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Assessment of Living Stature from Limb Long Bones by Computer Program

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The reconstruction of the stature is a part of the investigation of human bone remains. Data for postmortal stature and the lengths of three limb long bones is derived from measurements on 685 cadavers, of which 416 were Bulgarians (286 male and 130 female) and 269 were Hungarians (186 male and 83 female), for a period of 20-66 years. The lengths of humerus, fibula and tibia are measured bilaterally. On the basis of this data obtained by the use of regression analysis (original software, written in MATLAB 4.2) three ways are made for stature estimation: a) by regression equation, b) by nomograms; c) by computer program. The created program and the possibilities for prediction of living maximal and age corrected stature are presented the lengths of three bones taken separately, as well as through a combination of humerus and tibia, sex and age. The necessity of using of confidence intervals is commented and not the standard error of estimate.

Key words: forensic anthropology, confidence intervals, estimated stature, standard error of estimate.

Introduction

Developments in physical and forensic anthropology in recent years presuppose a new data base for contemporary individuals because of changes in stature and the proportions of human body throughout the last century [10, 13, 15] and modern regressive procedures in predicting living height by long bone lengths. The published regression equations are not equally valid for individuals of different nationalities and their practical application could lead to serious expert errors in forensic anthropology. The formulae give most accurate results when applied to a population on whose data they were created [1, 3, 20]. The well-known formulae always include a plus-minus number known as the sample standard error of the estimate. The standard error of the estimate is a measure of how much the individual observations of the original database deviate from the regression line [8, 14]. But in forensic anthropology it is more appropriate and practically important to determine the confidence interval of the stature calculated for each concrete case [16].

Stature estimates based on long bone lengths require a correction factor to compensate for stature decrease in older people [7]. The age correction is not investigated in this country, it is not known or applied because we examined and analyzed data from other authors [22] and generalized their information in one Table and five nomograms for practical application.

The reconstruction of the living stature is obligatory in investigating bones and bone remains in forensic medicine and in anthropology. In this connection the group with our participation made a new regression formulae and nomograms for determining the stature by humerus, by fibula, by tibia, by a combination of humerus and tibia for Bulgarians, for both sexes taking into account aging changes [21]. Living maximal stature is determined by the equations whereas its confidence limits can be calculated by the nomograms. With old and very old people actual stature can be determined by subtracting the age correction for the concrete age of the individual from its maximal stature. When the investigator uses formulae and nomograms, he has to do this correction additionally. When using a computer program, we obtain automatically results for maximal and age corrected stature.

The purpose of the present paper is to present the predicting possibilities of the created computer program and the necessity of using confidence intervals when calculating the living stature of a single individual.

Material and Methods

Six hundred and eighty-five forensic cadavers are examined of which 416 are Bulgarians for a period of 20-66 years. Postmortal stature and lengths of the humerus, fibula and tibia are measured in each case. The numeral procedures of regression analysis of all samples are described in our paper [18]. In this way are investigated the four regressions separately for Bulgarians and Hungarians, for both sexes, as well as for the united samples of Bulgarian and Hungarian males and Bulgarian and Hungarian females.

Distribution of Bulgarian population according to age is presented in Table. 1.

T a b l e 1. Distribution of Bulgarians according to age.

Age (years)	Females, (n=130)		Males, (n=286)	
20-30	13	10.0%	50	17.5%
31-42	16	12.3%	44	15.4%
43-54	31	23.8%	80	28.0%
55-66	70	53.8%	112	39.2%
Average	51.32		46.76	
SD	12.97		13.94	

The maximal stature begins to decline after the age of 45-50 years, which seems to be mostly caused by other factors than changes in the bones. Such studies have not been made in Bulgaria, so we use data from many authors [2, 4, 5, 6, 7, 9, 19] and they are analyzed, generalized and differentiated by sex in five variations and included in the software being offered.

Stature prediction by the computer program is on the basis of investigating regressions. According to bones that are subject to investigation we choose single or united (mixed) sample. We also choose a type of age correction that makes corrections

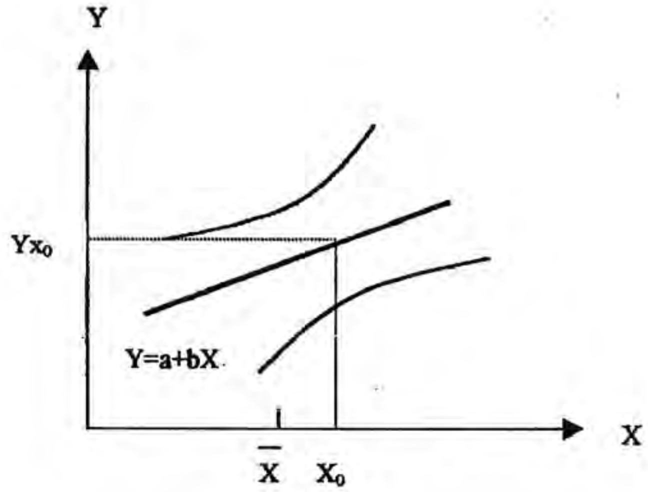

Fig. 1. Confidence intervals for single predicted value of y for given x (G i l e s, K l e p i n g e r, 1988)

of the sample's individuals (those that might need some) for regression analysis and also for the results obtained. It is possible to predict the stature by each of the four regressions — by humerus, by tibia, by fibula, by simultaneously humerus and tibia depending on the available bones of the individual investigated. Data for sex and age is also introduced excluding the length of the corresponding bone/bones. When the exact age is not known, a very regular occurrence, we introduce an approximate age. Using of formulae, nomograms or computer prediction has practically the same effect in our software because the three variations rest on the same basis.

With the interpretation of the results stature should not be estimated by determining the mean value of the assessments obtained from several equations each of which is derived from a different bone or combination of bones [20].

Using of confidence intervals for the assessment of predicted stature of a single individual is not well known and is not utilized enough in our country. G i l e s & K l e p i n g e r [8] and R a n c h o v [23] say that confidence intervals for predictions by regression equations are not parallel bands on either side of the regression line, but are the arms of a hyperbola.

The point at which the arms are the closest together is the mean of the *X* values; and the further the observed individual from the mean, the greater the confidence interval for the predicted Y value.

Therefore it is clear that the reliability of the prediction is greater when near the mean value of the distribution, and less in either end. Properly constructed confidence intervals should reflect this. The nonlinear nature of the confidence interval band is described by M a p l e s & R i c e [14] S n o w & L u k e [17].

In the present paper it is suggested not a formula for calculating the confidence intervals (although all the data needed are available) but their obtaining by an automated program system, created for this end.

Results and Discussion

Two examples of results from determining the living stature of a 64 years old woman, by the length of humerus and of a 50 years old woman, by the length of fibula — Bulgarians are presented in Table 2. The age correction is by the method of C l i n e et al. [4].

T a b l e 2. First example: a 64-year-old Bulgarian woman for whom we predict stature by the length of humerus

Nationality	Bulgarian
Sex	Female
Regression on	Humerus
Age correction	Cline

Individual:

Sex	Female
Humerus	29.6 [cm]
Maximal Stature	**157.1** [cm]
Age	64.0 [years]
Age Correction	**1.23** [cm]
Corrected Stature	**155.9** [cm]

Confidence Margins:

	Lower Stature	Upper Stature
95.0% (maximal)	153.1 [cm]	161.1 [cm]
99.0% (maximal)	151.8 [cm]	162.4 [cm]
99.9% (maximal)	**150.3** [cm]	**163.9** [cm]
95.0% (corrected)	151.9 [cm]	159.9 [cm]
99.0% (corrected)	150.6 [cm]	161.2 [cm]
99.9% (corrected)	**149.1** [cm]	**162.7** [cm]

In the first case the results show that the age-corrected stature is 1.23 cm smaller than the maximal predicted stature. The confidence margins (at a chosen 99.9% level of confidence) of the maximal (150.3cm÷163.9cm) and of age-corrected stature (149.1cm÷162.7cm) are of equal values — 13.6 cm. The standard error of estimate is 1.93 cm (1.64 cm÷2.34 cm). Obviously the doubled standard error, as K r o g m a n [12] says is considerably less than the confidence interval of the predicted stature. The right and precise conclusion that the specialist should come at is: an age-corrected stature was determined by the length of the humerus of a 64 years old woman. Her predicted stature is 155.9 cm with a confidence interval between 149.1-162.2 cm at 99.9% level of confidence.

The second example shows that the difference between maximal and age-corrected stature is just 0.04 cm (the woman is 50 year old), and the confidence interval of the predicted stature is 9.3 cm, a value, which also exceeds the standard error of estimate (1.26 cm), but not so extremely, as in the first case. The conclusion should be: the age-corrected stature of the 50 years old woman is 161.7 cm, which with a 99.9% level of confidence is in the interval between 157.1cm and 166.4 cm.

The prediction of the living stature by the lengths of limb long bones (humerus, fibula, tibia and a combination of humerus and tibia) can be realized by the regres-

T a b l e 3. Second example: a 50-year-old Bulgarian woman for whom we predict stature by the length of fibula

Nationality	Bulgarian
Sex	Female
Regression on	Fibula
Age correction	Cline
Individual:	
Sex	Female
Fibula	34.4 [cm]
Maximal Stature	**161.8** [cm]
Age	50.0 [years]
Age Correction	**0.04** [cm]
Corrected Stature	**161.7** [cm]

Confidence Margins:

	Lower Stature	Upper Stature
95.0% (maximal)	159.0 [cm]	164.5 [cm]
99.0% (maximal)	158.2 [cm]	165.4 [cm]
99.9% (maximal)	**157.1** [cm]	**166.4** [cm]
95.0% (corrected)	159.0 [cm]	164.5 [cm]
99.0% (corrected)	158.1 [cm]	165.3 [cm]
99.9% (corrected)	**157.1** [cm]	**166.4** [cm]

sion equations and nomograms, published by Radoinova et al. [21]. On the same database and for the same purpose we recommend a prediction with the created software. The advantages are that the value of maximal and age-corrected living stature of the investigated individual is obtained with its confidence interval automatically.

The results obtained show that it is also necessary to be made an age correction of the calculated stature in old and very old people. The examples confirm that in calculating stature of a single individual it is much more appropriate to use the confidence intervals of the predicted stature and not the standard error of estimate. The values of confidence intervals surpass considerably the size of the standard error. The more extreme the data for the observed individuals (tall or short), the wider the confidence intervals of the predicted stature. The final result should present the predicted stature by the concrete bone/s with its confidence intervals. The conclusions arrived at fully confirm these of G i l e s & K l e p i n g e r [8].

Conclusions

1. When calculating living stature by the limb long bones of a separate individual it is necessary to determine the confidence intervals of the predicted stature. It is incorrect to use the standard error of estimate.

2. It is also recommended to use the created computer program (original software) when investigating bones and bone remains for predicting maximal and age-corrected living stature with its confidence interval, on the basis of length of observed bone, sex and age. This program permits one to conduct practically unlimited expert

and experimental work with visualization of the results for application in forensic medicine and anthropology. In this way, using this software, it is possible to unify stature estimations by examined bones.

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