PRINT: ISSN 0972-0073 ONLINE: 2456-6802
Anthropologist, 24(3): 737-745 (2016)
DOI: 10.31901/24566802.2016/24.03.07

Body Height and its Estimation Utilizing Arm Span Measurements in Macedonian Adults

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KEYWORDS Prediction. Measurement. Stature. Arm Span. Macedonia

ABSTRACT The purpose of this study is to examine body height in Macedonian adults as well as its relationship with arm span, as an alternative to estimating body height. A total of 239 students (114 men and 125 women) participated in this study. The anthropometric measurements were taken according to the protocol of ISAK. The relationships between body height and arm span were determined using simple correlation coefficients at a ninety-five percent confidence interval. Then a linear regression analysis was performed to examine extent to which arm span can reliably predict body height. Results displayed that male Macedonians are 178.10±6.79cm tall and have an arm span of 178.78±7.71cm, while female Macedonians are 164.58±5.40cm tall and have an arm span of 164.41±6.42cm. The results have shown that both genders made Macedonians a tall nation but not even close to be in top tallest nations. Moreover, the arm span reliably predicts body height in both genders.

INTRODUCTION

The Republic of Macedonia is an independent, democratic state with a multiparty parliamentary system. The governmental system is based on the division of power into legislative, executive and judiciary. This country is one of the successor states of the former Yugoslavia, from which it declared independence in 1991. It became a member of the United Nations in 1993. However, it was admitted under the provisional reference of the Former Yugoslav Republic of Macedonia (FYROM), due to the dispute with Greece over its name (United Nations 1993). Today, the Republic of Macedonia covers the area of 25,713 square kilometers. It is located in the central Balkan Peninsula in southeast Europe and it is landlocked and borders Kosovo (as defined under UNSCR 1244/99) in the northwest, Serbia to the north, Bulgaria to the east, Greece to the south, and Albania to the west. The Republic of Macedonia is a landlocked country that is geographically clearly defined by a central valley formed by the Vardar River and framed along its borders by mountain ranges of the Shar Mountains and Osogovo. However, it is interesting to highlight that it belongs to two different mountain ranges, namely, the Shar Mountains that continues to the west of Vardar/Pelagonia group of mountains, also well known as the Dinaric range, as well as the Osogovo-Belasica mountain chain, also well known as the Rhodope range.

Total population of the Republic of Macedonia, according to the 2002 census, was 2,022,547 inhabitants (State Statistical Office 2005). Moreover, the ethnic population of the Republic of Macedonia is very diverse because of the country's turbulent past. According to the 2002 census, the largest ethnic group in the country is the Macedonian ethic group, representing 64.18 percent of the total population, while the second largest are the Albanians, who dominated much more in the northwestern part of the country and represent 25.17 percent of the total population. It is also very important to analyze the number of Roma in the country, mostly due to the reason the official estimations from the 2002 census registered just 53,879 persons from this ethnic group, while some unofficial estimation indicate that there are up to 260,000 Roma in the Republic of Macedonia (United Nations Development Program 2006).

The tallness of the nations in the Dinaric Alps was recognized by European anthropologists more than 100 years ago (Pineau et al. 2005). As the modern Macedonians, like the rest of the nations from former Yugoslavia, fall into the Dinaric racial classification, it is assumed by the

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researchers of this study that Macedonian adults might be equally tall or at least very close to the tallest nations in the Europe, in line with the Dutch (male: 183.8 centimeters; female: 170.7 centimeters), Montenegrins (male: 183.21 centimeters; female: 168.37 centimeters) and Serbians (male: 182.0 centimeters; female: 166.8 centimeters). Unlike the most other countries through Western Europe, Macedonia keeps poor records, and an update of average body heights among Macedonian populations is so beneficial as well as its estimation utilizing arm span measurements, mostly due to the reason that measurement of body height is important in many settings (Popovic et al. 2015).

It is already well known in scientific literature that the measurement of body height is an indispensable variable when assessing nutritional status (cited in Datta Banik 2011), as well as determination of basic energy requirements, standardization of measures of physical capacity and adjusting drug dosage, and evaluation of children's growth, prediction and standardization of physiological variables such as lung volumes, muscle strength, glomerular filtration and metabolic rate (Golshan et al. 2003; Golshan et al. 2007; Mohanty et al. 2001; Ter Goon et al. 2011). However, there are many conditions in which the exact body height cannot always be determined the usual way, for example, due to paralysis, fractures, amputation, scoliosis and pain (Quanjer et al. 2014). In such circumstances, an estimate of body height has to be derived from other reliable anthropometric indicators such as hand and foot lengths (Agnihotri et al. 2008; Agnihotri et al. 2007; Kanchan et al. 2008; Rastogi et al. 2008; Sanliet al. 2005; Uhrova et al. 2015), knee height (Fatmah 2005; Fogal et al. 2015; Hickson and Frost 2003; Karadag et al. 2012), length of the forearm (Ilayperuma et al. 2010), length of the sternum (Menezes et al. 2009; Menezes et al. 2011), vertebral column length (Nagesh and Pradeep 2006), sitting height (Fatmah 2005), length of scapula (Campobasso et al. 1998), arm span (Aggrawal et al. 2000; Bjelica et al. 2012; Bubanja et al. 2015; Datta Banik 2011; Fatmah 2005; Hickson and Frost 2003; Jalzem and Gledhill 1993; Mohanty et al. 2001; Popovic et al. 2015; Ter Goon et al. 2011; Vujovic et al. 2015) as well as cranial sutures (Rao et al. 2009), skull (Bidmos 2006; Bidmos and Asala 2005), facial measurements (Sahni et al. 2010) et cetera. Therefore, all these anthropometric indicators, which are used as an alternative to estimate body height, are very important in predicting age-related loss in body height. Also, 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 and Frost 2003).

According to all mentioned above, the researchers believed it would be reasonable to find the effectiveness of using various body indicators in estimating body height in the Macedonian population. Furthermore, several studies have reported the effectiveness of using various body parameters in predicting body height and arm span was found to be the most reliable one (Hickson and Frost 2003; Jalzem and 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 (Bjelica et al. 2012; Brown, Feng and Knapp 2002; Reeves et al. 1996; Popovic et al. 2013; Steele and Chenier 1990; Popovic et al. 2015), while the study conducted by Quanjer et al. (2014) has reported that the arm span to height ratio changes non-linearly with age and differs between males and females. Even though several studies of this nature are available on Western populations, very limited data is available on Macedonian subjects. In the light of rather scarce recent scientific literature, the purpose of this study was to examine the body height in both genders of Macedonian adults and the relationship between arm span and body height.

METHODOLOGY

The nature and scope of this study qualifies 239 students (114 men and 125 women) from the Ss. Cyril and Methodius University to be subjects. This group was chosen because the growth of an individual ceases by this age and there is no age-related loss in body height at this age. Although university-educated persons, according to Bjelica et al. (2012) have been taller than the general population in Poland (Kulaga et al. 2011; Wronka and Pawliñska-Chmara 2009), and Hungary (Bodzsár and Zsákai 2008; Eiben and Tóth 2000; Szöllõsi 1998), but not in Montenegro (Bjelica et al. 2012; Popovic et al. 2014), the researchers also believe that this sample could

fairly represent the whole population of Macedonia, as students were admitted into the Ss. Cyril and Methodius University regardless of geographical residence and socioeconomic status, as well as ethnicity. The average age of the male subject was 19.25±1.23 years old (range 18-24 years), while the average age of the female subject was 20.19±2.56 years old (range 18-28 years). It is also important to emphasize that the researchers could not accept students with physical deformities that could affect body height or arm span, and without informed consent were excluded from the study. The exclusion criterion was also being non-Macedonian. Accordingly, the researchers have purposely selected (deliberate sampling) the students from the Faculty of Physical Education at Ss. Cyril and Methodius University, as they believed that most of them could be eligible to participate in the study, as well as this is one of the highly ranked faculties of Physical Education in Macedonia, which brings together students from all parts of Macedonia.

Although photogrammetric anthropometry is an accurate way nowadays, this is not valid for arm span measurement (Penders et al. 2015) and 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 (Marfell-Jones et al. 2006). The trained anthropometrist (the same one for each measure) whose quality of performance was evaluated against the prescribed "ISAK Manual" prior to the study performed these measurements. The age of the individuals was determined directly from their reported date of birth.

The body height presents the perpendicular distance between the top of the head (the vertex) and the bottom of the feet. It was measured using a stadiometer to the nearest 0.1 centimeters in bare feet with the participants standing upright against a 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 have also been touching the stadiometer upright while 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) is 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 and eighty degree angle. It was measured using a calibrated steel tape to the nearest 0.1 centimeters bare feet on a level concrete floor with their upper backs, buttocks and heels against the wall, which provide 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 measurements were taken from one middle fingertip to the other middle fingertip, with the tape passing in front of the clavicles while two fieldworkers supported the elbows. The measurements were taken twice, and an average of the two readings was calculated. When the two measurements agreed within 0.4 centimeters, their average was taken as the best estimate for the true value. When the two initial measures did not satisfy the 0.4 centimeters 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 the Statistical Package for Social Sciences (SPSS) version 20.0. Means and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of body heights and arm spans within each gender group and between genders was carried out using a t-test. The relationships between body height and arm span were determined using simple correlation coefficients at ninety-five percent confidence interval. Then a linear regression analysis was performed to examine the extent to which the arm span can reliably predict body height. Finally, these relationships were plotted as scatter diagrams. Statistical significance was set at $p<0.05$.

RESULTS

A summary of the anthropometric measurements in both genders is shown in Table 1. The mean of the arm span for male subjects was 178.78±7.71 centimeters, which was 0.68±4.89 centimeters more than the body height and statistically significant ($t=-1.989$, $p<0.049$), and for female subjects it was 164.41±6.42 centimeters,

which was 0.17±5.39 centimeters less than the body height and statistically insignificant (t=0.562, p<0.575). The gender difference between body height and arm span measurements was statistically significant (body height: t=17.31; p<.000, and arm span: t=15.71; p<.000).

Table 1: Anthropometric measurements of the study subjects

Subjects	*Body height range (Mean±SD)*	*Arm span Range (Mean±SD)*
Male	156.0 - 195.0 (178.10 ± 6.79)	157.0 - 198.0 (178.78 ± 7.71)
Female	150.0 - 186.0 (164.58 ± 5.40)	148.0 -186.0 (164.41 ± 6.42)

The simple correlation coefficients and their ninety-five percent confidence interval analysis between the anthropometric measurements are presented in Table 2. The relationships between body height and arm span were significant (p<0.000) and high in this sample, regardless of gender (male: 0.879; female: 0.839).

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

Subjects	*Correlation Coefficient*	*95% confidence interval*	*significance p-value*
Male	0.879	-1.366 – -0.003	<0.000
Female	0.839	-0.443 – 0.795	<0.000

The results of the linear regression analysis are shown in Table 3. The first of all models were derived by including age as a covariate. However, it was found that the contribution of age was insignificant and therefore the age was dropped and estimations were derived as a univariate analysis. The high values of the regression coefficient (male: 0.879; female: 0.839) signify that arm span significantly predicts body height in both Macedonian genders (male: t=19.535, p<0.000; female: t=17.069, p<0.000), which confirms the R-square (%) for the male (77.3) as well as for the female (70.3) population.

The relationships between arm span measurements and body height among the above models is plotted as a scatter diagram (Fig. 1).

DISCUSSION

This study contributes to a very important update of average body heights among Macedonian males and females. The results proved that Macedonian males with an average tallness of 179.10 centimeters are close to the tallest nations in the Europe (Table 4), given 183.9 centimeters of the Bosnian and Herzegovinian male population (Popovic et al. 2015), 183.21 centimeters of the Montenegrin male population measured in 2011 (Bjelica et al. 2012), 182.4 centimeters of the Dutch male population measured in the lifestyle, preventive screening in 2010-2013 (Statistics Netherland 2015), and 182.0 centimeters of the Serbian male population measured in 2012 (Popovic et al. 2013), but not close enough. The average height of Macedonian men is still shorter than 181.3 centimeters of the Lithuanians (Tutkuviene 2005), 180.6 centimeters of the Icelanders (Dagbjartsson et al. 2000), 180.5 centimeters of the Croats (Juresa et al. 2012), 180.4 centimeters of the Swedes (Werner and Bodin 2006), 180.3 centimeters of the Slovenes (Starc and Strel 2011), Danes (Statistics Denmark 2011)

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

S. No.	*Country*	*Average body height*	*Source*
1.	Bosnia and Herzegovina	183.9	Popovic et al. 2015 Statistics 2015
2.	Netherland	182.4	Netherland
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

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

Subjects	*Regression coefficient*	*Standard error (SE)*	*R-square (%)*	*t-value*	*p-value*
Male	0.879	0.040	77.3	19.535	0.000
Female	0.839	0.041	70.3	17.069	0.000

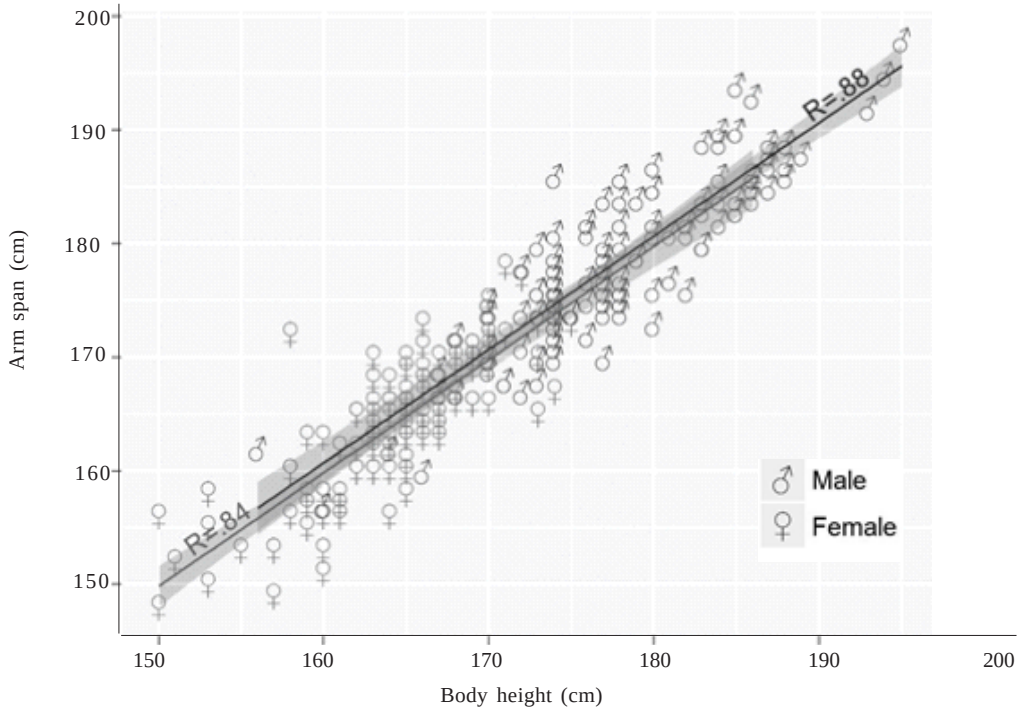

Fig. 1. Scatter diagram and relationship between arm span measurements and body height among both genders
Source: Authors

and Czechs (Vignerová et al. 2006) and several other nations, which made Macedonians the tall nation but not even close to being the top 10 tallest male nations on Earth.

On the other hand, the average body height of Macedonian females were 164.58 centimeters on average and this result proved that Macedonian females are tall comparing to the rest of the countries but not as tall as 168.8 centimeters of the Netherlands (Statistics Netherland 2015), 168.3 centimeters of the Montenegrins (Bjelica et al. 2012), 167.5 centimeters of the Lithuanians and several other nations ranked in the top 10 tallest female nations, according to the available record (Table 5).

However, there is a hypothesis that both genders of Macedonia did not reach their full genetic potential yet, since they have been influenced by various environmental factors (wars in the former Yugoslavia, poor economic situation that still is the fact) in the last few decades. Therefore, the researchers believe that these circumstances had a negative bearing on the secular trend in Macedonia as well as surrounding countries, while it is expected that the secular changes affecting height will go up in the following two decades, comparing it to developed countries where this trend has already completed.

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

S. No.	*Country*	*Average body height*	*Source*
1	Bosnia and Herzegovina	171.8	Popovic et al. 2015
2	Netherland	168.8	Statistics Netherland 2015
3	Montenegro	168.3	Bjelica et al. 2012
4	Germany	167.7	Hesse et al. 1997
5	Lithuania	167.5	Tutkuviene 2005
6	Slovenia	167.4	Starc and Strel 2011
7	Iceland	167.2	Dagbjartsson et al. 2000
8	Check Republic	167.2	Vignerová et al. 2006
9	Latvia	167.1	Gerhards 2005
10	Sweden	167.0	Werner and Bodin 2006

It is also interesting to mention that the density of very tall subjects appears not to be characteristic of the Macedonian males, since 2.7 percent measured 190 centimeters or more in body height. If 2.7 percent in Macedonia were be compared to 20.2 percent in the Bosnian and Herzegovinians (Popovic et al. 2015), twenty percent in the Netherlands (Pineau et al. 2005), fourteen percent in Serbia (Popovic et al. 2013), thirteen percent in Montenegro (Bjelica et al. 2012) and only 1.5 percent in France (Pineau et al. 2005), it would imply that the density of very tall subjects in Macedonian males does not appear frequently like in the Dinaric Alps in general and the Netherlands, and it is much closer to the non-Dianric Alps nations. On the other hand, the density of very tall subjects does not appear to be characteristic of the Macedonian females too, since less than one percent measured 180 centimeters or more in body height (Fig. 2).

The estimation of body height using various anthropometric measurements is very common from the past centuries and it has been attempted to be studied by many researchers. As it is already mentioned, all of them estimated body height from various anthropometric measurements, but it is important to emphasize that the arm span has been derived as the most reliable body indicator for predicting the body height of an individual (Mohantyet al. 2001; Ter Goon et al. 2011). However, it must be underlined that the individual and ethnic variations in respect to 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) have 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 centimeters more than the body height for Black population (105.36% body height), whereas for White population this difference was only 3.3 centimeters (102.04% body height). Mohanty et al. (2001) have noted in their study that the arm span was nearly 2.5 centimeters 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 centimeters more than body height for Nigerian males (103.3% body height), whereas for Nigerian females this difference was only 4 centimeters (102.5% body height), which is similar to that noted in the White population, although they are Black. The most recent studies conducted by Bjelica et al. (2012) that showed that arm span was 2.5 centimeters more than body height for Montenegrin males (101.4% body height), whereas for Montenegrin females this difference was only 0.24 centimeters but in favor of body height (99.9% body

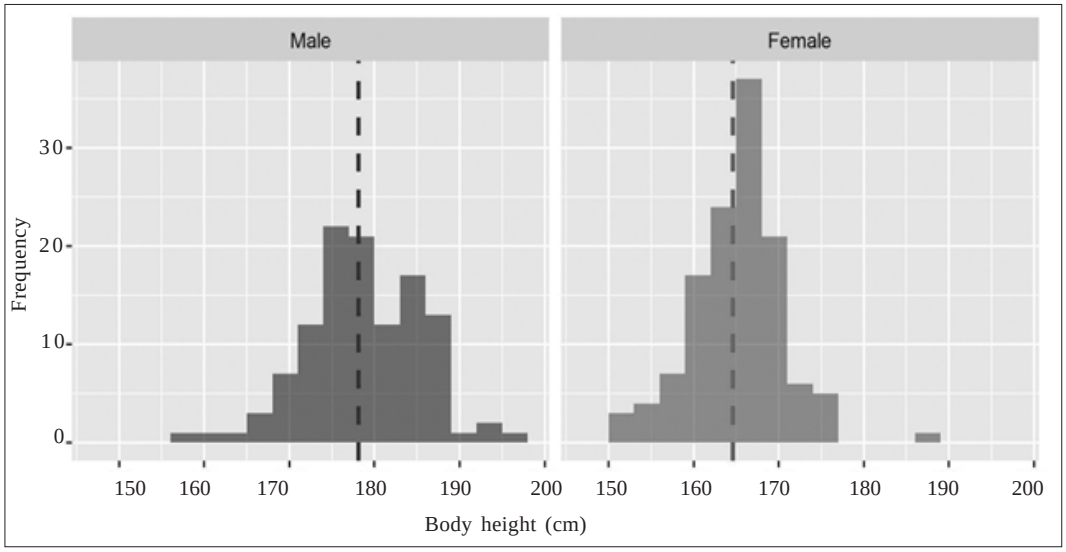

Fig. 2. Density of body height among both genders
Source: Authors

height) and Popovic at al. (2013) that showed that arm span was 2.8 centimeters more than body height for Serbian males (101.5% body height), whereas for Serbians females this difference was only 0.15 centimeters but in favor of body height (98.7% body height) as well as Popovic et al. (2015) that showed that arm span was 0.73 centimeters more than body height for Bosnian and Herzegovinian males (100.3% body height), whereas for Bosnian and Herzegovinian females this difference was only 1.97 centimeters but in favor of body height (98.9% body height), while Quanjer et al. (2014) has highlighted the body height estimated from the predicted arm span to height ratio may differ by up to ten percent from actual stature. All mentioned have confirmed again the necessity for developing separate height models for each population on account of ethnic differences, while some of latest studies found the regional differences among the same ethnic groups (Bubanja et al. 2015; Vujovic et al. 2015), which cause the need for additional caution. Therefore, the main goal of the current study was to find out if these facts are true for the Macedonian 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 was also observed that the arm span was 0.68 centimeters more than the body height in males (100.4% body height), while it was 0.17 centimeters less than the body height in Macedonian female population (99.9% body height). The arm span to height ratio in Macedonian males is quite low when compared with other Europeans but it is very close to the data that was reached in the measurement of the Montenegrin population (Bjelica et al. 2012), as well as Serbian population (Popovic et al. 2013) and Bosnian and Herzegovinian population (Popovic et al. 2015), while the arm span to height ratio in Macedonian females is a almost equal when compared with Montenegrin, Serbian, Bosnian and Herzegovinian population and other Europeans.

The results of the previous studies are also very similar to the correlation obtained in the present study (men: r=0.879; women: r=0.839). 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, and in Zverev's study (2003) correlation was r=0.87 for males and r=0.81 for the female population. In the most recent studies, Ter Goon et al. (2011) reported that correlation was r=0.83, Bjelica et al. (2012) reported that the correlation was r=0.861 for males and r=0.809 for female population, while in Popovic et al.'s study (2013) correlation was r=0.814 for males and r=0.822 for the female population. As the correlation between arm span and body height was high and significant in both Macedonian genders, the arm span measure therefore seems to be a reliable indirect anthropometric measurement for estimating body height in Macedonian adults. Even though these relations are similar, the estimation equations, which are obtained in the Macedonian population, are substantially different from other populations.

CONCLUSION

Although the results of this study confirm the necessity for developing separate height models for each population on account of ethnic differences, it must be emphasized that further researches should use larger samples for the prediction of body height utilizing arm span measurement, mostly due to the reason that this study as well as some other studies that has been attempted in the past have used quite small samples. A more precise estimation of the average body height and its prediction utilizing arm span measurements in Macedonian adults would require a large sample with sufficient geographical (type of the soil) and social heterogeneity (various ethnic groups), or a national survey that measures the whole population. Moreover, next to the small sample, the obvious limitation of this research study was the composition of the measured sample that consisted of university students. Since university-educated persons have been taller than the general population in Poland and Hungary, but not in Montenegro, the researchers cannot exclude the possibility that the body height of the students somewhat overestimates the average body height of contemporary Macedonians. On the other hands, it is also very important to highlight that body proportion measurement using photogrammetric anthropometry that is an accurate way nowadays is not valid for arm span measurement and it is recommended to keep the old fashion method of measuring this body proportion.

ACKNOWLEDGEMENTS

The researchers are grateful to Damjan Jakšic from the University of Novi Sad for his contribution to design of the picture and figures in this manuscript.

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Paper received for publication on November 2015
Paper accepted for publication on June 2016