

Body Height and its Estimation Utilizing Hand Length Measurements in Montenegrin: National Survey

Altura del Cuerpo y su Estimación Utilizando Medidas de Longitud de la Mano en Montenegrino: Encuesta Nacional

Marina Vukotic¹

VUKOTIC, M. Body height and its estimation utilizing hand length measurements in montenegrin: National survey. *Int. J. Morphol.*, 40(2):396-400, 2022.

SUMMARY: The purpose of this research is to determine a regression equation for estimation of stature from hand length measurements. This research was carried out on 1001 subjects (504 male and 497 female) among the population of Montenegrin adolescents. The stature and hand length measurements were taken according to the ISAK protocol, and the data were analyzed statistically; the relationships between stature and hand length measurements were derived using simple correlation. A comparison of the means of hand length measurements between sex was performed using a t-test, while a linear regression analysis was employed to examine the extent to which hand length t measurements can reliably predict stature. The results of this research study confirmed that hand length reliably predicts stature in both sexes of Montenegrin adolescents and revealed a very useful finding for physical anthropologists and experts from related fields.

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

INTRODUCTION

The research of the proportions in the relations of body proportions and the consequences of their variations enables us to have information of numerous fields of additional scientific research. Precisely because of the diversity of research, anthropometry was in the past appealing to scientists and artists such as Leonardo da Vinci and Albrecht Dürer. As a science, anthropometry starts to take its shape from the emergence of modern tools for the measurement of the accompanying development of anatomy (Ulijaszek & Mascie-Taylor, 2005; Albrizio, 2007). At the end of the 19th century, anthropometry became a new apparatus for medicinal practice and taxonomy as a way of measuring the overall health. Anthropometry is manifested in the measuring of the body height and width for the purpose of establishing the environmental effects on development during childhood (Ercan *et al.*, 2012). Many research endeavors have confirmed that anthropometry is in various ways significant for the measurement of individual body parts, i.e. for the provision of key data, used to quantitatively determine morphological features and to assess the objective picture of human growth (Chandra *et al.*, 2009).

Anthropometric measures represent important human characteristics whose development is affected by external factors, territorial and geographic areas of a specific population, as inward genetic factors (Popovic, 2019). The physical growth of humans is mainly influenced by genetic and environmental factors. Different dimensions of the physical growth are mainly influenced by the genetic factor, whereas the influence varies depending on the sex, age, etc. (Lai *et al.*, 2005). Body height is the main anthropometric parameter for the estimation of individuals and is significant in many situations (Gupta *et al.*, 2018). In addition, it is necessary for the evaluation of child growth for the calculation of nutrition indices of children and adults (Ibegbu, 2013), the prediction and standardisation of variables such as lung capacity, muscle strength, the standardisation of physical ability measures for the determination of a patient's proper dose, etc. (Golshan *et al.*, 2007). Furthermore, it can be a good parameter for diagnosing persons with various anomalies and body height loss after doctor medicinal activity on the spine (Mohanty *et al.*, 2001), as well as for predicting its loss in the case of the elderly (Popovic *et al.*,

¹ Faculty for Sport and Physical Education, University of Montenegro, Niksic, Montenegro.

2017). However, it is not always possible to determine precisely the height of the body, especially including the cases, for example, paralysis, fracture, amputation and various, deformities such as scoliosis, lordosis and kyphosis. In such cases, it is necessary to apply some other parameter for the estimation of body height. The prominent height of the Montenegrins is a fact which was promoted by European anthropology scientist more than 100 years ago. Robert V. Ehrlich measured the Montenegrin population and obtained data indicating that the Montenegrins could possibly have the highest average in all of Europe (Coon, 1975). Moreover, a study conducted by Pineau *et al.* (2005) showed that the population of the Dinaric Alps is on average the highest in Europe.

In order to conduct a comprehensive altitude survey, it is necessary to establish a reliable predictor, the fact that fist length is one of the reliable predictors of body height is confirmed by a study conducted in Egypt, which found a high linear correlation between body height and hand length (Muhmed, 2013). In some studies, where different body parameters have been used to predict body height, arm span has been shown to be the most reliable predictor of body height (Arifi, 2018), while hand length is a more reliable predictor of body height during adolescence, since shorter bone growth ends sooner than long bone growth (Amirshaybani *et al.*, 2000). Some contemporary scholars have attempted to estimate body height by combining forearm and fist lengths, and have found that height assessment is a major cause of controversy and research in forensics and anthropology (Choudhary *et al.*, 2014). Positive correlation have been found between body height and hand length in different populations and a regression coefficient has been offered (Varu *et al.*, 2015), however, the regression formula in one population is not always unique to another population and studies indicate the need to study population specificity.

For this reason, it is very important to establish the relationship between body height and hand length in Montenegrins at the national level-which has not been done yet-primarily because in some cases it can be very important to use precisely this anthropometric measure to determine body height, due to the above mentioned reasons.

MATERIAL AND METHOD

The sample in this research comprised 1001 adolescent, all of whom were in their final year of high school (504 males, 497 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 18.68 ± 0.35 years (age span 18–20), while the average age of the female subjects was 18.70 ± 0.33 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 hand 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. A t-test was used to verify the differences in the arithmetic means of anthropometric variables in relation to the subject's sex. The link between body height hand length and was processed using a correlation analysis with a reliability of 95 %. A linear regression analysis was used to determine the prediction of hand length on the criterion variable of body height with a significance level of $p < 0.05$. These relations are shown in a scatter diagram (Fig. 1).

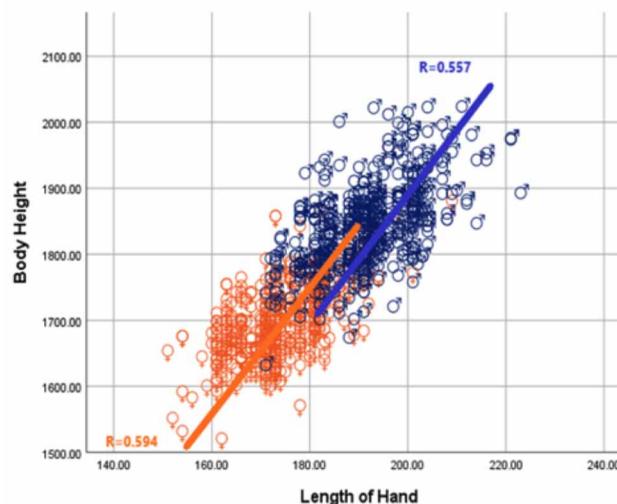


Fig. 1. Scatter diagram and relationship between hand length measurements and body height among both sexes.

RESULTS

The results of anthropometric measurements for both sexes are shown in Table I. The average body height for males is 184.09± 6.28, ranked with minimum and maximum values of 163.2-202.4 centimetres, while the hand length amounted to 19.12±9.08 centimetres. In the case of females, the average body height amounts to 170.27± 5.41 centimetres ranked with minimum and maximum values of 152.1-188.1 centimetres, while the hand length amounted to 17.46±8.22 centimetres. The sex difference was statistically significant (body height $t=37.273$; $p<0.000$, i hand length $t=30.954$; $p<0.000$).

Table II shows the results of the correlation analysis between stature and hand length with a confidence level of 95 % for subjects of both sexes. The connection, i.e. correlation between body height and hand length is statistically significant at the level of $p < 0.000$, both in case of male and female subjects. Correlation coefficients are very high: in the case of male subjects, this coefficient is 0.557, while in the case of female subjects, it amounts to 0.594. The results of the linear regression analysis are shown in Table III. In both sexes, the regression coefficients are identical to the correlation coefficients from the previous analysis and are very high. The high values of the regression coefficient (males: 0.557; females: 0.594) imply that the prediction of hand length on stature is statistically significant, i.e. that hand length can predict stature in the case of the Montenegrin population of both sexes (males $t=21.252$; p

<0.000 , females $t=16.430$; $p < 0.000$). Which is confirmed by R-coefficient of determination R-coefficient (%) for males is 31.1 and for females 35.2. The first of these models was performed by including age as a covariate. However, it was determined that the contribution of age was insignificant, so age was rejected, and the assessment was performed as a univariate analysis. Regression coefficient values imply that foot length predicts stature in Montenegrin adolescents of both sexes.

The relationship between the measurements of hand length and stature among the above mentioned models is shown using a scatter diagram (Fig. 1).

DISCUSSION

Anthropometry is significant in many ways for the measurement of individual body parts, i.e. for the provision of key data, used to quantitatively determine morphological features and to assess the objective picture of human growth (Chandra *et al.*). Consequently, anthropometry is becoming a new tool for clinical practice and taxonomy as a way of measuring the overall health. Anthropometric measures represent important human characteristics whose development is affected by external factors, territorial and geographic areas of a specific population, as well as internal genetic factors (Popovic). When population groups share the same genetic basis and live in similar environmental conditions, the average body height is often characteristic within the population (Bjelica *et al.*, 2012). For the purpose of this study, it is important to point out that the majority of the Montenegrin population is of the same origin, whereas the variations in their ethnicity are a result of ideological concepts and their religious beliefs. Studies have confirmed that there is a specific correlation between stature and other potential parameters in different populations (Agnihotri *et al.*, 2011).

The results presented in this study will provide relevant data on the correlation between stature and hand length among the Montenegrin population at the national

Table I. Anthropometric measurements of the study subjects.

Subjects	Body Height Range (Mean ± SD)	Hand Length Subjects (Mean ± SD)
Male	163.2 - 202.4 (184.09± 6.28)	17.1 – 22.3 (19.12± 9.08)
Female	152.1 - 188.1 (170.27± 5.41)	15.1 - 20.9 (17.46 ± 8.22)

Table II. Correlation between stature and hand length of the study subjects.

Subjects	Correlation Coefficient	95 % confidence interval	Significance p-value
Male	0.557	0.515 – 0.611	0.000
Female	0.594	0.531 – 0.653	0.000

Table III. Results of linear regression analysis where the hand length predicts the stature.

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Male	0.557	52.074	31.1	21.252	0.000
Female	0.595	43.630	35.2	16.430	0.000

level. The average body height of the male subjects equals 184.09 ± 6.28 cm and is similar to the average height of the tallest nations in Europe. The average body height of Montenegrin female adolescents equals 170.27 ± 5.41 cm and is similar to the average height among the tallest women in the world. The conducted research further elaborates the specific body proportions, primarily with the aim of improving the information on hand length as a reliable predictor of body height. Numerous studies have confirmed that hand length can account for 50 % of variations in relation to stature (Varu *et al.*), which indicates a correlation between body height and other anthropometric parameters as potential predictors in the case of both sexes. The above stated points to the necessity of developing separate models for the assessment of body height in relation to other anthropometric parameters. The average hand length of Montenegrin adolescents equals (males: 19.12 ± 9.08 cm; females: 17.46 ± 8.22 cm), which confirms the main notion of this study that the population of Montenegro has specific body proportions. The research conducted by Arifi *et al.* (2017) has demonstrated similar values. It was confirmed that there is a significant correlation between hand length and body height (males: 31.1 %, females: 35.1 %). Therefore, hand length has proven to be a predictor on the basis of which the actual body height can be estimated. The conducted research of hand length as a reliable body height predictor is of additional importance, because it is the only research of its kind that was conducted at the national level in accordance with proportional geographic sampling, which is also of crucial importance for future national and regional research of potential anthropometric predictors.

The results of this study can be used as baseline information for future research based on the Montenegrin adolescent population, and they confirm the need for the development of specific model when it comes to the analysis of both sexes of the Montenegrin population. It is important to note the comparison with the research on the body height of adolescents in Montenegro (Bjelica *et al.*), which reveals a lower body height than the one among the subjects in this research. Based on the above, additional questions arise in regard to the potential causes of differences in stature, primarily because some authors presume that the body's growth and development do not stop at this age, (Grasgruber *et al.*, 2017), because the full genetic potential of both sexes has not been achieved yet, and there are different economic and socioecological factors affecting it (Arifi), which was confirmed by this research. The period of secular growth, especially at the pace of growth, coincided with some studies conducted in the Australian population (Loesch *et al.*, 2000). This positive secular change seems to be the result of gradual changes in nutrition, health care and education in environmental and economic conditions. One possibility is

that different factors potentially affect premature hormonal changes, i.e. the onset of puberty at an earlier age. The obvious limitation of this study is the fact that neither of the Montenegrin genders have reached the full genetic potential and that a positive secular trend can significantly change the facts confirmed in this study. Control over the established facts in this study is necessary from time to time, because European sample showed realistic expectations based on previous experience (Fredriks *et al.*, 2005), and in the next two or three decades secular changes will occur, which will result with disrupted previously established relations.

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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 de la mano. Este estudio se llevó a cabo en 1001 sujetos (504 hombres y 497 mujeres) entre la población de adolescentes montenegrinos. Las medidas de estatura y longitud de mano se tomaron de acuerdo con el protocolo ISAK, y los datos se analizaron estadísticamente; las relaciones entre las medidas de estatura y longitud de la mano se derivaron mediante correlación simple. Se realizó una comparación de las medias de las medidas de la longitud de la mano entre sexos mediante una prueba t, mientras que se empleó un análisis de regresión lineal para examinar hasta qué punto las medidas t de la longitud de la mano pueden predecir la estatura de forma fiable. Los resultados de este estudio confirmaron que la longitud de la mano predice de manera confiable la estatura en adolescentes montenegrinos de ambos sexos y reveló un hallazgo muy útil para antropólogos físicos y expertos en áreas relacionadas.

PALABRAS CLAVE: Predicción; Antropometría; Longitud de la mano; Montenegrino.

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Corresponding author:

Marina Vukotic
Teacher Assistant
University of Montenegro
Faculty for Sport and Physical Education
Narodne omladine bb
81400 Niksic
MONTENEGRO

E-mail: marina.vukotic82@gmail.com
marinavuk@ucg.ac.me