ORIGINAL SCIENTIFIC PAPER

Stature and Its Estimation Utilizing Arm Span Measurements in Male Adolescents from Federation of Bosnia and Herzegovina Entity in Bosnia and Herzegovina

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ABSTRACT The purpose of this study was to evaluate stature in males from the Federation of Bosnia and Herzegovina Entity in Bosnia and Herzegovina (hereinafter BH) as well as the relationship between arm span as an alternative to estimating stature, which varies in different ethnic and racial groups. The nature and scope of this study analyse 193 male students (aged 20.84±2.08) from the University of Sarajevo and University of Mostar. Anthropometric measurements were used in accordance with the protocol of the ISAK. Means and standard deviations were obtained. Statures and arm spans were compared using a t-test. The relation between arm span and stature were determined using simple correlation coefficients and a confidence interval of them of 95%. A linear regression analysis was then executed to examine the extent to which stature can be reliably predicted by arm span. The results have shown that males from the Federation of Bosnia and Herzegovina Entity are 183.84±6.41 cm tall and have an arm span of 185.65±7.55 cm. In comparison to other studies, the results of this one show the BH population to be one of the tallest nations in the world, perhaps the tallest one. Moreover, arm span surely predicts stature in males (61.6%). However, the estimation equations, which were obtained in Bosnian Herzegovinians from mentioned entity, are substantially different alike in the population from other entities, since arm span was not close to statures (1.81±1.14 cm more than the stature). This confirms the need for developing individual height models for this population.

KEY WORDS Prediction, Body Height, Arm Span, Bosnia and Herzegovina.

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Introduction

The Republic of Bosnia and Herzegovina (hereinafter BH) as an independent and democratic state has a parliamentary system made of several different political parties. The governmental system is based on the division of power into legislative, executive and judiciary branches, and it has a bicameral legislature, and a three-member presidency constituted of a member of every major ethnic group (Bosniaks, Serbs, and Croats). The country, largely decentralized with highly limited central governmental power, is composed of two autonomous entities: the Federation of BH and Republic of Srpska, with the Brcko District as a third region, run under local government. This country declared independence in 1992 as one of the inheritor states of the former Yugoslavia. Despite being one of the youngest states in the world, this is a region which finds permanent human settlement back to the Neolithic age. It was populated by several Illyrian and Celtic civilizations. From the 6th to the 9th centuries AD Slavic peoples settled this area. This is why BH has very rich history, one of the richest in the region, culturally, socially and politically.

This area was occupied by the Ottoman Empire from the mid-15th to the late 19th centuries, after which

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it were under the Austro-Hungarian Empire, which lasted up until the World War I. BH was a part of the Kingdom of Serbs, Croats and Slovenes (from 1929 the Kingdom of Yugoslavia) until World War II, after which the country became a republic in a newly formed Socialist Federal Republic of Yugoslavia. Hence, this country has been one the largest crossroads of historic empires.

Nowadays, the Republic of BH covers an area of 51,197 km² (Central Intelligence Agency, 2014). It is in South-eastern Europe, on the Balkan Peninsula. It is bordered by Serbia to the east, Croatia to the north, west, and south, and Montenegro to the south-east, and it has 20 kilometres of coastline on the Adriatic Sea, around the town of Neum in the Herzegovina-Neretva Canton. Being surrounded by Croatian peninsulas, BH has rights of passage to the outer sea, per international law. The central and southern interior of the country is mountainous, the north-west is moderately hilly, and the northeast is predominantly flatland. The name of the country comes from two regions: Bosnia and Herzegovina. The border between them is not clearly defined. Bosnia occupies approximately four-fifths of the country, the north part, while Herzegovina occupies the rest. The country is mostly mountainous, encompassing the central Dinaric Alps. The Pannonian basin borders the north-eastern parts, while the Adriatic Sea borders it in the south. Dinaric Alps generally run in an east-west direction and rise towards the south. Overall, water covers less than 1%, while forest covers approximately 50% of the country. Herzegovina has dry Mediterranean climate in comparison to Bosnia where most forest areas are in the central, eastern and western parts. Northern Bosnia (Posavina) is very fertile agricultural land, which spreads along the River Sava; ir is heavily farmed. This farmland is a part of the Parapannonian Plain extending into neighbouring Croatia and Serbia.

There are three ethnic "constituent peoples in BH": Bosniaks, Serbs, and Croats. According to the 1991 census, BH had a population of 4,377,000 inhabitants (Institute for Statistics of Federation of BH, 2014); the 1996 UNHCR unofficial census showed a decrease to 3,920,000 inhabitants (Institute of International Cooperation of the German Adult Education Association, 2014). The Yugoslav wars in the 1990s caused large migrations of the population which have led to demographic shifts in the country. No census has was undertaken during war time, and political disagreements made it impossible to organize one later. A census planned for 2012 was delayed until 2014. The total population of the Republic of BH, by the 2014 census, was 3,871,643 inhabitants (Central Intelligence Agency, 2014). According to data collected by the Central Intelligence Agency (2014), the ethnic constitution of BH is Bosniaks 52.5 per cent of the population, Serbs 33.5 per cent, Croats 14 per cent, and around 1 per cent the others. Per the same source, Muslims account for 40 per cent of the population, Orthodox Christians 31 per cent, 15 per cent as Roman Catholics, and the rest (14 per cent) are others (atheists, Jews, and others). As ethnicity mostly corresponds to the religious affiliations, it is assumed that these differences are primarily based on religious backgrounds, and it is not based on biological facts. As this is a very sensitive question in BH, further analyses must take care with this conclusion.

The Dinaric Alps was recognized as an area with tall people by European anthropologists more than 100 years ago (Pineau, Delamarche, & Bozinovic, 2005). Bearing in mind that the modern BHs, like the other nations from Former Yugoslavia, fall more into the Dinaric racial classification than any other, the researchers of this study assumed that male BH adults may be a bit taller or equally tall than the tallest nations in the Europe (Bjelica, Popovic, Kezunovic, Petkovic, Jurak, & Grasgruber, 2012; Popovic, Bjelica, Molnar, Jaksic, & Akpinar, 2013; Popovic, Bjelica, Doina Tanase, & Milasinovic, 2015): BHs (183.9 cm; sampled in Republic of Srpska), Dutch (183.8 cm), Montenegrins (183.21 cm) and Serbians (182 cm). The researchers of this study believed that the BH population may be the tallest in the world. This is mostly because most the of previous studies analysed all the nations that have been contained in the sample of Pineau and collaborators (Bjelica et al., 2012; Popovic et al., 2013; Popovic et al., 2015; Popovic, Bjelica, Geogiev, Krivokapic, & Milasinovic, 2016), excluding the Federation of BH Entity in BH. However, previously analysed nations did not reach the height that Pineu and his collaborators (2005) confirmed. Because of that, the population from the Federation of BH Entity in BH may be the population that increased the average stature of the Dinaric Alps population measured by Pineu and his collaborators (2005). However, there are no available records from this region, unlike most other countries in Western Europe, and an update of average statures among its populations is beneficial as well as its estimation utilizing arm span measurements, mostly because that measurement of stature is significant in many context (Bjelica et al., 2012).

A well-established fact in the scientific literature is the importance of the measurement of stature in many contexts: as a measure of body size and an assessment of nutritional status (Datta Banik, 2011), an important measure for determining the basic energy requirements, also standardization of measures of physical capacity and adjusting drug dosage, evaluation of children's growth, prediction and standardization of physiological variables such as muscle strength, lung volumes, glomerular filtration and metabolic rate, etc. (Golshan, Amra, & Hoghoghi, 2003; M. Golshan, Crapo, Amra, Jensen, & R. Golshan, 2007; Mohanty, Babu, & Nair, 2001; Ter Goon, Toriola, Musa, & Akusu, 2011). However, there are many situations (i.e. conditions) where the exact stature cannot always be determined the usual way, for example, paralysis, amputation, fractures, scoliosis, or pain (Quanjer, Capderou, Mazocioglu, Aggarwal, Popovic, Datta Banik, Tayie, Golshan, Ip, & Zelter, 2014). In such situations, estimation of stature has to be derived from other reliable anthropometric indicators such as hand and foot lengths (A.K. Agnihotri, Purwar, Googoolybe, S. Agnihotri, & Jeebun, 2007; A.K. Agnihotri, S. Agnihotri, Jeebun, & Googoolye, 2008; Kanchan, Menezes, Moudgil, Kaur, Kotian, & Garg, 2008; Rastogi, Nagesh, & Yoganarasimha, 2008; Sanli, Kizilkanat, Boyan, Ozsahin, Bozkir, Soames, Erol, & Oguz, 2005; Uhrova, Benus,

UDC 572.512-053.8(497.6)

Masnicova, Obertova, Kramarova, Kyselicova, Dornhoferova, Bodorikova, & Nescakova, 2015), knee height (Fatmah, 2010; Fogal, Franceschini, Priore, Cotta, & Ribeiro, 2015; Hickson & Frost, 2003; Karadag, Ozturk, Sener, & Altuntas, 2012), length of the forearm (Ilayperuma, Nanayakkara, & Palahepitiya, 2010), length of the sternum (Menezes, Kanchan, Kumar, Rao, Lobo, Uysal, Krishan, Kalthur, Nagesh, & Shettigar, 2009; Menezes, Nagesh, Monteiro, Kumar, Kanchan, Uysal, Rao, Rastogi, Lobo, & Kalthur, 2011), vertebral column length (Nagesh & Pradeep, 2006), sitting height (Fatmah, 2010), length of scapula (Campobasso, Di-Vella, & Introna, 1998), arm span (Aggrawal, Gupta, Ezekiel, & Jindal, 2000; Bjelica et al., 2012; Bubanja, Vujovic, Tanase, Hadzic, & Milasinovic, 2015; Datta Banik, 2011; Fatmah, 2010; Hickson & Frost, 2003; Jalzem & Gledhill, 1993; Mohanty et al., 2001; Popovic et al. 2015; Ter Goon et al., 2011; Vujovic, Bubanja, Tanase, & Milasinovic, 2015) as well as cranial sutures (Rao, Sowmya, Yoganarasimha, Menezes, Kanchan, & Aswinidutt, 2009), skull measurements (Bidmos, 2006; Bidmos & Asala, 2005), facial measurements (Sahni, Sanjeev, Sharma, Harjeet, Kaur, & Aggarwal, 2010) and others. Therefore, in predicting age-related loss in stature, all these anthropometric indicators used as an alternative to estimate stature are crucial. Because of mobility problems and kyphosis (Hickson & Frost, 2003) it is difficult and sometimes impossible to measure precisely the stature of individuals with stature loss while having surgical procedures on the spine (Mohanty et al., 2001) or disproportionate growth abnormalities and skeletal dysplasia, as well as predicting stature with many older people.

Due to all the aforementioned, the researchers trusted it would be reasonable to find the effectiveness of using various body indicators while the estimating stature in BHs. Even though there is a study which covers just the Republic of Srpska entity (Popovic et al., 2015), it is more than necessary to conduct the same study in Federation of BH Entity as this update would fit a missing part of the picture from entire BH and its ethnic groups. Moreover, several studies have presented the effectiveness of using various body parameters in predicting stature and arm span as the most reliable one (Hickson & Frost 2003; Jalzem & Gledhill 1993; Mohanty et al., 2001; Ter Goon et al., 2011). Nevertheless, the associations of arm span and stature was found to differ in different ethnic and racial groups (Bjelica et al., 2012; Brown, Feng, & Knapp, 2002; Reeves, Varakamin, & Henry, 1996; Popovic et al., 2013; Steele & Chenier, 1990; Popovic et al., 2015), while the study conducted by Quanjer et al. (2014) reported that the arm span/height ratio changes non-linearly with age and varies between males and females. Although several studies of this nature are related to Dinaric Alps populations, there are very limited data on BH subjects and no studies conducted in the Federation of BH Entity where various ethnic groups live. In the light of rather poor recent scientific literature, the goal of this study was to examine the stature with BH adult males (Federation of BH Entity) and the relationship between arm span and stature.

Methods

The nature and scope of this study encompass 193 male students from the University of Sarajevo and University of Mostar as subjects. The students were chosen because the growth of an individual ceases by this age and because there is no age-related loss in stature at this age. Although university-educated persons, according to Bjelica et al. (2012) are taller in comparison to the general population in Poland (Kułaga, Litwin, Tkaczyk, Palczewska, Zajączkowska, Zwolińska, Krynicki, Wasilewska, Moczulska, Morawiec-Knysak, Barwicka, Grajda, Gurzkowska, Napieralska, & Pan, 2011; Wronka & Pawlińska-Chmara, 2009), and Hungary (Bodzsár & Zsákai, 2008; Eiben & Tóth, 2000; Szöllősi, 1998), but not in Montenegro (Bjelica et al., 2012, Popovic et al., 2014), the researchers also believed this sample might fairly represent the whole population of the Federation of BH Entity. The average age of the subject was 20.84±2.08 years old (range 18-31 yrs.). It should be emphasized that the researchers did not accept students with physical deformities that would affect stature or arm span, and those without informed consent were not included in the study. The exclusion criterion was also not having BH citizenship. Accordingly, the researchers have purposely selected (deliberate sampling) the students from the University of Sarajevo and University of Mostar.

Although photogrammetric anthropometry is precise nowadays, it is not valid for measurement of arm span (Penders, Brecheisen, Gerver, Van Zonneveld, & Gerver, 2015); the anthropometric measurements, including stature and arm span, were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al., 2006). The trained anthropometrist (the same one for each measure) whose quality of performance was evaluated according to the prescribed "ISAK Manual" prior to the study performed these measurements. The age of the students was determined directly from the date of birth they reported.

Using Statistical Package for Social Sciences (SPSS) version 20.0, the analysis was performed. Means and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of statures and arm spans was carried out using a t-test. The relationships between stature and arm span were determined using simple correlation coefficients and a 95% confidence interval. For examining the extent to which arm span can reliably predict stature, a linear regression analysis was performed. Finally, these relationships were plotted as scatter diagrams. Statistical significance was set at $p<0.05$.

Results

A summary of the anthropometric measurements is shown in Table 1. The mean value of the arm span for subjects was 185.65±7.55 cm, which was 1.81±1.14 cm more in comparison to the stature, and statistically significant ($t=5.343$, $p=0.000$).

TABLE 1 Anthropometric Measurements of the Study Subjects

Subject	Age (Mean±SD)	Stature Range (Mean±SD)	Arm Span Range (Mean±SD)
Male	18-31 (20.84±2.08)	169.0-205.4 (183.84±6.41)	170.0-213.4 (185.65±7.55)

The simple correlation coefficient and the 95% confidence interval analysis between the anthropometric measurements are presented in Table 2. High and significant relationships were found between stature and arm span in the sample.

TABLE 2 Correlation between stature and Arm Span of the Study Subjects

Subject	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.785	0.689-0.850	<0.000

The results of the linear regression analysis are shown in Table 3. The first models were derived by including age as a covariate. However, after it was found that age was insignificant, it was dropped, and estimates were gained as univariate analysis. The high values of the regression coefficient signify that arm span significantly predicts stature in males from the Federation of BH Entity in BH.

A scatter diagram shows the relationships between measurements of arm span and stature among the above model.

TABLE 3 Results of Linear Regression Analysis Where Arm Span Predicts Stature

Subject	Regression Coefficient	Standard Error	R-square (%)	t-value	p-value
Male	0.785	3.980	61.6	17.505	0.000

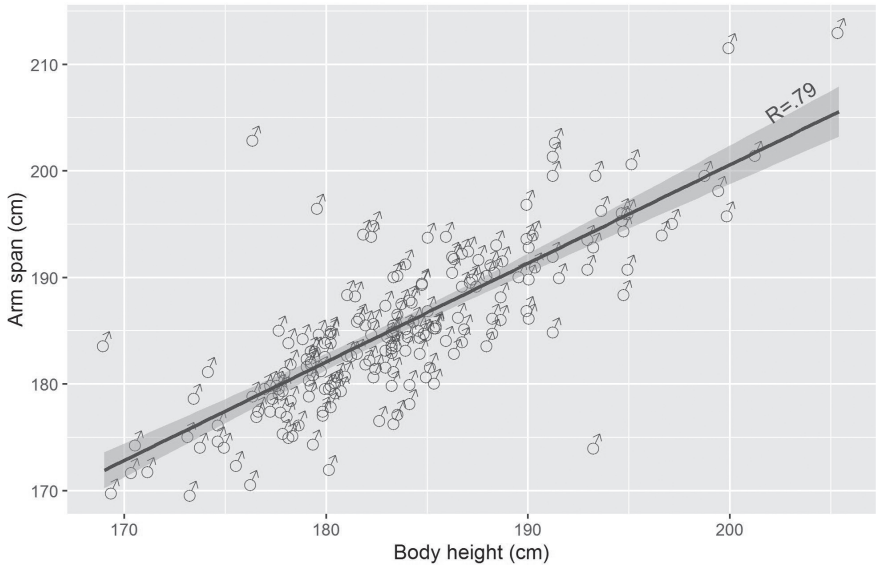

FIGURE 1. Scatter diagram and relationship between arm span measurements and body height among

Discussion

This study contributes to a major update of average statures among males from the Federation of BH Entity in BH. The results proved that males from that entity are very tall with an average of 183.84 cm, and this is within the range of the men from the other entity from BH who are 183.87 cm tall (Popovic et al., 2015), which is slightly more in comparison to the tallest nations in the Europe: the Dutch male population at 183.8 cm, which was measured in the last nationwide survey in 2010 (TNO, 2010), the Montenegrin male population at 183.74 cm measured in 2013 (Popovic, Bjelica, & Hadzic, 2014) and the Serbian male population measured in 2012 at 182 cm (Popovic et al., 2013). Consequently, the average height of BHs from the Federation of BH Entity is also taller than the 181.3 cm of the Lithuanians (Tutkuviene, 2005), the 180.6 cm of the Icelanders (Dagbjartsson, Hornórsson, Pálsson, & Arnórsson, 2000), the Croats at 180.5 cm (Juresa, Musil, & Tiljak, 2012), the Swedes at 180.4 cm (Werner & Bodin, 2006), the Slovenes at 180.3 cm (Starc & Strel, 2011), Danes (Statistics Denmark, 2011) and Czechs (Vignerová, Brabec, & Bláha, 2006) as

UDC 572.512-053.8(497.6)

well as several more nation that are taller than 180 cm. Consequently, BH males are the tallest in the world. Furthermore, there is a hypothesis that the male gender of BHs has not reached their full genetic potential yet since they have been influenced by various environmental factors (wars, poor economic situation, etc.) in recent few decades. Therefore, the researchers believe that these circumstances had a negative effect on the secular trend in BH as well as neighbouring countries such as Serbia, Montenegro and Macedonia (Bjelica et al., 2012; Popovic et al., 2013, Popovic et al., 2016), while it is expected that the secular changes which affect height are going to rise in the following two decades, in comparison to developed countries where this trend has already been completed.

To have a better perspective of the tallest nations around the world, the researchers have prepared Table 4 to give an overview of the top 10 tallest male populations in the world (the most of them are data from the national surveys).

TABLE 4. An Update of the Top 10 Tallest Male Nations in the World

#	*Country*	*Average* Stature	*Source*
1	Bosnia & Herzegovina	183.9	Popovic et al., 2015
1a	Bosnia & Herzegovina	183.8	Current study
2	Netherland	182.4	Statistics Netherland, 2015
3	Montenegro	183.2	Bjelica et al., 2012
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	Juresa et al., 2012
9	Sweden	180.4	Werner and Bodin, 2006
10	Slovenia	180.3	Starc and Strel, 2011

It is also interesting to note that the density of very tall subjects appears to be characteristic of the males from the Federation of BH Entity in BH (Figure 1) since 18.1% measured 190 cm or more in stature. If the 18.1% in Federation of BH Entity in BH (20.2% in Republic of Srpska entity in BH) would be compared to the 28% in Dinaric Alps (Pineau et al., 2005), 20% in the Netherlands (Pineau et al., 2005), 14% in Serbia (Popovic et al., 2013), 13% in Montenegro (Bjelica et al., 2012) and only 1.5% in France (Pineau et al., 2005), it would confirm that the denseness of very tall subjects in BH males is a fact, but less so than in the Dinaric Alps in general, according to the conclusions reached in Pineu and collaborator's study (2005). Therefore, the critical questions of who people are who increased the denseness of very tall subjects in Pineu and collaborator's study remains open, as most of the nations are excluded.

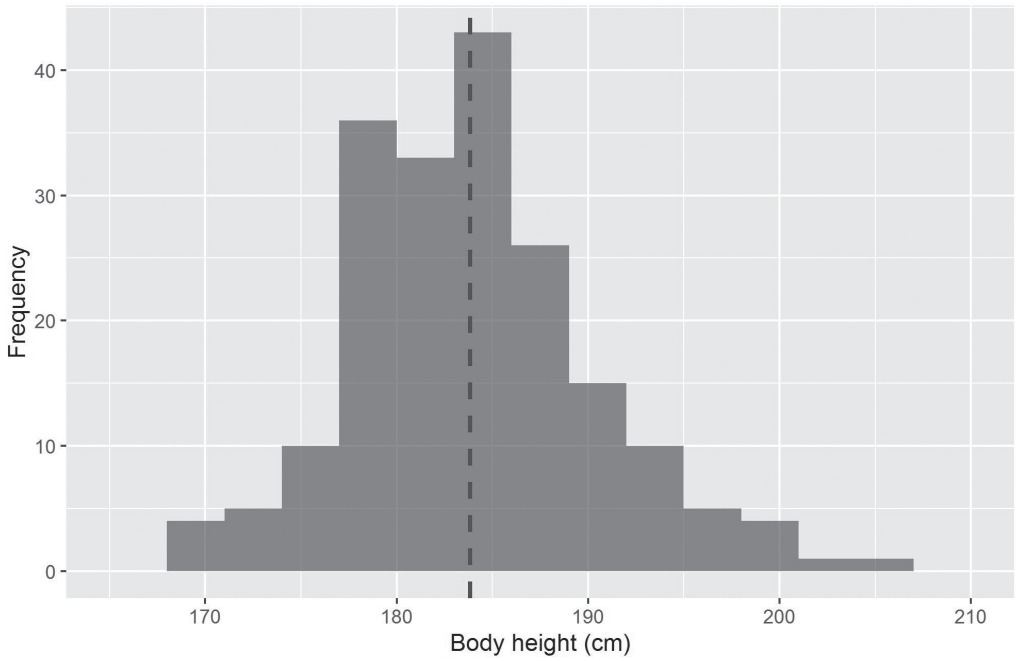

FIGURE 2. Density of Stature

Estimating the stature using various anthropometric measurements is an age-old investigation used previous centuries, and many researchers have attempted it. As already brought up, stature have been estimated from various anthropometric measurements by all of them, but it is important to underline that the arm span has been derived as being the most reliable body indicator for prediction stature of an individual (Mohanty et al., 2001; Ter Goon et al., 2011). However, it must be emphasized that the individual, as well as ethnic variations in respect of the relation og stature with arm span, were observed in European (Reeves et al., 1996) and African populations (De Lucia, Lemma, Tesfaye, Demisse, & Ismail, 2002), while Mohanty et al. (2001) have agreed that the estimating equation varies from race to race, and ethnic group to ethnic group. In Steele and Chenier's study (1990), arm span was almost 8.3 cm longer than stature for the black population (105.36% stature), where for the white population this difference was only 3.3 cm (102.04% stature). In Ter Goon et al.'s study (2011), arm span was 5.8 cm longer than stature for Nigerian males (103.3% stature). The latest studies run by Bjelica et al. (2012) showed that arm span was 2.5 cm longer than stature for Montenegrin males (101.4% stature) and Popovic at al. (2013) that showed that arm span was 2.8 cm longer than stature for Serbian males (101.5% stature), while Quanjer et al. (2014) have highlighted the stature and arm-span-to-height ratio may differ by up to 10% from actual stature. All the abovementioned have confirmed again the necessity for developing individual height models for each population on account of ethnic differences, while some recent studies found the regional differences among the same ethnic groups (Bubanja et al., 2015; Milasinovic, Popovic, Matic, Gardasevic, & Bjelica, 2016; Milasinovic, Popovic, Jaksic, Vasiljevic, & Bjelica, 2016; Vujovic et al., 2015), which cause the need for additional caution.

Because Bosnia and Hercegovina has two regions (entities) and three different ethnic groups, the main goal of the current study was to determine if these facts are true for the males from Federation of BH Entity in BH, since it is known that the estimating calculation varies from race to race, and ethnic group to ethnic group (Mohanty et al., 2001). Therefore, in this study, it is observed that the arm span was 1.81 cm longer than stature among men (100.3% stature). The arm span/height ratio in males from the Federation of BH Entity in BH is quite low when compared with other Europeans, but it is very close to the data reached when measuring the Montenegrin (Bjelica et al., 2012), Serbian (Popovic et al., 2013) and Macedonian populations as well as the other entity from BH (Popovic et al., 2015). It might be assumed that these similarities in body composition are caused by the joint genetic background of these nations.

The results of the aforementioned studies are also very similar to the correlation found in the present study (r=0.78). For example, Mohanty et al. (2001) observed the correlation r=0.82, while the correlation in Hickson and Frost's study (2003) was r=0.86, in Zverev's study (2003) it was r=0.87 for males population. In more recent studies, Ter Goon et al. (2011) reported the correlation r=0.83, while Bjelica et al. (2012) reported r=0.86, Popovic et al. (2013; 2015) reported the correlation high (r=0.81; r=0.88). Because the relation between arm span and stature is high and significant in the study sample, the arm span measure is apparently a reliable indirect anthropometric measurement used for estimating stature in males from the Federation of BH Entity in BH. As similar as these relations are, the estimation equations, obtained in the study population, might be substantially different from the population in another entity in BH as well as in other populations.

Although the results of this study confirm the need for developing individual height models for each population on account of ethnic differences, it must be emphasized that further research should use larger samples for the projection of stature using arm span measurement, mostly because this study as well as some other studies have used quite small samples. A more precise estimation of the average stature and its prediction using arm span measurements with BH adults would require a large sample with sufficient geographical and social heterogeneity (various ethnic groups), or a national survey that measures the whole population. Furthermore, in addition to the small sample, another limitation of this research study was the composition of the measured university students. Since university-educated persons have been proved to be taller than the rest of the population in Poland and Hungary, unlike in Montenegro, the possibility that the stature of the students somewhat overvalues the average stature of contemporary BH cannot be excluded. Furthermore, it is imperative to highlight that body proportion measurement using photogrammetric anthropometry, while nowadays accurate, is not valid for arm span measurement; keeping the old-fashioned method of measuring this body proportion is recommended.

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