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# Sex Determination of Chinese Femur by Discriminant Function

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**ABSTRACT:** The objective of this study was to provide a method of sex determination for Chinese femur, especially for fragmentary remains. Statistical analysis of 17 measurements based on 141 northeastern Chinese femora shows that all measurements have significant sex differences. Sex determination by the midpoint method of a single measurement can obtain an average accuracy of 76.8%. The results indicate that of all dimensions the maximum head diameter is the best discriminator of sex. It alone can determine the sex of a femur with 85.1% accuracy. The results also show that maximum head diameter, transverse head diameter, epicondylar breadth, upper breadth, and medial condylar length have higher sexual dimorphisms than the dimensions of length. According to the result to stepwise discriminant analysis and the need for sexing fragmentary remains, 22 discriminant functions composed of various combinations of variables were calculated which can determine the sex of the femur correctly 82.3 to 87.2%. The methods of sex determination provided by this paper can be used to sex poorly preserved femora.

**KEYWORDS:** physical anthropology, human identification, musculoskeletal system, femur, sex determination, discriminant function

Sex determination from long bones plays an important role in the field of anthropology and forensic medicine. Since Pons [*1*] used discriminant functions to determine the sex of Spanish femur and sternum many studies have been made [*2-6*]. However, most of these methods can be used only on well-preserved skeletons, and this is not practical as forensic anthropologists rarely acquire a well-preserved skeleton. So, recently, many researchers have stressed the importance of sexing fragmentary skeletal remains. Black [*7*] applied a single discriminant function using midshaft femoral circumference for sex determination. His method can determine sex 85% correctly, and he also found that sexual dimorphism of circumference and width exceed the length in long bones. DiBennardo and Taylor [*8,9*] confirmed the usefulness of Black's method. Although this method seems to be useful for determining sex of a fragmentary skeleton, the measurement available in sexing is limited to the specified part adopted by him. However, the degree of preservation of human bone varies considerably from site to site. Consequently, the method cannot cope with the variety of bone preservation in practice. This paper studied the sex differences of Chinese femur measurements and established sex discriminant functions which can be used to sex Chinese femur with various conditions of fragmentary remains.

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## Materials and Methods

Our sample of 141 modern Chinese femora was collected from the Jilin province of northeastern China. Some of the specimens were collected from autopsy and the sex is known. The sex of most specimens was determined by means of morphological observation of the whole skeletons, especially the pelvis and skull. Those include 74 males and 67 females. Measurements taken in Table 1 are those defined by Martin [*10*]. ($X_1$, $X_2$, and so forth are symbols in calculation.)

The statistical analyses include (1) means, standard deviation, and Student's *t*-test for sex differences of each measurements; (2) simple sex determination by means of a sectioning point which is the midpoint between male and female means of each measurements; and (3) multiple discriminant function analysis (stepwise and direct method). All these calculations are made by computer.

## Results

Table 2 shows the descriptive statistics and the sex differences between the sexes of all 17 measurements. Table 2 also presents the sectioning point for sexing the femur with a single measurement and its discriminant rate.

Table 2 shows that in all dimensions the male exceeds the female and the differences between the sexes are statistically significant ($p < 0.001$). In all these variables, maximum head diameter has the highest *t*-value and is the best single discriminator of sex when the midpoint between the male and the female means was used as the sectioning point for the assessment of sex. The following variables are upper breadth, transverse head diameter, epicondylar breadth, and medial condylar length which also have higher *t*-values and discriminant rates (above 80%).

Stepwise discriminant function analysis using these variables was performed to determine the optimal combination of variables for sex determination. Table 3 presents a summary of this procedure on 17 measurements.

Table 3 shows that there are seven variables chosen in the procedure. Among them such variables as upper breadth, maximum head diameter, maximum length, transverse head diameter, and so forth deal with the results of Table 2. But lower anteroposterior diameter,

TABLE 1—*The measurements of femur.*

| Variables | Measurements | Martin's Numbers [*10*] |
|---|---|---|
| $X_1$ | Maximum length | 1 |
| $X_2$ | Physiological length | 2 |
| $X_3$ | Trochanteric length | 3 |
| $X_4$ | Anteroposterior diameter at midshaft | 6 |
| $X_5$ | Transverse diameter at midshaft | 7 |
| $X_6$ | Circumference at midshaft | 8 |
| $X_7$ | Subtrochanteric transverse diameter | 9 |
| $X_8$ | Subtrochanteric anteroposterior diameter | 10 |
| $X_9$ | Lower anteroposterior diameter | 11 |
| $X_{10}$ | Lower transverse diameter | 12 |
| $X_{11}$ | Upper breadth | 13 |
| $X_{12}$ | Vertical head diameter | 18 |
| $X_{13}$ | Transverse head diameter | 19 |
| $X_{14}$ | Maximum head diameter | ... |
| $X_{15}$ | Epicondylar breadth | 21 |
| $X_{16}$ | Lateral condylar length | 23 |
| $X_{17}$ | Medial condylar length | 24 |

TABLE 2—*Descriptive statistics, t-value, sectioning point, and discriminant rate by midpoint method.*[a]

| Variables | Male Mean | Male SD | Female Mean | Female SD | $t$-Value | Sectioning Point | Discriminant Rate, % |
|---|---|---|---|---|---|---|---|
| Max. length | 431.3 | 25.8 | 394.1 | 17.5 | 9.93 | 412.7 | 79.4 |
| Phy. length | 426.8 | 25.9 | 390.4 | 17.4 | 9.69 | 408.6 | 75.9 |
| Troch. length | 403.8 | 25.7 | 369.3 | 17.9 | 9.17 | 386.5 | 75.1 |
| A-P dia. at mid. | 27.0 | 2.6 | 23.7 | 1.7 | 8.81 | 25.3 | 79.4 |
| Tran. dia. at mid. | 26.7 | 2.2 | 24.2 | 1.7 | 7.83 | 25.5 | 73.1 |
| Circum. at mid. | 84.6 | 6.9 | 75.7 | 4.5 | 9.02 | 80.2 | 79.4 |
| Subtro. tran. dia. | 31.9 | 3.1 | 28.6 | 2.4 | 6.97 | 30.2 | 69.5 |
| Subtro. A-P dia. | 26.1 | 2.2 | 22.9 | 1.6 | 9.43 | 24.5 | 78.0 |
| Lower A-P dia. | 27.1 | 2.9 | 24.4 | 2.2 | 6.17 | 25.7 | 66.7 |
| Lower tran. dia. | 37.6 | 4.5 | 34.5 | 3.3 | 4.66 | 36.0 | 62.4 |
| Upper breadth | 95.0 | 6.2 | 84.6 | 4.3 | 11.52 | 89.8 | 80.9 |
| Vertical h. dia. | 42.7 | 3.1 | 38.4 | 1.9 | 9.59 | 40.5 | 77.3 |
| Tran. h. dia. | 44.7 | 3.2 | 40.0 | 1.9 | 10.55 | 42.3 | 84.4 |
| Max. h. dia. | 45.3 | 3.2 | 40.4 | 1.9 | 11.12 | 42.9 | 85.1 |
| Epicon. breadth | 77.8 | 5.8 | 69.3 | 3.0 | 10.80 | 73.5 | 83.7 |
| Lat. con. length | 59.6 | 3.8 | 54.3 | 2.9 | 9.32 | 56.9 | 75.9 |
| Med. con. length | 58.0 | 4.2 | 52.5 | 2.8 | 9.09 | 55.3 | 80.1 |
| Average discriminant rate | | | | | | | 76.8 |

[a]All dimensions in millimetres.

TABLE 3—*Summary of the stepwise discriminant function analysis.*

| Step | Variables Entered | $F$ to Enter | Wilks' Lambda | Degres of Freedom |
|---|---|---|---|---|
| 1 | Upper breadth | 132.59 | 0.5118 | 1, 139 |
| 2 | Subtro. A-P dia. | 9.47 | 0.4789 | 2, 138 |
| 3 | Max. length | 4.88 | 0.4625 | 3, 137 |
| 4 | Phy. length | 1.75 | 0.4566 | 4, 136 |
| 5 | Max. h. dia. | 1.25 | 0.4524 | 5, 135 |
| 6 | Tran. h. dia. | 4.39 | 0.4381 | 6, 134 |
| 7 | Lower A-P dia. | 1.69 | 0.4326 | 7, 133 |

which has a lower $t$-value and a lower discriminant rate, was also selected. This is probably because the correlation relation among the variables prevents some variables from entrance. Even so, the stepwise discriminant analysis basically corresponds to the results of Table 2.

In Table 4, 22 discriminant functions are presented. The selection of variable combinations was performed with the direct method according to the result of stepwise discriminant analysis and the need of sexing fragmentary femur in practice.

## Discussion

The main purpose of this paper was to establish methods for sexing the fragmentary femur. Black [7] applied the midpoint of a single measurement between male and female for sex determination and obtained satisfactory results. But Black's method only used midshaft femoral circumference and cannot be applied to various conditions of fragmentary remains. For this reason, the present study used the midpoint method for all 17 measurements for sex determination. Table 2 shows that using the midpoint method for sex determination can obtain a good result in most of the measurements. The average accuracy for sex assessment

TABLE 4—*Sex discriminant functions of Chinese femur.*

| No. | Discriminant Function | Sectioning Point[a] | Discriminant Rate, % |
|---|---|---|---|
| 1 | $Z = X_1 + 10.1801X_4 + 11.2835X_5 - 4.2057X_6$ | 620.3 | 86.5 |
| 2 | $Z = X_3 + 10.1587X_{11} + 13.2802 + X_{14} + 4.2127X_{15}$ | 2178.0 | 87.2 |
| 3 | $Z = 0.1211X_2 + X_{11} + 1.3655X_{14} + 0.4433X_{15}$ | 230.5 | 87.2 |
| 4 | $Z = 1.4750X_8 + X_{11} + 0.4956X_{13} + 0.3407X_{17}$ | 165.7 | 86.5 |
| 5 | $Z = X_1 + 7.1108X_{11} + 11.4267X_{14}$ | 1541.3 | 86.5 |
| 6 | $Z = X_1 + 12.1609X_8 + 7.2139X_{11}$ | 1358.4 | 87.2 |
| 7 | $Z = X_1 + 0.4792X_6 + 9.6555X_8$ | 687.7 | 85.8 |
| 8 | $Z = X_3 + 9.6424X_{11} + 14.9271X_{14}$ | 1892.5 | 86.5 |
| 9 | $Z = 0.1208X_2 + 1.6498X_8 + X_{11}$ | 179.6 | 87.2 |
| 10 | $Z = X_3 + 10.0094X_{11} + 1.9250X_{16}$ | 1394.8 | 85.1 |
| 11 | $Z = X_3 + 12.7761X_8 + 7.7269X_{15}$ | 1267.8 | 84.4 |
| 12 | $Z = 0.1168X_2 + X_{11} + 0.7166X_{15}$ | 190.2 | 85.8 |
| 13 | $Z = X_6 + 3.7790X_{15} + 0.6731X_{16}$ | 396.4 | 82.3 |
| 14 | $Z = X_6 + 23.2407X_8 + 17.1416X_{15}$ | 1910.3 | 84.4 |
| 15 | $Z = X_1 + 7.5169X_{11}$ | 1087.6 | 85.1 |
| 16 | $Z = X_1 + 2.6407X_6$ | 624.5 | 85.1 |
| 17 | $Z = X_6 + 3.8033X_8$ | 173.4 | 83.7 |
| 18 | $Z = 0.2926X_6 + X_{11}$ | 113.2 | 82.3 |
| 19 | $Z = 1.4831X_8 + X_{11}$ | 126.1 | 84.4 |
| 20 | $Z = X_{11} + 0.7883X_{15}$ | 147.8 | 85.1 |
| 21 | $Z = X_{11} + 0.5217X_{17}$ | 118.6 | 84.4 |
| 22 | $Z = X_{14} - 0.1333X_9 + 0.3180X_{17}$ | 57.1 | 86.5 |
| Average discriminant rate | | | 85.4 |

[a]Discriminant scores less than the sectioning point would classify as female. Otherwise they would classify as male.

by means of this method is 76.8%. Among the 17 measurements there are 13 midpoints that can determine sex 75% correctly or better. The best discriminator of sex among them are maximum head diameter, transverse head diameter, epicondylar breadth, upper breadth, and medial condylar length which can sex the femur correctly 80.1 to 85.1%.

With regard to sexing by multiple discriminant functions, the selection of variables was in accordance with the result of stepwise discriminant analysis and the need for sexing fragmentary remains. The 22 discriminant functions include various combinations of the 17 measurements and can cope with the practical application for forensic medicine. The average accuracy of sexing is 85.4% better than the midpoint method (76.8%).

Black [*7*] noted that the sexual dimorphism in bone width and circumference often exceeds the sexual dimorphism in bone length. He further suggested that the former dimensions could be particularly useful in sexing fragmentary remains. Using femoral midshaft circumference as a discriminator of sex, he obtained a 85% accuracy.

DiBennardo and Taylor [*8,9*] employed the same research model using an American population and obtained accuracies of 83 and 73.1%. Nakahashi et al. [*11*] used midpoint of circumference at midshaft to determine sex of Japanese femur with an accuracy of 77%. Both DiBennardo et al. and Nakahashi et al. agreed with Black's idea that the circumference of femur is the most useful discriminator of sex. Maclaughlin [*12*] studied the sex difference of Scottish femur and said using the maximum anteroposterior diameter of the femoral shaft as a sex discriminator has an advantage over midshaft circumference.

In the present study, circumference at midshaft has an accuracy of 79.4% for sexing femur. This is equal to maximum length and higher than physiological length and trochanteric length. But the *t*-value of the circumference is lower than the three dimensions of length. So Black's assertion that circumference often exceeds length as an accurate discrimi-

TABLE 5—*Comparison of percentages of sex determination with single measurements.*

| Samples | Maximum Length | Circumference | A-P Diameter at Midshaft |
|---|---|---|---|
| American indians [7] | 89.4 | 85.0 | |
| American whites [8] | 80 | 83 | |
| American blacks [9] | | 73.1 | |
| Scottish [12] | | | 90.6 |
| Japanese [11] | | 77.8 | |
| Chinese (present study) | 79.4 | 79.4 | 79.4 |

nator of sex is not supported by the results of the present study. Table 2 indicates that upper breadth, transverse head diameter, maximum head diameter, epicondylar breadth, and medial condylar length have higher percentages as sex discriminators than dimensions of length and four of them also have higher $t$-values than dimensions of length. Among the five measurements, maximum head diameter is the best sex discriminator that can determine sex with an accuracy of 85.1% alone. But following the five measurements mentioned above, maximum length, anteroposterior diameter of midshaft, circumference at midshaft, and other measurements also have important discriminant values for sexing. The present study shows that sexual dimorphism of some dimensions of circumference and width exceed the length in Chinese femur.

For comparison with other studies, Table 5 presents the percentages of sex determination with some single measurements of the present study and others. Table 5 indicates that the sex discriminant rates of Chinese and Japanese femora with single measurements are lower than other groups. This may be due to the difference in races.

## Conclusion

In conclusion, the statistical analysis of 17 measurements of Chinese femora shows that all measurements have significant sex differences, and most of the measurements can be used to sex with a high discriminant rate. The average accuracy using the midpoint method is 76.4%. Among the 17 dimensions, maximum head diameter is the best discriminator of sex. It can determine sex with an accuracy of 85.1% alone. The present study also proved that some dimensions of width and circumference have higher sexual dimorphism than the dimensions of length. According to the practical application of forensic medicine, 22 multiple discriminant functions were calculated which included various combinations of the variables and could assess correctly the sex of Chinese femur 82.3 to 87.2%.

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