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Nationwide Stature Estimation from Forearm Length Measurements in Montenegrin Adolescents

Estimación de la Estatura a Partir de Mediciones de la Longitud del Antebrazo en Adolescentes Montenegrinos

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SUMMARY: The purpose of this research is to determine a regression equation for estimation of stature from forearm length measurements. This research was carried out on 1200 subjects (604 male and 596 female) among the population of Montenegrin adolescents. The stature and forearm length measurements were taken according to the ISAK protocol, and the data were analyzed statistically. Linear regression analysis determined the prediction of forearm length on the criterion variable a body height at the significance level of $p < 0.05$. These relations are presented in the form of scatter diagram. Thereby, we obtained the coefficient of determination, the multiple correlation coefficients, the partial correlation coefficient, the regression, t-test and standardized beta coefficient. The results of this research study confirmed that forearm length reliably predicts stature in both sexes of Montenegrin adolescents and revealed a very useful finding for physical anthropologists and experts from related fields. It was confirmed that there is a correlation between forearm length and body height (males: 31.9 %, females: 33.3 %).

KEY WORDS: Anthropometry; Prediction; Forearm Length; Montenegrin.

INTRODUCTION

The first records about the dimensions of man, his build and the relationships of parts are actually records that represent a set of unwritten rules, i.e. the law of composition, according to which paintings and sculptures in Egyptian art were shaped. When introducing the first measuring units, the ancient Egyptians used the human hand. The modern scientific practice of anthropometry has its roots in prominent figures such as Leonardo da Vinci and Albrecht Durer. In the book "Anthropometry" by Johan Sigismund Elsholtz, anthropometry takes shape as a science in the period of the emergence of modern tools for measuring the accompanying development of anatomy (Ulijaszek, & Mascie-Taylor, 2005; Albrizio, 2007).

The results of relevant studies based on the assessment of human body measurements of a certain population indicate that there are constant changes in body dimensions, so it is necessary to constantly update and collect anthropometric data (Hickson & Frost, 2003). Studies have confirmed that there is a certain correlation between body height and other potential parameters in different populations (Agnihotri *et al*., 2011). In the scientific literature, and it is also known that the measurement of body height is important in many situations (Agrawal, Mishra, Samantsinghar, & Chinara, 2013), it is necessary for the evaluation of the growth of children, for the calculation of nutritional indices in children and adults, the prediction and standardization of variables such as lung capacity (Amra, Jensen, & Golshan, 2007), muscle strength, standardization of measures of physical ability, to determine the correct dose in patients, etc. (Goon *et al*., 2011). In such situations, it is necessary to assess body height based on other reliable anthropometric indicators (Patel *et al*., 2012).

However, body height cannot always be determined precisely, especially in cases such as: e.g. paralysis, fracture, amputation and various deformities, such as: e.g. scoliosis, lordosis and kyphosis (Vukotic *et al*., 2021). In such cases, it is necessary to use some other parameter to predict body height, such as the length of the forearm, as well as a number

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of other less reliable indicators (Sandhya, 2015). Based on the mentioned anthropometric indicator, and on the basis of adequate formulas, it is possible to reach a result for the assessment of body height (Ilayperuma *et al*., 2009). Body height can be an important factor on which the success of athletes in various sports depends, and it can directly affect the success of a certain sports discipline. Then, it can be a good parameter for diagnosing people with different anomalies and loss of body height after spinal surgery (Mohanty *et al*., 2013), as well as for predicting its loss in old people (Sandhya, 2015).

Scientists Krishan & Sharma (2007) tried to estimate body height by combining forearm length. According to their conclusion, it is difficult to predict the physical identification of an individual. The results of this study show very significant *sex* differences, which require the need for separate data for both sexes. Based on other studies, it was determined that the length of the forearm is a reliable factor for estimating body height in women and men (Tang *et al*., 2012; Sandhya, 2015). For this reason, it is very important to determine the relationship between body height and forearm length in Montenegrins at the national level, primarily because in some cases it can be very important to determine body height with this anthropometric measure, for the above-mentioned reasons (Vukotic, 2020).

Therefore, the authors of this study expect specific features of forearm length in the adolescent population of both sexes, especially in Montenegro. Based on previous research, it can be seen that the assessment of body height compared to the length of the forearm as a potential predictor differs among different racial and ethnic groups, so the aim of this study is to determine the prediction of the longitudinal measure of the length of the forearm in the adolescent population in Montenegro based on the criterion of the variable body height, for both sexes separately.

MATERIAL AND METHOD

The sample in this research comprised 1200 adolescent, all of whom were in their final year of high school (604 males, 596 females) from the territory of Montenegro. There were two reasons for the selection of this population group, as follows: the first is connected with the fact that an individual's growth stops at this age, while the second is connected with the fact that there is no body weight loss at this age. The average age of the male subjects was 18.34±6.35 years (age span 18–20), while the average age of the female subjects was 18.81±3.43 years (age span 18–20). Also, it is important to point out that the authors excluded from the study adolescents with body deformities (scoliosis, kyphosis, lordosis, etc.), paralysis, fractures, amputations, and similar. The study complied with the Declaration of Helsinki.

Subjects which did not originate from the territory of Montenegro were also excluded from this research. According to Marfell-Jones *et al*. (2006), anthropometric measurements, including body height and forearm length, were taken in compliance with the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). The age of the subjects was determined by asking them to tell their date of birth.

Method of data processing. The statistical processing of the data was performed using the statistical programme (SPSS) 25.0. For both anthropometric variables, central and dispersive parameters were processed within the scope of basic statistics, as follows: range (minimum and maximum value), arithmetic mean and standard deviation. Linear regression analysis determined the prediction of forearm length on the criterion variable a body height at the significance level of $p < 0.05$. These relations are presented in the form of scatter diagram. Thereby, we obtained the coefficient of determination, the multiple correlation coefficients, the partial correlation coefficient, the regression, t-test and standardized beta coefficient.

RESULTS

The results of anthropometric measurements for both *sex* are shown in Table I. The average body height for males is 183.59± 4.28, ranked with minimum and maximum values of 164.1 - 203.4 centimetres, while the forearm length amounted to 19.12± 9.08 centimetres. In the case of females, the average body height amounts to 170.65± 3.43 centimetres ranked with minimum and maximum values of 170.65± 3.43 centimetres, while the forearm length amounted to 17.46 ± 8.22 centimetres (Fig. 1).

The results of the linear regression analysis are shown in Table II. In both sexs, the regression coefficients (R) are

Table I. Anthropometric measurements of the study subjects.

Subjects	Body Height Range	Forearm Length Subjects
	(Mean ± SD)	(Mean ± SD)
Male	164.1 - 203.4	17.1 – 22.3
	(183.59± 4.28)	(19.12± 9.08)
Female	154.1 - 184.7	15.1 - 20.9
	(170.65± 3.43)	(17.46 ± 8.22)

Table II. Results of linear regression analysis where the forearm length predicts the stature.

Subjects	R	R Square (%)	Adjusted R Square	Std. Error of the Estimate	t-value	p-value
Male	0.486[a]	.320	.319	45.543	18.041	.001*
Female	0.502[a]	.383	.333	43.543	18.842	.000*

identical to the correlation coefficients from the previous analysis and are very high. The high values of the regression coefficient (males: 0.486; females: 0.502) imply that the prediction of forearm length on stature is statistically significant, i.e. that forearm length can predict stature in the case of the Montenegrin population of both sexes (males t=18.041; p <0.000, females t= 18.842; p <0.000). Which is confirmed by R-coefficient (R Square) of determination R-coefficient (%) for males is 31.9 and for females 33.3. The first of these models was performed by including age as a covariate. Regression coefficient values imply that forearm length significantly predicts stature in Montenegrin adolescents of both sexes.

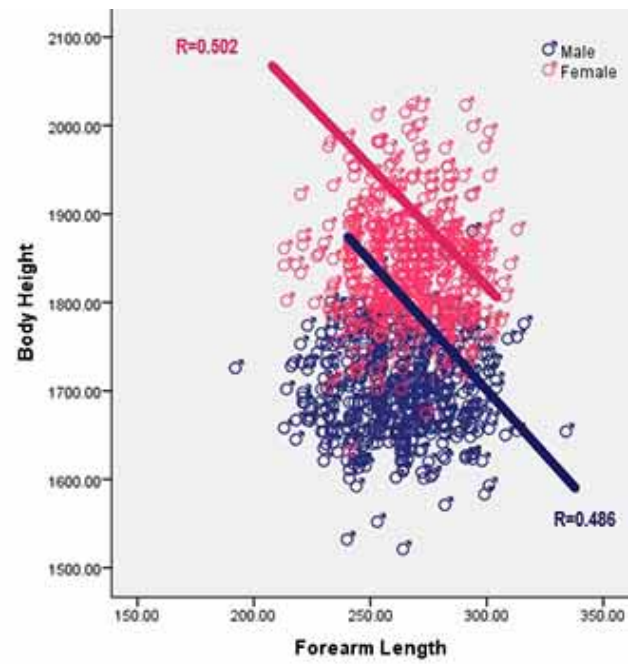

Fig. 1. Scatter Diagram and Relationship between Forearm Length Measurements and Body Height among Both Sexes

Information on the effect of predictor variable on criterion variable tested through a regression-based procedure, whose values are shown through Beta coefficient of regression (males: .234; females: .123), and standard errors of the regression coefficient (males: .234; females: .213) show confirmation of statistically significant impact of predictor variable on the criterion variable in both sexes of Montenegrin adolescents (Table III).

Table III. Results of coefficients regression analysis where the forearm length predicts the stature.

Subjects	Coefficients Beta	Std. Error	95% Confidence Lower	95% Confidence Upper
Male	.234	.234	3.345	3.436
Female	.123	.213	3.123	3.543

DISCUSSION

Based on previous research, it can be observed that the assessment of body height in relation to other anthropometric parameters as predictors differs in different racial and ethnic groups (Anas *et al*., 2010) This indicates the need for a study in which it will be possible to accurately define the relationship between body height and other longitudinal parameters of adolescents living in the territory of Montenegro, and through this research they want to examine the real anthropometric specificities of adolescents in Montenegro (Vukotic, 2022). Many studies have confirmed that there is a certain correlation between body height and other potential parameters in different populations (Ilayperuma *et al*., 2009). The results of this study will provide relevant data on the relationship between body height and forearm length at the national level in the Montenegrin population. The average body height of male respondents is 183.59± 4.28 cm and is similar to the average height of the tallest people in Europe. The average height of Montenegrin teenage girls is 170.65 ± 3.43 cm and is similar to the average height of the tallest women in the world. The conducted research additionally determines specific body proportions, primarily with the aim of improving information on the length of the forearm as a reliable predictor of body height. It has been confirmed in numerous studies that forearm length can explain 45 % of variations in relation to body height (Sandhya, 2015), this shows a significant correlation between body height in relation to other anthropometric parameters as potential predictors in both men and women (Ibegbu, 2013) The average forearm length of Montenegrin adolescents is (men: 19.12 ± 9.08 cm; women 17.46 ± 8.22 cm), which confirms the main goal of this study that the population in Montenegro has specific body proportions. Similar values were shown in the research conducted by Mohanty *et al*. (2013). It was confirmed that there is a significant correlation between forearm length and body

height (men: 31.9 %, women 33.3 %). Therefore, the length of the forearm proved to be a reliable predictor on the basis of which the actual body height can be estimated. The conducted research on the length of the forearm as a reliable predictor of body height is of additional importance, because it is the only research of this type conducted at the national level according to a proportional geographical sample, which is of crucial importance for further national and regional research of potential anthropometric predictors.

The results of this study can be used as initial information for further research based on the Montenegrin adolescent population, and confirm the need for the development of specific models when it comes to assessment in both sexes of the Montenegrin population. As a limitation of this research, it can be considered that the sample of this research consisted of final grade students, and in some studies it has been proven that the growth and development of the body has not yet ended at this age (Grasgruber *et al*., 2017). It is assumed that the full genetic potential of both sexes has not been achieved, because it is affected by various economic and socioecological factors (Arifi, 2018). This positive secular global change appears to be the result of gradual changes in nutrition, health care, education, environmental and economic conditions. One of the possibilities is that various factors potentially influence premature hormonal changes, ie. onset of puberty at an earlier age. On the other hand, in order to determine the relative body height, there is a need to conduct a study with a larger number of samples of different ages, where it would be determined whether these results will be the same or similar after reaching full growth and development. In the same way, we suggest to follow in detail the secular development, which is considered to have a great influence on the development of body height of adolescents living in Montenegro in the future, because the European sample showed realistic expectations based on previous experience (Fredriks *et al*., 2005).

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RESUMEN: El propósito de esta investigación fue determinar una ecuación de regresión para la estimación de la estatura a partir de medidas de la longitud del antebrazo. Esta investigación se llevó a cabo en 1200 sujetos (604 hombres y 596 mujeres) entre la población de adolescentes montenegrinos. Las medidas de estatura y longitud del antebrazo se tomaron de acuerdo con el protocolo ISAK y los datos se analizaron estadísticamente. El análisis de regresión lineal determinó la predicción de la longitud del antebrazo en la variable de criterio una altura del cuerpo en el nivel de significación de p <0,05. Estas relaciones se presentan en forma de diagrama de dispersión. De tal manera obtuvimos el coeficiente de determinación, los coeficientes de correlación múltiple, el coeficiente de correlación parcial, la regresión, la prueba t y el coeficiente beta estandarizado. Los resultados de este estudio confirmaron que la longitud del antebrazo predice de manera confiable la estatura en adolescentes montenegrinos de ambos sexos y reveló un hallazgo muy útil para los antropólogos físicos y expertos en áreas relacionadas. Se confirmó que existe una correlación entre la longitud del antebrazo y la altura del cuerpo (hombres: 31,9 %, mujeres: 33,3 %).

PALABRAS CLAVE: Antropometría; Predicción; Longitud del antebrazo; Individuos montenegrinos.

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