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Frequencies of Morphological Characteristics in Two Contemporary Forensic Collections: Implications for Identification*

ABSTRACT: Positive identification relies on comparison of antemortem and postmortem data. Some identifications are based on morphological features such as fracture, pathological condition, and surgical hardware, despite little literature indicating the frequencies of such traits. This study examines whether such features are sufficiently rare as to be deemed individualizing. Data were collected on two modern North American skeletal collections ($N = 482$ individuals). Presence/absence of features was scored by skeletal element and side. Results indicate that frequencies vary by geographic region (higher frequency of fractures and pathological conditions in New Mexico while individuals in Tennessee were more likely to have surgical interventions), many features such as fractures are remarkably common and that even suites of traits may not be individualizing. Caution is warranted when using written data rather than radiographic comparisons as the primary source of identification. The implications of these findings to missing person databases are also discussed.

KEYWORDS: forensic anthropology, forensic science, identification, osteology

Physical anthropologists routinely participate in many aspects of forensic investigations, ranging from local casework to international war crime investigations. Such involvement presents both the opportunity for research into previously unexplored areas and, unfortunately, the *ad hoc* use of untested methodologies. This paper addresses the validity of one such methodology, specifically the use of morphological features as a method of victim identification.

A morphological feature is defined as a physical characteristic that endures throughout the decomposition process and is recognizable postmortem. These identifiable characteristics represent permanent modifications to morphology that reflect antemortem life events. Examples include antemortem fractures and evidence of surgical intervention or pathological conditions. The use of such features as a means of positive identification through the comparison of ante- and postmortem radiographs is common and accepted (1–10). However, written records detailing past injury are often used in lieu of antemortem radiographs. An example of a large scale, institutionalized implementation of this practice can be found in the recent investigations of war crimes in the Former Yugoslavia. Before 2001, the use of third-party reported morphological features as the sole method of identifying victims of the Balkans conflict was an accepted, but untested, practice (11).

Traditional methods of identification include visual recognition, comparisons involving dental and medical records, fingerprints, and DNA. Unfortunately, because of the extended postmortem interval between the war in Bosnia (which ended in 1995) and the ongoing recovery efforts, the decayed state of the remains precluded visual recognition and fingerprinting. Inadequate documentation, destruction of records during the conflict as well as social factors (e.g., limited access to health care) restricted the use of dental and radiograph comparisons as a means of establishing identity. Finally, DNA testing on such a massive scale was considered too costly and required laboratory resources that were not available before the introduction of such resources by the International Commission for Missing Persons in 2001 (12).

To fill this void, identification protocols were created for the Former Yugoslavia that relied heavily on witness statements, recovered identification documents, the recognition of clothing, and personal effects by family members and the presence of morphological features noted during postmortem examination. The formal identification protocol was a deductive process that called for the comparison of antemortem data solicited from family members of missing persons with postmortem information obtained during autopsy or examination of remains. Identifications were made in cases where there was agreement between the antemortem and postmortem data supported by another factor such as the presence of documents (passport or ID card), a very limited number of DNA test results, family recognition of unusual clothing or a morphological feature such as an antemortem fracture, glass eye, or orthopedic repair (11). Personal observation and experience indicated that it was common for a single mass grave or group of graves from a single region to produce two or more individuals of similar age and sex who possessed similar fractures, surgical scars or dental characteristics. These observations challenge the assumption of the uniqueness of any individual characteristic or even a suite of features and therefore the identifications made on the basis of them.

While previous studies have examined the incidence of trauma and pathology in archaeological contexts (13,14) or the frequencies of dental characteristics within a population (15,16), little literature (17,18) exists on the overall frequency in modern North American populations of fractures, surgical interventions, and skeletal anomalies. Nor is it known how such features vary among different age and sex cohorts or by geographic location or socioeconomic status.

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This study will examine these questions and determine whether morphological features are sufficiently rare as to be deemed individualizing. The tragic events of September 11 illustrate that the problem of identification on a mass scale is as pressing in the United States as elsewhere (19) and the findings of this study are relevant to those tasked with establishing identity in cases of mass or natural disasters as well as local casework. The implications of these findings will also be discussed with regards to the reporting of morphological features in missing person databases.

Materials and Methods

Two contemporary North American skeletal populations provided data for this study. The first is housed at the Maxwell Museum of Anthropology at the University of New Mexico. This collection encompasses males and females ranging in age from infant to 101 years and representing diverse socioeconomic classes and ethnic affinities. The collection is composed of complete donated individuals ($N = 345$) with documented demographic information and positively identified forensic cases. The second collection, housed at the University of Tennessee Forensic Anthropology Research Center, also contains donated males and females ranging in age from 20 to 89 years, predominantly whites and blacks. The Tennessee sample provided an additional 137 individuals for this study, creating a total sample size of 482 individuals who died between the years of 1984 and 2002. A breakdown of the demographic information for each sample is provided in Table 1. The distribution of known ages at death is given in Table 2.

Data were collected on the following variables: documented sex, age, stature, and biological affinity. Morphological features were scored as present or absent by skeletal element affected and side. Morphological features were categorized as per the Balkan protocols (20) and recorded through direct observation of the remains. Categories included antemortem trauma, such as fractures and crush injuries; pathological conditions such as evidence of infection, arthritis, or cancer; and surgical interventions such as trephinations, amputations, or orthopedic plates. Anomalies such as spina bifida occulta or patent metopic sutures were noted, but their value is minimal as identifiable characteristics as the missing person, their family or physician would not normally be aware of such traits. Data on skeletal anomalies and dental conditions were collected but will be reported separately.

Both samples were entered into a statistical database program and analyzed separately and as a combined population using SAS version 8.02. Tests for statistical significance were run on the combined, New Mexico, and Tennessee samples using χ^2 analyses and Fisher's two-sided exact tests for samples with smaller cell sizes.

TABLE 1—*Distribution of sex and ethnicity within the samples.*

Sample	Number	Percentage/Sample
Tennessee ($N = 137$)		
Males	109	79.6
Females	28	20.4
White	114	83.2
Black	22	16.1
Hispanic	1	0.7
New Mexico ($N = 345$)		
Males	232	67.5
Females	113	32.5
White	216	62.6
Black	9	2.6
Hispanic	48	13.9
Native American	33	9.6
Ethnicity unspecified	39	11.3
Combined ($N = 482$)		
Males	341	71.0
Females	141	29.0
White	330	68.5
Black	31	6.4
Hispanic	49	10.2
Native American	33	6.8
Ethnicity unknown	39	8.1
White males	234	48.5
White females	96	19.9
Black males	26	5.4
Black females	5	1.0
Hispanic males	33	6.9
Hispanic females	16	3.3
Native American males	23	4.8
Native American females	10	2.1
Unknown males	25	5.2
Unknown females	14	2.9

TABLE 2—*Known age at death distribution within the combined sample.*

Known Age (years)	Sample Size
< 15	5
16–20	16
21–25	18
26–30	22
31–35	20
36–40	22
41–45	19
46–50	22
51–55	39
56–60	37
61–65	25
66–70	35
71–75	32
76–80	22
81–85	21
86–90	8
91+	4
Total sample	482
Age at death known	367
Age at death unknown	115

Results

There is a statistically significant difference in sex distribution by state. There are significantly more females within the New Mexico sample than the Tennessee sample ($p = 0.007$; 32.8% for New Mexico vs. 20.4% for Tennessee). In the combined sample, the overrepresentation of males persists, with 341 males (70.7%) and 141 females (29.3%).

There were no statistically significant differences in known age means between the two state samples. However, within the combined sample, males of known age were significantly younger than females of known age ($p = 0.004$; 51.9 years for males, 58.5 years for females). The median age for females was 66 years, while the median age for males was 53.5 years.

There is a statistically significant distribution of biological affinities by state ($p < 0.0001$), with Tennessee skewing predominantly white and African American and with no representation of Native Americans and only one Hispanic. The combined collection, however, provides an adequate sample size for all nonwhite populations.

TABLE 3—*Most frequently observed fractures by number of individuals in the combined and individual samples, as well as breakdowns by state and sex.*

Fractures	Number of Individuals				
	Combined ($n = 482$)	New Mexico ($n = 345$)	Tennessee ($n = 137$)	Males/ Combined Sample	Females/ Combined Sample
R nasal	70	67	3	64	6
L nasal	63	60	3	57	6
R rib(s)	44	36	8	33	11
L rib(s)	41	35	6	31	10
Maxillae*	26	25	1	23	3
L femur	15	14	1	10	5
L fibula	12	9	3	7	5
R humerus	11	11	0	4	7
R radius	10	10	0	5	5
R tibia	10	7	3	8	2
L hip	9	9	0	3	6
R femur	9	8	1	4	5
R fibula	9	8	1	8	1
L zygomatic	8	8	0	7	1
L humerus	7	6	1	6	1
L tibia	7	7	0	6	1
L clavicle	7	6	1	6	1
L hand†	7	7	0	5	2
L foot†	6	6	0	3	3
R foot†	6	5	1	3	3
Thoracic 8	6	6	0	3	3
L radius	5	5	0	3	2
R clavicle	5	4	1	4	1
R hip	5	5	0	2	3
R ulna	5	3	2	3	2
R zygoma	5	5	0	4	1
Thoracic 7	5	5	0	2	3
Thoracic 9	5	5	0	1	4
R hand†	2	2	0	1	1
L ulna	2	1	1	0	2

*The R and L maxillae were combined as fracture incidence was identical.
†Hand includes carpals, metacarpals, and phalanges; foot includes tarsals, metatarsals, and phalanges.
R, right; L, left.

The frequencies of fractures in the combined sample, as well as breakdowns by state and sex, are given in Table 3. Examining individual bone fracture frequency by side, no significant difference was seen in right and left nasal fractures. However, there were differences in the distribution of femoral fractures, with fractures to the left femora proving significantly more common. Significant differences were also seen in rib fractures, with right rib fracture more common in both single rib and multiple rib fracture patterns.

The frequencies of pathological conditions are given in Table 4.

The frequencies of surgical interventions are given in Table 5. Comparisons of surgery types by side reveal that left-hip replacement surgeries were significantly more common than right, as were surgical repairs to left versus right tibiae.

Table 6 provides the frequencies of total fractures per individual, as well as total pathologies and total surgeries. Chi-square comparisons by state reveal that individuals from the New Mexico sample are significantly more likely to have at least one fracture ($p = 0.0002$) or one type of pathological condition ($p = 0.0002$) than individuals from the Tennessee sample. However, individuals from the Tennessee collection are significantly more likely ($p = 0.011$) to have at least one surgical repair than individuals drawn from the New Mexico specimens.

Unless otherwise noted, all other comparisons were not statistically significant.

TABLE 4—*Most frequently observed pathological conditions by number of individuals in the combined sample, as well as breakdowns by state and sex.*

Pathological condition	Number of Individuals				
	Combined ($n = 482$)	New Mexico ($n = 345$)	Tennessee ($n = 137$)	Males/ Combined	Females/ Combined
Diffuse arthritis	84	73	11	53	31
TMJ disease	40	34	6	20	20
Infection					
Skull	36	30	6	27	9
Lower limbs	30	29	1	20	10
Upper limbs	19	15	4	16	3
Fused cervical vertebra	15	10	5	13	2
Spina bifida	14	12	2	11	3
Fused thoracic vertebra	12	3	9	8	4
Neoplasm	8	3	5	7	1
Shoulder dislocation	2	0	2	2	0

Discussion

Before analyzing the results, it is important to acknowledge the scope and limitations of the study. One potential limitation of this study is the selection bias inherent in donor-based skeletal collections. A further constraint is the regional nature of the collections. The collections largely reflect the ethnic affinities and socioeconomic conditions of the states in which they are housed. For example, the statistically significant differences seen in rates of fracture, pathology, and surgical repair between the two states may reflect differential access to health care in these states. We are not attempting to generalize the results to the entire United States. Rather, this study seeks to emulate the conditions typically encountered by regional medicolegal authorities attempting to identify Does within their jurisdictions.

The purpose of this study is not to identify those features that are sufficiently rare as to serve as the sole basis for a positive identification. Absent individualizing features such serial numbers on surgical appliances or antemortem radiographs of osteological features, such identifications would be ill advised. The position of a specific trait or feature in Table 3, 4, or 5 is not meant to be an

TABLE 5—*Most frequently observed surgeries by number of individuals in the combined sample, as well as a breakdowns by state and sex.*

Surgery	Number of Individuals				
	Combined ($n = 482$)	New Mexico ($n = 345$)	Tennessee ($n = 137$)	Males/ Combined	Females/ Combined
Cranial trephination	18	13	5	11	7
L femur repair	9	5	4	8	1
R femur repair	8	3	5	3	5
Sternotomy	8	2	6	4	4
L hip replacement	6	6	0	3	3
Facial repair	5	2	3	4	1
Left tibia repair	5	2	3	4	1
Mandible repair	4	4	0	3	1
R leg amputation	4	3	1	3	1
R hip replacement	4	4	0	2	2
Right tibia repair	3	2	1	2	1
L leg amputation	3	2	1	2	1
L knee replacement	3	2	1	2	1
R knee replacement	2	1	1	1	1

Categories are mutually exclusive.
R, right; L, left.

TABLE 6—*Frequencies of total fractures, pathologies, and surgeries per individual in the combined sample, by state and by sex.*

	Combined ($n = 482$)	New Mexico ($n = 345$)	Tennessee ($n = 137$)	Males ($n = 341$)	Females ($n = 141$)
Total Fractures					
0	300	197	103	209	89
1	58	36	22	39	18
2	45	36	9	38	7
3	21	20	1	15	4
4	27	26	1	23	4
5	18	17	1	9	9
6	8	8	0	4	4
7	2	2	0	2	0
8	1	1	0	1	0
9	0	0	0	0	0
10	1	1	0	1	0
11	1	1	0	1	0
Total Pathological Conditions					
0	252	162	90	186	65
1	150	116	34	102	45
2	65	55	10	44	20
3	10	9	1	6	4
4	5	3	2	4	1
Total Surgeries					
0	396	293	103	286	106
1	66	39	27	45	20
2	14	10	4	7	7
3	6	3	3	4	2

indication of its validity as a means of identification. Nor should the exclusion of any particular trait from the lists be interpreted as a statement of that trait's uniqueness or rarity. For this reason, an exhaustive list of every trait encountered only once in the entire sample is not provided. In addition, the variations in frequencies of traits observed between sexes, states, or anatomical sides should also not be used to determine the individualizing power of any one trait. Rather, these descriptive data are meant to demonstrate the ubiquity of many features, as well as the variations in frequencies among subsets of the sample.

The Tennessee sample used in this analysis was representative of the racial/ethnic distribution of the state, with 80.1% white non-Hispanics and 16.1% blacks in the sample compared with statewide percentages of 83.2% and 16.1%, respectively. White non-Hispanics were overrepresented in the New Mexico sample, with 62.6% (sample) compared with 45.4% (state). The sample also had fewer Hispanics than the state as a whole (13.9% vs. 42.1%). However, the distributions of Native Americans and blacks in the New Mexico sample were very similar to the distribution in the state, with 9.6% (sample) versus 9.5% (state) Native Americans and 2.6% (sample) and 1.9% (state) blacks (21).

The median income in New Mexico is lower than that of Tennessee ($36,043 vs. $38,794), and more people exist below the poverty line (18.4% vs. 13.5%) and without health insurance (26.1% vs. 14.2%) in New Mexico than Tennessee (21). Given this, the differences between the New Mexico and Tennessee samples are, in part, likely due to socioeconomic differences in each state's population.

Although a comparison of this study's regional data against national frequencies would be of interest, we could not identify any sources of information on national rates of the surgeries and fractures included in this study. Information available tended to be for very localized geographic areas, or for specific types of fractures in a well-defined population, such as hip fractures in patients with osteoporosis (17). Rates are available for broad classes of injuries (falls, collisions, occupational injuries) but are not further stratified by specific injury (fracture vs. sprain) or by specific anatomical region (upper limbs vs. lower limbs).

As anthropologists and investigators tasked with identification know all too well, it is often not the presence of any one morphological feature but rather a suite of characteristics that establishes identification. It is also the combination of osteobiographical data with reported morphological features that produce tentative matches in missing person database searches. However, the results seen in Table 6 indicate that even multiple fractures, pathologies, or surgeries per individual are common.

To test this hypothesis, a number of individuals with multiple biological identifiers were chosen at random. The study database was queried using the general demographic data for each individual as well as the presence of their known antemortem condition/biological identifiers.

The first individual selected was a 52-year-old white male, with a history of a broken nose and an orthopedic repair to his left distal tibia. Of the 481 individuals in the remaining combined sample (the test subject was removed from the database), 342 were males, of which 233 were white. Of these 233, 153 had an appropriate estimated age range. Of these 153, 42 had broken nasal bones. Of these 42, three had an orthopedic repair to the left tibia.

Similar results are seen if the sample is queried as it might be in cases of a missing person. For example, a search for a white female, 35 years of age or older, who had a medical history which included a sternotomy produces four individuals who matched these demographics. A search for a Hispanic male, 20–40 years of age, with bilateral broken nasals and bilateral-fractured ribs reveals two individuals who are virtually identical osteologically.

The implications of these results on missing person databases are worthy of examination. Currently, most missing person databases include information on visible identifiers such as hair color, height, and tattoos but do not list morphological features such as fractures or surgeries as standard protocol (22,23). Yet, in practice, the value of these features to medicolegal and law enforcement agencies is well established: a comparison of postmortem findings (including morphological features) with detailed missing persons reports is a common means of establishing a tentative identification for a Does and may even serve as the basis for excluding individuals from further consideration. This raises the question whether such information should be included as standard practice in missing person listings. At present, the inclusion of information on morphological features is left to the discretion of the law enforcement agency investigating the missing person. The ubiquity of many biological characteristics argues against including such features in missing person reports. However, ubiquity alone should not serve as grounds for exclusion. For example, the increase in popularity of tattoos have rendered certain designs so common they are of little value in terms of identification (24), yet tattoo description remains a vital component of a missing persons report. Of greater concern is the possibility that the next of kin reporting a missing person might be unaware of some or all of the missing person's medical history. This could potentially lead to the unjustified exclusion of an individual from further testing to confirm identity. As this risk outweighs the potential benefits, including morphological features in missing person reports should be approached with caution. Further research and consideration is clearly warranted.

Conclusions

The results of this study, while drawn from a limited sample size, raise the possibility that morphological features previously believed to be sufficiently unique as to provide a means of positive identification may, in fact, be quite common. Further confounding the issue of identification is the likelihood that even a suite of morphological characteristics, combined with the basic demographic information provided in a typical osteobiography, may not be sufficiently individualizing. Caution is warranted when relying solely on written medical records as the basis of identification. The practice of using third-party reported data coupled with postmortem examination results to produce identifications in postconflict or mass disaster situations must also be considered unreliable and an avenue of last resort. The merits of including information regarding morphological features such as fractures or surgeries in missing person databases are limited but deserve further research.

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