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Relationship between Tibia Length Measurements and Body Height: A Prospective Regional Study among Adolescents in the Eastern Region of Kosovo

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Abstract

This study aims to determine standing height in males and females from the Eastern Region in Kosovo and its association with tibia length, as an alternative to standing height prediction. A total of 364 individuals (185 male and 179 female) took part in this study. The anthropometric measurements were provided in accordance with the ISAK guidelines. The relationships between body height and tibia length were defined using simple correlation coefficients at a ninety-five per cent confidence interval. A means comparison in standing height and tibia length between males and females was performed using a t-test. In the end, a linear regression analysis was implemented to examine how tibia length can reliably predict standing height. The results showed that Eastern Kosovan males are 178.79±6.07 cm tall and have a tibia length of 38.58±2.49 cm, while Eastern Kosovan females are 164.74±4.89 cm tall and have a tibia length of 35.32±1.85 cm. This finding defines Eastern Kosovans, male and female, as a tall group, but slightly shorter than the general Kosovan population. Moreover, tibia length reliably predicts standing height in Kosovan males and females but not as sufficiently reliably as arm span does. This study also indicates the need to develop separate height models for each region in Kosovo because the results from Eastern Kosovans do not correspond to general values.

Keywords: *prediction, measurement, stature, tibia length, Kosovan*

Introduction

Kosovo is located in south-eastern Europe, in the central region of the Balkan Peninsula. Covering an area of 10,908 km², it has a population of 1,883,018 inhabitants (Gardasevic, 2019a; Arifi, Gardasevic, & Masanovic, 2018). Administratively, it is subdivided into five regions (Eastern, Western, Northern, Southern, and Central) and is bordered by four countries (Albania, Macedonia, Montenegro, and Serbia) (Arifi et al., 2017). This study aims to analyse the standing height of adolescents from the Eastern region of Kosovo and its estimation utilizing tibia length measurements. This region contains two districts (Ferizaj and Gjilan) and eleven municipalities (Ferizaj, Hani i Elezit, Kaçanik, Štimlje/Shtime, Štrpce/Shtërpcë, Gjilan, Kamenica, Klokot, Partesh, Ranilug, and Vitina). Covering an area of 2,236 km², it has a population of 366,589 inhabitants (Masanovic, Gardasevic, & Arifi, 2018; Gardasevic, 2019a; Arifi, Masanovic, & Gardasevic, 2020). While Kosovo is small, it has a highly varied terrain. One part belongs in the Dinaric Alps, so it can be assumed this fact might influence this study's main objective because of the type of the soil and other socio-economic and geographic characteristics as potential influencing factors (Popovic, 2018).

Many scientific studies confirm that the measurement of standing height is an essential element in assessing nutritional status and evaluating basic energy requirements (Arifi et al., 2017; Datta Banik, 2011; Popovic, Arifi, & Bjelica, 2017). It is

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also a significant factor in assessing children's growth, adjusting the measures of physical capacity, predicting drug dosages and setting standards of physiological variables, such as muscle strength, metabolic rate, lung volume, and glomerular filtration (M. Golshan, Crapo, Amra, Jensen, & R. Golshan, 2007; Ter Goon, Toriola, Musa, & Akusu, 2011; Gardasevic, Rasidagic, Krivokapic, Corluka, & Bjelica, 2017).

However, exact standing height is sometimes impossible to measure in the standard way (e.g., due to paralysis, fractures, amputation, scoliosis, and pain). In such situations, standing height estimation should be assessed from other reliable anthropometric indicators, such as hand and tibia length, foot length, knee height, length of the forearm, length of the sternum, vertebral column length, sitting height, length of scapula, arm span as well as cranial sutures, skull, facial measurements et cetera (Fredriks et al., 2005; Popovic, Gardasevic, Masanovic, Arifi, & Bjelica, 2017). All these anthropometric indicators, which are used as an alternative to standing height prediction, are also crucial in assessing decreases in body height that emerge as a result of ageing. They are also very helpful when it is necessary to determine the standing height of a person with disproportionate growth abnormalities, skeletal dysplasia, mobility problems, kyphosis, in a person with standing height loss during surgical procedures on the spine as well to anticipate standing height in older people who cannot keep upright or maintain erect posture due to ageing (Hickson & Frost, 2003; Masanovic, Arifi, & Gardasevic, 2019). Lastly, it should not be forgotten that this knowledge is relevant in sport science because standing height represents a significant factor influencing success in various sport disciplines (Gusic, Popovic, Molnar, Masanovic, & Radakovic, 2017; Popovic, 2017; Arifi, Bjelica, & Masanovic, 2019; Masanovic, 2019).

Numerous researchers emphasize the benefit of using various body parameters in predicting standing height, and almost all agree that arm span is the most reliable one in adults (Mohanty, Babu, & Nair, 2001; Brown, Feng, & Knapp, 2002; Bjelica et al., 2012; Masanovic, 2018). Some authors believe that foot length measurement is the most reliable predictor during adolescence (Jakhar, Pal, & Paliwal, 2010; Popovic et al., 2017), because ossification occurs earlier in the foot than in the long bones, and standing height will be more accurately predicted from this measurement than by using long bones during adolescence.

Furthermore, it has been established that the relationship of long bones and standing height varies in different ethnic and racial groups (Steele & Chenier, 1990; Reeves, Varakamin, & Henry, 1996; Quanjer et al., 2014; Khatun, Sharma, Jain, & Gupta, 2016) and also in various regions (Milasinovic, Popovic, Matic, Gardasevic, & Bjelica, 2016; Masanovic, Gardasevic, & Arifi, 2018a; Masanovic, Bavcevic, & Prskalo, 2019; Masanovic, Arifi, & Gardasevic, 2020; Masanovic, Arifi, & Gardasevic, 2020a); therefore, researchers propose designing specific formulas for calculating standing height from long bones for each ethnic or racial group, and for different regions. The mentioned variations might also be the case with tibia length predictions, mostly because the Dinaric Alps population has a specific body composition (Popovic, 2017; Starc et al., 2020; Popovic, Masanovic, Martinovic, Bjelica, & Gardasevic, 2020). Many studies on this subject are available worldwide; some data is available on Kosovan subjects, but most have covered the whole Kosovan population, and few have studied regional differences. Some studies confirm that Western Kosovans, Southern Kosovans, and Northern Kosovans have specific standing height/tibia length ratios compared to the general population in Kosovo (Gardasevic, 2019b; Gardasevic, Masanovic, & Arifi, 2018; Gardasevic, Masanovic, & Arifi, 2019). Considering the rather sparse recent scientific literature, the purpose of this research was to examine the standing height in both Eastern Kosovan genders and its association with tibia length.

Method

This research gathered 364 final-year high-school students (185 male and 179 female) from Kosovo's Eastern Region. The reasons that qualified the selected individuals are 1) related to the fact that the growth of an individual ceases by this age, and 2) related to the fact that there is no age-related loss in standing height at this age. The average age of the male subject was 18.20±0.40 years old (range 18–19 years), while the average age of the female subject was 18.15±0.36 years old (range 18–19 years). It is important to underline that the researchers have excluded from the data analysis the individuals with physical deformities and those without informed consent. Another exclusion criterion was being non-Eastern Kosovan.

The anthropometric measurements, including standing height and tibia length, were conducted according to the International Society for the Advancement of Kinanthropometry (ISAK) protocol (Marfell-Jones, Olds, Stew, & Carter, 2006). Trained measurers conducted the assessment of selected anthropometric indicators, while the quality of their performance was evaluated against the prescribed "ISAK Manual". Finally, the age of each subject was obtained directly from their birthdays.

The analysis was performed by using the Statistical Package for Social Sciences (SPSS) version 20.0 (Chicago, IL, USA) adjusted for use on personal computers. Means and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of standing height and tibia length between genders was performed using a t-test. The relationships between standing height and tibia length were determined using simple correlation coefficients at a ninety-five per cent confidence interval. Next, a linear regression analysis was carried out to examine the extent to which the tibia length can reliably predict standing height. Statistical significance was set at $p<0.05$.

Results

In Table 1, a summary of the anthropometric measurements in both genders is shown. The mean standing height for males was 178.79±6.07 centimetres, and tibia length was 38.58±2.49 centimetres, while for females the standing height was 164.74±4.89

Table 1. Anthropometric Measurements of the Study Subjects

Subjects	Body Height Range (Mean±Stand.Dev.)	Tibia Length Range (Mean± Stand.Dev.)
Male	161.4-193.0 (178.79±6.07)	30.1-45.7 (38.58±2.49)
Female	153.3-178.0 (164.74±4.89)	31.0-40.3 (35.32±1.85)

centimetres, and tibia length was 35.32±1.85 centimetres. The gender difference between standing height and tibia length measurements was significant (standing height: t=24.849; p<.000; and tibia length: t=14.177; p<.000).

In Table 2, the simple correlation coefficients and their ninety-five per cent confidence interval analysis between the anthropometric measurements are displayed. The associations between standing height and tibia length were significant (p<0.000) and high in this sample, regardless of gender (male: 0.671; female: 0.640).

Table 2. Correlation between Body Height and Tibia Length of the Study Subjects

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.671	0.562-0.779	<0.000
Female	0.640	0.526-0.754	<0.000

In Table 3, the results of the linear regression analysis are shown. The first of all models were extracted by including age as a covariate. However, it was found that the contribution of age was insignificant; therefore, it was eliminated as a factor from the study, and estimations were derived as a univariate analysis. The high values of the regression coefficient (male: 0.671; female: 0.640) signify that tibia length notably predicts standing height in both Eastern Kosovan genders (male: t=12.227, p<0.000; female: t=11.072, p<0.000), which confirms the R-square (%) for the male (45.0) as well as for the female (40.9).

Table 3. Results of Linear Regression Analysis Where the Tibia Length Predicts the Body Height

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Male	0.671	4.514	45.0	12.227	0.000
Female	0.640	3.638	40.9	11.072	0.000

The associations between tibia length measurements and standing height among the above models are plotted as a scatter diagram (Figure 1).

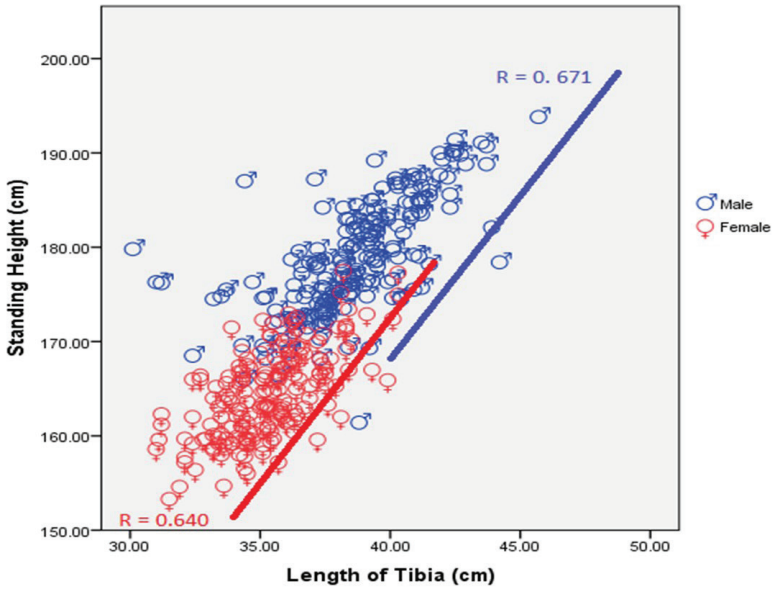

FIGURE 1. Scatter Diagram and Relationship between Tibia Length Measurements and Body Height among Both Genders

Discussion

Over the centuries, many researchers have studied the assessment of standing height using various anthropometric measures. It must be emphasized that arm span has been evaluated as the most reliable body indicator for predicting standing height (Ter Goon et al., 2011; Popovic, Bjelica, Georgiev, Krivokapic, & Milasinovic, 2016; Masanovic, Popovic, Jarani, Spahi, & Bjelica, 2020), while tibia length was a very close second (Agnihotri, Smita, Jowaheer, & Pratap, 2009; A. Kaore, B.P. Kaore, Kamdi, & S. Kaore, 2012; Khatun et al., 2016). Furthermore, it should be considered that the individual and ethnic variations referring to standing height and its association with tibia length can vary from among ethnic groups and races. Consequently, the effect of racial and ethnic differences on these measures reduces the possibility of generalization (Popovic, 2018; Masanovic et al., 2019). This study's findings are consistent with results of the study conducted by Agnihotri et al. (2009), which confirmed a very high linear correlation between standing height and tibia length in both genders of an Indo-Mauritian population, and with the results of the study conducted by Khatun et al. (2016), which showed a significant correlation between standing height and tibia length in

both genders of an Indian population, in which the correlation coefficient for tibia length is r=0.67 in males and r=0.58 in females. As the correlation between tibia length and standing height was significant in both Eastern Kosovan genders, the tibia length measure, therefore, seems to be a reliable indirect anthropometric indicator for estimating standing height in both genders of the Eastern Kosovan population.

The necessity of developing separate standing height models for each population on account of ethnic differences has been confirmed by several studies. Arifi et al. (2017) analysed the entire Kosovan population and found specific correlation coefficients between standing height and arm span in Kosovan male (r=0.794) and female (r=0.766) population. Also, some recent studies have confirmed the regional differences between the same ethnic groups (Arifi, 2017; Popovic et al., 2017). Care should be taken here because the three regional studies indicate the specificity for height prediction using the tibia. In the first study, Gardasevic (2019b) found specific correlation coefficients for standing height and tibia length in Western Kosovan males (r=0.538) and females (r=0.559) compared with the entire Kosovan population; in the second study, Gardasevic et al. (2018) found specific correlation coefficients for standing height and tibia length in Southern Kosovan males (r=0.734) and females (r=0.639) compared with the entire Kosovan population; in the third study, Gardasevic et al. (2019) found specific correlation coefficients in standing height and tibia length in Northern Kosovan males (r=0.730) and females (r=0.675) compared with the entire Kosovan population. Therefore, the main goal of this study is to examine whether this hypothesis also applies to the Eastern Kosovans (i.e., for one the of five Kosovan regions). The results of the studies mentioned previously confirm the necessity of developing separate standing height models for both genders in Kosovo, and also recommended that further studies should consider dividing the population of this country into regional subsamples and analysing them separately to remove the doubt that geographical differences exist (such as type of soil) influencing the average standing height in both Kosovan genders as well as its association with tibia length. This was based on the fact that the whole of Kosovo does not fall into the Dinaric Alps racial classification (Masanovic et al., 2019b). In parallel, this study confirms that assumption and also that it is necessary to develop separate standing height models for each population on account of regional variations in Kosovo.

Finally, it is necessary to point out that a limitation of this study might be the composition of the respondent sample, which comprised high school students. This limitation is based on the fact that some studies question whether the growth of an individual ceases by this age (Grasgruber et al., 2017). This assumption might be supported by the fact that university-educated individuals are taller than the high school graduate population in Hungary and Poland (Szollosi, 1998; Wronka & Pawlinska-Chmara, 2009). However, this was not the case in Montenegro (Popovic et al., 2017). This dilemma could be resolved by comparing the average standing height measures of this study to the results of a study with a sample of university students. Another limitation of this study is the fact that both genders of the subjects in Kosovo had not yet reached their full genetic potential, since various environmental factors controlled their development (war and the difficult economic situation of the previous three decades). Further continuous monitoring is necessary, mostly because the secular changes influencing standing height are expected to rise in the next two to three decades.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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