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TECHNICAL NOTE

ANTHROPOLOGY

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Evaluation of Stature Estimation from the Database for Forensic Anthropology*†

ABSTRACT: Trotter and Gleser's (1–3) stature equations, conventionally used to estimate stature, are not appropriate to use in the modern forensic context. In this study, stature is assessed with a modern (birth years after 1944) American sample ($N = 242$) derived from the National Institute of Justice Database for Forensic Anthropology in the United States and the Forensic Anthropology Databank. New stature formulae have been calculated using forensic stature (FSTAT) and a combined dataset of forensic, cadaver, and measured statures referred to as Any Stature (ASTAT). The new FSTAT-based equations had an improved accuracy in Blacks with little improvement over Ousley's (4) equations for Whites. ASTAT-based equations performed equal to those of FSTAT equations and may be more appropriate, because they reflect both the variation in reported statures and in cadaver statures. It is essential to use not only equations based on forensic statures, but also equations based on modern samples.

KEYWORDS: forensic science, forensic anthropology, stature estimation, stature formulae, biological profile, database for forensic anthropology

The field of forensic science has witnessed a significant increase in the amount of casework conducted by forensic anthropologists on the local, state, and federal levels. Law enforcement agencies have continually relied on the expertise of forensic anthropologists to assist in the recovery and analysis of skeletal material, especially in the identification process. Forensic anthropologists use skeletal criteria to estimate age, sex, race, and stature in the construction of a biological profile. As this profile relays demographic characteristics to aid law enforcement in searching for a match between skeletal remains and their missing persons' files, it is important to have relevant data from which to establish these criteria. The goal of this study is to use an updated Database for Forensic Anthropology in the United States (DFAUS) to calculate new stature formulae using traditional, inverse calibration regression techniques.

With the establishment of the DFAUS, Jantz and Moore-Jansen (5) made otherwise inaccessible skeletal data representing a modern American population available for analysis and casework application The DFAUS, consisting of 1523 individuals, was a product of NIJ Grant Number 86-IJ-CX-0021, which funded the establishment of the Forensic Anthropology Data Bank (FDB) housed at the University of Tennessee. The goal outlined in the initial construction of the FDB and DFAUS was to provide forensic anthropologists with a database reflecting the diversity of the American population in hopes to revise conventional standards used in the identification of human skeletal material. The DFAUS succeeded in establishing a comprehensive dataset for this purpose, which is available through the Intercollegiate Consortium of Political and Social Research (ICPSR) at http://webapp.icpsr.umich.edu/cocoon/ICPSR-STUDY/02581.xml but has been difficult to maintain. The most recent update to the DFAUS occurred in 2000 supplementing only the cranial metrics, while postcranial metrics have not been updated since 1997.

The FDB is constantly expanding through contributions from professionals and institutions and is comprised of 2561 individuals representing a diverse sample of ethnic groups within the United States. Its data are made available to practitioners through *FORDISC 3.0* (6). FORDISC is a computer software application available for purchase that provides customized discriminant function analysis using the FDB for practicing forensic anthropologists, academics, and students. White males and females comprise over half of all entries in the FDB. Black males and females constitute the next largest group. Continuous re-examination of the FDB dataset is critical to its relevance to the field. Therefore, this study details a re-evaluation of stature estimation using the postcranial long bone data within the DFAUS in conjunction with updates from the FDB.

Through an understanding of secular change and long bone allometry, researchers can validate existing stature formulae or construct more reliable and relevant formulae. If secular change in the long bones has occurred allometrically, as Meadows Jantz and Jantz (7) demonstrate, then stature formulae based on an older dataset would prove to be inappropriate in a modern forensic context. In other words, if the long bones have changed in their proportions over time, then their relationships to stature have also changed. This means that the older stature formulae that rely on a certain relationship of long bone length to stature may not hold true. In their study, Meadows Jantz and Jantz (7) found that "male

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secular change is stronger than female secular change, lower limb bone secular change is more pronounced than upper limb bone change, and distal bones change more than proximal bones."

Forensic anthropologists tend to rely upon stature estimations based on regression formulae using the long bones of a skeleton (i.e., femur, tibia, fibula, humerus, radius, and/or ulna). One of the most widely applied techniques is from Trotter and Gleser, even though there are several approaches, like the Fully method, that use all available skeletal data (1,2,8). Trotter and Gleser's (1,2) classic study provided stature estimation formulae for African Americans and European Americans derived from the regression of stature on long bone length with a corresponding confidence interval. One of the biggest problems with the application of these stature equations is the sample population's regional and temporal bias. Meadows and Jantz noted "the conventional use of Trotter and Gleser's equations by most anthropologists would have one believe that these equations are timeless when they are not" (9:762). For example, Trotter and Gleser's female groups are biased in modern applications, because they utilized the Terry Collection, in which the average birth date was between 1850 and 1900, a time period where the American population was known to be at its shortest (9). Several researchers have observed that the metric and morphological standards established using 19th-century collections, such as the Terry and Hammon-Todd Collections, are inappropriate for modern Americans because of secular change (4,9–12). Secular change results in the maximum stature attained by older people being less than that attained by adults born later (13). This requires the computation of new equations for both measured and forensic statures based on a more recent sample. Thus, stature formulae are not immune to sampling error, secular change, or population shifts.

While existing formulae may prove to be valid, they must be evaluated using current and modern data. Stature equations examined in this study will be evaluated using measured stature (MSTAT), a stature that is measured directly, and forensic stature (FSTAT), a stature derived indirectly through sources such as a driver's license or a family member; and Any Stature (ASTAT), any forensic, measured, or cadaver stature available. FSTATs and ASTATs will serve as the basis for deriving stature estimation formulae, predicting the stature for a given individual, and evaluating the confidence and prediction intervals associated with the estimation.

Forensic stature (FSTAT) and measured stature (MSTAT) are the most common statures used in regression analyses. FSTATs are those statures derived from driver's licenses, are self reported or are given by relatives; measured statures are those heights found in medical or military records. Both forensic and measured statures have errors inherent in their application, such as systematic biases relating to age and secular change. However, most error does not confound the derivation of stature equations. For example, driver's license heights tend to be inexact but correspond to how people perceive others (14). These forensic statures are often the only way of alluding to the dimensions of an individual (14). Measured statures are not free of error either (15). They are subject to diurnal changes (16), the measuring techniques of the observer (15), and interobserver variation (17). For instance, Snow and Williams (17) noted an example of interobserver variation of measured stature, in which an individual whose skeleton was found had 19 different measurements taken during life that ranged 5 inches. Forensic statures typically do not decrease with age, so their relationship with long bone length should remain constant (4). However, the aging process influences measured statures. Galloway (18) and Cline et al. (19) demonstrate metrically that as people age, especially after age 45, their height generally decreases, exhibiting a greater change in females. Age-related biases associated with measured statures can be accommodated through the application of correction factors, especially in post-1945 samples (13).

The goal in stature estimations is to obtain the smallest range of error that provides not only accurate but precise stature estimates (4). A smaller error range should yield stature estimates that are closer to the actual living height of an individual. For forensic casework, population- and sex-specific stature formulae have been developed in an attempt to provide more precise estimates. Forensic anthropologists tend to have precision, but less accuracy, when a stature equation derived from MSTATs is erroneously used to predict FSTATs. An FSTAT is what is typically reported on a missing person's NCIC report, because this is what the family may provide or is what is listed on the missing person's driver's license. On the other hand, when a data set like MSTAT is applied to another dataset, like cadaver statures, the estimates tend be less precise but more accurate. Ousley suggests focusing on improving the accuracy over precision of stature estimation formulae by using a data set that reflects the data for which it will be compared (4). This implies that the use of FSTATs as a means of deriving equations would be the most appropriate, because FSTATs are less susceptible to the changes found in MSTATs (i.e., age-related stature loss) and tend to reflect how others perceive a person more accurately.

Ousley demonstrated that equations derived from forensic statures have wider prediction intervals than the Trotter and Gleser (1) equations, which are derived from measured statures (1,4). He concludes that "[f]orensic stature estimation is generally less precise than [measured] stature estimation but is more accurate for modern forensic cases, because forensic stature is the only stature available for a missing person" (4:772). However, Ousley's investigation occurred at a time when the FDB had relevant demographic data (driver's license heights and long bone measurements) for only 192 individuals, whereas Trotter and Gleser utilized information from 800 individuals. Furthermore, Ousley's samples used all available individuals in the FDB with birth years ranging from 1898 to 1981. The continual addition of individuals to the FDB, since Ousley's publication, has produced a comparable sample size to systematically evaluate stature equations for more recent birth years. As a result of the growing number of individuals donated to the University of Tennessee Donated Collection and increased input from other forensic sources, a subsample of 242 with post-1944 birth years was taken to reflect current forensic casework.

As previously stated, stature estimations rely predominantly on formulae where stature is regressed on femur length for a specific population. Using terminology from Konigsberg et al. (20), the stature distribution of the femur sample is referred to as the "reference" sample, and the population-specific stature distribution is the "target" sample. Konigsberg et al. investigated the utility of several estimators using FDB, WWII, and Terry Collection data and recommend "using the regression of stature on long bone length(s) when there is some a priori reason for presuming that a case comes from the same stature distribution as represented within the reference (calibration) sample" (20:90). If a researcher is unable to assume the case is derived from the reference sample, then these authors recommend a classical calibration approach. In our study, we employ an inverse calibration approach for examining White and Black long bone and stature data to allow comparisons to formulae published by Ousley (4).

Materials and Methods

Long bone and stature data, acquired from the DFAUS and the FDB, were used to calculate new regressions equations for stature estimation. Confidence intervals and prediction intervals were calculated for each equation to compare the accuracy and precision of the new stature equations with those previously reported by Trotter and Gleser and Ousley (1,4). Mean squared error comparisons were used to test the predictability power of the equations.

Postcranial metric data are extracted from the outdated DFAUS ($N = 1008$ cases). Additional information collected from the DFAUS focuses on select fields with particular interest in biographical data, including sex, age, date of birth, ancestry, forensic and measured stature, and positive identification status. Data from the DFAUS were compared with the current FDB to eliminate any redundancy, and recent entries within the FDB were evaluated for accuracy of information and appended to the DFAUS ($n = 1723$). No data identifiable to a private person were utilized in this study.

The study sample focuses on those individuals with birth years after 1944, because this is the time period for which appropriate formulae are lacking. The samples were further separated based on sex and ancestry for those individuals that have both a reported stature and maximum long bone length measurements ($n = 242$). Only positively identified Black and White males and females were utilized because of the lack of available data for other groups. The updated DFAUS, supplemented by the new acquisitions in the FDB, was analyzed within software packages *JMP* and *SAS* (21).

To compare new formulae with previous stature estimation research, stature formulae using an inverse calibration model were calculated from the available data in the updated DFAUS. Stature was regressed on one or more long bone lengths and then used to solve for stature of an unknown. The reference sample's normal distribution for stature was used as the prior distribution. Regression formulae were calculated for White males and females and Black males and females using FSTAT and ASTAT. The confidence and prediction intervals for each equation were calculated, and these values were used as the basis for comparison with Trotter and Gleser's and Ousley's equations. These intervals permit direct comparisons of the accuracy and precision of the equations unlike standard error (1,4). A standard error simply reports the standard deviation, a point estimator, which is not as informative on the predictive abilities of an equation. The 95% confidence interval depends on the regression distribution and parameter inferences, in which the focus is on the mean of population. For this reason, the 95% and 90% prediction intervals (PI) are calculated for each equation. PIs reflect the precision of an estimate better, because they consider sample size and have an explicit probability. A PI also evaluates a random individual (future) observation rather than just the mean observation. PIs are calculated by:

$$\hat{Y} \pm t_{n-1,\alpha/2} \times \sigma \times \sqrt{1+\frac{1}{N}+\frac{\hat{X}-\bar{X}}{\sum (x_i-\bar{X})^2}}$$

where $\hat{Y}$ is the point estimate, t is the critical values for the student distribution given the sample size and a specified alpha level, σ is the standard deviation, $\hat{X}$ is the given bone length for the point estimate, and $\bar{X}$ is the mean bone length.

Representation of some groups in the updated DFAUS was too small to perform traditional linear regression analyses with confidence. For example, the DFAUS lacks substantial numbers of Hispanics. In these cases, a full Bayesian approach as proposed by Ross and Konigsberg (22) should be used to develop stature estimation formulae. This approach is outside the scope of this research and will be evaluated in future publications.

To evaluate the reliability of the FSTAT and ASTAT equations, these equations with the published Ousley equations derived from an earlier version of the DFAUS and the Trotter and Gleser equations using WWII and Terry samples were applied to a resampled subset of maximum long bone data from the post-1944 sample. The mean squared error obtained from the difference between the predicted and actual, recorded stature was used to compare each equation. In addition, the calculated prediction interval for the FSTAT- and ASTAT-based equations was used to directly compare with Ousley's equations (4).

Results

Equations were produced using both the FSTAT (Table 1) and ASTAT (Table 2) measures by regressing stature on long bone lengths of the humerus, radius, ulna, femur, tibia, and fibula, as well as combinations of bones in centimeters. Estimations using the femur have the narrowest confidence interval for most groups, ranging from 0.9 to 2.2, with the lower limb consistently outperforming the upper limb. Equations for the humerus, radius, ulna, tibia, and fibula, utilizing FSTATs, were generated for Black females, which were previously unavailable because of limited data sources. The relatively tight prediction intervals for the small Black female sample, especially for lower limb elements, result from high correlations of the long bones with stature when compared to other groups. The Black female sample has almost all long bone lengths

TABLE 1— *Stature estimation formulae using FSTAT.*

Constant	Bone (cm)	Factor	95% CI	95% PI at mean	90% PI at mean	N
White males						
58.389	Humerus	3.541	1.324	11.465	9.699	74
62.835	Radius	4.480	1.398	11.360	9.609	65
51.051	Ulna	4.632	1.322	10.981	9.289	68
41.967	Femur	2.835	1.094	9.724	8.226	78
68.205	Tibia	2.962	1.117	9.342	7.902	69
64.052	Fibula	2.916	1.268	10.140	8.578	63
35.084	Humerus + Femur	1.752	1.242	10.243	8.665	67
37.933	Femur + Tibia	1.603	1.075	8.796	7.441	66
30.623	Femur + Fibula	1.697	1.203	9.237	9.775	58
White females						
86.587	Humerus	2.527	1.437	10.656	9.084	54
75.621	Radius	3.870	1.244	8.796	7.499	49
77.889	Ulna	3.540	1.259	9.079	7.741	51
48.549	Femur	2.637	0.893	6.978	5.949	60
81.485	Tibia	2.311	1.296	9.070	7.733	48
73.747	Fibula	2.559	1.231	8.531	7.273	47
37.684	Humerus + Femur	1.692	1.045	7.464	6.364	50
57.754	Femur + Tibia	1.336	1.189	8.065	6.876	45
51.472	Femur + Fibula	1.423	1.143	7.670	6.539	44
Black males						
62.046	Humerus	3.371	1.879	11.306	9.323	23
38.372	Radius	5.168	2.203	10.008	8.233	21
33.641	Ulna	5.015	1.957	11.906	9.775	20
58.483	Femur	2.410	1.624	10.179	8.417	21
68.205	Tibia	2.628	1.613	11.385	9.335	21
60.030	Fibula	2.916	1.836	9.991	8.192	20
51.549	Humerus + Femur	1.507	1.539	9.870	8.167	21
57.345	Femur + Tibia	1.323	1.090	10.377	8.508	21
52.451	Femur + Fibula	1.395	1.410	9.267	7.598	19
Black females						
9.777	Humerus	5.01	2.665	9.206	7.627	17
40.624	Radius	5.198	2.502	10.333	8.549	15
83.054	Ulna	3.136	3.074	8.895	7.416	14
37.852	Femur	2.802	2.221	7.618	6.303	20
43.66	Tibia	3.217	3.043	7.568	6.261	13
33.128	Fibula	3.569	2.67	8.344	6.956	13
22.01	Humerus + Femur	1.877	2.394	7.221	5.974	16
33.78	Femur + Tibia	1.576	2.773	5.111	4.229	13
30.542	Femur + Fibula	1.634	2.477	6.256	5.228	13

TABLE 2— *Stature estimation formulae using ASTAT.*

Constant	Bone (cm)	Factor	95% CI	95% PI at mean	90% PI at mean	N
White males						
57.208	Humerus	3.574	1.319	11.427	9.667	94
61.218	Radius	4.525	1.400	11.371	9.619	85
53.331	Ulna	4.534	1.365	11.340	9.593	88
48.057	Femur	2.701	1.151	10.233	8.656	99
62.953	Tibia	2.891	1.211	10.129	8.568	90
66.958	Fibula	2.832	1.285	10.281	8.697	83
36.758	Humerus + Femur	1.728	1.254	10.339	8.745	87
44.193	Femur + Tibia	1.525	1.175	9.616	8.135	87
42.773	Femur + Fibula	1.556	1.279	9.824	9.742	78
White females						
86.622	Humerus	2.534	1.436	10.651	9.080	64
83.293	Radius	3.530	1.366	9.656	8.232	59
82.815	Ulna	3.346	1.267	9.139	7.792	60
49.263	Femur	2.624	0.921	7.193	6.133	69
80.108	Tibia	2.351	1.235	8.648	7.373	58
76.508	Fibula	2.487	1.210	8.384	7.148	57
46.712	Humerus + Femur	1.656	1.056	7.543	6.431	58
58.368	Femur + Tibia	1.330	1.192	8.083	6.891	55
54.894	Femur + Fibula	1.382	1.158	7.770	6.624	53
Black males						
65.455	Humerus	3.277	1.944	11.624	9.586	52
63.463	Radius	4.235	2.235	10.290	8.464	48
62.953	Ulna	3.979	1.945	11.842	9.722	45
56.661	Femur	2.455	1.919	9.753	8.065	53
75.477	Tibia	2.455	1.720	10.178	8.345	51
69.392	Fibula	2.665	1.997	9.168	7.517	49
50.692	Humerus + Femur	1.522	1.835	9.780	8.093	48
60.177	Femur + Tibia	1.295	1.572	9.571	7.847	49
57.175	Femur + Fibula	1.341	1.855	8.716	7.146	46
Black females						
47.347	Humerus	3.785	2.740	9.525	7.891	28
75.200	Radius	3.781	2.572	10.481	8.672	26
80.696	Ulna	3.285	3.058	8.841	7.372	24
54.863	Femur	2.449	2.128	9.001	7.447	31
58.204	Tibia	2.855	2.720	8.067	6.675	23
55.826	Fibula	2.993	2.450	9.075	7.566	22
46.119	Humerus + Femur	1.566	2.372	8.606	7.121	27
54.752	Femur + Tibia	1.34	2.558	7.373	6.101	23
54.281	Femur + Fibula	1.365	2.329	8.228	6.876	22

situated within one standard deviation from the mean. In contrast, the White male group has several statures and long bone lengths that do not correlate well with one another compared to the other groups, which indicates greater variation in this data.

When evaluating differences in slope, the ANOVA indicates the equations are significantly different at the 0.05 level except for White male humeri and ulnae and the Black female humeri. In each of these cases, Trotter and Gleser's equations are only slightly different at the mean but overestimate or underestimate at the extremes. As Ousley (4) stated that when applying an equation, derived from another sample with a different slope, the estimate is only accurate at the mean. This is why Trotter and Gleser's equations are not appropriate for modern forensic casework; moreover, this is why equations derived from a post-1944 birth year cohort would be more appropriate. The forensic stature samples used by Ousley had a combination of birth years pre- and post-1944 with some individuals having birth years corresponding to those found in the Terry Collection. In fact, close to half of all individuals in the White and Black samples had early 20th-century birth years. White females had the most post-1944 individuals, which accounts for the little difference between Ousley's and the FSTAT and ASTAT equations.

A comparison of the mean square errors (MSE) for each of the four equations used in this study quantifies the differences between each more clearly (Table 3). Mean squared error represents the difference between the actual/reported stature and the predicted stature. Trotter and Gleser's estimates have the highest MSE, while Ousley's equations produce estimates similar but larger than to that of the FSTAT- and ASTAT-derived equations. The FSTAT and ASTAT equations have the lowest mean squared error when applied to the modern cases, which indicates that the difference between the actual and predicted statures is smaller than the other equations.

Discussion

Meadows and Jantz indicated that a secular increase in stature was occurring in the U.S. population (9). Recent allometry work

TABLE 3—*Comparison of recalculated stature estimations using the forensic stature (FSTAT), any stature (ASTAT), Ousley, and Trotter and Gleser's equations.*

	FSTAT Equation*			ASTAT Equation*			Ousley (1995)†			Trotter & Gleser (1952)‡	
Group	*N*	MSE	SD	*N*	MSE	SD	*N*	MSE	SD	MSE	S.D.
Black females											
Humerus	20	18.8880	4.3460	28	18.2808	4.2756	–	–	–	43.3749	6.5860
Femur	23	17.4972	4.1830	31	16.3201	4.0398	18	19.3057	4.3938	21.4475	4.6311
Femur + Tibia	16	12.7012	3.5639	23	10.4964	3.2398	–	–	–	12.5167	3.5379
White females											
Humerus	65	35.3553	5.9460	64	34.3476	5.8607	45	37.5480	6.1276	47.3787	6.8832
Femur	70	13.6726	3.6976	69	13.6713	3.6975	48	14.3653	3.7902	17.1042	4.1357
Femur + Tibia	56	17.1809	4.1450	55	16.9867	4.1215	42	17.6885	4.2058	17.0649	4.1310
Black males											
Humerus	30	26.9231	5.1887	52	26.7546	5.1725	20	36.1709	6.0142	37.8077	6.1488
Femur	28	19.5101	4.4170	53	19.3311	4.3967	17	21.0718	4.5904	27.8270	5.2751
Femur + Tibia	28	17.0377	4.1277	49	16.9307	4.1147	–	–	–	20.8901	4.5706
White males											
Humerus	95	45.6609	6.7573	94	45.2482	6.7267	66	45.9494	6.7786	58.4549	7.6456
Femur	100	35.8549	5.9879	99	35.4005	5.9498	69	35.5038	5.9585	40.7711	6.3852
Femur + Tibia	88	36.4623	6.0384	87	35.5487	5.9623	62	36.0237	6.0020	36.4388	6.0365

*Equations based on sample with post-1944 birth years.

†Equations based on a mixed sampled with pre-1944 and post-1944 birth years.

‡Equations based on a sample with pre-1944 birth years.

supports this trend but also indicated a leveling of the increase in bone proportions after 1944 in White males and Black males compared to other populations. Changes, in the stature versus bone length relationship, warrant the evaluation of existing stature estimation formulae and if necessary the production of new formulae. The re-evaluation of stature estimation formulae as provided here reflects these changes.

Previously published studies have suggested the femur and tibia are the best indicators of stature, which is also demonstrated here. The lower limb bones (femur, tibia, and fibula maximum lengths) outperform the upper limb maximum bone lengths, with the femur length plus tibia length combination performing the best. The regressions for each bone support this conclusion, in which the femur consistently had the highest correlations between bone length and stature. The corresponding narrower confidence intervals correlate with the fact that the lower limb has direct bearing on the height of the individuals. Broader confidence intervals are seen in both Black males and females, which are explained by the small sample sizes when compared to the White males and females. However, the prediction intervals, which account for sample size, are in line with the White samples so suggest that these equations would be applicable to use in a forensic context. The poor correlation between statures and long bone length in the White male group suggests inconsistencies in recording or measuring of one or both variables, but the size of the samples offsets the variation in the dataset. As the White male group is the largest sample and is derived from a variety of different sources, there is a greater chance for error as has been previously described (4,14,15). The variation in the White males provides further support for the use of "any" available stature estimation formulae, because equations should reflect the types of data that estimations must be compared to in missing person's reports.

FSTAT, the most commonly available stature, and ASTAT, any stature available, were used as the basis for the derived formulae. Formulae for both were evaluated, because it is uncommon to have both FSTAT and MSTAT available. There are no significant differences between equations derived using FSTATs and those derived from ASTATs. The formulae derived from any available stature are no better or worse than just FSTAT in predicting an individual's height. In many cases, a cadaver stature is erroneously used in place of the MSTAT, even though an MSTAT is a greater reflection of the FSTAT. We believe the lack of consistency in the recording of all three makes it possible to group them together in the ASTAT category where there is a mixture of source data. Ousley suggests that there is a distinction and FSTAT should be preferentially used (4); however, this study indicates that using cadaver stature as a substitute provides a larger sample for research without being detrimental to the results. The FSTAT equations performed well on almost every case behind the ASTAT formulae.

Equations based on forensic stature have already been shown to be more accurate for use in modern forensic casework, but these equations did not fully represent modern individuals. The new formulae presented here reflect the addition of data to the FDB, specifically individuals born after 1944. Trotter and Gleser's equations are based on populations with late 19th- century and early 20th-century birth years and are based on measured statures so do not reflect the current U.S. population. A similar issue arises with Ousley's equations, because these used individuals with a wide range of birth years. As indicated by Ousley, forensic stature-based equations are the most appropriate to use for current forensic work. However, the forensic stature data should be based on truly modern samples that reflect the population from which current forensic materials are derived.

The high MSE in the Trotter and Gleser's estimates reflect the allometric and secular trend issues identified in the early 20th-century sample by prior researchers. These equations are inappropriate in modern forensic contexts, because they reflect a previous population and provide estimates that are not conservative enough for a stature estimate. Small differences between the error in Ousley's equations and the newly derived formulae are seen with the FSTAT and ASTAT formulae performing better. The little difference is not unexpected given these three datasets (Ousley, FSTAT, and ASTAT) are all derived from the DFAUS. However, we believe that the equations reported here should be preferentially used in lieu of Ousley's because of increase in sample sizes that focus on post-1944 birth years for all groups represented.

Conclusion

Stature is a vital part of the biological profile provided by law enforcement when describing a missing person, victim, or assailant. As such, forensic science practitioners need precise and accurate methodologies for estimating stature (4). This study provides stature equations that use data from a modern American population, so that relevant stature estimations are available for unknown skeletal remains. The DFAUS is a unique data source for forensic practitioners, providing modern case-based reference samples. Having stature formulae derived from recent and relevant samples provides the most accurate and precise stature estimations available. In fact, stature estimation formulae for White males and females and Black males are based on relatively large samples. However, Black female and Hispanic individuals with known stature are not well represented in the DFAUS. For these populations, we suggest estimating formulae using a full Bayesian approach with modern stature data on living populations used as an informative prior (as opposed to the traditional inverse calibration approach that is utilized in this study).

Stature estimation is a constantly changing target for forensic anthropologists because of secular trends in stature, allometric changes in long bones, and the migration of populations within the United States and the world. The current study provides researchers with updated stature estimation formulae based on late 20th-century data available in DFAUS. This study represents an initial re-examination and update of the DFAUS. With the expansion of the FDB and new contributors to the databank each year, we anticipate that the FDB will continue to provide a significant contribution to the forensic anthropology community.

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