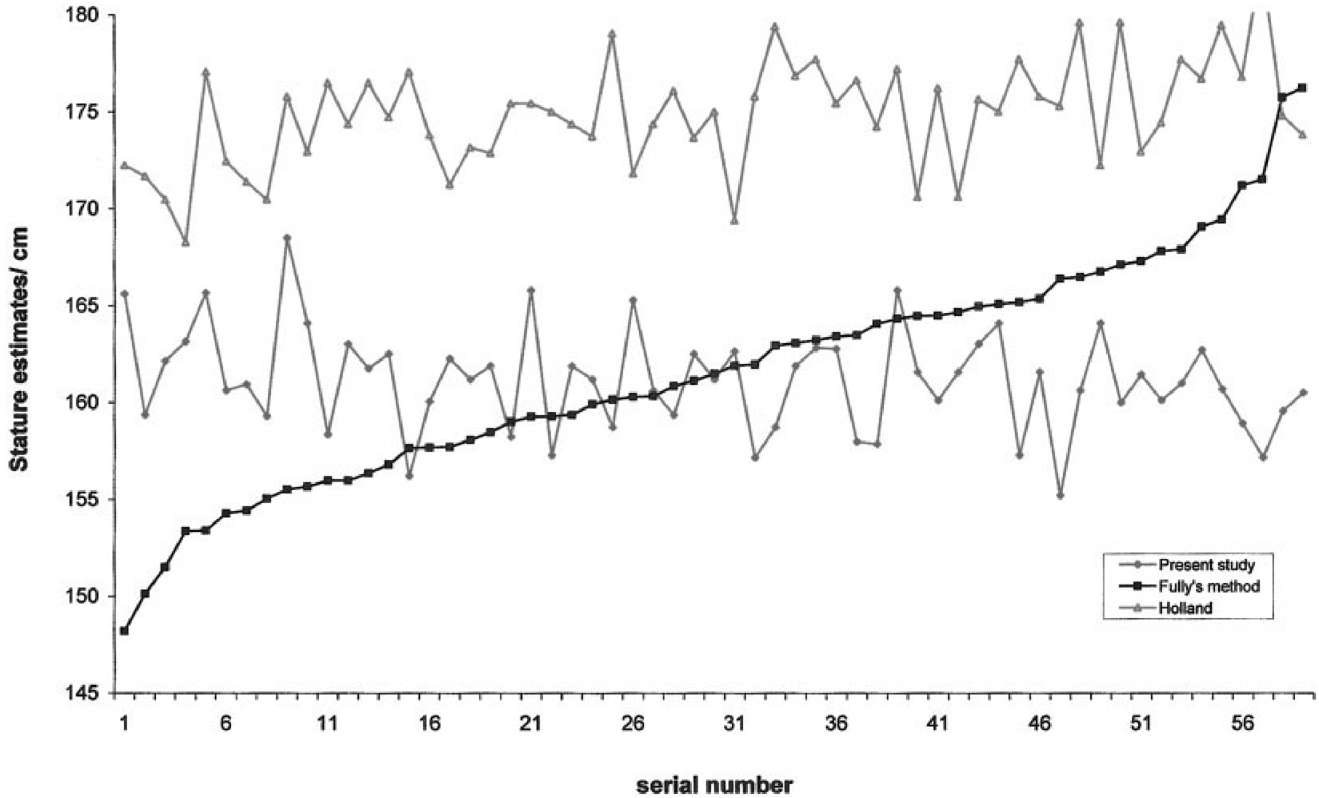

Fig. 1. Comparison between living stature estimates using method of Fully (1956), equation by Holland (1995) for MAXL, and regression equation for MAXL from present study for South African black males. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Comparison with equations of Holland (1995)

Holland (1995) used two measurements from the calcaneus and one from the talus to derive regression equations for estimation of living stature in American whites and blacks of both sexes. The calcaneal measurements used in the study were MAXL and PCAL. These were regressed against living statures obtained from antemortem medical record files kept at the United States Army Central Identification Laboratory, Hawaii. Living stature estimates were not present for some of the South African skeletons used in this study, and for those that were recorded, the reliability of such documented stature is doubtful. It was for this reason that the method of Fully (1956) was used for estimating skeletal height with the addition of an appropriate correction factor as suggested by him, in order to obtain estimated living stature.

Holland (1995) presented a correlation coefficient of 0.723 between MAXL and living stature. What is not clear is whether the correlation coefficient presented is the same for the four different subgroups (white males, white females, black males, and black females) he studied or just for one of them or the average for the subgroups. The correlation coefficients were not presented for the different combinations he used.

An attempt was made to find out how reliable the equations of Holland (1995) are in the estimation of stature of South African blacks. His regression equations for American blacks were used to estimate stature from the calcaneus of South African blacks. Regression equations derived for the maximum length of the calcaneus (MAXL) by Holland (1995) and in the present study were used to estimate living stature from the data collected for the samples in the present study. The value of MAXL obtained for each sample was substituted into the equations of Holland (1995) to obtain estimated living statures. These statures were compared with those obtained from the use of regression equations derived from the present study after the addition of correction factors as suggested by Fully (1956). Figures 1 and 2 reveal marked differences between living stature estimates from his equations and ours. This supports the earlier observation made by Trotter and Gleser (1952a,b) that anthropologists should limit the application of regression equations to the population from which they are derived. The author would like to reemphasize that this applies to the present study.

Limitations of the study and reliability of the equations on an independent sample

In the course of this study, some problems were encountered which might have influenced the prediction accuracy. The general principle in statistics is that the higher the sample size, the better the

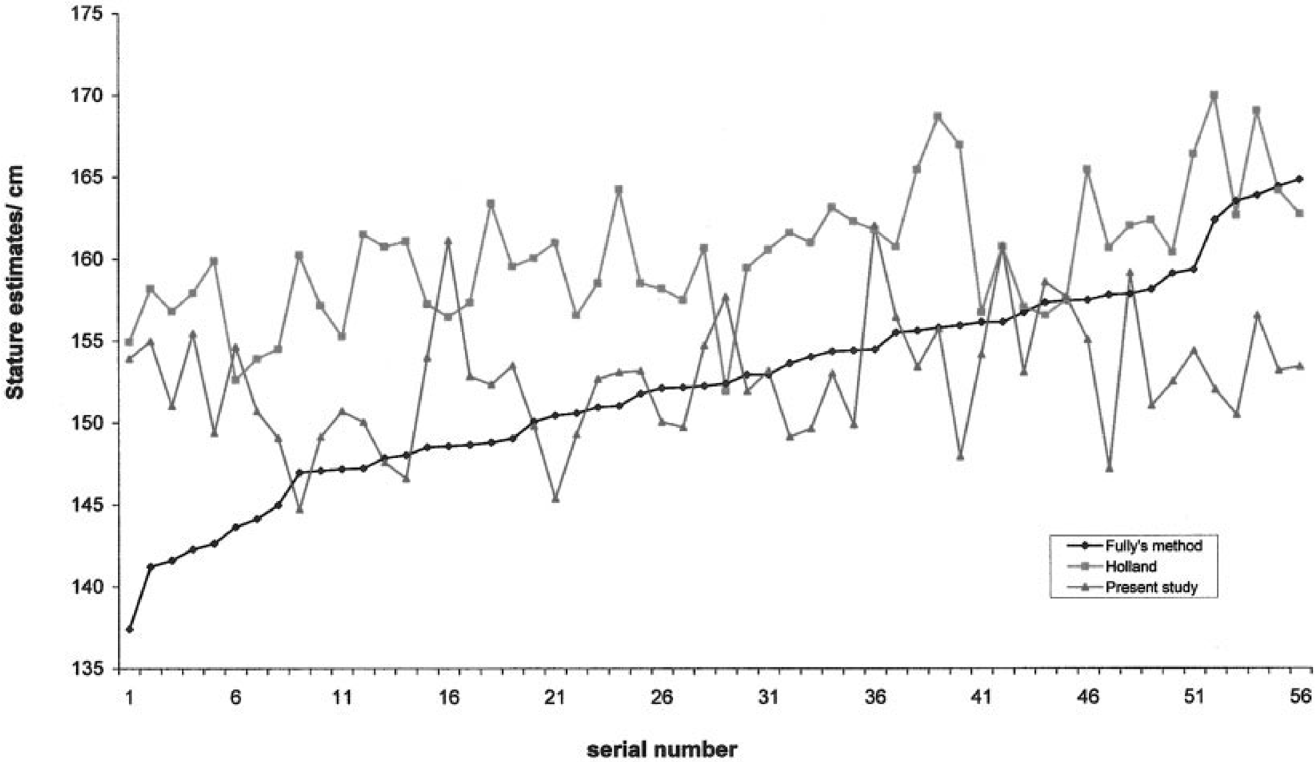

Fig. 2. Comparison between living stature estimates using method of Fully (1956), equation by Holland (1995) for MAXL, and regression equation for MAXL from present study for South African black females. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

resulting estimate. The constraint in using a higher sample size is due to a number of factors. These are the presence of a high number of skeletons with missing calvaria, missing vertebrae, fragmentary vertebrae, fused vertebrae, and the presence of excessive osteophytic lippings, especially with older skeletons. Also, there are more male skeletal remains in the Raymond Dart Collection compared to females.

The reliability of regression equations derived in the present study on an independent sample of recent skeletal materials showed that living statures of black males are more accurately estimated compared to females. This could be due to the fact that more recent male skeletal remains were used in the formulation of regression equations derived in the present study. The low accuracy obtained from equations derived for females might be due to the effect of secular change.

One would expect that in the continued acquisition of newer and complete skeletons in the collection, it would be possible to have a higher sample size in the future, which might provide a better estimate of stature and perhaps increased accuracy in the estimation of stature.

CONCLUSIONS

The present study showed the usefulness of the calcaneus in the estimation of stature among South African blacks. Regression formulae for stature estimation from individual variables and combinations of variables of the calcaneus were derived based on total skeletal height, as suggested by Fully (1956). When intact long bones are present, these bones should be used for the purpose of estimating stature.

However, when intact long bones are not available and only fragments of long bones or bones of the hands and feet are available, the calcaneus would be useful in providing a reasonably reliable estimate of stature, as evidenced by the low standard error of the estimate in this study. The maximum length (MAXL) and middle breadth (MIDB) are individually the most useful measurements of the calcaneus for stature estimation. Similar equations are being derived for South African whites.

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