Body height and its estimation utilising arm span measurements in Montenegrin adults

Duško Bjelica
University of Montenegro, sportmont@t-com.me

Stevo Popović
University of Montenegro, stevop@ac.me

Miroslav Kezunović
University of Montenegro, miroslavkezunovic@hotmail.com

Jovica Petković
University of Montenegro, jovicapetkovic@t-com.me

Gregor Jurak
University of Ljubljana, gregor.jurak@fsp.uni-lj.si

Pavel Grasgruber
Masaryk University, centrum74@gmail.com

Abstract
The unusual height of Montenegrin inhabitants of the highland region has been recognised by European anthropologists more than 100 years ago. In light of rather sparse recent scientific literature, the purpose of this research study was to examine the body height in both sexes of Montenegrin adults nowadays. Furthermore, the relationship between arm span and body height, which varies in different ethnic and racial groups, was used as an alternative to estimating the body height for some groups of the population. The nature and scope of this study analyses 285 students (178 men, aged 20.97±2.44 and 107 women, aged 20.86±2.63) from the University of Montenegro. The anthropometric measurements were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). Means and standard deviations were obtained. A comparison of means of body heights and arm spans within and between the sexes were carried out using a t-test. The relationships between body height and arm span were determined using simple correlation coefficients and their 95% confidence interval. A linear regression analysis was then performed to examine the extent to which arm span can reliably predict

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body height. The results have shown that male Montenegrins are 183.21±7.06 centimetres tall and have an arm span of 185.71±8.17 centimetres, while female Montenegrins are 168.37±5.27 centimetres tall and have an arm span of 168.13±6.58 centimetres. Comparing the results with other studies has shown that both sexes of Montenegrins make Montenegro the second tallest nation in the world, while arm span reliably predicts body height in both sexes. However, the estimation equations that have been obtained among the Montenegrins are substantially different than in all other populations, since arm span was close to body height: in males 2.50±4.15 centimetres more than the body height and in females 0.24±3.88 centimetres less than the body height. This confirms the necessity for developing separate height models for each population on account of ethnic differences.

KEYWORDS: prediction, standing height, stature, arm span, Montenegro

Introduction

The Republic of Montenegro covers an area of 13,812 sq. kilometres and borders Albania, Kosovo (as defined under UNSCR 1244/99), Serbia, Bosnia and Herzegovina, Croatia, and the Adriatic Sea in the south-west of the Balkan Peninsula. 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 are Montenegrins, 28.73% are Serbs, 8.65% are Bosnians, and 4.91% are Albanians, etc. It is interesting to compare the results of the most numerous ethnic groups to the results of the 1981 census. The population living in the same area in 1981 numbered 68.54% of Montenegrins and 3.32% Serbs, while "Bosnians" did not exist as a category at that time; they were referred to according to their religion, i.e. "Muslims". However, these differences were not caused by some great migrations, as it might seem at first sight. It is the result of the ideological sentiments of a number of citizens of Montenegro, who changed beliefs during the difficult and turbulent time of the 1990s. Thus, it is important for this research study to underline that most of Montenegro's population has the same origin and the variations of their ethnicities are the outcome of the ideological concepts and their religious affiliations. When populations share a genetic background and live in the same environmental conditions, the average height is frequently characteristic within the group; for this reason, the authors consider all people who live in Montenegro to be Montenegrins.

The unusual height of Montenegrin highlanders is a fact recognised by European anthropologists more than 100 years ago. A sample of 800 Montenegrin men measured by Robert W. Ehrich (Coon 1975) at the beginning of the 20th century gave the highest average in all of Europe (177 cm), with some districts approaching 178 centimetres. Furthermore, a more recent study conducted by Pineau, Delamarche, & Božinović (2005) showed that the male population of the Dinaric Alps is on average the tallest in the whole of Europe. Thus, this study has challenged many scientists to believe that Montenegrins are still the tallest population in Europe. This assumption was supported by the fact that many Montenegrin males did conform to standard Dinaric specifications, but were all taller than most Dinarics elsewhere. According to data collected by Coon (1975), Montenegrin

males were taller than people from Herzegovina (175-176 cm), Bosnia (171-174 cm) and the coastal zone stretching from Istria to Dalmatia (166-171 cm). However, the problem is that, unlike most other countries, Montenegro keeps poor records and this assumption could not be proven thus far.

Pineau et al. (2005) also contributed to an update of average body heights among European populations. Although this study does not contain the exact data of the Montenegrin population, it represents the most recent study related to the average body height of modern Montenegrins. Pineau et al.'s investigation showed that, contrary to the general belief, the male population of the Dinaric Alps is on average, the tallest in the whole of Europe. With an average height of 184.6 centimetres in 17-years old males (still with unfinished growth), they were taller than the Dutch of the Netherlands who had been regarded as the tallest population in Europe with 184 centimetres on average. It is also interesting to add that the female population in the Dinaric Alps, with an average height of 171 centimetres comes a close second to females in the Netherlands (Pineau et al. 2005).

It is well known in scientific literature that the measurement of body height is important in many settings: it is an important measure of body size and gives an assessment of nutritional status (Datta Banik 2011), as well as an important measure of determination of basic energy requirements, standardisation of measures of physical capacity and adjusting drug dosage, and evaluation of children's growth, prediction and standardisation of physiological variables such as lung volumes, muscle strength, glomerular filtration and metabolic rate etc. (Golshan, Amra & Hoghoghi 2003; Golshan, Crapo, Amra, Jensen & Golshan 2007; Mohanty, Babu & Nair 2001; Ter Goon, Toriola, Musa & Akusu 2011). However, the exact body height cannot always be determined the usual way because of various deformities of the extremities or in patients who have undergone amputations or similar injuries. In such circumstances, an estimate of body height has to be derived from other reliable anthropometric indicators, such as hand and foot lengths (Agnihotri, Agnihotri, Jeebun & Googoolye 2008; Agnihotri, Purwar, Googoolybe, Agnihotri & Jeebun 2007; Kanchan et al. 2008; Rastogi, Nagesh & Yoganarasimha 2008; Sanli et al. 2005), knee height (Fatmah 2005; Hickson & Frost 2003; Karadag, Ozturk, Sener & Altuntas 2010), length of the sternum (Menezes et al. 2009; Menezes et al. 2011), vertebral column length (Nagesh & Pradeep 2006), sitting height (Fatmah 2005), length of scapula (Campobasso, Di-Vella & Introna 1998), arm span (Aggrawal, Gupta, Ezekiel & Jindal 2000; Datta Banik 2011; Fatmah 2005; Hickson & Frost 2003; Jalzem & Gledhill 1993; Mohanty, Babu & Nair 2001; Ter Goon et al. 2011) as well as cranial sutures (Rao et al. 2009), skull (Bidmos 2006; Bidmos & Asala 2005), and facial measurements (Sahni et al. 2010) etc. Therefore, all these anthropometric indicators that are used as an alternative to estimate body height are very important in predicting age-related loss in body height, for example, in identifying 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 predicting body height in many older people, as it is very difficult to measure it precisely, and sometimes impossible because of mobility problems and kyphosis (Hickson & Frost 2003).

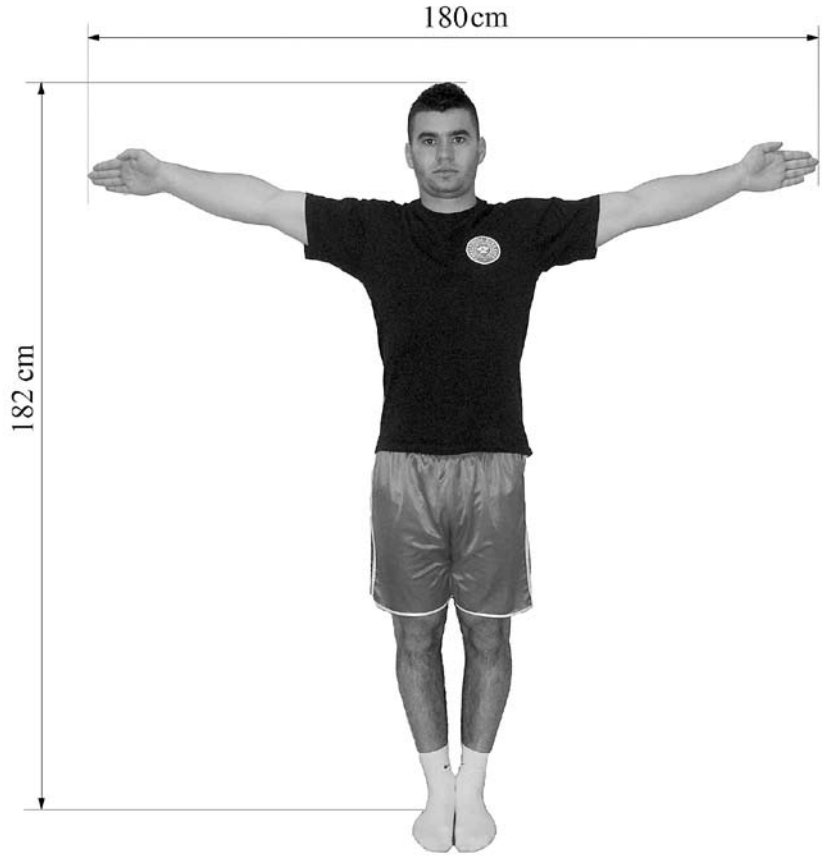

Figure 1: Typical body composition of Montenegrins

According to all mentioned above, the authors believed it would be reasonable to find the effectiveness of using various body indicators in estimating body height in the Montenegrin population because of their specific anthropometrical characteristics, such as very long legs, very high trunks and sitting height, correspondingly large chests and extremely low relative span, as well as short arms (Coon 1975). Several studies have reported the effectiveness and reliability of using various body parameters in predicting body height and arm span (Hickson & Frost 2003; Jalzem & Gledhill 1993; Mohanty et al. 2001; Ter Goon et al. 2011). However, the associations of arm span and body height was found to vary in different ethnic and racial groups (Brown, Feng & Knapp 2002; Reeves, Varakamin & Henry 1996; Steele & Chenier 1990). Even though several studies of this nature are available on western populations, very limited data is available on Montenegrin subjects. In the light of rather scarce recent scientific literature, the purpose of this study was to examine the body height in both sexes of Montenegrin adults and the relationship between arm span and body height.

Methods

The nature and scope of this study encompassed 285 students (178 men and 107 women) from the University of Montenegro as subjects. This group was chosen because the growth of an individual ceases by the time a person enters university and there is no age-related loss in body height at this age. The authors have also believed this sample could fairly represent the whole population of Montenegro, as students were admitted into the University of Montenegro regardless of geographical residence and socio-economic status, or ethnicity. The average age of the male subject was 20.97±2.44 years old (range 18–36 yrs.), while the average age of the female subject was 20.89±2.63 years old (range 18–37 yrs.). It is also important to emphasise that the authors could not accept students with physical deformities that could affect body height or arm span, and that those without informed consent were excluded from the study. Another exclusion criterion was being non-Montenegrin (two participants were excluded from the data pool). Accordingly, the authors purposely selected the students from the Faculty for Sport and Physical Education at University of Montenegro as they believed that most of them would be eligible to participate in the study; this is the only faculty for sport and physical education in Montenegro that brings together students from all parts of Montenegro.

According to Marfell-Jones, Olds, Stew & Carter (2006), the anthropometric measurements, including body height and arm span were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). A trained anthropometrist, whose quality of performance was evaluated according to the ISAK Manual prior to the study, performed these measurements(the same one for each measure). The age of the individuals was determined directly from their reported date of birth.

The body height is the perpendicular distance between the top of the head (the vertex) and the bottom of the feet. It was measured using stadiometer to the nearest 0.1 centimetres in bare feet with the participants standing upright against the stadiometer. The respondents had to put their feet together and move back until their heels touched the bottom of the stadiometer upright. Their buttocks and upper part of their back were in contact with the stadiometer upright, but their head did not have to touch the stadiometer. The respondent's head had to be in the Frankfort horizontal plane. This was achieved when the lower edge of the eye socket (the orbitale) was horizontal with the tragion. The vertex was the highest point on their head, otherwise the respondents had to raise or lower their chin until it was in the Frankfort horizontal plane to align their head properly.

The arm span is the anthropometric measurement of the length from the tip of the middle fingers of the left and right hands when raised parallel to the ground at shoulder height at a one-hundred eighty degree angle. It was measured using a calibrated steel tape to the nearest 0.1 centimetres in bare feet on a level concrete floor with their upper backs, buttocks and heels against the wall providing support. The participant's head was also in the Frankfort horizontal plane and the arms were outstretched at right angles to the body with palms facing forwards. The measurement were taken from one middle fingertip to the other middle fingertip, with the tape passing in front of the clavicles while two field workers supported the elbows. The measurements were taken twice, and an average of the

two readings was calculated. When the two measurements were within 0.4 centimetres of each other, their average was taken as the best estimate for the true value. When the two initial measures did not satisfy the 0.4 centimetres criterion, two additional determinations were made and the mean of the closest records was used as the best score.

The analysis was carried out using Statistical Package for Social Sciences (SPSS) version 10.0. Means and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of body heights and arm spans within and between the sexes was carried out using a t-test. The relationships between body height and arm span were determined using simple correlation coefficients and their 95% confidence interval. Linear regression analyses were then performed to examine the extent to which arm span can reliably predict body height. Finally, these relationships were plotted as scatter diagram. Statistical significance was set at $p<0.05$.

Results

A summary of the anthropometric measurements in both sexesis shown in Table 1. The mean of the arm span for male subjects was 185.71±8.17 centimetres, which was 2.50±4.15 centimetres more than the body height and statistically significant ($t=3.093$, $p<0.002$); for female subjects it was 168.13±6.58 centimetres, which was 0.24±3.88 centimetres less than the body height and statistically insignificant ($t=0.291$, $p<0.771$). The sex difference between body height and arm span measurements was statistically significant (body height: $t=18.80$; $p<.000$, and arm span: $t=18.87$; $p<.000$).

Subjects	Body Height Range (Mean±SD)	Arm span Range (Mean±SD)
Male	161.6-201.5 (183.21±7.06)	156.0-206.0 (185.71±8.17)
Female	156.9-182.2 (168.37±5.27)	152.0-184.7 (168.13±6.58)

Table 1: Anthropometric measurements of the population

The simple correlation coefficient and their 95% confidence interval analysis between the anthropometric measurements are presented in Table 2. The relationships between body height and arm span are high and significant in the sample, regardless of sex.

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.861	0.817–0.900	<0.000
Female	0.809	0.735–0.866	<0.000

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

The results of the linear regression analysis are shown in Table 3. The first of all models was derived by including age as a covariate. However, it was found that the

contribution of age was insignificant and therefore age was dropped and estimates were derived as a univariate analysis. The high values of the regression coefficient signify that arm span significantly predicts body height in both Montenegrin sexes.

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Male	0.861	0.033	74.2	22.499	0.000
Female	0.809	0.046	65.4	14.079	0.000

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

The relationships between arm span measurements and body height among the above models is plotted as a scatter diagram.

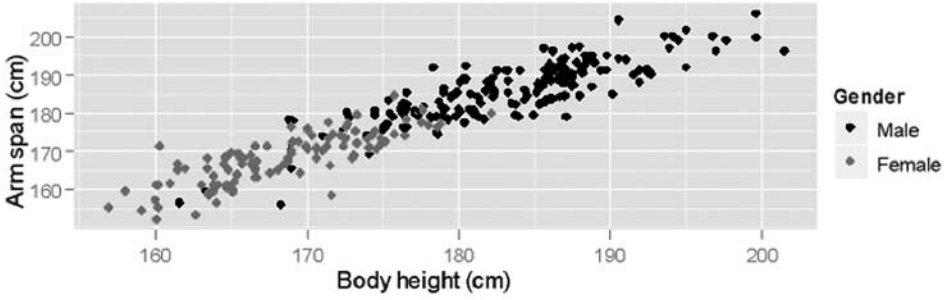

Figure 2: Scatter diagram and relationship between arm span measurements and body height among both sexes

Discussion and conclusion

Although there was some hypothesis that Montenegrin males are the tallest male population in all of Europe, which has not been proved yet because of poor records, this study contributes to a very important update of average body heights among Montenegrin males and females. The results proved that Montenegrin males are very tall with an average of 183.21 centimetres but this is not the tallest in Europe. It does not come close to 184.6 centimetres documented by Pineau et al. (2005) and 183.8 centimetres of the Dutch male population measured in the last nationwide survey in 2010 (TNO 2010). However, the 183.21 centimetres average height of Montenegrin men is taller than the 181.3 centimetres of Lithuanians (Tutkuviene 2005), the 180.9 centimetres of Serbs (J. Grozdanov, personal communication, 1 December 2011), the 180.6 centimetres of Icelanders (Dagbjartsson, Thornórsson, Pálsson & Arnórsson 2000), the 180.5 centimetres of Croats (Juresa, Musil & Tiljak 2012), the 180.4 centimetres of Swedes (Werner & Bodin 2006), the 180.3 centimetres of Slovenes (Starc & Strel 2011), Danes (Statistics Denmark 2011) and Czechs (Vignerová, Brabec & Bláha 2006) and the 141.7 centimetres of the shortest ethnic group in the world, the Mbuti Pygmies (cited in Froment 1993), which would make Montenegro the second-tallest nation in the world.

From the other side, the average body height of Montenegrin females was less than it expected. The results proved that Montenegrin females are 168.37 centimetres tall on average but not as tall as the 171.1 centimetres of the female population in the Dinaric Alps (Pineau et al. 2005) and the 170.7 centimetres of the Netherlands (TNO 2010), but still the second tallest nation in the world, according to the available record (unfortunately, some regions of the Dinaric Alps were excluded because of unavailable records). However, there is a hypothesis that both sexes of Montenegrins did not reach their full genetic potential yet, since they have been influenced by various environmental factors (wars, poor economic situation, etc.) in recent decades. Therefore, the authors believe that these circumstances had a negative bearing on the secular trend in Montenegro, while it is expected that the secular changes affecting height will go up in the following 20 years, comparable to developed countries where this trend has already stopped.

For better viewing of the average body height around the world, the authors have prepared Table 4 to present a summary of the available recent data for both sexes in European countries as a continent where the tallest people live, while the summary of the data from the rest of the world is sorted in Table 5 (most of the data are from national surveys).

Country	Average Body Height		Source
	Male	Female	
Belgium	179.5	166.3	DINBelg 2005
Czech Republic	180.3	167.2	Vignerová et al. 2006
Croatia	180.5	166.3	Juresa et al. 2012
England	177.6	163.4	NHS 2009
Finland	178.4	165.2	Peltonen et al. 2008
France	177.8	164.2	InVS 2007
Hungary	177.5	164.4	Bodzsár & Zsákai 2008
Ireland	176.3	163.3	Sproston & Mindell 2006
Island	180.6	167.2	Dagbjartsson et al. 2000
Italy	176.5	162.6	Cacciari et al. 2006
Latvia	177.6	167.1	Gerhards 2005
Lithuania	181.3	167.5	Tutkuviene 2005
Montenegro	183.2	168.3	Present study
Netherland	183.8	170.7	TNO 2010
Poland	178.5	165.1	Kułaga et al. 2010
Russia	177.2	164.1	Brainerd 2006
Slovenia	180.3	167.4	Starc & Strel 2011
Serbia	180.9	167.3	J. Grozdanov, per. communication 2011
Spain	177.3	164.0	Carrascosa Lezcano et al. 2008
Sweden	180.4	167.0	Werner & Bodin 2006
Turkey	173.6	161.9	Işeri & Arslan 2009
Wales	177.0	162.0	Statistics for Wales 2010

Table 4: Average body height in European countries

Country	Average Body Height		Source
	Male	Female	
Australia	174.8	163.4	ABS 1995
Argentina	174.5	161.0	Del Pino et al. 2005
Bahrain	171.0	156.6	Gharib & Shah 2009
Bolivia	166.6	155.4	Baya Botti et al. 2009
Brazil	170.7	158.8	IBGE 2010
Cameroon	170.6	161.3	Kamadjeu et al. 2006
China	173.4	161.2	Ji & Chen 2005
Egypt	170.3	158.9	El-Zanaty & Way 2008
Ghana	170.0	158.0	Schulz 2003
India	165.2	152.0	Mamidi et al. 2011
Iran	173.4	159.9	Haghdoost et al. 2008
Ivory Coast	171.0	159.0	Schulz 2003
Malaysia	166.3	154.7	Lim et al. 2000
Mexico	168.0	155.3	Del Río Navarro et al. 2007
Mongolia	168.4	157.7	WHO 2007
New Zealand	177.0	165.0	OSHS 1997
Nigeria	167.2	160.3	Ter Goon et al. 2011
Qatar	170.8	161.1	Bener & Kamal 2005
Saudi Arabia	168.9	156.3	El Mouzan et al. 2010
South Africa	168.0	159.0	OrcMacro 2007
South Korea	174.2	161.3	Kim et al. 2008
Sri Lanka	165.6	154.0	Ranasinghe et al 2011
United Arab Emirates	173.4	156.4	Abdulrazzaq et al. 2008
United States of America	176.3	162.2	McDowell et al. 2008

Table 5: Average body height in the rest of the World

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 centimetres or more in body height. If 13% in Montenegro would be compared to 28% in Dinaric Alps, 20% in the Netherlands and only 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 Netherlands.

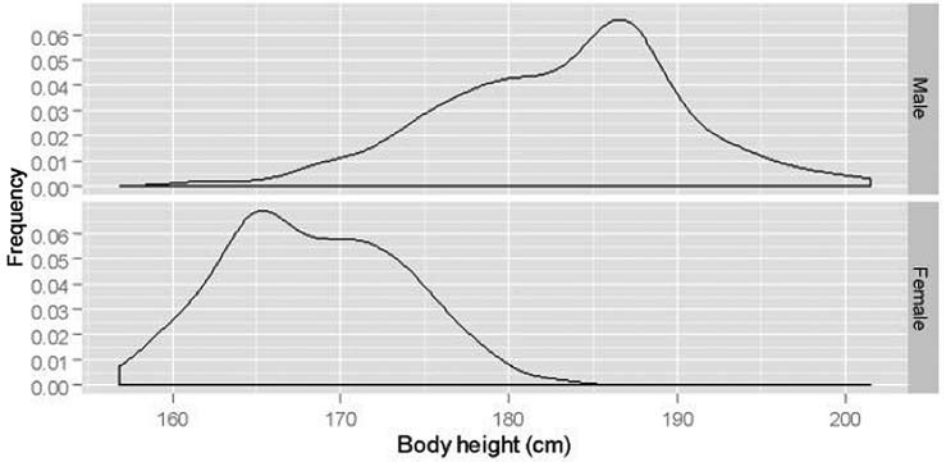

Figure 3: Frequency of body height among both sexes

The estimation of body height using various anthropometric measurements has attempted by many authors in many studies over the centuries. As already mentioned, all of them estimated body height from various anthropometric measurements, but it is important to emphasise that the arm span has been derived the most reliable body indicator for predicting the body height of an individual (Mohanty et al. 2001; Ter Goon et al. 2011). However, it must be emphasised that the individual and ethnic variations in respect of body height and its relation with arm span were already observed in European (Reeves et al. 1996) and African populations (De Lucia et al. 2002), while Mohanty et al. (2001) stated that the estimating equation varies from race to race, and ethnic group to ethnic group. In Steele and Chenier's study (1990), the arm span was nearly 8.3 centimetres more than the body height for the black population (105.36% body height), whereas for the white population this difference was only 3.3 centimetres (102.04% body height). Mohanty et al. (2001) have noted in their study that the arm span was nearly 2.5 centimetres more than the body height in South Indian females (101.4% body height), which is similar to that noted in the white population. In Ter Goon et al.'s study (2011), arm span was 5.8 centimetres more than body height for Nigerian males (103.3% body height), whereas for Nigerian females this difference was only 4 centimetres (102.5% body height) which is similar to that noted in the white population. Therefore, the main goal of the present study was to find out if these facts are true for the Montenegrin population, since it is known that the estimating equation varies from race to race, and ethnic group to ethnic group (Mohanty et al. 2001). Hence, in the present study it is also observed that the arm span was 2.5 centimetres more than the body height in males (101.4% body height), while it was 0.24 centimetres less than the body height in Montenegrin female population (99.9% body height). The arm span/height ratio in Montenegrin males is quite low when compared with other Europeans, and it has obviously not changed in the course of the last century, as evidenced by pre-World War II data cited by Coon (1975).

The results of the abovementioned studies are also very similar to the correlation obtained in the present study (men: r=0.861; women: r=0.809). For example, Mohanty et al. (2001) reported that the correlation was r=0.82, while in Hickson and Frost's study (2003) correlation was r=0.86; in Zverev's study (2003), the correlation was r=0.87 for males and r=0.81 for the female population, and in Ter Goon's study (2011) correlation was r=0.83. As the correlation between arm span and body height was high and significant in both Montenegrin sexes, the arm span measure therefore seems to be a reliable indirect anthropometric measurement for estimating body height in Montenegrin adults.

Even though these relations are similar, the estimation equations which are obtained in the Montenegrin population (especially in the female population) are substantially different from other populations. Therefore, it is necessary to develop separate models for each population, on account of ethnic differences, using bigger samples for the prediction of body height utilising arm span measurement, as with the sample of this study, as well as some other previous studies (Aggrawal et al. 2000; Hickson & Frost 2003; Kwok & Whitelaw 1991; Steele & Chenier 1990; Ter Goon et al. 2011; Zverev 2003). A more precise estimation of the average body height and its prediction utilising arm span 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; Wronka & Pawliñska-Chmara 2009), and Hungary (Bodzsár & Zsákai 2008; Eiben & Tóth 2000; Szöllősi 1998), the authors cannot exclude the possibility that the body height of the students somewhat overestimates the average body height of contemporary Montenegrins.

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POVZETEK

Evropski antropologi so nenavadno višino Črnogorcev zaznali že več kot pred 100 leti. V luči redkih znanstvenih študij je namen te raziskave preučiti današnjo telesno višino pri obeh spolih odraslih Črnogorcev in razmerje med razponom rok in telesno višino. Le-to je namreč različno glede na različne etnične in rasne skupine ter predstavlja alternativo določanja telesne višine za določene skupine populacije. Glede na namen je bilo v študijo vključenih 285 študentov (178 moških, starih 20,97±2,44 in 107 žensk, starih 20,86±2,63) Univerze Črne gore. Antropološke meritve so bile izvedene skladno z ISAK protokoli. Izračunane so bile aritmetične sredine in standardni odkloni. Primerjavo med aritmetičnimi sredinami telesne višine in razpona rok za vsak spol in med spoloma smo naredili s t-testom. Razmerje med telesno višino in razponom rok smo določili z uporabo korelacijskega koeficienta na podlagi njegovega 95% intervala zaupanja. Z linearno regresijo smo ugotovili, kako zanesljivo razpon rok napoveduje telesno višino. Rezultati so pokazali, da so moški Črnogorci visoki 183,21±7,06 centimetrov, razpon rok pa imajo 185,71±8,17 centimetrov. Črnogorke so visoke 168,37±5,27 centimetrov, razpon rok pa imajo 168,13±6,58 centimetrov. Primerjava rezultatov z drugimi študijami kaže, da so Črnogorci ne glede na spol drugi najvišji narod na svetu, pri tem pa razpon rok zanesljivo napoveduje telesno višino pri obeh spolih. Vendar pa je enačba med navedenima antropometričnima merama pri Črnogorcih precej drugačna kot pri vseh drugih populacijah, ker so vrednosti razpona rok precej bližje telesni višini: pri moških 2,50±4,15 centimetra več od telesne višine, pri ženskah pa 0,24±3,88 centimetra manj od telesne višine. To potrjuje potrebo po razvoju ločenih alternativnih modelov določanja telesne višine za vsako populacijo na podali etničnih razlik.

KLJUČNE BESEDE: napovedovanje, stojna višina, velikost, Črna gora

CORRESPONDENCE: STEVO POPOVIĆ, Faculty for Sport and Physical Education, University of Montenegro, Narodne omladine b.b., 81400 Nikšić, Montenegro. E-mail: stevop@ac.me.