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Sex determination from partial segments and maximum femur lengths in Koreans using computed tomography

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Background: The aim of this study was to establish standards for determining sex from fragmentary and complete femurs in a Korean population.
Materials and methods: The statistical analysis of 12 variables (6 about breadth and 6 about length) based on 100 Korean femurs (from 50 males and 50 females) showed that all variables have significant sex differences.
Results: The most accurate discriminant variable was the condylar breadth parallel with epicondylar breadth (87.6% accuracy). In contrast, the transverse shaft diameter was not a discriminant variable for sex determination (67.0% accuracy). Breadth-related variables were generally more accurate than length-related variables. Three variables (vertical diameter of the neck [VDN], medial epicondylar length [MCL], and condylar breadth [CB]) were selected from stepwise analysis for discriminating sex (93.5% accuracy). The discriminating equation was as follows: $0.171 \times VDN + 0.172 \times MCL + 0.128 \times CB2 - 21.471$.
Conclusions: The results of this study are helpful for determining sex, even if a femur is found in a fragmented condition in the field. (Folia Morphol 2014; 73, 3: 353–358)

Key words: sex determination, femur, Korean

INTRODUCTION

Sex determination of unidentified skeletal remains from crime scenes or excavations is an important component of forensic anthropology. For this process, the femur has been the most commonly used bone to determine sex [19]. Special emphasis has been given to long bones, particularly the femur, since this is the largest bone in the human skeleton and, thus, the most likely to remain preserved [19]. For this reason, numerous studies have been conducted to determine sex from measurements of the femur [1–3, 5, 7, 11–14, 17–21].

However, many authors [2, 4, 6, 7, 12, 13, 18–21] did not report uniform values for all races studied in different populations. Anthropometric dimensions vary among populations, even in subjects on the same continent, and these variations are attributed to genetic and environmental factors. In Asian populations, the discriminant values for Chinese, Japanese, and Thai populations have been established, whereas those for Korean populations are lacking.

In Korea, research regarding discriminating sex from metric or nonmetric studies using various human bones is ongoing. Valuable results of the pelvis and

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bones of the face and neck have been published during the last 10 years [4, 6, 8–10, 15, 16]. However, less emphasis has been placed on the femur. Femurs found in the forensic field are often fragmented. As such, the discriminating values for the Korean population using femurs must be obtainable using not only complete bones but also those in a fragmented condition.

The aim of this study was to obtain such standards for variables including femoral breadth and length in the Koran population

MATERIALS AND METHODS

Computed tomographic data from maximum and partial femoral lengths were obtained for 100 adult Korean cadavers (50 men and 50 women) 21–62 years of age (mean 53 years). These images were collected from the Digital Korean Human Model Database (http://digitalman.kisti.re.kr) at the Korea Institute of Science and Technology Information. The femurs were reconstructed and measured by a computer program (Mimics Version 16; Materialise, Leuven, Belgium; Fig. 1). The data were analysed using SPSS (Version 15.0; SPSS Inc., Chicago, IL, USA).

The variables were as follows (Fig. 2):

1. Length variables:
   — ML: maximum femoral length;
   — MCL: medial epicondylar length in the posterior view;
   — LCL: lateral epicondylar length in the posterior view;
   — LG: distance from the most prominent point of the lesser trochanter to the most supromedial point of the greater trochanter;
   — IFLM: distance from the most proximal point of the intercondylar fossa to the most prominent point of the lesser trochanter';
   — IFGP: distance from the most proximal point of the intercondylar fossa to the most supromedial point of the greater trochanter.
2. Breadth variables:
   — VDH: vertical diameter of the femoral head;
   — VDN: vertical minimal diameter of the femoral neck;
   — TDS: transverse minimal diameter of the femoral shaft;
   — EB: epicondylar breadth on the inferior view;
   — CB1: condylar breadth on the inferior view parallel to the EB;
   — CB2: condylar breadth parallel to the infracondylar plane.

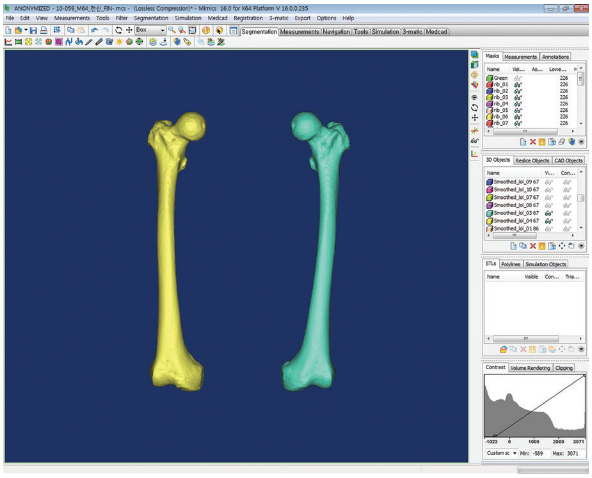

Figure 1. The reconstructed femur in three dimensions.

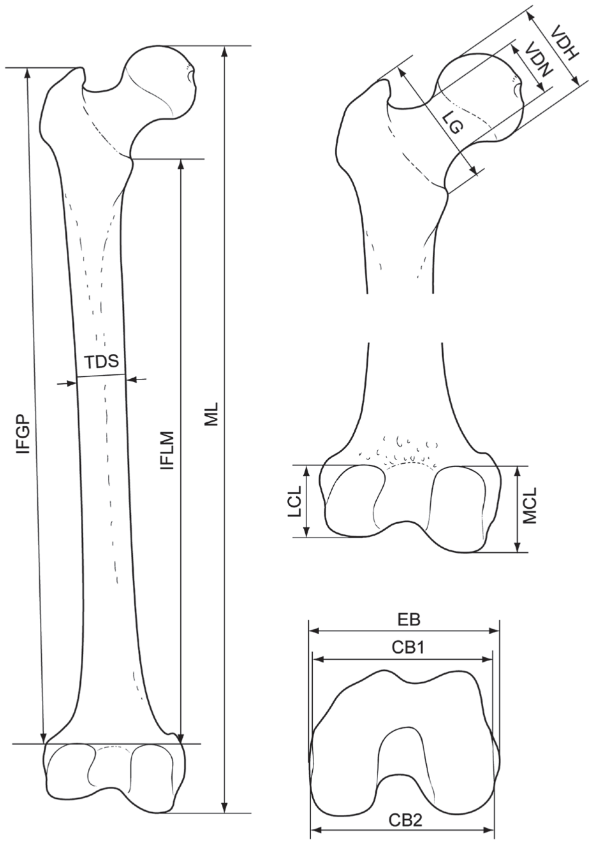

Figure 2. Measurements used for sex determination; VDH — vertical diameter of the head; VDN — vertical minimal diameter of the neck; TDS — transverse minimal diameter of the shaft; EB — epicondylar breadth; CB1 — condylar breadth parallel with EB; CB2 — condylar breadth; MCL — medial epicondylar length; LCL — lateral condylar length; LG — distance from the midpoint of the lesser trochanter to the most proximal point of the greater trochanter; IFLM — distance from the intercondylar fossa (most proximal point) to the lesser trochanter (midpoint); IFGP — distance from intercondylar fossa (most proximal point) to the greater trochanter (most proximal point); ML — maximal length.

Table 1. Means (with standard deviation [SD]) of measured variables

Variable		Male		Female	
		Mean	SD	Mean	SD
Length [mm]	MCL	41.6	2.4	36.9	2.2
	LCL	39.1	2.7	34.3	2.2
	LG	69.6	4.6	62.1	3.7
	IFLM	324.9	18.5	302.1	17.9
	IFGP	384.2	20.5	355.1	19.8
	ML	442.6	23.3	406.0	21.5
Breadth [mm]	VDH	48.0	2.7	43.1	2.4
	VDN	35.4	2.5	30.5	2.1
	TDS	26.0	1.6	24.4	2.0
	EB	83.1	4.3	74.0	3.0
	CB1	71.2	3.9	62.5	3.3
	CB2	75.5	4.1	66.2	3.2

Abbreviations as in Figure 2

Table 2. Discriminant function coefficient and sexing accuracy of the variable of femur

	Variable	Demarking point [mm]	Wilk's Lamda	F-ratio	Significance	Accuracy (%)
Length	MCL	F < 39.26 < M	0.494	202.839	0.000	86.0
	LCL	F < 36.64 < M	0.503	194.935	0.000	84.5
	LG	F < 66.04 < M	0.554	156.942	0.000	79.5
	IFLM	F < 313.42 < M	0.716	77.214	0.000	71.0
	IFGP	F < 367.29 < M	0.655	102.564	0.000	73.0
	ML	F < 420.65 < M	0.597	133.590	0.000	77.0
Breadth	VDH	F < 45.59 < M	0.522	181.573	0.000	83.0
	VDN	F < 33.02 < M	0.470	222.294	0.000	86.0
	TDS	F < 25.26 < M	0.830	40.691	0.000	67.0
	EB	F < 79.07 < M	0.422	250.970	0.000	85.9
	CB1	F < 67.30 < M	0.401	273.654	0.000	87.6
	CB2	F < 70.80 < M	0.391	285.230	0.000	87.0

F — female; M — male; rest abbreviations as in Figure 2

Table 3. Sex discriminant functions of Korean femur

Coefficient [mm]	Significance	Correct (%)
0.171 × VDN + 0.172 × MCL + 0.128 × CB2 – 21.471	0.000	93.5

RESULTS

No statistically significant difference was seen between the right and left bone lengths (paired t-test; $p > 0.05$). Therefore, regression analysis was performed using the right bones only. Because there was a statistically significant difference in bone length between men and women, the discriminant values were made independently for each sex ($p < 0.05$).

Table 1 presents the means and standard deviations of all variables for both sexes. The t-test showed that all measurements used in the present study were significantly higher in men than in women ($p < 0.05$).

Table 2 presents the discriminant function coefficient and sexing accuracy of the femoral variables. The functions based on a single variable are displayed. For each discriminant function, a discriminant score that is smaller than the demarking point indicates a female individual. Generally, the breadth variables were better predictors than length variables. The results showed that CB1 is the best predictor of sex, while TDS is the worst predictor.

Table 3 presents a stepwise discriminant analysis of the variables, and VDN, MCL, and CB2 were selected for discriminant analysis. The sectioning point was set to zero; when the product of the predictor variable and its coefficient added to the constant is higher than zero, the individual is classified as male, whereas a constant below zero indicates a female.

DISCUSSION

This investigation was performed for a sample from the Korean population in which it was possible to directly determine sex. Almost all other studies of discriminant sexing using the femur measured ML, VDH, and EB (Table 4). For the ML, the Croatian population had the highest femoral length, and the difference from the Korean population was approximately 30.0 mm. The ML of the Japanese population was the shortest, and our study showed an approximate difference of 26.0 mm. The population differences existed even when they were located in East Asia. Other variables such as EB and VDH also demonstrated differences (Table 4). If a Korean femur was found in the scene, it might be used as the demarking point from discriminant function analysis using a Korean population. For this reason, the results of this study are important for the determination of sex using femurs (Table 2).

The results of this study showed that Korean femur is a good skeletal component for determining sex, with a classification accuracy of 67.0–87.6% (Tables 2, 5). The variables (MCL, VDN, EB, CB1, and CB2) were seen as good discriminators (sexing accuracy > 85%; Table 2).

The variables of this study were divided into being femoral breadth- and length-related. The breadth-related variables were better predictors than the length-related variables; in fact, the sexing accuracy of all of the breadth-related variables, except TDS, was 80% (Tables 2, 5). As shown in Table 5, many other researchers who investigated femoral sex determinants focused on breadth-related variables. Chinese populations [21] were studied to discriminate sex using 6 variables (3 about length and 3 about breadth), which had a classification accuracy range of 75.9–83.7%. The most valuable variable was EB, but it was not determined that breadth-related variables were better discriminators than length-related variables. However, in studies of South African [3], German [13], and Indian [18] populations, breadth-related variables were better discriminators than length-related variables. Iscan and Shihai [7] supported the findings of earlier studies indicating that breadth and circumference measurements of long bones are often more sexually dimorphic than linear dimensions such as length. This fact is advantageous because bones are often found in a fragmentary condition [7, 11, 19].

As shown in Table 5, the most frequently used variables were VDH and EB. VDH was the most accurate variable in Chinese populations (94.9%) [7]; however, it was also the worst (77.3%) [21]. These 2 studies were not significantly different in terms of materials or methods; as such, these differences may reflect a secular trend. The EB generally had a high accuracy rate (83.7–95.4%), the highest being in a French population [20] (approximately 10% different than the findings of this study; Table 5).

Purkait [17] and Asala et al. [3] insisted that femur head diameters are important parameters for determining sex. Asala et al. [3] stated that overall, the upper end of the femur is more useful in sex identification than the lower end of the femur. This may be due to the very important role that this part of the femur plays in the transmission of the weight of the body from the axial skeleton to the lower limb and also to the greater range of the movements of the hip joint in which the upper part of the femur is involved. Purkait and Chandra [18] also insisted that the extremities of the bone are areas in which a number of muscles make their insertions and thus are subjected to more pull than the point of origin. We think these factors would be expected to be influenced by sex.

According to Kranioti et al. [12], the secular trends in Americans are more pronounced in lower limbs compared with upper limbs and in distal bones compared with proximal parts. They also insisted that the femur is a very useful bone for sex determination. This study's results were not compared with those of that study, but the point using the femur of the lower limbs was a good opportunity for determining sex.

Table 4. Comparison of mean values with single measurement

Variable		Chinese (1989)	Chinese (1995)	Thai (1998)	German (2000)	South African (2001	Croatian (2003)	South African (2004)	Indian (2004)	French (2008)	Japanese (2008)	This study
		Male/female	Male/female	Male/female	Male/female	Male/female	Male/female	Male/female	Male/female	Male/female	Male/female	Male/female
Length	MCL	58.0/52.5						63.7/57.6				41.6/36.9
	LCL	59.6/54.3						64.0/58.9				39.1/34.3
	LG											69.6/62.1
	IFLM											324.9/302.1
	IFGP											384.2/355.1
	ML	426.8/390.4	442.2/401.0	429.4/397.0	464.0/434.0		469.6/439.4		450.1/403.6		416.7/382.0	442.6/406
Breadth	VDH	42.7/38.4			49.0/44.0	48.4/42.3		45.4/40.7	45.3/38.7			48.0/43.1
	VDN											35.4/30.5
	TDS											26.0/24.4
	EB	77.8/69.3	80.3/70.6	79.7/70.0	84.0/77.0		86.7/75.2	78.9/71.8	78.7/66.8	84.3/74.8	78.2/68.9	83.1/74.0
	CB1											71.2/62.5
	CB2											75.5/66.2

Abbreviations as in Figure 2

Table 5. Comparison of percentages of sex determination with single measurement

Variable		Chinese (1989)	Chinese (1995)	German (2000)	Croatian (2003)	South African (2004)	Indian (2004)	French (2008)	Japanese (2008)	This study
Length	MCL	80.1				80.5				86.0
	LCL	75.9				75.6				84.5
	LG									79.5
	IFLM									71.0
	IFGP									73.0
	ML	79.4		67.7			88.7		84.4	77.0
Breadth	VDH	77.3	94.9	86.8		82.6	92.7			83.0
	VDN									86.0
	TDS	73.1								67.0
	EB	83.7			91.3		90.3	95.4	93.0	85.9
	CB1									87.6
	CB2			81.4		81.5				87.0

Abbreviations as in Figure 2

CONCLUSIONS

In this study, the femur was used to determine sex. To our knowledge, no other study has determined sex in Korean subjects using a fragmented femur. The technique described here allows for more accurate sex determination and improvement of the process of identifying missing persons.

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