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Body Height and Its Estimation Utilizing Arm Span Measurements in Serbian Adults

Altura Corporal y su Estimación Utilizando Mediciones de Envergadura en Adultos Serbios

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SUMMARY: Anthropologists recognized the tallness of nations in the Dinaric Alps long time ago. As the modern Serbians fall more into the Dinaric racial classification than any other does, the purpose of this study was to examine the body height in Serbian adults as well as the relationship between arm span as an alternative to estimating the body height, which vary in different ethnic and racial groups. The nature and scope of this study analyzes 394 students (318 men, aged 20.13±1.47 and 76 women, aged 19.59±1.46) from the University of Novi Sad to be subjects. The anthropometric measurements were taken according to the protocol of the ISAK. Means and standard deviations were obtained. A comparison of means of body heights and arm spans within each gender group and between genders 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. Then a linear regression analysis was performed to examine the extent to which the arm span can reliably predict body height. The results have shown that male Serbians are 181.96±6.74 cm tall and have an arm span of 184.78±8.41 cm, while female Serbians are 166.82±5.88 cm tall and have an arm span of 164.67±8.09 cm. Compared to other studies, the results of this study have shown that both genders make Serbian population one of the tallest nations on the earth. Moreover, the arm span reliably predicts body height in both genders. However, the estimation equations, which were obtained in Serbians, are substantially different alike in other populations, since arm span was close to body heights: in men 2.82±4.89 cm more than the body height and in women 2.15±4.68 cm less than the body height. This confirms the necessity for developing separate height models for each population.

KEY WORDS: Prediction; Standing height; Stature; Armspan; Serbia.

INTRODUCTION

The Republic of Serbia, formerly the political and cultural center of Yugoslavia, 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 also the northern remain of the former State Union of Serbia and Montenegro. In 2006 Montenegro voted, after a referendum in favor of independence, to leave the State Union. So Serbia has been obliged to officially proclaim its independence on 5 June 2006, as the successor state to the State Union of Serbia and Montenegro. Today, The Republic of Serbia covers the area of 88,361 sq. kilometers. It is located at the crossroads of Central and Southeast Europe, covering the southern part of the Pannonian Plain and the central part of the Balkan Peninsula. Republic of Serbia is landlocked and borders Hungary to the north, Romania and Bulgaria to the east, the Former Yugoslav Republic of Macedonia to the south, and Croatia, Bosnia and Herzegovina, and Montenegro to the west. Additionally, it borders Albania through Kosovo (as defined under UNSCR 1244/99), whose status as part of Serbia is disputed. Northern Serbia is mainly flat, while central parts are highlands. Going to the south, the hills gradually turn into mountains. The mountains of Serbia can be divided into the Rhodope Mountains, the Carpathian–Balkan Mountains and the Dinaric Alps. Up to 30 mountain peaks are over 2000 meters above sea level. It is also interesting to mention that most of Serbia has a temperate continental climate. A continental climate prevails in the mountainous, whilst the climate in the Serbian southwest borders on the Mediterranean subtropical and continental (Ministry of Environment and Spatial Planning, 2010).

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The total population of the Republic of Serbia, according to the 1991 census, was 7,595,636 inhabitants, and according to the 2002 census 7,498,001 and 2011 census 7,241,295. Those data are only estimation taking into account that census was not conducted in Kosovo, which has been under United Nations administration since 1999 (according to CIA estimates, Kosovo has around 1.8 million inhabitants). However, 2011 census included over 200,000 internally displaced persons from Kosovo, who has been counted as a permanent population. Estimates show that during the period 1991–2011, there was a significant increase in population growth due to intense violent migrations during the 1990s. Moreover, the ethnic population of the Republic of Serbia is very diverse because of the country's turbulent past. Serbs are the majority and represent the largest ethnic group in Serbia, representing 83% of the total population, while 37 nationalities live jointly with them in Serbia. With a population of 290,000, Hungarians are the second largest ethnic group in Serbia, representing 3.9%. Other minority groups include Bosnians, Roma, Albanians, Croats, Bulgarians, Montenegrins, Macedonians, Slovaks, Vlachs, Romanians, and Chinese (Ministry of Environment and Spatial Planning). It is also important to highlight that Serbia has the largest refugee population in Europe (Tanjug, 2007). Refugees and internally displaced persons in Serbia contain about half a million people (between 7% and 7.5% of its population) sought refuge in the country following the series of Yugoslav wars, mainly from Croatia, and to a lesser extent from Bosnia and Herzegovina and the internally displaced persons from Kosovo, which are currently the most numerous at over 200,000. Meanwhile, it is estimated that 300,000 people left Serbia during the 1990s alone, and around 20% of those had college or higher education (Yugoslav Survey, 2003; EMG, 2008). Serbia has a comparatively old overall population (among the 10 oldest in the world), mostly due to low birth rates. In addition, Serbia has among the most negative population growth rates in the world, ranking 218th out of 230 countries overall (Central Intelligence Agency, 2012).

The tallness of the nations in the Dinaric Alps has been recognized by European anthropologists more than 100 years ago (Pineau *et al.*, 2005). As the modern Serbians, like the rest of the nations from Former Yugoslavia, fall more into the Dinaric racial classification than any other, it is assumed by the authors of this study that Serbian adults might be equally tall or at least very close to the tallest nations in the Europe: Dutch (male: 183.8 cm; female: 170.7 cm) and Montenegrins (male: 183.21 cm; female: 168.37 cm). Unlike the most other countries through Western Europe, Serbia keeps poor records and an update of average body heights among Serbian 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 (Bjelica *et al.*, 2012).

It is already 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, 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 etc. (Golshan *et al.*, 2003, 2007; Mohanty, 2001; Ter Goon *et al.*, 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 *et al*., 2007, 2008; Kanchan *et al*., 2008; Rastogi *et al.*, 2008; Sanli *et al*., 2005), knee height (Fatmah, 2005; Hickson & Frost, 2003; Karadag *et al.*, 2012), length of the forearm (Ilayperuma *et al.*, 2010), length of the sternum (Menezes *et al*., 2009, 2011), vertebral column length (Nagesh & Pradeep Kumar, 2006), sitting height (Fatmah), length of scapula (Campobasso *et al.*, 1998), arm span (Aggrawal *et al*., 2000; Bjelica *et al.*; Datta Banik; Fatmah; Hickson & Frost; Jarzem & Gledhill, 1993; Mohanty *et al.*; Ter Goon *et al*.) as well as cranial sutures (Rao *et al.*, 2009), skull (Bidmos, 2006; Bidmos & Asala, 2005), facial measurements (Sahni *et al*., 2010) etc. 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*.), 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).

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 Serbian 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 & Frost; Jarzem & Gledhill; Mohanty *et al*.; Ter Goon *et al*.). However, the associations of arm span and body height was found to vary in different

ethnic and racial groups (Bjelica *et al*.; Brown *et al*., 2002; Reeves *et al*., 1996; Steele & Chenier, 1990). Even though several studies of this nature are available on western populations, very limited data is available on Serbian 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 Serbian adults and the relationship between arm span and body height.

MATERIAL AND METHOD

The nature and scope of this study qualifies 394 students (318 men and 76 women) from the University of Novi Sad 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. The authors have also believed this sample could fairly represent the whole population of Serbia as students were admitted into the University of Novi Sad regardless of geographical residence and socio-economic status, as well as ethnicity. The average age of the male subject was 20.13±1.47 years old (range 18-30 yrs), while the average age of the female subject was 19.59±1.46 years old (range 18-26 yrs). It is also important to emphasize that the authors could not accept students with physical deformities that could affect body height or arm span, and without informed consent wereexcluded from the study. The exclusion criterion was also being non-Serbian (eight participants, two male and seven female were excluded from the data pool). Accordingly, the authors have purposely selected (deliberate sampling) the students from the Faculty of Sport and Physical Education at University of Novi Sad 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 Faculty of Sport and Physical Education in Serbia which brings together students from all parts of Serbia.

According to Marfell-Jones *et al*. (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). The trained anthropometrist (the same one for each measure) whose quality of performance was evaluated against 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 stadiometer to the nearest 0.1 cm 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 eighty degree angle. It was measured using a calibrated steel tape to the nearest 0.1 cm in 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 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 agreed within 0.4 cm, their average was taken as the best estimate for the true value. When the two initial measures did not satisfy the 0.4 cm 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 each sex group and between 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. Then a linear regression analysis was performed to examine the extent to which 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 sexes is shown in Table I. The mean of the arm span for male subjects was 184.78±8.41 cm, which was 2.82±4.89 cm more than the body height and statistically significant

(t=4.673, p<0.000), and for female subjects it was 164.67±8.09 cm, which was 2.15±4.68 cm less than the body height and statistically insignificant (t=1.876, p<0.063). The sex difference between body height and arm span measurements was statistically significant (body height: t=18.01; p<.000, and arm span: t=18.86; p<.000).

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

The results of the linear regression analysis are shown in Table III. 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 estimates were derived as univariate analysis. The high values of the regression coefficient signify that arm span significantly predicts body height in both Serbian sexes.

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

Table I. Anthropometric Measurements of the Study Subjects.

Subjects	Body Height Range	Mean±SD	Arm span Range	Mean±SD
Male	166.0-204.0	181.96±6.74	162.8-210.2	184.78±8.41
Female	154.0-182.0	166.82±5.88	135.1-182.0	164.67±8.09

Table II. Correlation between Body Height and Arm Span of the Study Subjects.

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.814	0.759–0.854	<0.000
Female	0.822	0.751–0.887	<0.000

Table III. Results of Linear Regression Analysis Where the Arm Span Predicts the Body Height.

Subjects	Regression Coefficient	Standard Error	R-square (%)	t-value	p-value
Male	0.814	0.026	66.2	24.868	0.000
Female	0.822	0.048	67.5	12.403	0.000

Table IV. Top 10 Tallest Male Nations on the Earth.

	Country	Average Body Height	Source
1	Netherlands	183.8	TNO (2010)
2	Montenegro	183.2	Bjelica *et al.* (2012)
3	Serbia	182.0	Current Study
4	Lithuania	181.3	Tutkuviene (2005)
5	Iceland	180.6	Dagbjartsson *et al.* (2000)
6	Croatia	180.5	Juresa *et al.* (2012)
7	Sweden	180.4	Werner & Bodin (2006)
8	Slovenia	180.3	Starc & Strel (2011)
9	Denmark	180.3	Statistics Denmark (2011)
10	Czeck Republic	180.3	Vignerová *et al.* (2006)

Table V. Top 10 Tallest Female Nations on the Earth.

	Country	Average Body Height	Source
1	Netherlands	170.7	TNO (2010)
2	Montenegro	168.3	Bjelica et al. (2012)
3	Lithuania	167.5	Tutkuviene (2005)
4	Slovenia	167.4	Starc & Strel (2011)
5	Iceland	167.2	Dagbjartsson *et al*. (2000)
6	Czeck Republic	167.2	Vignerová *et al*. (2006)
7	Latvia	167.1	Gerhards (2005)
8	Sweden	167.0	Werner & Bodin (2006)
9	Serbia	166.8	Current Study
10	Croatia	166.3	Juresa *et al*. (2012)

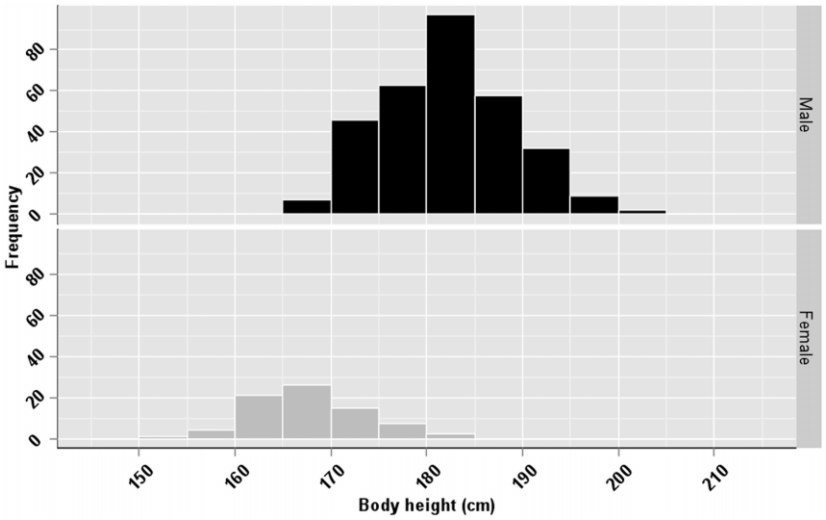

Fig. 1. Frequency of body height among both sexes.

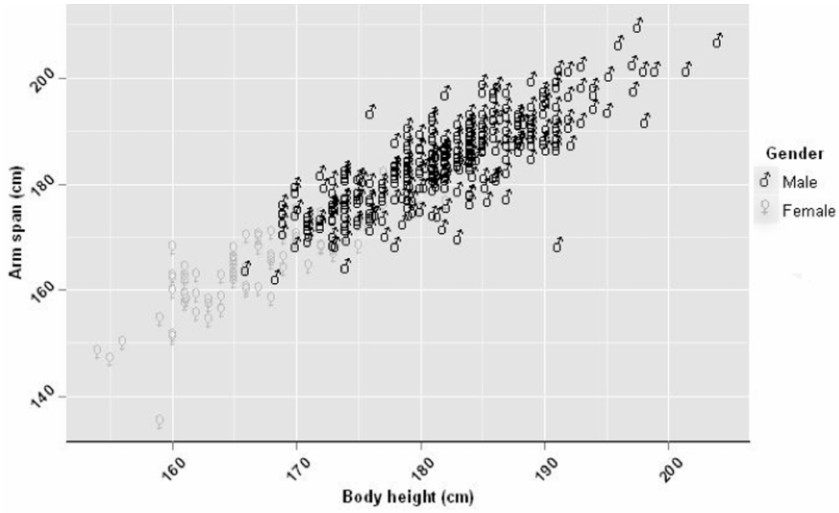

Fig. 2. Scatter diagram and relationship between arm span measurements and body height among both sexes.

DISCUSSION

This study contributes to a very important update of average body heights among Serbian males and females. The results proved that Serbian males are very tall with an average of 181.96 cm and it is very close to the tallest nations in the Europe: 183.8 cm of the Dutch male population measured in the last nationwide survey in 2010 (TNO, 2010) and 183.21 cm of the Montenegrin male population measured in 2011 (Bjelica *et al*.). On the other hand, the average height of Serbian men is taller than 181.3 cm of the Lithuanians (Tutkuviene, 2005), 180.6 cm of the Icelanders (Dagbjartsson *et al.*, 2000), 180.5 cm of the Croats (Juresa *et al.*, 2012), 180.4 cm of the Swedes (Werner & Bodin, 2006), 180.3 cm of the Slovenes (Starc & Strel, 2011), Danes (Statistics Denmark, 2011) and Czechs (Vignerová *et al*., 2006) and 141.7 cm of the shortest ethnic group in the whole World, Mbuti Pygmies (Froment, 1993), which made Serbians the third tallest nation on the earth. From the other side, the average body height of Serbian females was 166.82 cm on average and this result proved that Serbian females are tall but not as tall as 170.7 cm of the Netherlands (TNO), 168.3 cm of the Montenegrins (Bjelica *et al*.), 167.5 cm of the Lithuanians, 167.4 cm of the Slovenes (Starc & Strel), 167.2 cm of the Icelanders and Czechs (Dagbjartsson *et al*.; Vignerová *et al*.), 167.1 cm of the Letts (Gerhards, 2005), and 167 cm of the Swedes (Werner & Bodin), but still the ninth tallest nation on the earth, according to the available record. However, there is a hypothesis that both sexes of Serbians did not reach their full genetic potential yet, since they have been influenced by various environmental factors (wars, poor economic situation, etc.) in the last few decades. Therefore, the authors believe that these circumstances had a negative bearing on the secular trend in Serbia 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.

For better viewing of the tallest nations around the World, the authors have prepared Table IV to present an overview of the top 10 tallest male populations on the earth, while the overview of the data from the female population is sorted in Table V (the most of them are data from the national surveys).

It is also interesting to mention that the density of very tall subjects appears to be characteristic of the Serbian males, since 14% measured 190 cm or more in body height. If 14% in Serbia would be compared to 28% in Dinaric Alps (Pineau *et al*.), 20% in the Netherlands (Pineau *et al*.), 13% in Montenegro (Bjelica *et al*.), and only 1.5% in France (Pineau *et al*.), it would imply that the density of very tall subjects in Serbian males appears, but not frequently like in the Dinaric Alps in general and the Netherlands. From the other side, the density of very tall subjects doesn't appear to be characteristic of the Serbian females, since less than 3% measured 180 cm or more in body height.

The estimation of body height using various anthropometric measurements are quite the age-old investigations over the past centuries and it has been attempted by many authors. 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 the most reliable body indicator for predicting body height of an individual (Mohanty *et al*.; Ter Goon *et al*.). However, it must be underlined 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*.) 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 cm more than the body height for black population (105.36% body height), whereas for white population this difference was only 3.3 cm (102.04% body height). Mohanty et al., have noted in their study that the arm span was nearly 2.5 cm 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, arm span was 5.8 cm more than body height for Nigerian males (103.3% body height), whereas for Nigerian females this difference was only 4 cm (102.5% body height) which is similar to that noted in the white population, although they are black. The most recent study conducted by Bjelica *et al.*, showed that arm span was 2.5 cm more than body height for Montenegrin males (101.4% body height), whereas for Montenegrin females this difference was only 0.24 cm but in favour of body height (99.9% body height) which confirmed again the necessity for developing separate height models for each population on account of ethnic differences. Therefore, the main goal of the current study was to find out if these facts are true for the Serbian population, since it is known that the estimating equation varies from race to race, and ethnic group to ethnic group (Mohanty *et al*.). Hence, in the present study it is also observed that the arm span was 2.8 cm more than the body height in males (101.5% body height), while it was 0.15 cm less than the body height in Montenegrin female population (98.7% body height). The arm span/height ratio in Serbian males is quite low when compared with other Europeans but it is very close to the data that were reached in the measurement of Montenegrin population (Bjelica *et al*.), while the arm span/height ratio in Serbian females is a litlle bit smaller when compared with other Montenegrin population and other Europeans.

The results of the above mentioned studies are also very similar to the correlation obtained in the present study (men: r=0.814; women: r=0.822). For example, Mohanty *et al.*, reported that the correlation was r=0.82, while in Hickson and Frost's study correlation was r=0.86, 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*., reported that correlation was r=0.83, while Bjelica *et al.* reported that the correlation was r=0.861 for males and r=0.809 for female population. As the correlation between arm span and body height was high and significant in both Serbian sexes, the arm span measure therefore seems to be a reliable indirect anthropometric measurement for estimating body height in Serbian adults.

Even though these relations are similar, the estimation equations which are obtained in Serbian population, if the authors exclude Montenegrin population, are substantially different from other populations, especially in Serbian female population. Although this confirms the necessity for developing separate height models for each population on account of ethnic differences, it must be emphasized that further researches has to use larger samples for the prediction of body height utilizing arm span measurement, mostly due to the reason this study as well as some other studies that has been attempted in the past (Aggrawal *et al*.; Bjelica *et al.*; Hickson & Frost; Kwok & Whitelaw, 1991; Steele & Chenier; Ter Goon *et al*.; Zverev) used quite small samples. A more precise estimation of the average body height and its prediction utilizing arm span measurements in Serbian adults would require a large sample with sufficient geographical and social heterogeneity or a national survey that measures the whole population. Moreover, next to the small sample, especially

in female population, the obvious limitation of this research study was the composition of the measured sample that consisted of university students. Since university-educated persons, according to Bjelica *et al.* (2012), have been taller than the general population in Poland (Kuaga *et al*., 2011; Wronka & Pawliñska-Chmara, 2009), and Hungary (Bodzsár & Zsákai, 2008; Eiben & Tóth, 2000; Szöllo˝si, 1998), the authors cannot exclude the possibility that the body height of the students somewhat overestimates the average body height of contemporary Serbians.

POPOVIC, S.; BJELICA, D.; MOLNAR, S.; JAKSIC, D. & AKPINAR, S. Altura corporal y su estimación utilizando mediciones de envergadura en adultos serbios. ***Int. J. Morphol., 31(1)***:271-279, 2013.

RESUMEN: Los antropólogos estimaron la altura de las naciones en los Alpes Dináricos hace mucho tiempo. Como los Serbios modernos caen en la clasificación racial de Dináricos, el propósito de este estudio fue examinar la altura corporal en adultos serbios, así como la relación con la longitud de la envergadura de brazo a brazo como una alternativa a la estimación de la altura corporal, que varía en los diferentes grupos étnicos y raciales. Se analizó a 394 estudiantes (318 hombres y 76 mujeres, con edades entre 20,13±1,47 años y 19,59±1,46 años, respectivamente) de la Universidad de Novi Sad. Las medidas antropométricas fueron tomadas de acuerdo con el protocolo de ISAK, obteniendo Medias y DE. La comparación de la media de altura corporal y envergadura dentro de cada grupo y entre sexos se realizó con la prueba t. Las relaciones entre estatura y envergaduras se determinaron mediante coeficientes de correlación simple, con un intervalo de confianza del 95%. También se realizó un análisis de regresión lineal para examinar el grado en que la envergadura puede prever con exactitud la altura corporal. Los resultados mostraron que los hombres Serbios tienen una altura de 181,96±6,74 cm, y una envergadura de 184,78±8,41 cm, mientras que las mujeres una altura de 166,82±5,88 cm y una envergadura de 164,67±8,09 cm. En comparación con otros estudios, estos resultados demuestran que para ambos sexos, la población Serbia es una de las más altas. Por otra parte, la envergadura predice confiablemente la altura corporal en ambos sexos. Sin embargo, las ecuaciones de estimación obtenidas en esta población son sustancialmente diferentes a otras poblaciones, ya que la envergadura fue cercana a la altura corporal: en hombres 2,82±4,89 cm mayor a la altura corporal y en mujeres 2,15±4,68 cm menor a ésta. Esto confirma la necesidad de desarrollar diferentes modelos de para determinar la altura en cada población.

PALABRAS CLAVE: Predicción; Postura de altura; Estatura; Envergadura; Serbia.

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