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Sex Determination from the Tibia: Standards for Contemporary Japan

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ABSTRACT: It is vital that skeletal biologists and forensic anthropologists observe populations over time so that changes can be detected and monitored. The purpose of this study is to determine if temporal changes are manifest in the skeleton and, if so, develop appropriate standards to determine sex from the tibia in the contemporary inhabitants of Japan. Osteometric data were obtained from 84 recent Japanese skeletons located at Jikei Medical University, Tokyo. The collection was assembled from the anatomy dissecting room between 1960–1970. With a mean age of about 56 years for males and 51 for females, this sample represents individuals who lived through WWII. Seven tibial measurements were taken and subjected to SPSS-X discriminant function analysis. Results indicated that proximal and distal breadth measurements were selected by the stepwise procedure as the most discriminating. In addition, a number of combinations of measurements were used to develop formulae that would be suitable for fragmentary bones. Average prediction accuracy ranged from 80% from minimum shaft circumference to 89% with proximal epiphyseal breadth. Classification accuracy was higher in males (96%) than in females (79%). Compared with earlier studies of the Japanese, Jikei tibiae are longer, especially in females and thus exhibit less sexual dimorphism. The present research provides new standards that better reflect the Japanese people of today. Furthermore, unlike earlier length based formulae, these results allow sexing from fragmentary bones.

KEYWORDS: physical anthropology, biological anthropology, human identification, musculoskeletal system, sex determination, tibia, discriminant function, Japanese

The human skeleton responds to changes in both its internal and external environments and reflects differences within and between populations. Forensic osteologists must always be aware that changes may affect the standards established to diagnose demographic characteristics, especially in the case of osteometric based techniques. Events such as famine, war and other sociopolitical and economic upheavals can have far reaching consequences on human growth, development and maintenance. Studies indicate that many aspects of life have undergone considerable change over time in Japan, including nutrition, population size, demographics and mobility [*1*]. While significant anatomic

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and physiologic modifications have been delineated anthropometrically and auxologically, less attention has been focused on the skeleton.

Assessment of skeletal change is particularly important to forensic osteology because this field deals primarily with the skeletal characteristics of contemporary humans. It relies heavily on up-to-date techniques to provide accurate information to the medico-legal system [*2–4*]. However, most skeletal studies of the Japanese were carried out two decades ago or earlier [*5*].

Long bones are frequently used for osteometric sexing. In the last 15 years, sex differences in the tibia have been evaluated in a number of populations, including Asian Indians [*6*], American blacks and whites [*7–10*], Italians [*11*], South African blacks and whites [*12*], and Lithuanians [*13*]. These studies clearly indicate that metric standards are highly population specific.

There have been several studies dealing with sex differences in the postcranial skeletons of the Japanese [*15–17*]. Of these, only Hanihara [*14,15*] investigated the tibia along with other long bones. However, most of the individuals in his sample died before World War II. The existence of a more contemporary skeletal collection at Jikei Medical University makes it possible to determine if significant change has occurred over time. Therefore, the purpose of this research is to assess skeletal change in the current Japanese population and develop appropriate standards for determining sex from the tibia.

Materials and Methods

The skeletal remains used in this study are housed at Jikei Medical University in Tokyo. The collection is composed of about 90 relatively complete, well-preserved, adult skeletons of known provenience who died between 1960 and 1970. Thus, they represent individuals who lived through World War II. Mean age is 56 years in males and 52 in females.

A total of seven tibial dimensions were obtained from 84 skeletons. The method used in this study is based on İşcan's earlier works [*7,8*]. The following measurements [also see *2*] were taken:

Tibial length: distance from the lateral condyle to the medial malleolus (measured with osteometric board) [*18*].

Proximal epiphyseal breadth: maximum distance between the condyles (sliding caliper).

Distal epiphyseal breadth: distance from the deepest center of the fibular notch to the most medial surface of the malleolus tangent to the vertical axis of the bone (sliding caliper).

Anteroposterior and transverse diameters: taken at nutrient foramen level (sliding caliper).

Shaft circumference: taken at the nutrient foramen level (with steel tape following contour of the bone).

Minimum shaft circumference: minimum dimension of the bone (with steel tape following contour of the bone).

Data were analyzed using several SPSS-X subroutines [*19*]. The analysis of variance was applied to measure the variation within and between groups, then the stepwise discriminant function procedure was used to determine the relative contribution of each variable. The variables thus selected were then subjected to a direct discriminant analysis to calculate specific discriminant function formulae for the proximal, shaft or distal segments that can be used on fragmentary specimens.

Results

Table 1 contains descriptive statistics, including means and standard deviations, for each dimension. Males are clearly larger than females in all dimensions and the F-ratios

TABLE 1—*Mean, standard deviation and univariate F ratios.*

	Males (N = 44)		Females (N = 34)		
Variables (mm)	Mean	SD	Mean	SD	F-Ratio[a]
Tibial length	333.6	15.80	310.1	20.83	32.17
Prox epiphyseal br	73.5	2.78	65.8	4.68	81.70
Anteroposterior dia	33.3	3.10	30.3	5.53	15.12
Transverse dia	24.6	2.71	21.5	2.79	24.30
Dist epiphyseal br	45.3	2.18	40.5	2.55	79.52
Circ at nutrient for	91.6	4.66	82.4	8.32	37.72
Min circumference	73.0	3.94	65.9	5.75	41.90

[a]Degrees of freedom = 1,76. All significant at $P < 0.001$.

indicate these differences are statistically significant ($P < 0.001$). The standard deviation suggests that females exhibit more variation than males.

The results of the stepwise discriminant function analysis appear in Table 2. Of the seven measurements entered into the function, only proximal and distal epiphyseal breadths were selected. In this case, the F-ratio determines how much variation exists within and between the sexes and the significance level of the variance. Wilks' lambda calculates how useful a given variable is in the stepwise analysis. Proximal breadth is the first variable selected by the stepwise discriminant function. Once the proximal breadth was removed from the analysis, in the second step the remaining variables were reassessed and selected according to the lambda level. After Step 2, it was determined that only the distal epiphyseal breadth contributed to the discriminant function.

Once the variables that gave the best separation were determined by the stepwise analysis, the direct approach was applied to produce several additional functions for use on fragmentary bones. Table 3 lists all the functions, coefficients and sectioning points. The raw (unstandardized) coefficient is used to calculate the discriminant scores for all functions. Values larger than the sectioning point (the average of the male and female means shown in Table 1) classify an individual as male. The standardized coefficient indicates how much a given variable contributes to the over all classification. As anticipated from Table 2, proximal breadth is the most powerful variable. The structure coefficient measures the correlation between the variables and function. It is also an indicator of the contribution of each variable to a function. Again, proximal breadth had the highest correlation (r = 0.91). The reliability of a discriminant score increases with its distance from the sectioning point (see Table 3 for specific figures).

The direct approach was employed to choose the variables that would give the best separation when the bone is fragmentary. In Functions 4–7, only one variable was selected. In these functions, it is only necessary to compare the actual measurement with the sectioning point.

Table 4 presents the classification results. Accuracy ranged from 80% to 89%. As expected, the most discriminatory dimension was proximal epiphyseal breadth. In all

TABLE 2—*Stepwise discriminant function analysis.*

Step Variable Entered	Wilks' Lambda	Equivalent F Ratio	Degrees of Freedom
1. Prox epiphyseal br	0.482	81.70	1, 76
2. Dist epiphyseal br	0.435	48.67	2, 75

TABLE 3—*Canonical discriminant function coefficients and sectioning points.*

Functions and Variables (mm)	Raw Coeff.[a]	Stand. Coeff.	Structure Coeff.	Sectioning Point
1. Prox epiphyseal br	0.1529167	0.57	0.91	−0.15
Dist epiphyseal br	0.2284790	0.54	0.90	
Constant	−20.5825300			
2. Prox epiphyseal br	0.2447224	0.91	0.99	−0.13
Circ at nutrient for	0.0213940	0.14	0.68	
Constant	−19.02956			
3. Dist epiphyseal br	0.3659270	0.86	0.98	−0.13
Min circumference	0.0449891	0.22	0.71	
Constant	−18.94278			
4. Prox epiphyseal br	0.2683954	1.00	1.00	−0.13
Constant	−18.81521			
	females < 69.5 < males[b]			
5. Dist epiphyseal br	0.4260344	1.00	1.00	−0.13
Constant	−18.39048			
	females < 42.5 < males			
6. Circ at nutrient for	0.1536506	1.00	1.00	−0.09
Constant	−13.452822			
	females < 87 < males			
7. Min circumference	0.4260344	1.00	1.00	−0.14
Constant	−18.39048			
	females < 69.5 < males			

[a]These coefficients are used to calculate discriminant function scores. A discriminant score greater than the sectioning point classifies an individual male and less than that female.
[b]These values may also be used to determine sex.

functions, classification accuracy was higher for males than females. Figs. 1 and 2 depict the posterior probability of correct sex classification for the combined and single variables. These figures may be used to quickly estimate the affinity of an unknown specimen. This statistic quantifies the relationship between the discriminant score and classification accuracy. For example, a score of 2.5 obtained from proximal and distal epiphyseal breadths has a 99.7% posterior probability of being male; a score of 0.5 has only about an 81% probability of being male.

Discussion

By now, most experts recognize that interpopulational differences necessitate the development of group specific standards for the identification of individuals around the

TABLE 4—*Percentage of correct group membership.*

Functions	Total *N*	Males %	Males *N*	Females %	Females *N*	Average %
1. Prox epiphyseal br +Dist epiphyseal br	78	93.2	41/44	79.4	27/34	87.2
2. Prox epiphyseal br +Circ at nutrient for	79	93.3	42/46	79.4	27/34	87.3
3. Dist epiphyseal br +Min circumference	80	87.0	40/46	79.4	27/34	83.8
4. Prox epiphyseal br	79	95.6	43/45	79.4	27/34	88.6
5. Dist epiphyseal br	80	87.0	40/46	79.4	27/34	83.8
6. Circ at nutrient for	80	87.0	40/46	70.6	24/34	80.0
7. Min circumference	81	83.0	39/47	76.5	26/34	80.3

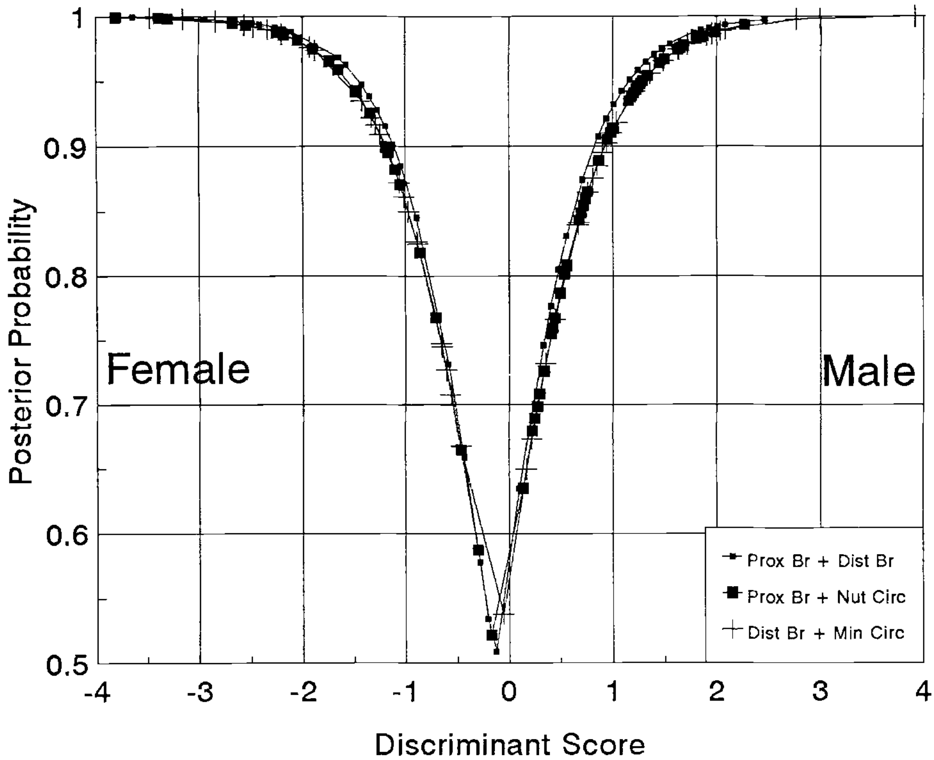

FIG. 1—*Posterior probability* (Y axis) *of correct sex classification as a function of discriminant scores* (X axis). *Posterior probability is determined from the discriminant score calculated from Functions 1–3 listed in Table 3.*

world. However, many ignore the need to update methods to reflect changes over time within a particular population, especially when they have been subjected to great changes in their environment. Nowhere have the devastating disruptions of World War II and the extraordinary postwar recovery been felt more strongly than in Japan. Therefore, forensic scientists are now dealing with essentially new populations that differ biologically and culturally from their immediate ancestors of only 45 years ago. As mentioned earlier, these changes must have affected the skeleton; consequently, bones must be reassessed continuously as new samples become available.

This study focuses on sex determination from the tibia. Accuracy is lower than that obtained by Hanihara [*14*] from his prewar sample. He achieved 96% classification within that group from which the discriminant analysis selected tibial length, minimum circumference, proximal epiphyseal breadth and anteroposterior diameter of the midshaft as significant contributors. Hanihara's 1981 study [*15*] was more comprehensive and incorporated many different bones and teeth. Tibial measurements included in these functions weie biarticular length, proximal epiphyseal breadth, anteroposterior diameter of the midshaft, minimum circumference, minimum thickness a cross-section of the compact bone, and thickness of the compact bone at the posterior border. Various combinations of measurements yielded accuracies ranging from 94% to 96%. The best result was obtained from the length, proximal breadth, anteroposterior diameter of the midshaft, and least circumference.

Although Hanihara was a pioneer in the application of discriminant function statistics

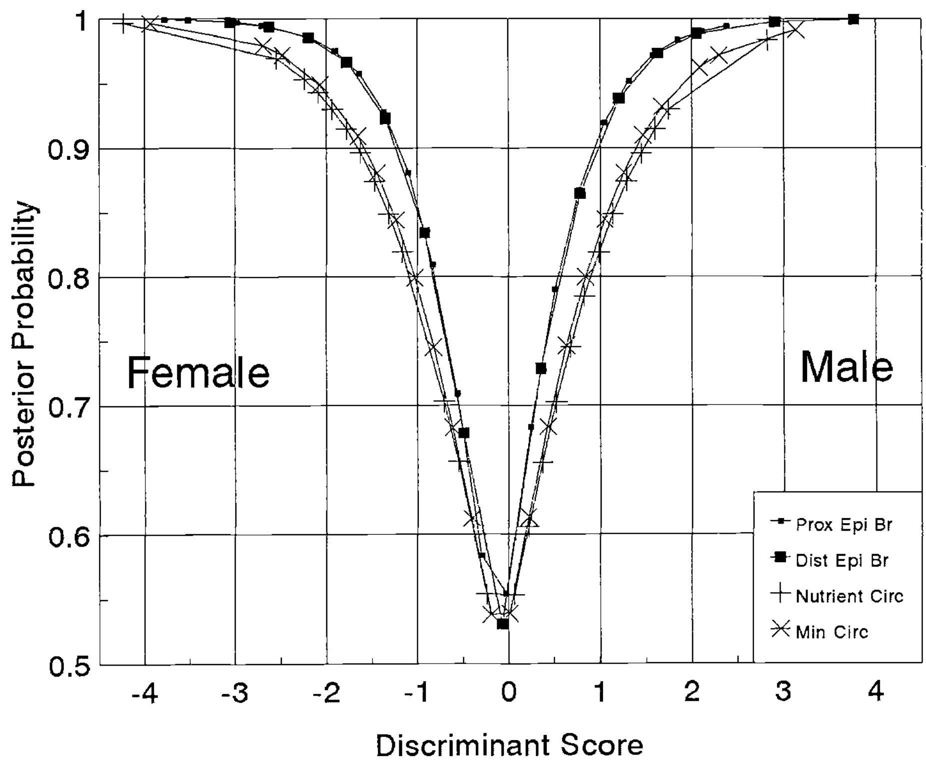

FIG. 2—*Posterior probability* (Y axis) *of correct sex classification as a function of discriminant scores* (X axis). *Posterior probability is determined from the discriminant score calculated from Functions 4–7 listed in Table 3.*

to osteology, the collection used in his studies dated from the prewar era (personal communication); therefore, they do not take into account the changes observed in the contemporary people used in the present study. Furthermore, while it would have been interesting to test Hanihara's formulae directly on the Jikei sample, it is not possible to do so in this case because there is only one measurement that was exactly the same in both studies and it was not selected by the functions as being significant. Variables for the present study were chosen for their potential to reflect sexual dimorphism and give the widest range of sites in a complete or partial bone. This research was not designed to merely test Hanihara's standards.

That different dimensions were selected by the functions may, in itself, be an important indicator of differences between the contemporary and earlier populations. It is, therefore, unlikely that his formulae would produce the same accuracy on the Jikei skeletons. This assumption is supported by the fact that the length of the tibia has increased at least 10mm in females but only a minimum of 4mm in males. (The actual differences are even greater—by at least 3–5mm—because our values were derived from condylar length, whereas Hanihara used maximum length). At the same time, tibial shaft dimensions remained about the same. These findings indicate two important changes: 1) postwar Japanese people are considerably larger than their predecessors, and 2) sexual dimorphism has decreased over time. A recent study of Jikei crania by the authors has uncovered a similarly disproportionate increase in several female dimensions [*18*]. These results agree with studies summarized in Bogin [*1*].

As expected, the present study revealed metrically detectable changes in the postwar Japanese population and resulted in the development of new standards reflecting skeletal changes over time. Formulae for fragmentary bones were also generated making possible the assessment of many cases to which Hanihara's standards (heavily dependent on complete tibial length) cannot be applied. The current research reemphasizes that dimensions like circumference and epiphyseal breadths are sometimes better indicators of sexual dimorphism than length. This finding agrees with observations of American whites in which the length did not contribute significantly when proximal epiphyseal breadth and circumference at the nutrient foramen were known [7]. It also indicates racial differences in the skeleton, as length *did* contribute to the function for American blacks.

Our study also underscores the necessity of maintaining and amassing current assemblages like the Jikei Collection. Only in that way can temporal change be monitored. The temporal composition of Jikei resulted in new standards that are more representative of the contemporary Japanese. In the United States, attempts have been made to collect osteometric data using skeletal remains from current forensic cases [for example, 20]. However, this is not a substitute for assembling a large up-to-date collection of complete skeletons from known individuals. Finally, forensic osteologists should be aware that a local sample may not necessarily represent the population at large, because diverse stresses may operate differently in specific geographic regions, thus creating microracial variation within a population.

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