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Original Article

Sex determination from calcaneus in Gujarati population by discriminant function analysis

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ABSTRACT

Introduction: Sex, age and racial affinity are the three most vital determinations that must be made when dealing with skeletal remains. Success in sex determination from skeletal remains is limited as most of the bones are available in fragments. The calcaneus, the largest tarsal bone, is apt for studying sexual dimorphism as it is relatively well preserved due to its density.
Methods: Eleven measurements of 51 adult human calcanei (31 male and 20 female) have been taken to determine accuracy of calcaneus in sex determination and to derive sex discriminant function equations specific for Gujarati population.
Results: The correct sex classification rate after the direct discriminant function analysis of all parameters is 94.25%. Subsequent to stepwise analysis, two parameters (dorsal articular facet length and middle breadth) have been selected as the best sex determinants with an accuracy of 94.3%. Among the dimensional groups, the breadth dimensional group has the highest accuracy. The sex discriminant function equations specific for Gujarati population have been derived.
Discussion: The accuracy rate in sex determination obtained in the present study is comparable to the accuracy rates reported by previous researchers.

1. Introduction

Skeletal remains contain an abundance of information which can lead to reliable determination of age, sex, race and stature of the individual in life.[1] Sex determination is considered as the first and most important step in the biological identification process of skeletal remains. It is the basis of not only age and stature estimation but population affinity also.[2]

Most of the bones that are conventionally (e.g. pelvis, skull, long bones) used for sex determination are often recovered either in a fragmented or incomplete state, thus, it has become necessary to use denser bones that are often recovered intact e.g. patella, calcaneus and talus for sex determination studies.[3]

Bones of the foot have recently gained interest as subjects of study for sex estimation using osteometric analysis. The foot and ankle are weight bearing parts of the body and therefore have a tendency to exhibit large size differences between males and females. Fessler and coworkers[4] found that in individuals of similar body height males tend to have longer foot than females.[5]

The calcaneus is the largest tarsal bone.[6] It is a compact bone that is relatively well preserved due to the wearing of footgear[7] and also the density of this bone provides it ability to withstand the majority of postmortem alteration.[6] Thus, it is an ideal bone for sex determination studies.

Sex determination is done either by assessing morphological features or by doing osteometric measurements. Assessment of sex by morphological features is subjective and many subtle peculiarities may be missed or misinterpreted by an inexperienced examiner.[8] The metrical method is the preferred method because of its objectivity and repeatability.[7] Discriminant function analysis is increasingly used to determine the sex from skeleton. But, the results obtained from discriminant function analysis are population specific and thus cannot be applied to other geographical areas due to population differences.[8]

The sexual dimorphism of the calcaneus has been studied in India[9,10] and in other population groups.[2,6,7,11–17] These authors have derived discriminant function equations from calcaneal measurements and its indices specific for their population groups.

India is a country harboring nearly all types of geographical and climatic conditions and is characterized by wide variation in anthropometric dimensions among its population types. This

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necessitates the study of sexual dimorphism in a more localized way to establish specific osteometric standards for different regions in India.[18] Thus, the present study is an attempt to derive discriminant function equations for sex determination from calcaneus specifically for Gujarati population.

2. Materials and methods

51 adult human calcanei extracted from 10 female cadavers (20) and 16 male cadavers (31) of known age have been studied to know the accuracy of calcaneus in sex determination. These cadavers were available in the Department of Anatomy, Pramukhswami Medical College, Karamsad that are used for dissection by MBBS and Physiotherapy students. The permission for this study has been taken from the Institutional Ethics Committee.

One calcaneus of a male cadaver has been excluded from the study since it was damaged. Only calcanei with intact required osteometric landmarks have been included in the study.

Eleven measurements of the calcaneus of both sides have been taken using digital sliding vernier caliper to the nearest millimeter (mm). All the measurements have been taken by single author and twice to avoid any interobserver and intraobserver error.

The measurements of the calcaneus have been taken in three dimensional groups (length, breadth and height). The methodology for the measurements has been adopted from Kim et al[2] except body height. The modifications has been made in the measuring technique of body height in the present study.

2.1. Length dimensional group

1) Maximum length (MAXL): Linear distance between the most anterior point of the calcaneus and the most posterior point on the calcaneal tuberosity (Fig. 1).

2) Load arm length (LAL): Linear distance between the most anterior point on the calcaneus and the most posterior point on the posterior articular facet (Fig. 1).

3)Dorsal articular facet length (DAFL): Linear distance between the most posterior and the most anterior points on the posterior articular facet of the calcaneus (Fig. 2).

2.2. Breadth dimensional group

1) Middle breadth (MAXB): Linear distance between the most lateral point on the posterior articular facet and the most medial point on the sustentaculum tali (Fig. 2).

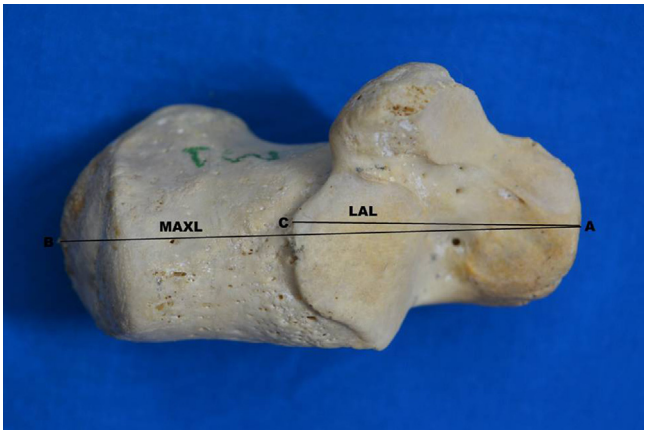

Fig. 1. Superior view of calcaneus illustrating length measurements: AB = Maximum length(MAXL); = Load arm length(LAL).

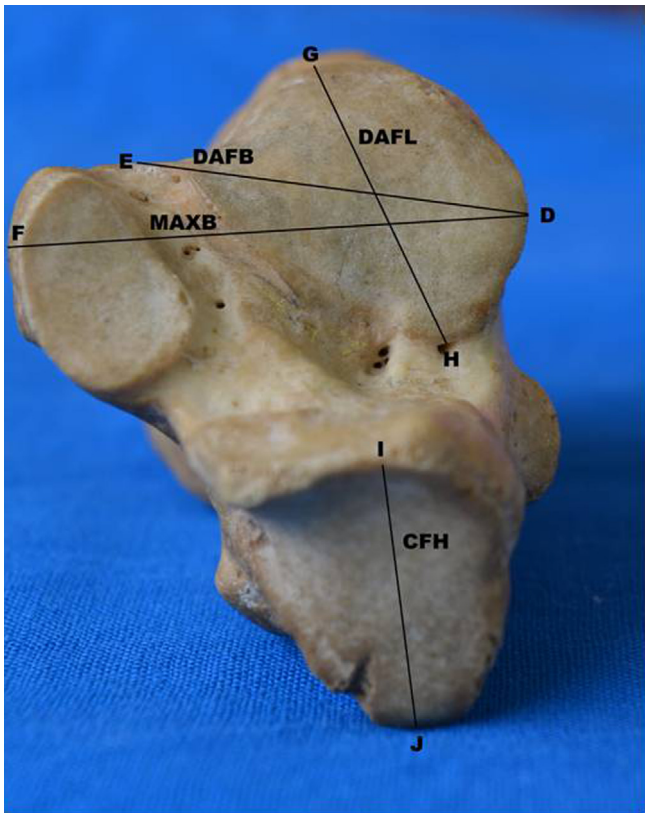

Fig. 2. Anterior view of calcaneus illustrating measurements: DE = Dorsal articular facet breadth(DAFB); DF = Middle breadth(MAXB); GH = Dorsal articular facet length(DAFL); IJ = Cuboidal facet height(CFH).

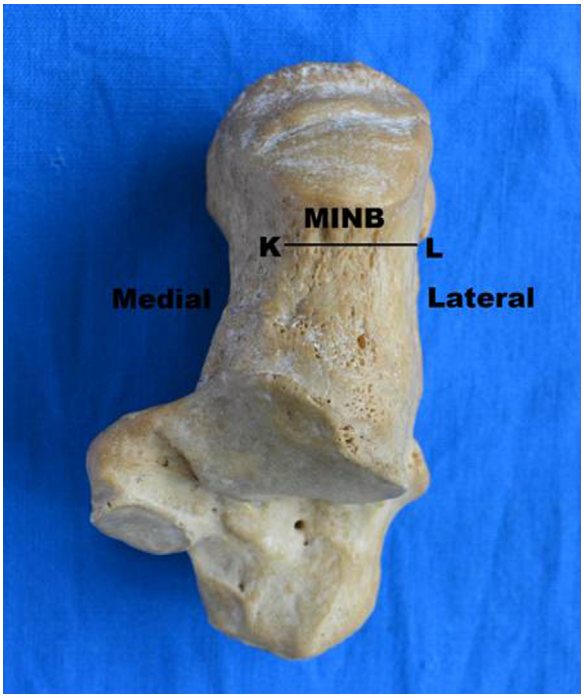

Fig. 3. Superior view of calcaneus illustrating measurement of Minimum breadth (KL = MINB).

2) Minimum breadth (MINB): Distance between the medial and lateral surfaces of the body of the calcaneus (Fig. 3).

Steele commented that this measurement usually lies anterior to the calcaneal tuberosity and posterior to the posterior talar articular surface.

3) Dorsal articular facet breadth (DAFB): Distance from the most medial to the most lateral points on the posterior articular facet (Fig. 2).

2.3. Height dimensional group

1) Cuboidal facet height (CFH): Linear distance between the most superior and the most inferior points on the cuboidal articular facet (Fig. 2).

2) Maximum height (MAXH): Distance between the most superior and the most inferior points on the calcaneal tuberosity (Fig. 4).

3) Body height (BH): This measurement has been taken at three levels. There is difference in the prominence of the processes of the calcaneal tuberosity so measurements have been taken from both medial and lateral sides.

a) BH(a): Height at the level of the most superior point of the posterior articular facet (Fig. 4).

b) BH(b): Height between the following two points: 1) On the dorsal surface, midpoint between most posterior point of the posterior articular facet and most anterior point of calcaneal tuberosity 2) On the plantar surface, lateral process of the calcaneal tuberosity (Fig. 5).

In some calcanei, the point on the plantar surface lies in front of lateral process of the calcaneal tuberosity.

c) BH(c): Height between the following two points: 1) On the dorsal surface, midpoint between most posterior point of the posterior articular facet and most anterior point of calcaneal tuberosity 2) On the plantar surface, concavity present in front of medial process of the calcaneal tuberosity (Fig. 4).

In some calcanei, the point on the plantar surface lies at the level of medial process of calcaneal tuberosity.

All the calcaneal parameters have been subjected to direct and stepwise discriminant function analysis using the Statistical Product and Service Solution (SPSS) software program.

3. Results

Table 1 shows the mean values and p-values of length, breadth and height measurements of calcaneus. The mean values of all calcaneal parameters are greater in males than females and all parameters are statistically highly significant for sex determination (p value <0.001).

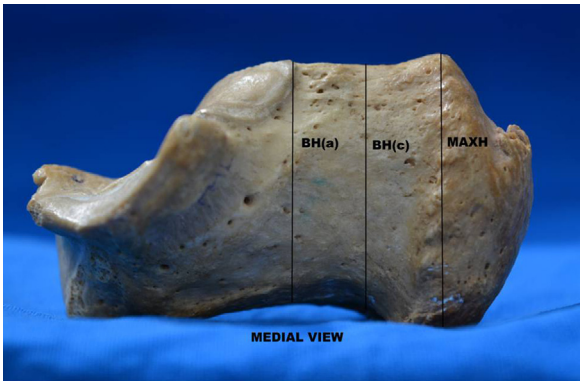

Fig. 4. Medial view of calcaneus illustrating measurement of body height at two levels BH(a); BH(c) and Maximum height(MAXH).

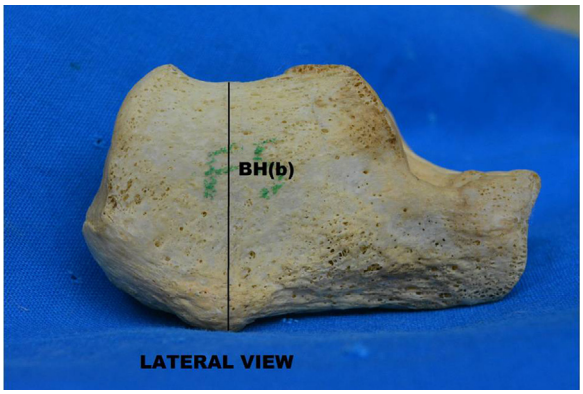

Fig. 5. Lateral view of calcaneus illustrating measurement of body height BH(b).

3.1. Direct discriminant function analysis of all parameters

All calcaneal parameters have been entered into discriminant function analysis by the direct method. Table 2 shows the unstandardized discriminant function coefficients, constants and sectioning points of all parameters of the calcaneus. The accuracy in sex determination of all calcaneal parameters by direct discriminant function analysis is 94.25%. The following discriminant function equation has been derived:

(D1) $y = (-0.067) \times MAXL + 0.281 \times LAL + 0.171 \times MINB + 0.174 \times MAXB + (-0.054) \times BH(a) + 0.083 \times MAXH + 0.163 \times DAFL + 0.183 \times DAFB + 0.100 \times CFH + (-0.273) \times BH(b) + (-0.102) \times BH(c) - 18.647$

y = Discriminant function score. The sectioning point for this equation is 0.004035.

3.2. Stepwise discriminant function analysis of all parameters

All calcaneal parameters have been entered into stepwise discriminant function analysis. Subsequent to stepwise analysis, two best parameters have been selected (DAFL = Dorsal articular facet length and MAXB = Middle breadth) that gives correct sex classification rate of 94.3% which is equivalent to the correct sex classification rate of all calcaneal parameters by direct discriminant function analysis.

Table 2 shows unstandardized coefficients, constants and sectioning points of the two best sex determinants and the following discriminant function equation has been derived:

(D2) $y = 0.265 \times MAXB + 0.266 \times DAFL - 17.823$

3.3. Direct discriminant function analysis of dimensional groups

The three dimensional groups (length, breadth and height) have been entered into direct discriminant function analysis. Table 3 shows that breadth dimensional group has the highest accuracy (91.8%) followed by height (88.6%) and length (84.5%).

The following discriminant function equations have been derived:

Length dimensional group:

(D3) $y = 0.090 \times MAXL + 0.098 \times LAL + 0.253 \times DAFL - 18.119$

Breadth dimensional group:

(D4) $y = 0.175 \times MINB + 0.141 \times DAFB + 0.214 \times MAXB - 16.741$

Height dimensional group:

(D5) $y = 0.221 \times CFH + 0.206 \times MAXH + 0.277 \times BH(a) + (-0.105) \times BH(b) + (-0.133) \times BH(c) - 14.860$

Table 1
Mean, standard deviation, p-value and confidence intervals (CI) of difference between the sexes.

Dimension	Parameter	Pooled (n = 51) Mean (SD)	Male (n = 31)	Female (n = 20)	p value	95% CI of difference	
						Lower	Upper
Length	**MAXL**	74.4(6.1)	78.0(4.8)	68.8(2.9)	<**0.001**	6.7	11.5
	LAL	45.7(4.3)	48.3(3.1)	41.6(2.1)	<**0.001**	5.1	8.3
	DAFL	27.5(3.1)	29.4(2.1)	24.6(1.9)	<**0.001**	3.7	6.0
Breadth	**MAXB**	39.5(3.7)	41.8(2.6)	36.0(1.8)	<**0.001**	4.5	7.2
	MINB	24.3(3.6)	26.5(2.6)	20.9(1.8)	<**0.001**	4.2	6.9
	DAFB	28.6(3.3)	30.5(2.4)	25.7(1.9)	<**0.001**	3.6	6.2
Height	**MAXH**	41.0(4.4)	43.4(3.3)	37.3(3.2)	<**0.001**	4.2	8.0
	BH(a)	36.9(3.9)	38.9(3.3)	33.8(2.4)	<**0.001**	3.4	6.9
	BH(b)	36.2(4.0)	38.0(3.2)	33.5(3.7)	<**0.001**	2.5	6.5
	BH(c)	36.4(4.3)	38.3(3.7)	33.6(3.6)	<**0.001**	2.6	6.8
	CFH	21.9(2.8)	23.3(2.6)	19.9(1.6)	<**0.001**	2.1	4.7

Table 2
Discriminant function analysis of all parameters for Gujarati calcanei

Functions	Coefficient		Eigen value	Canonical correlation	Wilk's Lambda	Sectioning point	Accuracy (%)			
	Standard-ized	Unstandard-ized					Original			Cross Validated
							Male	Female	Pooled	
D1:All parameters Direct			3.559	0.884	0.219	0.004035	93.5	95.0	94.25	91.0
MAXL	−0.279	−0.067								
LAL	0.779	0.281								
MINB	0.394	0.171								
MAXB	0.405	0.174								
BH (a)	−0.162	−0.054								
MAXH	0.274	0.083								
DAFL	0.330	0.163								
DAFB	0.410	0.183								
CFH	0.228	0.100								
BH (b)	−0.927	−0.273								
BH (c)	−0.375	−0.102								
(Constant)	−0.279	−18.647								
D2:All parameters Stepwise			1.996	0.816	0.334	0.00298	93.5	95.0	**94.3**	92.6
MAXB	0.537	0.265								
DAFL	0.616	0.266								
(Constant)		−17.823								

Table 3
Direct Discriminant function analysis of dimensional groups for Gujarati calcanei.

Functions	Coefficient		Eigen value	Canonical correlation	Wilk's Lambda	Sectioning point	Accuracy (%)			
	Standard -ized	Unstandard-ized					Original			Cross Validated
							Male	Female	Pooled	
D3:Length			1.808	0.802	0.356	0.003	83.9	85.0	84.5	82.8
MAXL	0.376	0.090								
LAL	0.271	0.098								
DAFL	0.510	0.253								
(Constant)		−18.119								
D4:Breadth			2.1	0.823	0.323	0.003245	93.5	90.0	91.8	91.7
MINB	0.403	0.175								
DAFB	0.316	0.141								
MAXB	0.497	0.214								
(Constant)		−16.741								
D5:Height			1.356	0.759	0.424	0.00259	87.1	90.0	88.6	82.8
CFH	0.503	0.221								
MAXH	0.681	0.206								
BH (a)	0.833	0.277								
BH (b)	−0.357	−0.105								
BH (c)	−0.489	−0.133								
(Constant)		-14.860								

3.4. Stepwise discriminant function analysis of dimensional groups

Subsequent to stepwise discriminant function analysis, it has been found that breadth dimensional group has highest accuracy (91.8%) followed by length (87.7%) and then height (83.6%) (Table 4).

The following discriminant function equations have been derived:

Length dimensional group

(D6) y = 0.198 x LAL + 0.261 x DAFL – 16.260

Breadth dimensional group:

(D7) y = 0.231 x MINB + 0.261 x MAXB – 15.906

Height dimensional group

(D8) y = 0.195 x CFH + 0.222 x MAXH – 13.386

The accuracy of breadth dimensional group is same in direct and stepwise analysis (91.8%). Subsequent to direct discriminant function analysis, the accuracy of height dimensional group (88.6%) is more than that of length dimensional group (84.5%) in contrary to results of stepwise analysis where the accuracy of height dimensional group (83.6%) is less than that of length dimensional group (87.7%). The probable reason for this is that in direct discriminant function analysis, the number of height variables (five variables) are more as compared to that of length variables (three variables) and each variable contributes in sex determination. In contrast to that, in stepwise analysis the number of length and height variables are same and the length variables have more sex discriminatory power as compared to that of height variables.

3.5. Each parameter

MAXB (Middle breadth) has the highest accuracy (90.2%) among 11 parameters and the equation is as follows:

(D9) y = 0.431 x MAXB – 17.024

The eigen value of this equation is 1.564, the canonical correlation is 0.781 and wilks lambda is 0.390.

The significance of all the discriminant function equations (D1 to D9) listed above is:

- The measurements of the mentioned calcaneal parameters has to be entered in the discriminant function equation.
- The discriminant function equation will give value of discriminant function score (y).
- The value of discriminant function score(y) has to be compared with the value of sectioning point of that particular equation mentioned in Tables 2–4.
- If the value of y is greater than sectioning point, it indicates male calcaneus.
- If value of y is less than sectioning point, it indicates female calcaneus.

4. Discussion

The present study has provided a baseline data for sex determination from calcaneus in Gujarati population and sex can be determined from it with an accuracy of 94.25%.

There are two methods to study for sex determination from skeletal remains viz. morphologic and metric method.[19] In the hands of expert the observation technique is astonishingly accurate, but it requires training and experience and is inaccurate when used by the layman. Methods based on measurements and statistical techniques, on the other hand, do not call for special training and therefore are more serviceable for use in sex determination.[20] The success for sex determination depends not only upon the method used but also upon the statistical technique applied. The multivariate discriminant function analysis which is the most widely used statistical technique for sex determination from skeletal measurements has been used in the present study. The equations using discriminant function analysis are useful for sex determination and have frequent application these days.

The accuracy of calcaneus in sex determination has been studied by some researchers in Indian population as well as in other population groups.[2,6,7,9–17]

Table 5 shows that accuracy of calcaneus in sex determination in present study is comparable to the accuracy rates reported by other researchers. Table 5 also shows that the mean values of all calcaneal measurements in males stands at a higher level vis-a-vis females of the same region in given racial groups. The same cannot be categorically stated in mixed groups or races as there is evident overlap. Thus, the mean values of calcaneal paramaters of different racial groups should not be compared. Consequently, sex determination should necessarily be preceded by race determination.

Bidmos and Asala[7] and Gualdi-Russo[16] inferred from their studies that length and breadth measurements contribute more to sex determination than height measurements. But in the present study, subsequent to direct discriminant function analysis, height dimensional group contributes more to sex determination than length dimensional group. Similarly, Kim et al[2] reported in his

Table 4
Stepwise Discriminant function analysis of dimensional groups for Gujarati calcanei.

Functions	Coefficient		Eigen value	Canonical correlation	Wilk's Lambda	Sectioning point	Accuracy (%)			
	Standard -ized	Unstandard -ized					Original			Cross Validated
							Male	Female	Pooled	
D6:Length			1.670	0.791	0.375	0.00267	90.3	85.0	87.7	87.6
LAL	0.551	0.198								
DAFL	0.527	0.261								
(Constant)		−16.260								
D7:Breadth			1.953	0.813	0.339	0.00283	93.5	90.0	91.8	88.5
MINB	0.531	0.231								
MAXB	0.605	0.261								
(Constant)		−15.906								
D8:Height			1.017	0.710	0.496	0.002125	87.1	80.0	83.6	81
CFH	0.442	0.195								
MAXH	0.735	0.222								
(Constant)		−13.386								

Table 5
Comparison of mean values of calcaneal parameters and accuracy rate of present study with other population groups (unit: mm).

Population	MAXL	LAL	DAFL	MAXB	MINB	DAFB	MAXH	CFH	Accuracy rate
Korean[2]	80.54(M)	46.77(M)	26.27(M) 23.91(F)	43.08(M)	**27.95(M)**	27.95(M)	49.10(M)	27.22(M)	89.4% (Direct DFA)
	73.77(F)	42.45(F)	23.91(F)	39.62(F)	**24.44(F)**	24.44(F)	44.60(F)	24.95(F)	
Modern American[6]	87.81(M)	**54.4(M)**	–	44.61(M)	–	–	–	–	86.69%
	79.79(F)	**48.82(F)**	–	39.44(F)	–	–	–	–	
Indian[9]	79.28(M)	**48.43(M)**	–	41.27(M)	26.81(M)	–	50.24(M)	–	65%–93% (Univariate DFA)
	71.26(F)	**41.94(F)**	–	35.25(F)	24.35(F)		44.20(F)		
South African Whites[7]	84.78(M)	48.19(M)	31.18(M)	41.96(M)	–	**24.02(M)**	47.72(M)	22.98(M)	92.1% (Direct DFA)
	75.87(F)	43.32(F)	27.49(F)	37.94(F)		**20.21(F)**	43.39(F)	20.22(F)	
New Zealand[14]	**80.33(M)**	49.67(M)	–	44.21(M)	25.32(M)	–	–	–	88.4% –93.5%
	71.34(F)	46.17(F)	–	40.58(F)	22.43(F)	–	–	–	
Japanese[17]	73.85(M)	46.65(M)	29.1(M)	39.65(M)	26.25(M)	21.6(M)	44.9(M)	22.9(M)	88%–90%
	67.75(F)	42.5(F)	26.05(F)	36.45(F)	23.5(F)	19.45(F)	40.0(F)	21.05(F)	(Direct DFA)
Gujarati	78.00(M)	48.30(M)	29.40(M)	**41.80(M)**	26.50(M)	30.50(M)	43.40(M)	23.30(M)	94.25%
	68.80(F)	41.60(F)	24.60(F)	**36.00(F)**	20.90(F)	25.70(F)	37.30(F)	19.90(F)	(Direct DFA)

Values in bold indicates the mean values of the best sex discriminant among all parameters in that study; DFA = Discriminant function analysis.

studies that after direct discriminant analysis height dimensional group contributes more to sex determination than breadth dimensional group. Thus, the best sex determinants varies in different population groups (Table 6).

In the present study, direct discriminant function analysis and stepwise analysis of calcaneus yielded correct sex classification rate of 94%. After stepwise analysis, two parameters (dorsal articular facet length and middle breadth) have been selected for accurate sex determination. Thus, by using discriminant function equation with only two measurements instead of eleven measurements, the sex from calcaneus in Gujarati population can be determined with an accuracy of 94.3%. This shows that the predictive value of sexual dimorphism does not depend upon the number of parameters but upon the sex discriminatory power of the parameters. Kazuhiro Sakaue[17] has stated that in practice, functions with reduced set of measurements obtained by a stepwise procedure would be more applicable because of the probability of some breakages of bones.

DiMichele and Sradley[6] concluded subsequent to their studies in Modern American population that load arm width (equivalent to middle breadth of the present study) and load arm length measurements, which measure dorsal articular facet, proved to be the most accurate of the univariate measurements taken. Bidmos and Asala[7] also concluded that dorsal articular facet breadth and middle breadth are among the most accurate parameters subsequent to stepwise analysis in South African Whites. In the present study also, dorsal articular facet length and middle breadth which involve measuring of dorsal articular surface have been selected as the best sex determinants. Dwight[21] has stated that it is demonstrated that the differences in the size of articular surfaces in the sexes is very much more marked than that of the length of the respective bones. Wilbur[13] also suggested that the most accurate measurements on the calcaneus are those that include articular facets. DiMichele and Spradley[6] stated that possible explanation for the higher accuracy rates of articular surface measurements may lie in bone mechanics and the changes that occur in the human skeleton in response to musculature stresses. The two measurements (dorsal articular facet length and middle breadth) selected as the best sex determinants in the present study and which involve measuring of articular surfaces, can be measured even if posterior 1/3rd part of calcaneus is broken.

Johnson et al[22] has found that the best discriminators for race are not necessarily the best for sex. The sex within each race is best described by a unique discriminant function. The population specificity of the discriminant function equations has been highlighted by many researchers.[11,13,23] The discriminant function equations for sex determination from calcaneus has been derived by previous researchers, but these equations are specific for their population groups. Thus, the discriminant function equations derived in present study for sex determination from calcaneus are specific for Gujarati population.

Table 6
Comparison of accuracy rates(%) of dimensional groups of the present study with other population groups.

Dimensional group	Bidmos and Asala[7]	Kim et al, 2013[2]	Present study
Length	86.7%(D)	**84.6%(D)**	81.5%(D)
	88.7%(S)	**81.7%(S)**	87.7%(S)
Breadth	**89.1%(D)**	81.7%(D)	**91.8%(D)**
	91.1%(S)	**82.7%(S)**	**91.8%(S)**
Height	81.7%(D)	83.7%(D)	88.6%(D)
	80.9%(S)	81.7%(S)	83.6%(S)

D = Direct discriminant function analysis; S = Stepwise discriminant function analysis.
Values in bold indicates the dimensional group with highest accuracy.

5. Conclusions

1) The sex can be determined from calcaneus in Gujarati population with an accuracy of 94.25%.
2) The two best sex determinants in the present study are dorsal articular facet length and middle breadth with a correct classification rate of 94.3%.
3) The sex discriminant function equations from calcaneus derived in the present study are specific for Gujarati population.

Conflict of Interest

None.

References

1. Buchner A. The identification of human remains. *Int Dent J*. 1985;35:307–311.
2. Kim DI, Kim YS, Lee UY, et al. Sex determination from calcaneus in Korean using discriminant analysis. *Forensic Sci Int*. 2013;228(177):e1–e7.
3. Bidmos MA, Dayal MR. Sex determination from the talus of South African Whites by discriminant function analysis. *Am J Forensic Med Pathol*. 2004;24 (4):322–328.
4. Fessler DM, Haley KJ, Lal RD. Sexual dimorphism in foot length proportionate to stature. *Ann Hum Biol*. 2005;32(1)44–59 Cited from Kittikun Viwatpinyo, D Troy Case, Pasuk Mahakkanukrauh. Sex estimation from navicular bone in a Thai population. Siriraj Med J 2014; 66(6): 210-8.
5. Viwatpinyo Kittikun, Troy Case D, Mahakkanukrauh Pasuk. Sex estimation from navicular bone in a Thai population. *Siriraj Med J*. 2014;66(6):210–218.
6. DiMichele DL, Spradley MK. Sex estimation in a Modern American osteological sample using a discriminant function analysis from the calcaneus. *Forensic Sci Int*. 2012;221(152):e1–e5.
7. Bidmos MA, Asala SA. Discriminant function sexing of the calcaneus of the South African Whites. *J Forensic Sci*. 2003;48(6):1–6.

8. Wankhede KP, Bardale RV, Chaudhari GR, et al. Determination of sex by discriminant function analysis of mandibles from a Central Indian population. *J Forensic Dent Sci*. 2015;7(1):37–43.
9. Ajay K, Tyagi Y, Sharma SKGA, et al. Sex determination by morphology of calcaneum bone. *J Indian Acad Forensic Med*. 2008;30(4):207–211.
10. Ajay K, Sunil KGA, Tyagi A, et al. Sex determination using discriminant function analysis in adult talus and calcaneum bones. *Int J Med Toxicol Legal Med*. 2009;12(1):4–12.
11. Steele DG. The estimation of sex on the basis of the talus and calcaneus. *Am J Phys Anthropol*. 1976;45:581–588.
12. Introna F, Di Vella G, Campobasso CP, et al. Sex determination by discriminant analysis of calcanei measurements. *J Forensic Sci*. 1997;42(4):725–728.
13. Wilbur AK. The utility of hand and foot bones for the determination of sex and the estimation of stature in a prehistoric population from West Central Illinois. *Int J Osteoarchaeol*. 1998;8:180–191.
14. Murphy AMC. The calcaneus: sex assessment of prehistoric New Zealand Polynesian skeletal remains. *Forensic Sci Int*. 2002;129:205–208.
15. Bidmos MA, Asala SA. Sexual dimorphism of the calcaneus of South African blacks. *J Forensic Sci*. 2004;49(3):446–450.
16. Gualdi-Russo E. Sex determination from the talus and calcaneus measurements. *Forensic Sci Int*. 2007;171:151–156.
17. Sakaue K. Sex assessment from the talus and calcaneus of Japanese. *Bull. Natl. Mus. Nat. Sci.* 2011;37:35–48 Ser. D.
18. Srivastav R, Siani V, Rai RK, et al. A study of sexual dimorphism in the femur among North Indians. *J Forensic Sci*. 2012;57(1):19–23.
19. Kayalvizhi I, Arora S, Dang B, et al. Sex determination by applying discriminant function analysis on patellar morphometry. *Int J Sci Res*. 2015;11(4):1511–1515.
20. Kajanoja P. Sex determination of Finnish crania by discriminant function analysis. *Am J Phys Anthropol*. 1966;24(1):29–33.
21. Dwight T. The size of the articular surfaces of the long bones as characteristic of sex; an anthropological atudy. *Am J Anat*. 1905;4:19–31 Cited from DiMichele DL, Spradley MK. Sex estimation in a Modern American osteological sample using a discriminant function analysis from the calcaneus. Forensic Sci Int 2012; 221: 152 e1- 5.
22. Johnson DR, Higgins PO, Moore WJ, et al. Determination of race and sex of the human skull by discriminant function analysis of linear and angular dimensions. *Forensic Sci Int*. 1989;41:41–53.
23. Johnson DR, Higgins PO, Moore WJ, et al. Determination of race and sex of the human skull by discriminant function analysis of linear and angular dimensions. An appendix. *Forensic Sci Int*. 1990;45:1–3.