ISSN (electrónico): 1699-5198 - ISSN (papel): 0212-1611 - CODEN NUHOEQ S.V.R. 318

ARÁN

Nutrición Hospitalaria

Trabajo Original

Valoración nutricional

Body height and its estimation utilizing foot length measurements in Montenegrin adolescents: a national survey

Uso de la medida de la longitud del pie como estimación de la estatura en la Encuesta Nacional de Montenegro

Marina Vukotic

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

Abstract

Background: the purpose of this research was to determine a regression equation for the estimation of stature based on foot length measurements.

Methods: this research was carried out in 1,001 subjects (504 male and 497 female) from the population of Montenegrin adolescents. The stature and foot length measurements were taken according to the ISAK protocol, and the data were analyzed statistically. A linear regression analysis determined the prediction of foot length for the criterion variable of body height at a significance level of $p < 0.05$. These relations are presented in the form of a scatter diagram. We obtained the coefficient of determination, multiple correlation coefficients, a partial correlation coefficient, the regression, a t-test and a standardized beta coefficient.

Results: the results of this research study confirmed that foot length reliably predicts stature in Montenegrin adolescents of both genders, and revealed a very useful finding for physical anthropologists and experts from related fields.

Conclusions: it was confirmed that there is a correlation between foot length and body height (males: 41.9 %, females: 44.3 %). Therefore, foot length has proven to be a reliable predictor on the basis of which actual body height can be estimated.

Keywords:

Prediction. Anthropometry. Foot length. Montenegrin.

Resumen

Antecedentes: el propósito de esta investigación es establecer una ecuación de regresión para la estimación de la estatura a partir de la medida de la longitud del pie.

Métodos: la investigación se realizó en una muestra de 1001 adolescentes montenegrinos (504 varones y 497 mujeres). La medición de la estatura y la longitud del pie se realizaron de acuerdo con el protocolo ISAK. Estudio estadístico: la relación entre estatura y longitud del pie se hizo mediante correlación simple. La comparación de medias entre sexos se realizó mediante t de Student; para el estudio de valoración de la fiabilidad de la medida de la longitud del pie como estimador de la estatura se usó una regresión lineal.

Resultados: los resultados confirmaron que la medida de la longitud del pie predice de una forma fiable la estatura en ambos sexos en adolescentes de Montenegro. Este hallazgo puede ser de gran utilidad para los antropometristas y otras áreas relacionadas.

Conclusiones: se confirmó que existe una buena correlación en la medida de la longitud del pie y la estatura (varones 41,9 %, mujeres 44,3 %). Por lo tanto, esta medida puede ser un predictor fiable a partir de la cual se puede estimar la estatura.

Palabras clave:

Predicción. Antropometría. Longitud del pie. Montenegro.

Received: 20/02/2020 • Accepted: 03/04/2020

All ethical guidelines, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc., have been completely observed by the author.

Conflicts of interest: The author declares none. No financial or nonfinancial benefits have been received or will be received from any activity directly or indirectly related to the subject of this article.

Vukotic M. Body height and its estimation utilizing foot length measurements in Montenegrin adolescents: a national survey. Nutr Hosp 2020;37(4):794-798

DOI: http://dx.doi.org/10.20960/nh.03056

Correspondence:

Marina Vukotic. Faculty of Sport and Physical Education. University of Montenegro. Narodne omladine bb. 81400 Niksic, Montenegro
e-mail: marina.vukotic82@gmail.com; marinavuk@ucg.ac.me

INTRODUCTION

The research of proportions and their relations between body parts, as well as the consequences of their variations, allows to obtain information on numerous fields of additional scientific research (6). The physical growth of humans is mainly influenced by genetic and environmental factors (22). Different dimensions of physical growth are mainly influenced by genetic factors, and their influence also varies depending on gender, age, etc. (16). Body height is a primary anthropometric parameter and is significant in many situations (13). In addition, it is necessary for the evaluation of child growth, for the calculation of nutrition indices in children and adults (15), for the prediction and standardization of variables such as lung capacity and muscle strength, for the standardisation of physical ability measures, for the determination of a patient's proper dose, etc. (10). Furthermore, it can be a good parameter for diagnosing persons with various anomalies and body height loss after medical interventions on the spine (19), as well as for predicting height loss in the elderly (26). However, it is not always possible to determine precisely body height, especially in cases of, for example, paralysis, fracture, amputation, and various deformities such as scoliosis, lordosis and kyphosis (32). In such cases it is necessary to apply some other parameter for the estimation of body height. The prominent height of Montenegrins is a fact that was promoted by European anthropology scientists more than 100 years ago. Robert V. Ehrich (8) measured the Montenegrin population and obtained data indicating that Montenegrins could possibly have the greatest average height in all of Europe. Moreover, a study conducted by Pineau, Delamarche and Bozinovic (24) showed that the population of the Dinaric Alps is on average the highest population in Europe.

In order to carry out comprehensive stature research, it is necessary to determine a reliable predictor. The fact that foot length is one of the most reliable predictors of body height was confirmed in a study conducted by authors from China (7), where a high linear correlation was established between stature and foot length. Furthermore, research conducted by Popovic, Arifi and Bjelica (25) established that foot length reliably predicts stature on a sample of Kosovars, but not as reliably as arm span. The results obtained in a study conducted in Egypt (21) showed that, in both genders, foot length demonstrated the highest correlation with stature. In some studies—in which different body parameters for stature prediction were applied—it was revealed that arm span is the most reliable stature estimation predictor in adults (3), whereas foot length is a more reliable stature predictor during the adolescence period, because short bones stop growing earlier than long bones (27). Foot length was found to be increasing significantly on weight bearing between 3 and 18 years of age in both genders (22). Many scientists in the field of medicine studied different aspects of the foot for a long period of time (23), because in traffic and aviation accidents feet often remain intact thanks to the shoes, so it is possible to determine the person's stature and gender on the basis of foot length.

For this reason, it is very important to establish a relationship between body height and foot length in Montenegrins at a 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. So the authors of this study expect specificities of foot length in the adolescent population of both genders in Montenegro. Based on the research done so far, it can be observed that the estimation of body height in comparison with foot length as potential predictor differs among different racial and ethnic groups, so the aim of this study was to determine the prediction of the longitudinal measure of foot length in the adolescent population of Montenegro about the variable body height in both genders separately.

MATERIAL AND METHOD

The sample in this research comprised 1,001 adolescents, all of whom were in their final year of high school (504 males, 497 females) in 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 any adolescents with body deformities (scoliosis, kyphosis, lordosis, etc.), paralysis, fractures, amputations, etc. The study complied with the Declaration of Helsinki.

Subjects who did not originate in the territory of Montenegro were also excluded from this research. According to Marfell-Jones, Olds, Stewart, and Carter (18), anthropometric measurements, including body height and foot 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 v. 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 linear regression analysis determined the prediction of foot length on the criterion variable of body height at a significance level of $p < 0.05$. These relations are presented in the form of a scatter diagram. Thereby, we obtained the coefficient of determination, the multiple correlation coefficients, the partial correlation coefficient, the regression, the t-test, and the standardized beta coefficient.

RESULTS

The results of the anthropometric measurements for both genders are shown in table I. The average body height for males was 184.09 ± 6.28, with a range of 163.2-202.4 centimetres, while foot length amounted to 26.96 ± 1.48 centimetres. In the case of females, average body height was 170.27 ± 5.41 centimetres with a range of 152.1-188.1 centimetres, whereas foot length amounted to 24.43 ± 1.06 centimetres.

The results of the linear regression analysis are shown in table II. In both genders, the regression coefficients (R) are identical to the correlation coefficients from the previous analysis, and are very high. The high values of regression coefficients (males: 0.648; females: 0.666) imply that the prediction of foot length on stature is statistically significant, i.e., that foot length can predict stature in the case of the Montenegrin population of both genders (males, $t = 19.041$; $p < 0.000$; females, $t = 19.842$; $p < 0.000$). This is confirmed by the R-coefficient (R square) of the determination: the R-coefficient (%) for males is 41.9 and for females 44.3. The first of these models was performed by including age as a covariate. The regression coefficient values imply that foot length significantly predicts stature in Montenegrin adolescents of both genders.

Information on the effect of the predictor variable on the criterion variable tested through a regression-based procedure, whose values are shown through a beta coefficient of regression (males: 0.006; females: 0.012) and standard errors of the regression coefficient (males: 0.170; females: 0.167) show confirmation of a statistically significant impact of the predictor variable on the criterion variable in both genders of Montenegrin adolescents.

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

Table I. Anthropometric measurements of the study subjects

Subjects	Body height range (mean ± SD)	Foot length (mean ± SD)
Male	163.2-202.4 (184.09 ± 6.28)	23.2-30.9 (26.96 ± 1.22)
Female	152.1-188.1 (170.27 ± 5.41)	20.9-28.0 (24.43 ± 1.06)

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

Subjects	Coefficients Beta	Std. Error	95 % confidence interval	
			Lower	Upper
Male	0.112	0.170	3.007	3.657
Female	0.034	0.167	3.041	3.701

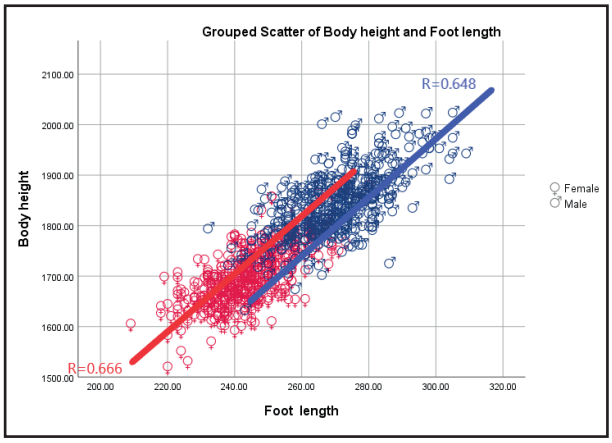

Figure 1.

Scatter diagram and relationship between foot length measurements and body height in both genders.

DISCUSSION

Many studies have confirmed that there is a specific correlation between stature and other potential parameters in different populations (1). The results presented in this study will provide relevant data on the correlation between stature and foot length among the Montenegrin population at a national level. The average body height of 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 on the specific body proportions, primarily with the aim of improving the information on foot length

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

Subjects	R	R square (%)	Adjusted R square	Std. error of the estimate	t-value	p-value
Male	0.648[a]	0.419	0.418	47.811	19.041	0.000*
Female	0.666[a]	0.443	0.442	40.478	19.842	0.000*

as a reliable predictor of body height. Numerous studies have confirmed that foot length can account for 77 % of variations in relation to stature (30), which indicates a significant correlation between body height and other anthropometric parameters as potential predictors in the case of both genders among the Slovene population, whereas the highest correlation coefficient was detected for the variable of foot length (males, $r = 0.71$; females, $r = 0.63$). The above points to the necessity of developing separate models for the assessment of body height in relation to other anthropometric parameters. The average foot length of Montenegrin adolescents is: males, 26.96 ± 1.22 cm; females, 24.43 ± 1.06 cm), which confirms the main notion of this study that the population of Montenegro has specific body proportions. The research conducted by (2) has demonstrated similar values. It was confirmed that there is a correlation between foot length and body height (males: 41.9 %, females: 44.3 %). Therefore, foot length has proven to be a reliable predictor on the basis of which actual body height can be estimated. The conducted research of foot length as a reliable body height predictor is of additional importance because it is the only research of its kind that was conducted at a national level in accordance with proportional geographic sampling, which is also of crucial importance for future national and regional research on 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 a specific model when it comes to the analysis of both genders of the Montenegrin population. It is important to note the comparison with the research on the body height of adolescents in Montenegro (4), which reveals a lower body height as compared to 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, (12) because the full genetic potential of both genders has not been achieved yet, and there are different economic and socioecological factors affecting it (3), which was confirmed by this research. The period of secular growth, especially the pace of growth, coincided with some studies conducted in the Australian population (17). This positive secular change seems to be the result of gradual changes in nutrition, health care, and education in environmental and economic conditions (11). One possibility is that different factors potentially affect premature hormonal changes, i.e., the onset of puberty at an earlier age. Adolescents experience several types of maturation (28). The complex series of biologic transitions are known as puberty, and the most visible changes during puberty are growth in stature and development of secondary characteristics (20). However, many studies have used variations of Tanner's original description (29). The majority of studies have combined the secondary sexual characteristics (5). Improvement of the method may validate its use in population-based studies. Sexual development and maturation is essential for the appropriate assessment of growth in children and adolescents, and is of paramount importance to the analysis of adequate growth and of adequate timing of pubertal development of an individual (31).

The obvious limitation of this study is the fact that neither of the Montenegrin genders has reached its full genetic potential, and that a positive secular trend can significantly change the facts confirmed in this study. Based on this reasoning, a prerequisite is the establishment of adequate control of the facts, on a regular basis, as there are evident expectations based on the European sample (5), which forsee secular changes in stature in the following decades; therefore, all current assumptions will be questioned.

REFERENCES

1. Agnihotri A, Kachhwaha S, Googoolye K, Allock A. Estimation of stature from cephalo-facial dimensions by regression analysis in Indo-Mauritian population. Journal Forensic Legal Medicine 2011;18(5):167-72. DOI: 10.1016/j.jflm.2011.02.006
2. Arifi F, Bjelida D, Sermaxhaj S, Gardasevic J, Kezunovic M, Popovic S. Stature and Its Estimation Ulilizing Arm Span Measurements in Kosovan Adults: National Survey. International Journal of Morphology 2017;35(3):1161-7. DOI: 10.4067/S0717-95022017000300055
3. Arifi F. Stature of Adolescents in Kosovo and its Relationship with Other Anthropometric Measures as Potential Predictors. Doctoral Dissertation, University of Montenegro: Faculty for Sport and Physical Education, Niksic; 2018.
4. Bjelica D, Popović S, Kezunović M, Petković J, Jurak G, Grasgruber G. Body height and its estimation utilizing arm span measurements in Montenegro adults. Anthropological Notebooks 2012;18(2):69-83.
5. Boas SR, Falsetti D, Murphy TD, Orenstein DM. Validity of self-assessment of sexual maturation in adolescent male patients with cystic fibrosis. J Adolesc Health 1995;17(4):42-5. DOI: 10.1016/1054-139X(95)00042-Q
6. Chandra A, Chandna P, Deswal S, Kumar R. Ergonomics in the office enviroment; A review. In Proceedings of the international Conference of Energy and Environment. Chandigarh, Haryana, India; 2009.
7. Cheng JC, Leung SS, Chiu BS, Tse PW, Lee CW, Chan AK, et al. Can we predict body height from segmental bone lenght measurement? A study of 3,647 children. Journal of Pediatric Orthopeadics 1998;18:387-93. DOI: 10.1097/01241398-199805000-00022
8. Coon CS. The Race of Europe. Westport, Greenwood Press; 1975; pp. 587-95.
9. Fredriks AM, Buuren S, Heel WJ, Dijkman-Neerincx RH, Verloove-Vanhorick SP, Wit JM. Nationwide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. Arch Dis Child 2005;90(8):807-12. DOI: 10.1136/adc.2004.050799
10. Golshan M, Crapo RO, Amra B, Jensen RI, Golshan R. Arm span as an independent predictor of pulmonary function parameters: Validation and reference values. Respirology 2007;12:361-6. DOI: 10.1111/j.1440-1843.2007.01070.x
11. Goran MI, Gower, BA. Longitudinal study on pubertal insulin resistance. Diabetes 2001;50(5):2444-50.
12. Grasgruber P, Popovic S, Bokuvka D, Davidovic I, Hrebícková S, Ingrová P, et al. The mountains of giants: an anthropometric survey of male youths in Bosnia and Herzegovina. R Soc Open Sci 2018;4(4):161054.
13. Gupta C, Palimar V, Guru P. Estimation of stature from the arm span of an individual in South Indian population. Annals of Bioanthropology 2003;4(1):17-9.
14. Hickson M, Frost G. A comparison of three methods for estimating height in the acutely ill elderly population. J Hum Nutr Diet 2003;(16):13 20.
15. Ibegbu AO. Association of Hand Length with Height in Nigerian School Children. Journal of Biology and Life Science 2013;4(2):83-92.
16. Lai C, Parnell L, Ordovas J. The APOA1/C3/A4/A5 gene cluster, lipid metabolism and cardiovascular disease risk. Curr Opin Lipidol 2005;6(2):153-66.
17. Loesch DZ, Stokes KM, Huggins RM. Secular trend in body height and weight of Australian children and adolescents. Am J Phis Anthropol 2005;111(4):545-56.
18. Marfell-Jones M, Olds T, Stew AD, Carter JEL. International standards for anthropometric assessment. Potchesfstroom: International Society for the Advancement of Kinanthropometry; 2006.

19. Mohanty SP, Babu SS, Nair NS. The use of arm span as a predictor of height. A study of South Indian women. Jornal Orthopedic Surgery (Hong Kong) 2001;9(1):19-23.
20. Moran A, Jacobs DR, Steinberger J. Insulin resistance during puberty: results from clamp studies in 357 children. Diabetes 1999;48(1):2039-44.
21. Muhmed MH (2013). Measurement of foot and hand dimensions and their correlation with height in adult upper Egyptians. Al-Alhar Assiut Medical Journal 10(4):300-16.
22. Peker T, Turgut HB, Anil A, Ulukent SC. An examination of the relationship between foot length, T1, T2, T3, T4, T5 (toe lengths), ankle circumference and calf circumference of Turkish University students aged between 17–25 years. Morphologie 1997;81(254):13-8.
23. Philip TA. Formulae for establishing stature from foot size by regression method. J Ind Acad Forensic Med 1990;12:57-62.
24. Pineau JC, Delamarche P, Bozinovic S. Average height of adolescents in the Dinaric Alps. Comptes Redus Biologies 2005;328(9):841-6. DOI: 10.1016/j.crvi.2005.07.004
25. Popović S, Arifi F, Bjelica D. Standing Height and its Estimation Utilizing Foot Length Measurements in Adolescents in Kosovan Adults: National Survey. International Journal of Applied Exercise Physiology 2017;6(2):1-7. DOI: 10.22631/ijaep.v6i2.150
26. Popovic S. Nationwide Stature Estimation from Sitting Height Measurements in Kosovan Adolescents. International Journal of Morphology 2019;37(2):504-8. DOI: 10.4067/S0717-95022019000200504
27. Singh A, Kumar A, Khavali HK, Harish D. Use of arm-span and foot lenght for estimation of height of the person. Journal Punjab Acad Forensic Med Toxicol 2012;12(2):87-91.
28. Tanner JM. Growth at adolescence. 2nd ed. Oxford: Blackwell Scientific; 1962.
29. Travers SH, Jeffers BW, Bloch CA, Hill JO, Eckel RH. Gender and Tanner stage differences in body composition and insulin sensitivity in early pubertal children. J Clin Endocrinol Metab 1995;80(4):172-8.
30. Urhova P, Benus R, Masnicova S, Obertova Z, Kramarova D, Kyselicova K, et al. Estiamtion of stature using hand and foot dimensions in Slovak adults. Legal medicine 2015;17(2):92-7. DOI: 10.1016/j.legalmed.2014.10.005
31. Uwaifo GI, Nguyen TT, Keil MF. Differences in insulin secretion and sensitivity of Caucasian and African American prepubertal children. J Pediatr 2002;140(8):673-80. DOI: 10.1067/mpd.2002.124312
32. Waghmare V, Gaikwad R, Herekar N. Estimation of the stature from the antropometric measurment of the hang length. The Internet of Biological Anthropology 2010;4(2):1-5.