Stature Estimation for Bosnian Male Population

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Abstract

Since 1996, the Trotter and Gleser formulae to determine the stature of recovered missing persons in Bosnia and Herzegovina have been used. The purpose of this study is to develop appropriate stature estimation formulae from the length of the femur, tibia and fibula for use in the Bosnia and Herzegovina to help in identifications of the victims. Research was undertaken on 50 male cadavers, of individuals who died between the ages of 23 to 54 years. The cadaver length was measured and the length of the long bones was obtained from X-ray photographs. The length of the cadavers of the individuals who died after age of 45 years was corrected according to Giles' table. This study established that using Trotter and Gleser's formulae underestimate stature of tall people in the current population of Bosnia and Herzegovina. Smallest standard error of estimate is observed in the formula that uses the sum of the length of femur and fibula. There are no statistically significant differences between the length of the bones from the left and right sides of the body. Therefore, formulae developed from the average length of bone pairs are recommended for use

KEY WORDS: forensic science, forensic anthropology, stature estimation, Bosnian population

Introduction

Estimation of stature from human skeletal remains continues to have an important role in the determination of a biological profile. Previous research has demonstrated that the most reliable formulae are based on long bone lengths, particularly the bones of the lower limbs (1). Regression formulae, developed by Trotter and Gleser (2, 3) from American White, have been widely used in Bosnia and Herzegovina to calculate statures of recovered skeletal remains of missing persons since 1996. However, based on studies of males from Trotter's data from the Terry Collection and World War II casualties and more recent data from the Forensic Data Bank, Meadows and Jantz (4) and Ousley and Jantz (5) conclude that it is generally inappropriate to use regression formulae based on earlier samples, such as the Terry Collection, to estimate stature in the recently deceased because of secular changes in lower limb segment proportions. Similarly, Klepinger concludes that the application of Trotter and Gleser formulae to recent cases requires revised confidence intervals for estimated stature, because taller indi-

viduals may be more frequently presented (6). Ross and Konigsberg (7) demonstrate that variation exists among American Whites and Bosnians in the shape and proportion of long bones. These results further suggest that stature prediction formulae developed from American Whites are unsuitable for use on a Bosnian population. The recent war in Bosnia and Herzegovina, 1992 to 1995, resulted in approximately 30 000 missing persons, believed to be dead. More then 14 000 of them are still missing. The Trotter and Gleser stature formula used as part of the identification process has not achieved appropriate results. Therefore, the main purpose of this study is to develop stature estimation formulae from the lengths of the femur, tibia and fibula for the current local male population.

Material and Methods

The stature was measured of 50 Bosnian male cadavers in supine position with a graduated ruler and scaled strap at the lower end of the ruler, according to the Terry (8). All cadavers were in state of rigor mortis. The corpses were free of any pathological condition that could influence the taking of accurate measurements. The ages ranged from 23 to 54 (mean 39,62, standard deviation 8,51). For those over 45 years of age, stature was corrected according to Giles' table (9). Radiographs of the left and right lower limb of each cadaver were taken and measurements of femur, tibia and fibula were obtained. Leg was placed in the horizontal position. In order to minimize error in measurements resulting from incorrect positioning and magnification, a calibrated metallic ruler was placed at the outer side of the each leg at the same level as the middle long axis of the bone. The ruler was included in each radiograph to measure the distortion of the distance on metallic ruler and then calculate correct length of the radiographed bones. This approach was consistently used for every X-ray photograph. Lengths of the bones were obtained from the X-ray photographs according to the rules for measuring maximum lengths of the femur, tibia and fibula (10). Statistical analysis was made using SPSS, as follows: paired and unpaired t-tests, linear regression analysis and analysis of variances (ANOVA). Descriptive statistic of long bone lengths and stature is shown in Table 1.

Results

Initial comparison of the length of the bones from the left and right side of the body using a paired t-test revealed no significant differences (Table 2). Therefore, in the next analysis only mean values from the both sides were used. The relationship between recent population, presented with the length of the bones in our study, and the length of the bones of the control sample that consisted of recovered skeletal remains from missing persons (N = 172) was examined. Unpaired t-test showed no significant differences (Table 3), what confirmed that this sample could be taken as random sample of studied population. The regression equations for estimation of stature, the standard errors and the correlation coefficients calculated from these equations are presented in Table 4. Stature, length of the bones and standard errors (SE) in cmOnly regression of the sum of the lengths of the femur and tibia on stature is shown in Figure 1, because smallest standard error of estimate is observed in this formula.

	STATURE	LEFT			RIGHT			MEAN		
		Femur	Tibia	Fibula	Femur	Tibia	Fibula	Femur	Tibia	Fibula
MEAN	175,24	472,74	385,23	383,81	471,99	384,74	383,01	472,36	384,99	383,46
SD	7,77	24,05	20,79	20,08	23,83	20,03	20,01	23,91	20,33	20,04
MIN	158,40	412,23	331,91	335,01	409,84	339,05	340,19	411,03	335,48	337,60
MAX	190,88	517,96	422,41	418,57	513,69	423,61	417,78	515,83	422,65	419,54

*Stature in cm and length of the long bones in mm

TABLE 1. Descriptive statistics. Mean, standard deviation, minimum and maximum long bone length and stature*

	LEFT	RIGHT	T
FEMUR	472,74	471,99	1,98*
TIBIA	385,23	384,74	0,91*
FIBULA	383,81	383,01	1,43*

*P>0,05

TABLE 2. Comparison of the length of the bones from the left and right side of the body (mm)

	CONTROL SAMPLE		THIS STUDY	
	Femur[1]	Tibia[2]	Femur[1]	Tibia[2]
MEAN	471,45	385,01	472,36	384,99
N	172	172	50	50
SD	22,22	20,14	23,91	20,33
MIN	419	335	411,03	335,48
MAX	532	450	515,83	422,65

[1]t =-0,23*; [2]t =0,007*; *P>0,05

TABLE 3. Comparison of the mean length of bones between this study and control sample (mm)

	FORMULAE									SE	R
STATURE =	0,268	x	Femur			+	48,62	+/-	4,44	0,83
STATURE =	0,329	x	Tibia			+	48,69	+/-	4,01	0,86
STATURE =	0,345	x	Fibula			+	42,79	+/-	3,57	0,89
STATURE =	0,160	x	(Femur + Tibia)			+	37,89	+/-	3,62	0,89
STATURE =	0,163	x	(Femur + Fibula)			+	35,53	+/-	3,48	0,90
STATURE =	0,106	x	Femur +	0,221	x Tibia	+	39,86	+/-	3,83	0,90
STATURE =	0,069	x	Femur +	0,274	x Fibula	+	37,52	+/-	3,51	0,90

TABLE 4. Stature regression equations for Bosnian population

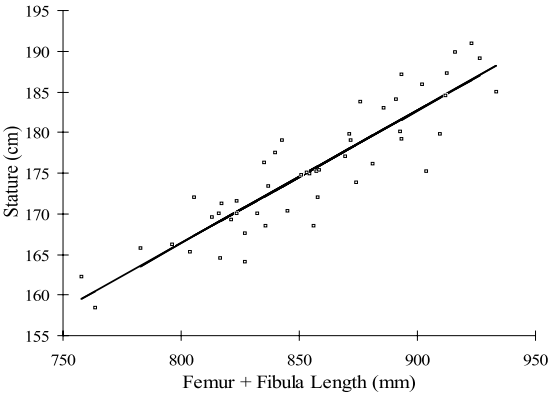

FIGURE 1. Regresion of sum of length of femur and fibula on stature

Discussion

Until 1992 there were no research studies about stature estimation for population in former Yugoslavia. Rollet's formulae (11) were recommended even if they were developed prior to introducing the regression analysis that are currently mostly applied in developing formulae for estimation of stature. Solution for the issue of living stature-cadaver length still does not exist. Different authors used different ratios, some used only the cadaver length as a reference while some others thought there was no difference (12, 13, 14). Most authors agree that higher values for stature are received when living person is measured not in standing but in supine position, explaining it by relative flattening of intervertebral discs and stronger muscle tonus in persons standing. Variations in the height of living persons during a day are also mentioned (8, 15, 16). Since in our study the body length was measured at the time when rigor mortis was distinct, above mentioned reasons which usually lead to increased height of persons in supine position did not exist. Consequently, with a distinct contraction of the muscles there could be no extension of intervertebral discs in supine position, while relative shortening of muscles is in this condition more distinct than in normal muscle tonus. This is significantly different from conditions in which Terry measured cadaver length (8). His results were used by Trotter and Glesser for showing that the cadaver body length is in average 2,5 cm longer than living stature. Therefore in our study cadaver length is treated as living stature. The smallest standard error in estimation of stature was received in formulae that use respectively the sum of lengths of femur and fibula, fibula and sum of femur and tibia length. This indicates that in estimation of stature better precision can be reached if both bones, meaning femur and one of the long bones of the lower leg are used. This way, slightly better precision is reached by using the femur and fibula. We believe that using formulae which include both femur and one of the long bones of lower leg is very

	THIS STUDY	TROTTER & GLESER 52	TROTTER & GLESER 58	F
FEMUR	175,258	173,833	175,119	0,87*
	(-3,576)	(-3,84)	(-3,596)	
TIBIA	175,244	175,636	175,097	0,12*
	(-2,974)	(-3,394)	(-3,405)	
FIBULA	175,238	175,636	175,186	0,09*
	(-2,743)	(-3,104)	(-3,094)	
FEMUR+TIBIA	175,261	174,746	175,116	0,1*
	(-3,063)	(-3,148)	(-3,204)	
FEMUR+FIBULA	175,266		175,156	0,1*
	(-2,876)		(-2,952)	

( ) : Mean absolute difference; *P>0,05

TABLE 5. Comparison of the stature estimation using formulae developed in this study and Trotter & Gleser from 1952 and 1958

important because of noticed individual disproportions, and different relations of these bones in tall and short people. Trotter and Gleser in their study did not recommend using fibula, supporting this statement with a fact that this is a very thin bone which breaks easier than tibia so it can rarely be found in available skeletal material. However, the results of their study from 1958 show the smallest standard error in formulae developed based on fibula measurements (3). Using the analysis of variance (ANOVA), formulae created in our study were compared with Trotter and Gleser's formulae from 1952 and 1958 (Table 5). Their formulae from 1952 were recommended for general use (17). No statistically significant difference was noticed. However the mean absolute difference, calculated for our study, was smaller for each individual bone as well as for the sum of the length of bones in comparison with the mean absolute difference calculated with Trotter and Gleser's formulae. This proves that stature estimation in male Bosnian population was more precise by using the regression formulae developed in our study. The results of this study show the noticeable difference in stature estimation of tall persons between our formulae and Trotter and Gleser formulae, which constantly underestimate the stature of tall persons (Figure 2). The results of ANOVA and Tukey-Kramer test showed that differences in stature estimation for small persons exist but they are not really important because they are significant only in persons under 160 cm height, who are not too many in male population. However, differences in stature estimation of taller persons are already significant for persons higher then 185 cm (Table 6). There are situations when due to lack of time, particularly during examination of remains from large mass graves when it is not possible to calculate the stature based on formulae, we presented a table (Table 7) from which the estimated stature can be read. Stature is calculated from lengths of femur, tibia or fibula as well as the sum of femur and tibia or femur and fibula.

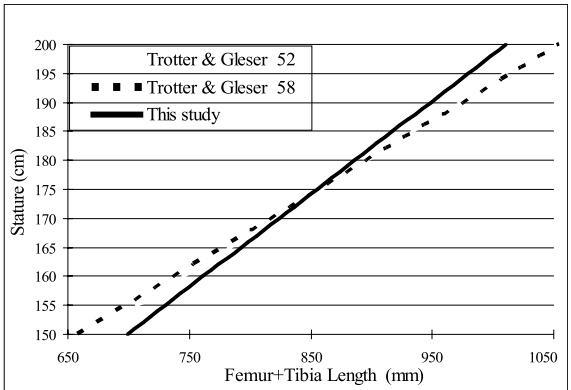

FIGURE 2. Comparison of results of stature estimation using different regression equations

COMPARISON	MEAN DIFFERENCE	(95% CONFIDENCE INTERVAL)	P
A vs B	-26,077	(-29,5301 to -22,6239)	P < 0,001
A vs C	-29,529	(-32,9825 to -26,0763)	P < 0,001
B vs C	-3,452	(-6,9055 to 0,0007)	P = 0,050

A = This study, B = Trotter & Gleser 1952, C = Trotter & Gleser 1958

TABLE 6. Differences in stature estimation of persons higher then 185 cm

STATURE	FEMUR	TIBIA	FIBULA	FEM+TIB	FEM+FIB
150	37,8	30,8	31,0	69,9	70,1
151	38,2	31,1	31,3	70,5	70,7
152	38,6	31,4	31,6	71,2	71,3
153	38,9	31,7	31,9	71,8	71,9
154	39,3	32,0	32,2	72,4	72,5
155	39,7	32,3	32,5	73,0	73,1
156	40,1	32,6	32,8	73,6	73,7
157	40,4	33,0	33,1	74,3	74,4
158	40,8	33,3	33,4	74,9	75,0
159	41,2	33,6	33,6	75,5	75,6
160	41,6	33,9	33,9	76,1	76,2
161	41,9	34,2	34,2	76,8	76,8
162	42,3	34,5	34,5	77,4	77,4
163	42,7	34,8	34,8	78,0	78,0
164	43,0	35,1	35,1	78,6	78,6
165	43,4	35,4	35,4	79,3	79,2
166	43,8	35,7	35,7	79,9	79,9
167	44,2	36,0	36,0	80,5	80,5
168	44,5	36,3	36,3	81,1	81,1
169	44,9	36,6	36,5	81,8	81,7
170	45,3	36,9	36,8	82,4	82,3
171	45,7	37,2	37,1	83,0	82,9
172	46,0	37,5	37,4	83,6	83,5
173	46,4	37,8	37,7	84,2	84,1
174	46,8	38,1	38,0	84,9	84,8
175	47,1	38,4	38,3	85,5	85,4
176	47,5	38,7	38,6	86,1	86,0
177	47,9	39,0	38,9	86,7	86,6
178	48,3	39,3	39,1	87,4	87,2
179	48,6	39,6	39,4	88,0	87,8
180	49,0	39,9	39,7	88,6	88,4
181	49,4	40,3	40,0	89,2	89,0
182	49,8	40,6	40,3	89,9	89,7
183	50,1	40,9	40,6	90,5	90,3
184	50,5	41,2	40,9	91,1	90,9
185	50,9	41,5	41,2	91,7	91,5
186	51,3	41,8	41,5	92,4	92,1
187	51,6	42,1	41,8	93,0	92,7
188	52,0	42,4	42,0	93,6	93,3
189	52,4	42,7	42,3	94,2	93,9
190	52,7	43,0	42,6	94,8	94,6
191	53,1	43,3	42,9	95,5	95,2
192	53,5	43,6	43,2	96,1	95,8
193	53,9	43,9	43,5	96,7	96,4
194	54,2	44,2	43,8	97,3	97,0
195	54,6	44,5	44,1	98,0	97,6
196	55,0	44,8	44,4	98,6	98,2
197	55,4	45,1	44,6	99,2	98,8
198	55,7	45,4	44,9	99,8	99,4
199	56,1	45,7	45,2	100,5	100,1
200	56,5	46,0	45,5	101,1	100,7

TABLE 7. Stature calculated from long bone length (cm)

Conclusion

Trotter and Gleser's formulae underestimate stature of tall people in the current population of Bosnia and Herzegovina. Stature estimation formulae, developed in this study, which use respectively the sum of lengths of femur and fibula, fibula and sum of femur and tibia length are recommended for use.

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