Bojan Masanovic [1] *
Dusko Bjelica [1]
Stevo Popovic [1]
Jovan Gardasevic [1]

ESTIMATION OF BODY HEIGHT IN MONTENEGRIN ADULTS USING FOOT LENGTH MEASUREMENTS: NATIONAL SURVEY

OCENA TELESNE VIŠINE S POMOČJO DOLŽINE STOPALA PRI ČRNOGORCIH: NACIONALNA RAZISKAVA

ABSTRACT

The aim of this research was to examine the body height of Montenegrin adults - students of the University of Montenegro of both sexes, and the foot length which was used as an alternative to estimating the body height. The nature and scope of this study was to analyze 713 individuals (370 men, aged 21.78±2.13 and 343 women, aged 21.01±1.57). The protocol of the ISAK was used for anthropometric measurements. Means and standard deviations were obtained. The t-test was used to compare the means of foot lengths and body heights between the sexes. The relationship between body heights and foot lengths was determined by using simple correlation coefficients and their 95% confidence interval. A linear regression analysis was then performed to examine the extent to which foot length can be a reliable predictor body height. The results have shown that Montenegrin males are 183.23±7.16 centimeters tall and have a foot length of 26.85±1.55 centimeters, and Montenegrin females are 168.38±6.78 centimeters tall and have a foot length of 24.13±1.29 centimeters. In accordance with previous studies, it has been confirmed that Montenegrin adults are the second highest nation in Europe, with both sexes. It was also confirmed that foot length reliably predicts body height for both sexes.

Keywords: body height, foot length, Montenegrin adults, measurement, prediction

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

IZVLEČEK

Namen raziskave je bil preučiti telesno višino odraslih Črnogorcev - študentov Univerze Črne gore obeh spolov in dolžine stopala, ki je bila uporabljena kot alternativa za oceno telesne višine. Narava in obseg te študije je bila analiza 713 posameznikov (370 moških, starih 21,78±2,13 let in 343 žensk, starih 21,01±1,57 let). Za antropometrične meritve smo uporabili protokol ISAK. Dobili smo povprečje in standardne deviacije. T-test je bil uporabljen za primerjavo povprečja dolžine stopal in telesne višine med spoloma. Razmerje med telesno višino in dolžino stopal je bilo določeno z uporabo preprostih korelacijskih koeficientov in njihovega 95-odstotnega intervala zaupanja. Nato je bila izvedena linearna regresijska analiza, s katero smo ugotavljalo, v kolikšni meri je dolžina stopala lahko zanesljiv napovedovalec telesne višine. Rezultati so pokazali, da so črnogorci visoki 183,23±7,16 centimetra in imajo dolžino stopala 26,85±1,55 centimetra, črnogorke pa 168,38±6,78 centimetra in dolžino stopala 24,13±1,29 centimetra. V skladu s prejšnjimi študijami je bilo potrjeno, da so odrasli Črnogorci drugi najvišji narod v Evropi, tako za moške kot za ženske. Ugotovili smo tudi, da dolžina stopala zanesljivo napoveduje telesno višino obeh spolov.

Ključne besede: telesna višina, dolžina stopala, odrasli Črnogorci, meritev, napoved

Corresponding author: Bojan Masanovic*, *University of Montenegro*, *Faculty for Sport and Physical Education*, *Narodne omladine bb, Niksic, Montenegro*
E-mail: bojanma@ucg.ac.me

INTRODUCTION

The Republic of Montenegro extends to the surface of 13,812 sq. kilometers and borders Croatia, Bosnia and Herzegovina, Serbia, Kosovo (as defined under UNSCR 1244/99), Albania and the Adriatic Sea in the south-west of the Balkan Peninsula (Figure 1).

Figure 1. Geographical Location of Montenegro.

According to the 2011 census (Monstat 2011), the population of this area numbered 620,029 inhabitants: 50.61% are women, and 49.39% are men. The main features of the ethnic structure of the population of Montenegro areas follows: 44.98% of the population is Montenegrins, 28.73% are Serbs, 8.65% are Bosnians, and 4.91% are Albanians, etc. The authors look on all people who live in Montenegro as Montenegrins, as these populations live in the same environmental conditions and share a genetic background, where the average height is characteristic within the group. Montenegrin highlanders are recognized by European anthropologists more than 100 years ago as people of unusual height. The highest average in all of Europe (177 cm), with some districts approaching 178 centimeters, was given after measuring the sample of 800 Montenegrin men measured by Robert W. Ehrich (Coon, 1975) at the beginning of the 20th century. Some authors also contributed to an update of average body heights among European populations (Pineau, Delamarche, & Božinović, 2005). The researches carried out by European anthropologists a century ago, have proved the assumption that the tallest people inhabit the Dinarides (Pineau et al., 2005) where an average height of 184.6 centimeters was recorded with 17-years old males (still with unfinished growth). They were found to be taller than the Dutch of the Netherlands who had been regarded as the tallest population in Europe with an average height of 184 centimeters. It is also interesting to add that

the female population in the Dinaric Alps, with an average height of 171 centimeters comes a close second to females in the Netherlands (Pineau et al., 2005).

Previous researches provided findings that body height measurement when assessing nutritional status (Datta Banik, 2011; Golshan, Crapo, Amra, Jensen, & Golshan, 2007; Mohanty, Babu, & Nair, 2001; Ter Goon, Toriola, Musa, & Akusu, 2011) is important variable when assessing the growth of children, evaluating the basic energy requirements, adjusting the measures of physical capacity, determining drug dosage and setting standards of physiological variables (e.g. muscle strength, metabolic rate, lung volumes and glomerular filtration). Nonetheless, the exact body height, cannot always be identified the usual way (e.g. due to paralysis, fractures, amputation, scoliosis and pain) (Quanjer, 2014). Because of these factors, an estimate of body height has to be acquired from other reliable anthropometric indicators such as hand and foot lengths (Masanovic, Gardasevic, & Arifi, 2018; Agnihotri, Purwar, Googoolye, Agnihotri, & Jeebun, 2007; Masanovic, Gardasevic, & Arifi, 2019), tibia length (Gardasevic, 2019), knee height (Hickson & Frost, 2003), length of the forearm (Ilayperuma, Nanayakkara, & Palahepitiya, 2010), sternum length (Menezes et al., 2011), length of the vertebral column (Nagesh & Kumar, 2006), sitting height (Fatmah, 2010; Gardasevic, 2018), length of scapula (Campobasso, 1998), arm span (Jarzem & Gledhill, 1993; Bjelica et al., 2012; Gardasevic, Rasidagic, Krivokapic, Corluka, & Bjelica, 2017). All these anthropometric indicators are of high value for diagnosing individuals with disproportionate growth abnormalities and skeletal dysplasia or body height loss during surgical procedures on the spine (Mohanty et al., 2001), as well as for anticipating body height in older people as it is very difficult to measure it precisely, sometimes even impossible, due to the mobility problems and kyphosis (Hickson & Frost).

The aim of this research was to examine the body height of Montenegrin adults and the researchers of this study trusted it would be reasonable to find benefits of using foot length in estimating body height in the Montenegrins population.

METHODS

Participants

The sample of this research gave extension to 713 adults (370 men and 343 women) from the University of Montenegro. Because the growth of an individual ceases by the time a person

enters University influenced this group to be chosen and there is no age-related loss in body height at this age. Montenegro as small country has only one University and considering that the students in Montenegro were admitted into the University regardless of geographical residence and socio-economic status, or ethnicity, the authors believed this sample could fairly represent the whole Montenegrin population. The male subjects average age was 21.78±2.13 years old (range 19-33 years), while the female subjects average age was 21.01±1.57 years old (range 18-28 years). It is important to highlight that the researchers have excluded the individuals with physical deformities as well as those without informed consent from the data analysis. The exclusion criterion was also not being Montenegrin.

All participants signed the consent form approved by the Institutional Review Board of the University of Montenegro, which was in accordance with the Declaration of Helsinki as amended by the World Medical Association Declaration of Helsinki (World Medical Association, 2013).

Variables

The protocol of the ISAK (Marfell-Jones, Olds, Stew, & Carter, 2006) (International Society for the Advancement of Kinanthropometry) was used for anthropometric measurements-body height and foot length. The same trained measurers have measured each selected anthropometric indicator while the quality of their performance was evaluated against the prescribed "ISAK Manual". Finally, the age of each subject was obtained directly from the birth date.

Data and Statistical Analysis

The analysis was performed using the Statistical Package for Social Sciences (SPSS) version 23.0. Means and standard deviations (SD) were obtained for both anthropometric variables. The t-test was used to compare the means of foot lengths and body heights between the sexes. The relationship between body heights and foot lengths was determined by using simple correlation coefficients and their 95% confidence interval. The first of all models was extracted by including age as a covariate. However, it was found that the contribution of this covariate was insignificant and therefore the age covariate was dropped and estimations were derived as a univariate analysis. A linear regression analysis was performed to examine the extent to which foot length can be a reliable predictor body height. Statistical significance was set at $p<0.05$.

RESULTS

A summary of the anthropometric measurements for both sexes is presented in Table 1. The mean of the body height for male was 183.23±7.16 centimeters and foot length was 26.85±1.55 centimeters, while for female the body height was 168.38±6.78 centimeters and foot length was 24.13±1.29 centimeters. The sex difference between body height and foot length measurements was statistics significant (body height: t=26.532; p<0.001 and foot length: t=25.424; p<0.001).

Table 1. Anthropometric Measurements of the Montenegro Adults.

Subjects	Body Height Range (Mean±SD)	Foot Length Range (Mean±SD)
Male	154.4-202.2 (183.23±7.16)	19.5-31.1 (26.85±1.55)
Female	146.2-199.9 (168.38±6.78)	21.0-28.1 (24.13±1.29)

In Table 2, the simple correlation coefficients and their ninety-five percent confidence interval analysis between the anthropometric measurements are shown. The body height and foot length ratio was significant (p<0.001) in this sample, regardless of sex (male: 0.526; female: 0.430).

Table 2. Correlation between Body Height and Foot Length of the Study Subjects.

Subjects	R- correlation coefficient	95% confidence interval	Significance p-value
Male	0.526	0.450–0.600	0.000
Female	0.430	0.328–0.534	0.000

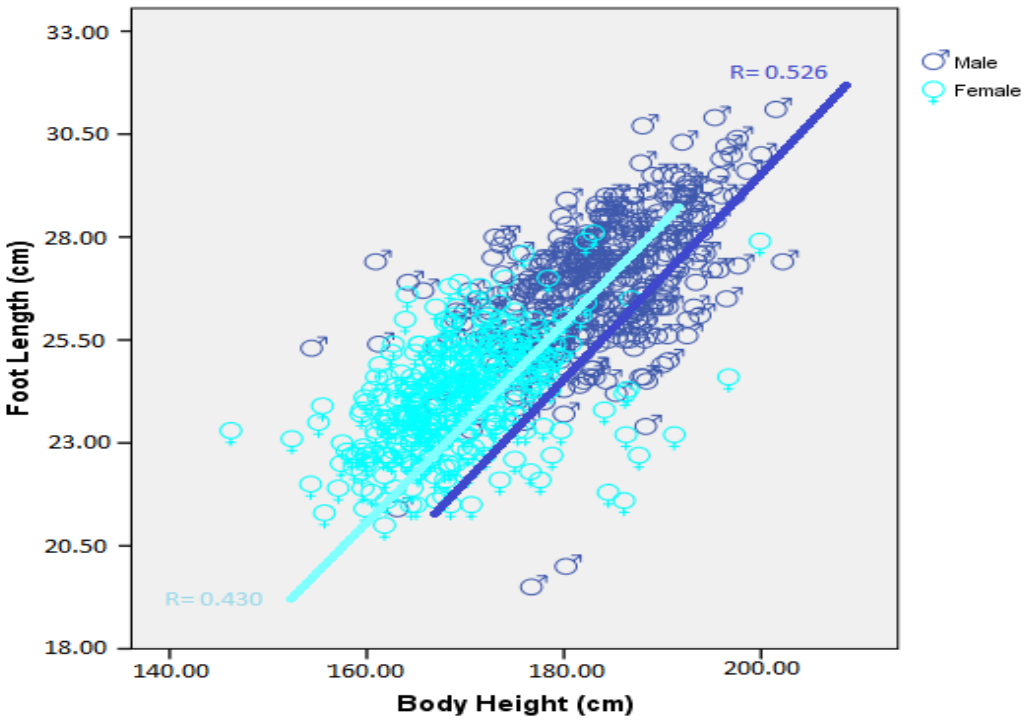
The results of the linear regression analysis are shown in Table 3. The values of the regression coefficient (male: 0.526; female: 0.430) signify that foot length can notably predict body height in both Montenegrin sexes (male: t=11.899, p<0.001; female: t=8.814, p<0.001), which confirms the R-square (%) for the male (27.7) as well as for the female (18.5).

Table 3. Results of Linear Regression Analysis where the Foot Length Predicts the Body Height.

Subjects	R-regression coefficient	Standard error (SE)	R-square (%)	t-value	p-value
Male	0.526	6.098	27.7	11.899	0.000
Female	0.430	6.133	18.5	8.814	0.000

The relationship between the measurements of foot length and body height among the above models is sketched in a scatter diagrams (Figure 2).

Figure 2. Scatter Diagram and Relationship between Body Height and Foot Length Measurements among both Sexes.



DISCUSSION

This study gives a great contribution of providing results of average body height among both Montenegrin sexes. The results of this study confirmed the research that Montenegrin males (Bjelica et al., 2012), with an average height of 183.2 cm, but this is not the tallest in Europe (Table 4), given 183.9 cm of the Bosnians (Gardasevic et al., 2017). The average stature of

Montenegrin males is taller than 182.4 cm of the Dutch measured in the lifestyle, preventive screening in 2010-2013 (Statistics Netherlands), 182.0 cm of the Serbians measured in 2012 (Popovic, Bjelica, Molnar, Jaksic, & Akpinar, 2013), Lithuanians with 181.3 cm (Tutkuviene, 2005), 180.9 cm of the Estonians (Kaarma et al., 2008), Icelanders with 180.6 cm (Dagbjartsson, Thorsson, Palsson, & Arnorsson, 2000), Croats with 180.5 cm (Jureša, Musil, & Tiljak, 2012), Swedes with 180.4 cm (Werner & Bodin, 2006), Slovenes with 180.3 cm (Starc & Strel, 2011), Danes (Statistics Denmark, 2011) and Czechs (Vignerová, Brabec, & Bláha, 2006) and several other nations, which would make Montenegro the second-tallest nation in the world.

Table 4. World`s Top 10 Nations with the Tallest Men.

	Country	Average body height	Source
1	Bosnia and Herzegovina	183.9	Popovic et al., 2015
2	Montenegro	183.2	Bjelica et al., 2012
3	Netherland	182.4	Statistics Netherlands, 2016
4	Serbia	182.0	Popovic et al., 2013
5	Lithuania	181.3	Tutkuviene, 2005
6	Estonia	180.9	Kaarma et al., 2008
7	Iceland	180.6	Dagbjartsson et al., 2000
8	Croatia	180.5	Jureša et al., 2012
9	Sweden	180.4	Werner & Bodin, 2006
10	Slovenia	180.3	Starc & Strel, 2011

With regards to the opposite sex, the average body height of Montenegrin females were 168.38 centimeters on average and this result confirmed the research that that Montenegrin females are tall compared to the rest of the countries (Bjelica et al., 2012), but not as tall as Bosnians with 171.8 cm (Gardasevic et al., 2017), and Dutch with 168.8 (Statistics Netherlands). The average stature of Montenegrin females is taller than 167.5 cm of the Lithuanians (Tutkuviene, 2005), Slovenes with 167.4 cm (Starc & Strel, 2011) and several other nations ranked in the top 10 tallest female nations, according to the available sources (Table 5).

Table 5. World's Top 10 Nations with the Tallest Women.

	Country	Average body height	Source
1	Bosnia and Herzegovina	171.8	Popovic et al., 2015
2	Netherland	168.8	Statistics Netherland, 2016
3	Montenegro	168.3	Bjelica et al., 2012
4	Germany	167.7	Hesse et al., 1997
5	Lithuania	167.5	Tutkuviene, 2005
6	Slovenia	167.4	Starc & Strel, 2011
7	Iceland	167.2	Dagbjartsson et al., 2000
8	Check Republic	167.2	Vignerová et al., 2006
9	Latvia	167.1	Gerhards, 2005
10	Sweden	167.0	Werner & Bodin, 2006

However, there is a hypothesis that residents of Montenegro have not reached their full genetic potential yet, due to various environmental factors that might influenced their development (wars in the former Yugoslavia, continued poor economic situation that is still a fact) in the last couple of decades. Consequently, the researchers are of the opinion that these circumstances had a negative bearing on the secular trend in Montenegro and surrounding countries alike, while it is expected that the secular changes influencing stature will ascend in the next two or three decades, comparing it to developed countries where this trend has already completed such as for Dutch (Schönbeck et al., 2013).

It is also interesting to note that the high frequency of very tall subjects appears to be characteristic of the Montenegrin males, since 13% measured 190 centimeters or more in body height. If 13% in Montenegro would be compared to 28% in Dinaric Alps, 20.2 percent in Bosnia and Herzegovina (Gardasevic et al., 2017), 20% in the Netherlands and only 2.7% in Macedonia (Popovic et al., 2016) or 1.5% in France (Pineau et al., 2005), it would imply that very tall males are still not as frequent in Montenegro as in the Dinaric Alps in general and in the Bosnia and Herzegovina and in the Netherlands.

The assessment of body height using various anthropometric measures is very typical from the past centuries and it has been attempted to be studied by many researchers. However, it is important to accentuate that the arm span has been recognized as the most reliable body indicator for predicting the body height of an individual (Mohanty et al., 2001; Ter Goon et al., 2011), while foot length is was very close (Masanovic et al., 2018). The results obtained in this study showed that foot length is a very reliable predictor in the assessment of body height in

Montenegrin adults as well. It is important to emphasize that the ethnic and individual variations referring to foot length and its association with body height might differ from one ethnic group to another as well as from one race to the other, because the racial and ethnic differences can affect these measures and reduce the possibility of generalizing (Bjelica et al., 2012). This fact approves the study conducted by Uhrova and her collaborators (2015) shows significant correlation in both genders of Slovak population, between body height and foot length. The highest correlation coefficient (r=0.71) was found for foot length in males, and also for females (r=0.63).

CONCLUSION

All the above-mentioned has confirmed the necessity for developing separate body height models for each population from the aspect of ethnic differences. Nevertheless, recent researches have confirmed the regional differences between the same ethnic groups which demands additional caution. Therefore, the main aim of this research was to examine body height and test the hypothesis of whether foot length is a reliable predictor for its assessment for the Montenegrin adults. Correlation between foot length and body height was significant in both Montenegrin genders. Statistical data processing showed the foot length measurement to be a reliable indirect anthropometric indicator for estimating body height in both genders of Montenegro population.

The estimation of body height based on length of foot which are obtained in the Montenegrin population are substantially different from other populations. Accordingly, on account of ethnic differences, it is necessary to develop separate models for each population, using bigger samples for the prediction of body height utilizing foot length measurement, as with the sample of this study, as well as some other studies. A more precise estimation of the average body height and its prediction utilizing foot length measurements in Montenegrin adults would require a larger sample with sufficient geographical and social heterogeneity or a national survey that measures the whole population. Thus, the obvious limitation of this research study was the composition of the measured sample that consisted of university students. Since university-educated persons are taller than the general population in Poland (Kułaga et al., 2011), and Hungary (Bodzsár & Zsákai, 2008), the authors cannot exclude the possibility that the body height of the students somewhat overestimates the average body height of contemporary Montenegrins. Another obvious limitation of this study is also the

aforementioned fact that both genders of Montenegro did not reach their full genetic potential yet, since various environmental factors might have had an impact on their development. Further, continuous monitoring is necessary, mostly by cause of the reason it is expected that the secular changes influencing body height will ascend in the coming two or three decades.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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