

ASB Best Practice Recommendation 212, First Edition
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**Best Practice Recommendation for Stature Estimation in
Forensic Anthropology**

DRAFT



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Best Practice Recommendation for Stature Estimation in Forensic Anthropology

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Foreword

The objective of this document is to support the implementation of ANSI/ASB Standard 045. This document is not a standard operating procedure or an instruction manual for stature estimation; rather, it is a best practice document recommending the preferred methods, techniques, and considerations to improve the accuracy, quality, objectivity, and consistency of estimating stature under optimal conditions. Informative references are provided for guidance, not as a substitution for adequate comprehension and application of the published methods. It is incumbent upon practitioners to utilize the most appropriate, validated research for the estimation of stature.

Anthropological conclusions derived from the morphologic and metric analyses of human remains are often supported by statistical frequencies, error probabilities, and confidence intervals from available reference data in the peer-reviewed published literature. It is acknowledged that the reference samples used in various methods do not reflect the totality of global human variation; therefore, conclusions cannot always be supported by these statistical measures. As such, this document encourages continued research and scholarly debate to improve the scientific validity of estimating stature.

Stature estimation is one component of the anthropological biological profile. The purpose of the biological profile is to provide demographic estimations to inform investigative leads regarding the identification of an unidentified decedent. As noted above, the complexities of human variation directly affect anthropological methods; therefore, the components of a biological profile are reported as intervals or estimations and are meant to serve as investigative parameters. It is acknowledged that the known demographics of a missing person may fall outside of the interval/estimation reported by a forensic anthropologist. Anthropological estimates of biological characteristics are typically only used with consideration of multiple lines of evidence to contribute to the inclusion or exclusion of a missing person as a match to an unidentified decedent.

The American Academy of Forensic Sciences established the Academy Standards Board (ASB) in 2015 with a vision of safeguarding Justice, Integrity and Fairness through Consensus Based American National Standards. To that end, the ASB develops consensus based forensic standards within a framework accredited by the American National Standards Institute (ANSI), and provides training to support those standards. ASB values integrity, scientific rigor, openness, due process, collaboration, excellence, diversity and inclusion. ASB is dedicated to developing and making freely accessible the highest quality documentary forensic science consensus Standards, Guidelines, Best Practices, and Technical Reports in a wide range of forensic science disciplines as a service to forensic practitioners and the legal system.

This document was revised, prepared, and finalized as a standard by the Anthropology Consensus Body of the AAFS Standards Board.

Questions, comments, and suggestions for the improvement of this document can be sent to AAFS-ASB Secretariat, asb@aafs.org or 410 N 21st Street, Colorado Springs, CO 80904.

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Keywords: *stature estimation; biological profile; personal identification.*

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Annex A (informative) Bibliography

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Best Practice Recommendation for Stature Estimation in Forensic Anthropology

1 Scope

This document provides best practice recommendations for preferred metric methods for estimation of stature from skeletal remains. This document does not provide minimum requirements for estimating stature, as these are covered in ANSI/ASB Standard 045.

2 Normative References

The following reference is indispensable for the application of the standard. For dated references, only the edition cited applies. See Annex C, Bibliography, for informative references.

ANSI/ASB Standard 045, *Standard for Stature Estimation in Forensic Anthropology*. 1st Ed. 2019^a.

3 Terms and Definitions

For purposes of this document, the following definitions apply.

3.1

accuracy

The closeness of agreement between a test result or measurement result and the true value.

3.2

anatomical method

complete skeletal method

A method of estimating living stature that involves measuring all bones contributing to stature, summing those measurements, and correcting for the missing soft tissue.

3.3

biological profile

The description of an individual's estimated age, skeletal sex, population affinity, and stature derived from an anthropological analysis.

3.4

cadaveric stature

The measured stature of a body after death, usually taken in a supine position; often referred to as CStats.

3.5

forensic stature

The reported stature of an individual on official documents (e.g., government identification, police report); often referred to as FStats.

^a Available from: www.aafs.org/academy-standards-board

- 33 **3.6**
 34 **linear regression method**
 35 Method of estimating stature based on a statistical procedure for describing a relationship between
 36 stature and bone dimension that can be used to predict the former from the latter.
- 37 **3.7**
 38 **living stature**
 39 **biologic stature**
 40 A person's recorded height, which may be derived from various sources including self-reported
 41 stature, family remembrance, or direct measurement.
- 42 **3.8**
 43 **osteometric board**
 44 An instrument used to collect osteometrics of the postcranial skeleton that can be utilized in the
 45 estimation of biological profile parameters.
- 46 NOTE 1 The instrument consists of a flat, rigid board with a fixed vertical end and a sliding vertical piece that
 47 can be adjusted to collect linear measurements.
- 48 NOTE 2 Some osteometric boards contain a removable segment or opening in the fixed vertical end to
 49 accommodate measurements of the tibia.
- 50 **3.9**
 51 **population affinity**
 52 A measure (e.g., distance, probability of membership) of similarity between the individual and
 53 reference groups.
- 54 **3.10**
 55 **precision**
 56 The measure of the closeness of agreement between a series of measurements obtained from
 57 multiple samplings of the same homogenous sample.
- 58 **3.11**
 59 **prediction interval**
 60 The lower and upper bounds for a predicted dependent variable based on a single independent
 61 variable.
- 62 **3.12**
 63 **SI units**
 64 A standard scientific unit of measurement
- 65 **3.13**
 66 **skeletal sex**
 67 Variation in the expression of skeletal traits influenced by sexual dimorphism.
- 68 **3.14**
 69 **sliding caliper**
 70 An instrument used to collect osteometrics of the cranial and postcranial skeleton and dentition
 71 that can be utilized in the estimation of biological profile parameters.

72 NOTE The instrument consists of a fixed arm and a sliding arm that can be adjusted to collect the dimension
73 of the object being measured.

74 **3.15**
75 **spreading calipers**

76 An instrument used to collect osteometrics of the cranial and postcranial skeleton that can be
77 utilized in the estimation of biological profile parameters.

78 NOTE The instrument consists of two hinged arms that can be adjusted to measure the distance between two
79 points.

80 **3.16**
81 **stadia rod**

82 A vertical measuring tool that can be used to estimate an individual's height.

83 **3.17**
84 **standard error**

85 Variation or deviation from actual and predicted values.

86 **4 Recommendations**

87 **4.1 Procedure**

88 **4.1.1** Stature estimation from skeletal elements is necessary when disarticulation has occurred.

89 **4.1.2** Practitioners should implement ANSI/ASB Std 045, *Standard for Stature Estimation in*
90 *Forensic Anthropology* to the extent applicable, practical and appropriate:

91 "stature estimation shall follow methods that are published in peer-reviewed sources and
92 validated; stature estimates shall be reported as a prediction interval; stature shall be estimated
93 from the skeleton using one of two methods: anatomical or linear regression; and when more
94 than one method is appropriate for the condition and representation of skeletal elements, the
95 method with the smallest standard error should be used."

96 **4.1.3** Practitioners should follow specific recommendations in 4.2 through 4.8 when
97 implementing ANSI/ASB Std 045, *Standard for Stature Estimation in Forensic Anthropology*.

98 **4.1.4** Methods to estimate stature in adults do not apply to subadults.

99 **4.2 Measurements**

100 **4.2.1** Bone measurements should be taken as specified in the method being used, including
101 following the unit of measurement (e.g., mm vs. cm).

102 NOTE Most often, these measurements include the maximum length or height of the skeletal element(s) of
103 interest.

104 **4.2.2** Skeletal elements without damage, pathological conditions, or anomalies should be selected.

105 **4.2.3** Practitioners should consult the details of the method to determine whether measurements
106 should be taken unilaterally or bilaterally.

107 **4.3 Methods**

108 **4.3.1 General**

109 **4.3.1.1** The condition of the remains and presence of certain skeletal elements should be
110 considered when deciding whether to use the anatomical method or linear regression method.

111 **4.3.1.2** If the appropriate skeletal elements are available, and in a condition to yield reliable
112 measurements, the anatomical method should be used due to its increased precision and accuracy
113 compared to the linear regression method.

114 **4.3.2 Equipment**

115 **4.3.2.1** While an osteometric board is appropriate for the linear regression method of estimating
116 stature, and a combination of an osteometric board, spreading calipers, and sliding calipers are
117 appropriate for the anatomical method, other equipment (such as stadia rods) can be used.

118 **4.3.2.2** All equipment should be acquired from a forensic service provider that calibrates the
119 equipment against a measurement reference standard traceable to SI units.

120 **4.3.2.3** All equipment should undergo periodic calibration checks against a measurement
121 reference standard.

122 **4.3.3 Considerations**

123 **4.3.3.1 Data source**

124 The source of the data used to develop a method (i.e., living/biologic statures, cadaver lengths, or
125 forensic statures), should be considered in order to understand the inherent error of the method
126 and the type of stature being estimated.

127 **4.3.3.1.1** The source of the reported height of the missing person should be considered to
128 understand any potential bias or inaccuracies.

129 **4.3.3.2 Incorrect biological profile estimates**

130 Errors in biological profile parameters will lead to incorrect selection of the most appropriate
131 method for stature estimation.

132 **4.3.3.3 Fragmentation**

133 Stature can be estimated for fragmented or incomplete remains based on an assumed correlation
134 between a segment of bone and the total length of the bone (e.g., Holland^[13], Steele^[28], Simmons et
135 al.^[27], Wright and Vasquez^[34]). This, however, leads to wider prediction intervals and lessened
136 probative value. Further, many stature estimation methods rely on the use of bone landmarks,
137 which may not be present in the fragment being measured. Because of these difficulties and
138 increased error potential, practitioners should not use these methods when complete long bones
139 are present for stature estimation.

140 **4.3.3.4 Asymmetry**

141 Asymmetry between antimeres may impact stature estimation accuracy. Current literature does
142 not provide sufficient guidance regarding the effect of asymmetry on stature estimation.

143 **4.3.3.5 Pathological conditions**

144 Pathological conditions may affect the accuracy of stature estimation.

145 In cases where postcranial metric lengths may be affected by the presence of bony pathology, the
146 long bone of the opposite (unaffected) side should be measured.

147 **4.3.4 The Anatomical Method (also known as the Complete Skeletal Method)**

148 **4.3.4.1 Background**

149 **4.3.4.1.1** The anatomical method of stature estimation involves the summation of measurements
150 from skeletal elements contributing to height and correction factors, such as spinal curvature, soft
151 tissue, or age.

152 **4.3.4.1.2** The method can be used independently of skeletal sex or population affinity
153 estimations, which is useful in a forensic context when these biological profile parameters are
154 unknown. This method also accounts for skeletal variations such as an anomalous number of
155 vertebrae and atypical body proportions, and can be used to create sex- and population-specific
156 regression formulae.

157 **4.3.4.2 General**

158 **4.3.4.2.1** The most often used method is Raxter et al.^[24], which is a revision of the original
159 Fully^[6,7] method.

160 **4.3.4.2.2** Maijanen^[19] reported low average error for several anatomical methods, including
161 Raxter et al.^[24].

162 **4.3.4.2.3** Damage on a skeletal element may introduce error to the final stature estimate.

163 **4.3.4.2.4** When available, validation studies should be consulted to understand how the
164 anatomical method performs across different groups, and the absence of such studies should be
165 clearly acknowledged as a limitation.

166 **4.3.4.3 Measurements**

167 **4.3.4.3.1** Practitioners should take bone measurements as specified by the specific method being
168 used.

169 NOTE The anatomical method typically requires measurement of the cranium, vertebrae, femur, and tibia.
170 Additional measurements that may be required include the sacrum, and ankle. Guidance for taking vertebral
171 height measurements and whether to average lengths of bilateral elements varies by method.

172 **4.3.4.4 Equipment**

173 The following equipment should be used, unless otherwise specified in the method:

- 174 spreading calipers for measuring cranial height;
- 175 an osteometric board for measuring long bones; and
- 176 sliding calipers for measuring vertebrae, sacral segments, and skeletal elements of the ankle.

177 **4.3.4.5 Considerations**

178 **4.3.4.5.1** The anatomical method requires that all skeletal elements contributing to height are
179 present and in a condition to yield reliable measurements.

180 **4.3.4.5.2** The anatomical method is more time consuming, as many of these measurements are
181 typically not collected during a routine assessment of the biological profile.

182 **4.3.5 The Linear Regression Method**

183 **4.3.5.1 Background**

184 The linear regression method statistically assesses the association between long bone length and
185 stature. Skeletal lengths are measured and inserted into appropriate regression formulae and
186 regression lines, slopes, and intercepts are generated. This can be accomplished through software
187 (e.g., FORDISC) or stature estimation equations.

188 **4.3.5.2 General**

189 **4.3.5.2.1** When estimating stature, consideration should be given to the individual's known or
190 estimated skeletal sex, population affinity, and/or temporal cohort.

191 **4.3.5.2.2** At minimum, a 90% prediction interval should be used.

192 **4.3.5.2.3** Long bones showing a higher correlation with stature result in more accurate and
193 precise stature estimates.

194 **4.3.5.2.4** Using more than one skeletal element typically increases stature estimate accuracy and
195 precision.

196 **4.3.5.2.5** The use of FORDISC^[17] is commonly used for linear regression estimation of stature, as
197 it takes into consideration secular changes in height and the populations from which linear
198 regression models have been derived.

199 **4.3.5.2.6** The method with the smallest standard error should be used when more than one
200 method is appropriate for the condition and representation of skeletal elements. Accuracy and
201 precision of the model, as well as variance and potential bias, should be considered.

202 **4.3.5.2.7** Practitioners should be aware of the assumption of linearity between bone length and
 203 stature (i.e., that stature is expected to change in a straight-line fashion with bone length) and
 204 recognize its limitations.

205 **4.3.5.2.8** Damage on a skeletal element may introduce error to the final stature estimate.

206 **4.3.5.3 Validation**

207 Regression equations should be derived from published research and applied to appropriate
 208 reference populations; limitations should be acknowledged when used outside the population for
 209 which they were developed.

210 **4.3.5.4 Measurements**

211 **4.3.5.4.1** Bone measurements should be taken as specified in the method to be used, including
 212 the unit of measurement (e.g., mm vs. cm)

213 NOTE The linear regression method requires the length of a single skeletal element or multiple skeletal
 214 elements to be taken. Most often, these measurements include the maximum length or height of the skeletal
 215 element(s) of interest.

216 **4.3.5.4.2** Skeletal elements without damage, pathological conditions, or anomalies should be
 217 selected.

218 **4.3.5.4.3** Practitioners should consult the details of the method to determine whether
 219 measurements should be taken unilaterally or bilaterally.

220 **4.3.5.5 Equipment**

221 **4.3.5.5.1** Practitioners should defer to the specific method regarding equipment used for
 222 measurements.

223 **4.3.5.6 FORDISC**

224 **4.3.5.6.1** 20th Century FStats should be used as the reference population for modern remains.

225 NOTE This option uses forensic stature measurements or long bone measurements from the Forensic
 226 Anthropology Data Bank.

227 **4.3.5.6.2** 19th Century CStats should be used as the reference population for historic remains.

228 NOTE This option uses cadaveric statures and/or long bone measurements from the Terry Anatomical
 229 Collection and the Trotter and Gleser^[30] dataset^[16].

230 **4.3.5.6.3** Trotter MStats should be used as the reference population for U.S. historic war dead
 231 (i.e., WWII-era U.S. males) or similar populations.

232 NOTE 1 This option uses living/biologic stature measurements obtained from medical records and/or long
 233 bone measurements of WWII personnel.

234 NOTE 2 There have been documented issues with tibia measurements for this reference sample (see Lynch et
 235 al.^[18] and Jantz et al.^[15]).

- 236 **4.3.5.6.4** Measurements should be taken according to the FORDISC help manual.
- 237 **4.3.5.6.5** If skeletal sex or population affinity are not known, "Any" may be used after choosing
238 the appropriate temporal or contextual option.
- 239 **4.3.5.6.6** The appropriate prediction interval should be chosen based on guidance from 4.3.5.2.2.
- 240 **4.3.5.6.7** Regression equations available within FORDISC are derived from published reference
241 datasets that have been evaluated in the forensic anthropology literature; practitioners should
242 consider the applicability of the selected reference population and acknowledge any limitations
243 when interpreting results.
- 244 **4.3.5.7 Linear Regression Equations**
- 245 **4.3.5.7.1 General**
- 246 If FORDISC is not available, or if the reference populations within FORDISC are not appropriate,
247 population-specific linear regression equations should be used.
- 248 NOTE Linear regression equations based on the closest reference population should be used.
- 249 **4.3.5.8 Adjustments**
- 250 **4.3.5.8.1 Older Age**
- 251 Researchers have noted that maximum height typically decreases as adults reach older ages
252 (Giles^[9], Galloway^[8], Cline et al.^[4]). Correction factors for stature estimates using linear regression
253 equations are published (e.g., Giles^[9]), but have not been widely validated for forensic applications.
- 254 **4.3.5.9 Documentation**
- 255 **4.3.5.9.1 Technical Record**
- 256 The technical record should include the equation used to estimate stature; the type and the version
257 of software used to estimate stature; the type of equipment used to measure the skeletal element;
258 and any considerations or adjustments that may affect the stature estimate.
- 259 **4.3.5.9.2 Report**
- 260 **4.3.5.9.2.1 General**
- 261 The following should be included in the report:
- 262 skeletal estimate, including the unit of measurement;
- 263 skeletal element(s);
- 264 measurement type (e.g., maximum femur length), value, and unit;

- 265 stature estimate;
- 266 prediction interval;
- 267 stature estimation method;
- 268 reference population used in linear regression analyses; and
- 269 any deviations or limitations (e.g., approximated stature estimates from incomplete skeletal
- 270 elements).

271 **4.3.5.9.2.2 Multiple Estimates**

272 According to ANSI/ASB Std 045 “The results from multiple stature estimations shall not be
 273 combined into a single estimate unless explicitly outlined for the particular method.” If more than
 274 one stature estimate is calculated for a set of remains, the estimates should be recorded and
 275 reported separately following that specific method and ANSI/ASB Standard 045.

276 **4.3.6 Quality Assurance**

277 The following regular quality assurance activities should be considered to evaluate accuracy,
 278 consistency, and defensibility of stature estimation methods: periodic proficiency assessments,
 279 either through internal programs or external providers, to evaluate analytical competency and
 280 measurement precision; technical or peer review of measurement procedures, calculations and
 281 results when feasible, particularly in casework settings; and the maintenance and calibration of
 282 equipment.

283 **4.3.7 Error and Bias Mitigation**

284 **4.3.7.1** To reduce cognitive and measurement bias in stature estimation, practitioners should,
 285 when possible:

- 286 review the selected method to confirm correct application and understanding of its limitations;
- 287 demonstrate proficiency in osteometrics and use equipment that has been quality-checked and
- 288 calibrated;
- 289 conduct analyses under blinded conditions, when feasible, to minimize contextual bias;
- 290 repeat measurements, when possible, to assess intra-observer reliability;
- 291 independently verify all stature calculations to minimize error;
- 292 seek technical or peer review of measurements or results when resources allow;

293 follow a structured workflow that records observations and measurements first and only
294 considers potentially biasing contextual information afterward; and

295 engage in ongoing training on the recognition and mitigation of cognitive bias in forensic
296 decision-making.

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Annex A (informative)

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