Arm-span measurement as an alternative estimation of true height in Montenegrin young adults of both sexes: A national survey

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Abstract
The purpose of this investigation is to examine standing height and its association with arm span as an alternative to estimating true height in both sexes among Montenegrins. The study included a cohort of 2,088 individuals, 981 males and 1107 females from all Montenegrin municipalities. The anthropometric measurements were made following the ISAK protocol. Correlation coefficients at a ninety-five per cent confidence interval were carried out to measure the linear association between physical height and arm span. Then, a linear regression analysis was carried out to examine to which extent arm span can reliably predict true height. The results showed that Montenegrin males are 183.34±6.89 cm tall and have arm spans of 184.56±8.28 cm, while Montenegrin females are 169.36±6.37 cm tall and have arm spans of 168.04±7.52 cm. The results of this study confirmed our assumptions that both men and women in Montenegro are among the tallest people in the world. In addition, it is also confirmed that arm span represents a reliable predictor of true height in the Montenegrin population.

KEYWORDS: stature, nutritional-status, ethnic-groups, growth, length

Introduction
Montenegro is an independent, democratic country with a multiparty parliamentary system. It is one of the successor states of the former Yugoslavia, after which it was in a federation with Serbia in 1992, from which it declared independence in 2006. Hence, it is one of the newest "old countries" in the world, because its statehood began in the distant past. Montenegro gained complete independence during the Berlin Congress in 1878, becoming the 27th independent country in the world (Central Intelligence Agency 2016). However, it lost its independence in 1918, immediately following a disputable decision of the Podgorica Assembly that annexed Montenegro to Serbia (Popovic et al. 2014a), making it a part of the newly born country of Southern Slavs (Kingdom of Serbs, Croats, and Slovenes, later renamed as Yugoslavia). Since 1878, Montenegro has taken part in two world wars, two

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Balkan wars, and several local conflicts but, fortunately, it avoided the Balkan conflicts in the 1990s. However, the surrounding conflicts did not spare Montenegro, and this has affected its interpersonal and interethnic relations. The history of Montenegro is turbulent.

From the geographical perspective (Central Intelligence Agency 2016), Montenegro covers an area of 13,812 square kilometres (water: 360 square kilometres and land: 13,452 square kilometres), and it extends over the south-western Balkan Peninsula. Montenegro is bound by land on three sides (north, west, and east), and it borders five countries: Albania (186 km of border), Kosovo under UNSCR[1] 1244 (76 km), Serbia (157 km), Bosnia and Herzegovina (242 km), and Croatia (19 km), while the southern side opens Montenegro to the Adriatic Sea (length of the coast is 293.5 km) and international waters that are shared with Italy. Estimations from the same source (Central Intelligence Agency 2016) regarding the distribution of the land use in Montenegro states 38.2 per cent agricultural land (ploughed land: 12.9%; continual crops 1.2%; continual pasture 24.1%), forests about 40.4 per cent and the remaining accounting for 21.4 per cent. It is noteworthy that the highest population density is concentrated in the south and southwest areas, while the extreme eastern border is the least populated area in Montenegro. The urban population accounts for 64 per cent of the Montenegrin population and, officially, more than one quarter of the total population lives in the capital city, Podgorica.

The total population of Montenegro is 620,029 (Monstat 2011). According to the same source, 50.61 per cent are women, and 49.39 per cent are men. The aforementioned specific historical events made the ethnic issue in Montenegro highly distinct and complex, mostly because attitudes about ethnicity are prone to change. According to the recent census (Monstat 2011), the largest ethnicity in the country is the Montenegrin ethnic group, representing 44.98 per cent of the total population, followed by Serbs, taking 28.73 per cent of the total population, Bosniaks with 8.65 per cent, Albanians with 4.91 per cent and the rest, 13.03 per cent. In contrast, the last census conducted before the breakup of Yugoslavia (cited in Popovic et al. 2014a) presented the results in which the population living in the same area in 1981 had 68.54 per cent Montenegrins and 3.32 per cent Serbs; Bosniaks did not exist, as such, at that time, because they called themselves 'Muslims' (they recognised themselves ethnically by religion). However, it is crucial to underline that these differences were not caused by some great migrations, as it seems at first glance. It is the result of the ideological sentiments and changing beliefs during the difficult and turbulent time of the 1990s. Thus, it is essential to highlight that most Montenegrin citizens have the same origin (based on dominant y-DNA haplogroup) and the variations of their ethnicities are mostly the outcome of ideological constructs and their religious affiliations (Bjelica et al. 2012).

The investigations carried out by European anthropologists a century ago proved the assumption that the tallest people live in the Dinarides (Pineau et al. 2005). As modern Montenegrins fall into this racial classification, it is believed by the investigators of this study that Montenegrin adults might be one of the tallest populations in Europe and beyond (cited in Mrehic et al. 2016; NCD Risk Factor Collaboration 2016; Popovic et al. 2016), taller or at least equal to the Dutch (males: 183.8 cm; females: 170.7 cm), Bosnian and

[1] UN Security Council Resolutions

Herzegovinians (males: 182.8 cm; females: 167.4 cm), Serbians (males: 182.0 cm; females: 166.8 cm), Estonians (males: 181.6 cm; females: 168.7 cm), and Latvian (males: 181.4 cm; females: 169.8 cm), mostly because some previous studies mentioned that this fact might be currently true. Specifically, Robert W. Ehrich measured male populations (Coon 1975) at the beginning of the 20th century, finding that Montenegrins were the tallest nation in Europe (177 cm), while a recent study confirmed the assumption that Montenegrin students are among the tallest on Earth (Bjelica et al. 2012).

In contrast, the most recent study that analyses a century of trends in adult human height did not cover the Montenegrin population adequately (NCD Risk Factor Collaboration 2016). Therefore, the present study might be a meaningful update, mostly because it contains current data as well as some historical perspective on human height within this country. Compared to the western European countries, Montenegro keeps poor records, and the expected data about the average stature among Montenegrin populations are quite beneficial as well as the relationship with arm span measurements, mostly because the measurement of physical height is essential in many settings (Gardasevic et al. 2017; Popovic et al. 2015).

The scientific literature has provided findings in which the measurement of physical height or estimations thereof are a vital variable in various settings: when assessing nutritional status, when assessing an accurate height measurement, which is part of the BMI equation to evaluate weight status, when determining resting energy expenditure, calculating the creatinine height index and cardiac function indices, as well as when assessing the growth of children, evaluating basic energy requirements, adjusting the measures of physical capacity, and predicting the drug dosage and setting standards of physiological variables, such as muscle strength, metabolic rate, lung volume and glomerular filtration (Datta Banik 2011; Golshan et al. 2003, 2007; Mohanty et al. 2001; Lahner et al. 2017; Ter Goon et al. 2011).

Furthermore, being taller is related to enhanced longevity, with this group of people suffering less from heart disease and more from several types of cancers (NCD Risk Factor Collaboration 2016; Schonbeck et al. 2013). According to the same source, the measurement of physical height and its trend is also an essential variable when assessing social, economic and political determinants, e.g., taller people may be more successful in school, earn more money, get better positions, et cetera. Physical height can also significantly influence success in some sport disciplines (Popovic et al. 2012; Popovic et al. 2014b). Therefore, it is valuable to have certain information on the true height and its development, as this knowledge might significantly aid in improving human life, from both medical and socio-economic points of view.

However, true height, according to Quanjer et al. (2014) and Lahner & Kassier (2016), cannot always be resolved in the usual way and identified by its gold standard (stretch stature method) because of numerous internal and external factors, such as paralysis, fractures, amputation, scoliosis, dorsal kyphosis, osteoporosis, osteomalacia, postmenopausal hormone imbalances, pain, et cetera. When the measurement of stretch stature is not possible, an estimate of the true height has to be acquired from other reliable body parameters, such as hand and foot lengths, vertebral column length, length of the forearm, length of the sternum, sitting height, scapula length, trochanteric height, leg length, thigh length, cranial sutures, skull circumference, facial measurements, sitting

height, knee height, ulna length, arm measurements, such as arm span, recumbent length, et cetera (Kewal & Sharma 2006; Popovic et al. 2016). Therefore, all the mentioned anthropometric parameters are a significant alternative to estimate the true height and crucial in predicting losses in physical height connected with ageing. Furthermore, they are valuable indicators to diagnose individuals with disproportionate growth abnormalities and skeletal dysplasia or physical height loss during surgical procedures on the spine (Mohanty et al. 2001), as well as to anticipate physical height in elderly adults (Hickson & Frost 2003) as it is challenging to measure it precisely (sometimes it is impossible because of mobility problems and kyphosis).

As stated above, the investigators of this study believed it would be reasonable to determine the benefit of using various body indicators in estimating true height in the population who live in Montenegro, mostly because people from this country have long been recognised as having a specific body composition (very long legs, large shoulder breadth and chests as well as extremely low relative span, very high trunks and sitting height, as well as short arms (Coon 1975)). Additionally, several investigators (Hickson & Frost 2003; Mohanty et al. 2001; Ter Goon et al. 2011) have reported the benefits of using various body parameters in predicting true height; the arm span happened to be the most reliable one. However, the relationship of physical height and arm span was determined to vary in various ethnic and racial groups (Bjelica et al. 2012; Brown, et al. 2002; Reeves et al. 1996; Steele & Chenier 1990), while the study conducted by Quanjer et al. (2014) reported that the relationship between the arm span and height changes non-linearly with age and differs between boys and girls. Even though many studies of this topic are available on Western populations, only limited data are available on Montenegrin subjects. There was just one research study (Bjelica et al. 2012) with the same research goal; it sampled the university students in Montenegro. However, some previous studies confirmed that university-educated individuals are taller than the general population in Hungary (Szollosi 1998), Poland (Wronka & Pawlinska-Chmara 2009) and Bosnia and Herzegovina (Gardasevic et al. 2017; Grasgruber et al. 2017; Mrehic et al. 2016; Popovic et al. 2015). This might also be the case in Montenegro; this study needs to test it and to analyse unusual height in Montenegro. Considering a specific body composition as well as significant lack of reliable literature references in this area of research in Montenegro, the main goal of this investigation was to analyse the true height in both sexes in Montenegro as well as its relationship with arm span at the national level.

Methods

As its subjects, this research included 2,088 high-school students in their final year of high school studies (981 males and 1107 females) from Montenegro. Two reasons qualified the selected individuals: the first is related to the fact that the growth of an individual ceases by this age, while the second is related to the fact that there is no age-related loss in physical height at this age. The average age of the males was 18.37±0.61 years old (range 17-20 years), while the average age of the females was 18.30±0.61 years old (range 17-20 years). It is important to emphasise that the researchers have excluded all individuals with physical

deformities from the data, as well as those who did not hold Montenegrin citizenship at the time of measurement.

Although photogrammetric anthropometry is currently the most precise measurement method, it is not a legitimate method for arm span measurement (Penders et al. 2015), and the measurements were carried out with the conventional technique according to the ISAK protocol (Marfell-Jones et al. 2006). The trained measurers have measured selected anthropometric indicators (same measurer for each indicator), while the quality of their performance was evaluated against the prescribed 'ISAK Manual'. Lastly, the age of each subject was attained directly from their birthdays.

The data were analysed with IBM SPSS 20 software. Estimations of true height and arm span, as well as the ages for each sex, were calculated at the national level. A t-test was performed to analyse a comparison of means of stature and arm spans within each sex group and between sexes. The correlation coefficients at a ninety-five per cent confidence interval were carried out to calculate the linear association between physical height and arm span. Then, a linear regression analysis was carried out to estimate if the arm span can reliably predict true height in the specified population. Statistical significance was set at $p<0.05$.

Results

A summary of the anthropometric measurements in both sexes is shown in Table 1. The mean of the arm span for males was 184.56±8.28 centimetres, which was 1.22±1.39 centimetres more than the physical height and statistically significant ($t=-3.555$, $p<0.000$); for females it was 168.04±7.52 centimetres, which was 1.32±1.15 centimetres less than the physical height and statistically significant ($t=4.458$, $p<0.000$). The sex difference between physical height and arm span measurements was statistically significant (height: $t=48.183$; $p<.000$, and arm span: $t=47.779$; $p<.000$).

Table 1: Anthropometric measurements of the study subjects

Subjects	Body Height Range (Mean±SD)	Arm span Range (Mean±SD)
Boys	160.9-204.2 (183.34±6.89)	152.1-210.0 (184.56±8.28)
Girls	150.2-197.7 (169.36±6.37)	141.2-205.0 (168.04±7.52)

In Table 2, the simple correlation coefficients between the anthropometric measurements were calculated, and the confirmed associations between physical height and arm span were significant ($p<0.000$) and high in this sample, regardless of sex (males: 0.823; females: 0.830).

Table 2: Correlation between stature and arm span of the study subjects

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Boys	0.823	0.788–0.859	<0.000
Girls	0.830	0.797–0.863	<0.000

The results of the linear regression analysis are shown in Table 3. The first models were extracted by including age as a covariate. However, it was found that the contribution of age was insignificant; therefore, it was omitted, and estimations were derived as a univariate analysis. The high values of the regression coefficient (males: 0.823; females: 0.830) signify that arm span notably predicts physical height in both Montenegrin sexes (males: t=45.384, p<0.000; females: t=49.470, p<0.000), which confirms the R-square (%) for the males (67.8) as well as for the females (68.9).

Table 3: Results of linear regression analysis where the arm span predicts the stature

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Boys	0.823	3.912	67.9	45.384	0.000
Girls	0.830	3.552	68.9	49,470	0.000

The ratio between physical height and arm-span measurements among the analysed models is displayed as a scatter diagram (Figure 1).

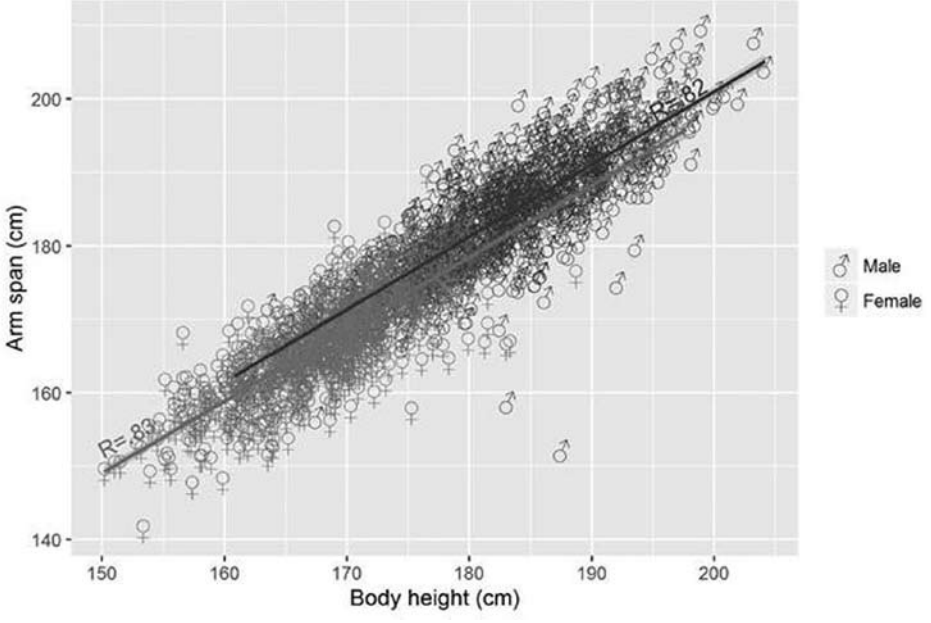

Figure 1: Scatter diagram and relationship between arm span measurements and body height among both sexes

Discussion and conclusion

First, this study provides a true picture of the physical height of Montenegrins, since a national survey in Montenegro has not been conducted for over 100 years; studies on the sample of university students (Bjelica et al. 2012) indicate that Montenegrin males even after 100 years remain among the tallest nations in the world. As already mentioned, Montenegrin males, at the beginning of the 20th century, with an average height of 177 centimetres were the tallest people in the world (Coon 1975), and after 100 years they grew 6.34 centimetres, on average, and they are still highly ranked; at this moment, they are the second-tallest nation in the world, immediately behind the Dutch, who with an average physical height of 183.8 centimetres represent the tallest nation in the world.

In contrast, regarding Montenegrin females, no research has been conducted thus far in the form of a national survey (the aforementioned measurement carried out by Robert W. Ehrich did not include the female population). The current research, for the first time, determines the average physical height of the Montenegrin females, which is 169.36 centimetres, which also places the female Montenegrin population among the tallest nations in the world, also in the second place, immediately following the Lithuanians, who have an average physical height of 169.8 centimetres, representing the tallest female nation in the world.

It is necessary to add that this study represents a significant addition to the global study conducted by NCD Risk Factor Collaboration (2016), which established the century-long trend in global physical height; although they covered most of the countries around the world, this group of scientists failed to acquaint themselves with the research of Robert W. Ehrich and the fact that the Montenegrins were the tallest nation at the beginning of the 20th century. They did not possess current data from Montenegro to be included in an article published in the eLife magazine (NCD Risk Factor Collaboration 2016), even though it was expected that the Montenegrin population would play a significant role with regard to physical height. Therefore, the current study, among other things, is a significant addition to the aforementioned global study, in which it was stated that Montenegrin males, on average, are 178.3 centimetres tall and Montenegrin males 164.9 centimetres; these values are at great discrepancy with the situation on the field.

Table 4: An update of the top 10 tallest male nations on the earth

#	Country	Average Body Height	Source
1	Netherland	183.8	Schonbeck et al. 2013
2	Montenegro	183.2	Current Study
3	Bosnia and Herzegovina	182.8	Mrehic et al. 2016
4	Belgium	181.7	NCD Risk Factor Collaboration 2016
5	Estonia	181.6	NCD Risk Factor Collaboration 2016
6	Lithuania	181.3	Tutkuviene, 2005
7	Denmark	181.4	NCD Risk Factor Collaboration 2016
8	Croatia	180.8	NCD Risk Factor Collaboration 2016
9	Iceland	180.6	Dagbjartsson et al. 2000
10	Serbia	180.6	NCD Risk Factor Collaboration 2016

Physical height has always provoked the interest of people from different fields, both scientists and those whose focus is not directly on research, because, throughout the development of humanity, physical height was a factor that significantly influenced people's lives in different ways, as has already been explained in this study. It is therefore vital to refresh the list of the tallest populations in the world. The male population is presented in Table 4, and the female population in Table 5.

Table 5: An update of top 10 tallest female nations on the earth

#	Country	Average Body Height	Source
1	Latvia	169.8	NCD Risk Factor Collaboration 2016
2	Montenegro	169.4	Current Study
3	Netherland	168.7	NCD Risk Factor Collaboration 2016
4	Estonia	168.7	NCD Risk Factor Collaboration 2016
5	Czech Republic	168.5	NCD Risk Factor Collaboration 2016
6	Serbia	167.7	NCD Risk Factor Collaboration 2016
7	Slovakia	167.5	NCD Risk Factor Collaboration 2016
8	Lithuania	167.5	Tutkuviene 2005
9	Slovenia	167.4	Starc & Strel 2011
10	Denmark	167.2	NCD Risk Factor Collaboration 2016

It is crucial to pay attention to the frequency of very tall individuals in Montenegro (Figure 2), since the research on the student population indicated that there could be a high percentage of very tall Montenegrin males and females. In the male population in Montenegro, the frequency of taller than 190 centimetres is 18.2%, which indicates that almost every fifth adult male inhabitant of Montenegro is taller than 190 centimetres. Comparing these data with results from other countries (cited in Arifi et al., 2017b), similar results are found in the Netherlands (20%) and Bosnia and Herzegovina (20.2%), while in Serbia the percentage taller than 190 centimetres stopped at 14%, Kosovo 5.1%, Macedonia 2.7%, and France 1.5%. In contrast, the female population in Montenegro taller than 180 centimetres is just 5%.

Although the above-average physical height of the inhabitants living in the Dinaric Alps has been known by anthropologists for a long time, the question of what influenced people in this region to grow taller on average more than people in other areas remains a matter of debate. While physical height is highly hereditary, other factors are also influenced by growth, above all, the environmental factor, which includes the daily diet, then the exposure to various infections, as well as the socio-economic status, especially during childhood (Subramanian et al., 2011). Although the fact that 43 countries in Europe and the United States have identified a significant correlation between y-DNA Haplogroup I-M170 and physical height (cited in Grasgruber 2017), opinions are divided regarding this topic, since there is also a significant number of arguments against the correlation; therefore, the question of which gene dominantly affects human growth remains.

In contrast, economic and social changes in the environment, or lifestyle can

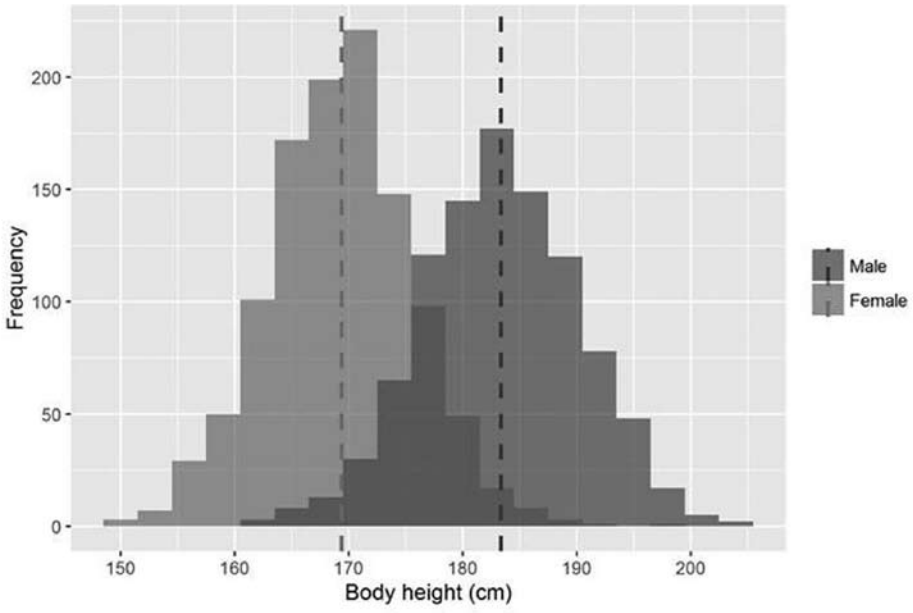

Figure 2: Frequency of body height among both sexes

influence growth and development (Starc & Klincarov 2016), especially in childhood, and the socio-economic status is precisely the one that has been confirmed to be in a significant correlation with physical height in developed countries. Therefore, in addition to the examples already mentioned, that university students are taller than the general populations in Poland, Hungary, and Bosnia and Herzegovina, there is also the study of Subramanian et al. (2011) that confirms this fact in another 10 European countries and emphasises that educated men and educated women are taller than the general population in their countries (men: by 1.6-3.0 cm, women: by 1.2-2.2 cm).

However, this research does not concur with the aforementioned facts, since the results of the survey on the sample of educated respondents and the general population in Montenegro did not show significant differences. These data point to the fact that the secular trend is only expected in the territory of Montenegro, and that it is highly probable that the Montenegrin male population will again be the tallest nation in the world in the next two decades, since the secular trend in the Netherlands is over (Schonbeck et al. 2013), while for Lithuania there are no available data of this kind.

Assessing true height using different anthropometric measures is a method that has been used by a great number of researchers. However, it was not unusual for clinical studies to assess true height without considering possible factors that could influence the outcome of the research. Therefore, it is vital to accurately define the population that represents the sample of the research, since in previous studies it has been established that racial and ethnic differences significantly influence the outcome of the research (Popovic

et al., 2012). The lack of research describing the assessment of true height using different anthropometric measures at the national level in Montenegro represented the main motive for the author of this study to carry out such research, especially since it has long been known that the population living on the territory of Montenegro has a specific body composition (Coon 1975), particularly with regard to parameters that are usually used to estimate true height (arm length, leg length, seating height, etc.).

However, it is also known from the available literature that, thus far, arm span is the most reliable indicator for assessing true height (Mohanty et al., 2001; Ter Goon et al., 2011), and that individual and ethnic variations have been established in different European (Reeves et al., 1996) and African nations (De Lucia et al., 2002), so it was natural to expect certain specificities to be established in the Montenegrin population, especially since during its history this population excelled in above-average physical height and unusual lengths of upper and lower extremities, which were, in comparison with other nations, shorter (upper) and longer (lower) (Coon 1975). Therefore, it is not surprising that the data obtained in this study, which is congruent with the results of Mohanty et al. (2001), who found that the estimation of the true height with the help of an arm span varies from ethnic to ethnic group, as well as from race to race, but also with results obtained in the research on the student population in Montenegro, which pointed out the necessity of this research and indicated the unique results at the national level (Bjelica et al. 2012), when the general population is concerned. The results of this study are consistent with the results obtained in Bjelica et al.'s research (2012) with regard to the male population: the difference in measured physical height and arm span was statistically significant; however, it is noteworthy that in the student population the arm span was longer by 2.5 centimetres (101.4% body height) than physical height, while in the general population the difference was smaller, i.e., 'only' 1.22 centimetres (100.7% body height). Regarding the female population, the differences between research involving the student and general population are more dramatic. The difference in measured physical height and arm span was not statistically significant in the student population, and the arm span was shorter by 0.2 centimetres (100.1% body height); however, the difference in measured physical height and arm span was statistically significant in the general population, and the difference was significantly larger, i.e., 1.32 centimetres (100.8% body height).

It is interesting that in the student population a statistically significant difference was not found in Bjelica et al.'s study (2012) when the difference in measured physical height and arm span was in question, while in the general population this difference was statistically significant. In the student population, the arm span was shorter by 0.24 centimetres (99.2% body height) than physical height, while in the general population the difference was dramatically higher, that is, 1.32 centimetres in favour of physical height (100.7% body height), which is a distinctive feature of the general female population in Montenegro, not only in relation to the student population, but also in relation to other nations, both in the surroundings, as well as in Europe and in the world. For this reason, this study confirms the need to develop separate height models for each population individually.

To make it easier to see the specific results obtained on the general population in Montenegro, it is worth comparing them with Steele and Chenier's research (1990),

which found that the arm span is longer on average, as much as 8.3 centimetres from physical height among the black population (105.36% physical height), while the differences among the white population are drastically smaller, i.e., the arm span is longer by "only" 3.3 centimetres (102.04% physical height).

Mohanty et al. (2001) examined the female population in South India and found that the arm span was longer by 2.5 centimetres (101.4% physical height) than the physical height, while Ter Goon et al. (2011) found that the arm span was longer by 5.8 centimetres (103.3% physical height) than the physical height in Nigerian men, while this difference in the female population was 4 centimetres (102.3% physical height) in favour of physical height.

In contrast, research available in the region in which Montenegro is located does not show such drastic differences, as is the case when compared with other races. Popovic et al.'s research (2013) found that the arm span was longer by 2.8cm (101.5% physical height) than the physical height of Serbian men, while the female population was only 0.15 centimetres (98.7% physical height) in favour of physical height. Another study by Popovic et al. (2015) found that the arm span was longer only by 0.73 centimetres (100.3% physical height) than physical height in men in Bosnia and Herzegovina, while the female population in the same country was 1.97 centimetres (98.9% physical height) in favour of physical height: this result is the highest response to the result obtained in this study. Popovic et al. (2016) conducted a study in Macedonia, and the results in this former Yugoslav republic proved to be specific, i.e., it was established that the arm span was longer by only 0.68 centimetres (100.4% physical height) than physical height in men, while in the female population the difference was 0.17 centimetres (99.9% physical height) in favour of physical height.

It is evident that the differences between nations exist, and it is necessary to develop separate height models for each nation, when estimating true height with the help of arm span; regional research should be conducted, because several studies have identified regional specificities (Arifi et al., 2017a; Milasinovic et al., 2016a, 2016b). These differences could be conditioned by the type of soil, or it is notable that the same ethnic groups living on mountain ranges, such as the Dinaric Alps, are significantly taller than those living in the area of other mountain ranges. A typical example is the Albanians in Kosovo, whose average male physical height is 179.52 centimetres and female 165.72 centimetres (Arifi et al. 2017b), while the average physical height in male Albanians is 174.0 centimetres, while women are 161.8 centimetres tall (Albania DHS survey 2010).

The regression coefficients found in this study (men: $r = 0.823$; women: $r = 0.830$) are congruent with the results obtained in previous studies. For example, the results obtained in the student population in Montenegro (men: $r = 0.861$; women: $r = 0.809$) indicate a high correlation between the anthropometric measures used in this study, that is, the physical height and arm span. In both cases, the coefficient of regression is very high, with differences in nuances occurring, that is, the coefficient is slightly increased in the female population, while in the male population it is reduced by a similar value. Regarding the results of the research carried out in the region, Arifi et al.'s research (2017) found lower correlation values on a population sample from Kosovo (men: $r=0.794$; women: $r=0.766$),

as well as in Popovic et al.'s research (2013) where they also appeared for the nuance of a lower correlation value in the Serbian population (men: r=0.814; women: r=0.822).

In Popovic et al.'s research (2013) with the Macedonian population, more correlation values were found in both sexes (men: r=0.879, women: r=0.839), as well as Popovic et al.'s research (2016) on the sample from Bosnia and Herzegovina (men: r=0.876, women: r=0.887). In contrast, results outside the region are also consistent with the results obtained in this study, with regard to the coefficient of regression. For example, Hickson and Frost (2003) found a correlation of r=0.86, while the correlation in Mohanty et al.'s research (2001) was r=0.82; in Zverev's study (2003), the correlation value was r=0.87 for men and r=0.81 for women, while Ter Goon et al. (2011) determined a correlation of r=0.83. All in all, the abovementioned results confirm the fact that arm span represents the most reliable anthropometric measure for estimating true height.

As has been emphasised several times during this study, the results unambiguously point to the further need to develop separate height models in terms of gender, ethnicity, race, and geographic location. Therefore, the creation of a separate model for both sexes at the level of the entire population in Montenegro is an original contribution to science; however, it is necessary to emphasise that the population in this research consists of students of the final year in Montenegrin secondary schools, and this fact can be a limitation, as there are assumptions that growth and development does not end at age 18, as we previously believed, but rather growth and development systematically continues in the torso after 18 years of age (Starc, personal communication), which would ultimately cause an increase in physical height, while the length of the arm or arm span would remain unchanged. Consequently, the relation of physical height and arm span can be significantly changed, or the created model can be disturbed.

Furthermore, one recommendation for future research is to take into account the effects of a secular trend that can cause a difference between the maximum height and the current skeleton height (Lahner et al. 2017), which is expected to be present in the coming decades on the population living in the Montenegro area, and this factor may also be a significant limitation regarding the results obtained in this study, especially since the subsequent growth requires re-measurement and a new determination of the relationship between physical height and arm span.

Another limitation of this study was the limited time and limited financial resources that made it impossible to measure the overall population of the final-year students in Montenegro but also to consider other age categories, which would allow for a precise assessment of growth and development, and after 18 years of life. In contrast, the dedication of this study is reflected, first, in the results that represent the development of a separate height model at the national level, that is, the first study that analysed factors that influence the above-average values of the physical height of Montenegrin males and Montenegrin females and its relationship with the arm span as the most reliable indicator for assessment of true height in Montenegro.

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Povzetek

Namen te raziskave je bil preučiti stoječe višine in njeno povezavo z razponom rok kot alternativo ocenjevanju prave višine obeh spolov med Črnogorci. Študija je vključevala kohorto 2.088 posameznikov, 981 moških in 1107 žensk iz vseh črnogorskih občin. Antropometrijske meritve so bile opravljene po protokolu ISAK. Koeficient korelacije pri intervalu zaupanja med devetdeset in petimi odstotki je bil opravljen za merjenje linearne povezave med telesno višino in razponom rok. Izvedli smo linearno regresijsko analizo, s katero smo preučili, v kolikšnem obsegu razpona rok lahko zanesljivo napovedujemo pravo višino. Rezultati so pokazali, da so črnogorski moški visoki 183,34 ± 6,89 cm in imajo razpon rok 184,56 ± 8,28 cm, medtem ko so črnogorske ženske visoke 169,36 ± 6,37 cm in imajo razpon ročaja 168,04 ± 7,52 cm. Rezultati te študije so potrdili naše domneve, da so moški in ženske v Črni gori med najvišjimi ljudmi na svetu. Poleg tega je tudi potrjeno, da razpon rok predstavlja zanesljiv napovedovalec prave višine med črnogorskim prebivalstvom.

KLJUČNE BESEDE: status, prehranski status, etnične skupine, rast, dolžina

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