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

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Abstract

The purpose of this research is to examine standing height in both Kosovan genders in the Eastern Region as well as its association with foot length, as an alternative to estimating standing height. A total of 364 individuals (185 male and 179 female) participated in this research. The anthropometric measurements were taken according to the protocol of ISAK. The relationships between body height and foot length were determined using simple correlation coefficients at a ninety-five percent confidence interval. A comparison of means of standing height and foot length between genders was performed using a t-test. After that a linear regression analysis were carried out to examine extent to which foot length can reliably predict standing height. Results displayed that Eastern Kosovan male are 178.79±6.07 cm tall and have a foot length of 26.03±1.21 cm, while Eastern Kosovan female are 164.60±4.72 cm tall and have a foot length of 23.38±0.94 cm. The results have shown that both genders made Eastern-Kosovans a tall group, but a little bit shorter than general Kosovan population. Moreover, the foot length reliably predicts standing height in both genders; but, not reliably enough as arm span. This study also confirms the necessity for developing separate height models for each region in Kosovo as the results from Eastern-Kosovans don't correspond to the general values.

Key words: *prediction, measurement, stature, foot length, Kosovan*

Introduction

According to Komunat e Kosovës (2013), Kosovo is a democratic, multi-ethnic and secular republic which administratively is subdivided into seven districts (Ferizaj, Gjakova, Gjilan, Mitrovica, Peja, Pristina and Prizren) and five regions (Eastern, Western, Northern, Southern and Central). This study analyzes the standing height and its estimation utilizing foot length measurements in adolescents in eastern region which contains two districts (Ferizaj and Gjilan) and eleven municipalities (Ferizaj, Hani iElezit, Kaçanik, Štimlje/Shtime, Štrpce/Shtërpcë, Gjilan, Kamenica, Klokot, Partesh, Ranilug and Vitina). This region (Figure 1) covers the area of 2,236 square kilometers and has population of 366,589 inhabitants, while average density per square kilometer is 255 inhabitants (Komunat e Kosovës, 2013). Although Kosovo doesn't have too big territory, it has a very varied relief that mostly belongs to Dinarides range and the author assumed this fact might influence the main objective of this study, because of the type of the soil as well as other socio-economical and geographical characteristics as a potential influencing factors (Arifi, 2013; Arifi, Sermaxhaj, Zejnullahu-Raçi, Alaj, & Metaj, 2017b).

There are lots of scientific findings which confirms that the measurement of standing height is a vitally important variable when assessing nutritional status (Arifi et al., 2017a; DattaBanik, 2011; Popovic & Bjelica, 2016), as well as when assessing the growth of children, evaluating the basic energy requirements, adjusting the measures of physical capacity and predicting the drug dosage and setting standards of physio-

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Figure 1. Geographical Location of Eastern Region in Kosovo

logical variables such as muscle strength, metabolic rate, lung volumes and glomerular filtration (Golshan, Amra, & Hoghogi, 2003; Golshan, Crapo, Amra, Jensen, & Golshan, 2007; Mohanty, Babu, & Nair, 2001; Ter Goon, Toriola, Musa, & Akusu, 2011). However, according to Quanjer and his collaborators (2014), the exact standing height cannot always be identified and resolved in the usual way (e.g. paralysis, fractures, amputation, scoliosis and pain). Because of these factors, an estimate of standing height has to be acquired from other reliable anthropometric indicators such as hand and foot lengths, 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 (Gardasevic, Rasidagic, Krivokapic, Corluka, & Bjelica, 2017; Popovic, 2017). Therefore, all these anthropometric indicators, which are used as an alternative to estimate standing height, are very important in predicting loss in standing height connected with aging. Also, to diagnose individuals with disproportionate growth abnormalities and skeletal dysplasia or standing height loss during surgical procedures on the spine (Mohanty et al., 2001), as well as to anticipate standing height in many older people as it is very difficult to measure it precisely, and sometimes impossible because of mobility problems and kyphosis (Hickson & Frost, 2003). Lastly, it is important to state that this knowledge finds its importance in sport science the standing height represents a significant factor which influences the success in various sport disciplines (Popovic, 2017).

Several researches have reported the benefit of using various body parameters in predicting standing height, and arm span happened to be one of the most reliable ones in adults (Mohanty et al., 2001; Ter Goon et al., 2011; Hickson & Frost, 2003; Jalzem & Gledhill, 1993), while foot length measurement is the most reliable predictor during adolescent age, due to the fact that ossification and maturation occurs earlier in the foot than the long bones and standing height could be more accurately predicted from foot measurement as compared to long bones during adolescent age (Singh, Kumar, Chavali, & Harish, 2012). In addition, the relationship of long bones and standing height was found to vary in different ethnic and racial groups (Bjelica et al., 2012; Brown, Feng, & Knapp, 2002; Popovic, Bjelica, Georgiev, Krivokapic, & Milasinovic, 2016; Popovic, Bjelica, Molnar, Jaksic, & Akpinar, 2013; Popovic, Bjelica, Tanase, & Milasinovic, 2015; Masanovic, 2017; Reeves, Varakamin, & Henry, 1996; Steele & Chenier, 1990) as well as various regions (Arifi, 2013; Arifi et al., 2017b; Milasinovic, Popovic, Matic, Gardasevic, & Bjelica, 2016a; Milasinovic, Popovic, Jaksic, Vasiljevic, & Bjelica, 2016b). Hence, researchers have derived a specific formula for calculating standing height from long bones for each ethnic/race group. The mentioned variations might be the case with foot length predictions too, mostly due to the fact that the Dinaric Alps population has specific body composition than national as well as regional point of view (Popovic, 2017). Even though many studies with this essence are available on neighboring countries as well as worldwide population, only narrow data is available on Kosovan subjects, just one conducted by Popovic, Arifi and Bjelica (2017a; Popovic & Bjelica, 2017) that has covered whole Kosovan population, and one regional analyses that confirmed Western-Kosovans have specific standing height/foot length ratio, comparing to general population in Kosovo (Popovic, Gardasevic, Masanovic, Arifi, & Bjelica, 2017b; Masanovic, Gardasevic, & Arifi, 2018). Considering 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 foot length.

Methods

The nature of this research gave extension to the 364 high-school students last year (185 male and 179 female) from Eastern Region of Kosovo to be subjects. Two reasons which qualified the selected individuals are: the first is related to the fact that the growth of an individual ceases by this age, while the second is 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 of the individuals with physical deformities as well as those without informed consent. The exclusion criterion was also being non-Eastern Kosovan.

The anthropometric measurements, including standing height and foot length, were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (Marfell-Jones, Olds, Stew, & Carter, 2006). The trained measurers have measured selected anthropometric indicators (same measurer for each indicator), while the quality of their performance was evaluated against the prescribed "ISAK Manual". Lastly, the age of the each subject was reached directly from the birthdays.

The analysis were performed by 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 standing height and foot length between genders was performed using a t-test. The relationships between standing height and foot length were determined using simple correlation coefficients at ninety-five percent confidence interval. Then a linear regression analysis were carried out to examine the extent to which the foot length can reliably predict standing height. 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 standing height for male was 178.79±6.07 centimeters and foot length was 26.03±1.21 centimeters, while for female the standing height was 164.60±4.72 centimeters and foot length was 23.38±0.94 centimeters. The sex difference between standing height and foot length measurements was statistically significant (standing height: t=24.951; p<.000, and foot length: t=23.389; p<.000).

Table 1. Anthropometric Measurements of the Study Subjects

Subjects	Body Height Range (Mean±SD)	Foot Length Range (Mean±SD)
Male	161.4-193.8 (178.79±6.07)	22.40-29.50 (26.03±1.21)
Female	153.3-177.5 (164.60±4.72)	21.50-26.80 (23.38±0.94)

In Table 2, the simple correlation coefficients and their ninety-five percent confidence interval analysis between the anthropometric measurements are displayed. The associations between standing height and foot length were significant (p<0.000) and high in this sample, regardless of gender (male: 0.681; female: 0.626).

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

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.681	0.550–0.755	<0.000
Female	0.626	0.493–0.716	<0.000

The results of the linear regression analysis are shown in Table 3. The first of all models were extracted 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: 0.681; female: 0.626) signify that foot length notably predicts standing height in both Eastern-Kosovan genders (male: t=12.58, p<0.000; female: t=10.69, p<0.000), which confirms the R-square (%) for the male (46.4) as well as for the female (39.2).

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

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Male	0.681	4.456	46.4	12.58	0.000
Female	0.626	3.690	39.2	10.69	0.000

The associations between foot length measurements and standing height among the above models is sketched as a scatter diagrams (Figure 2).

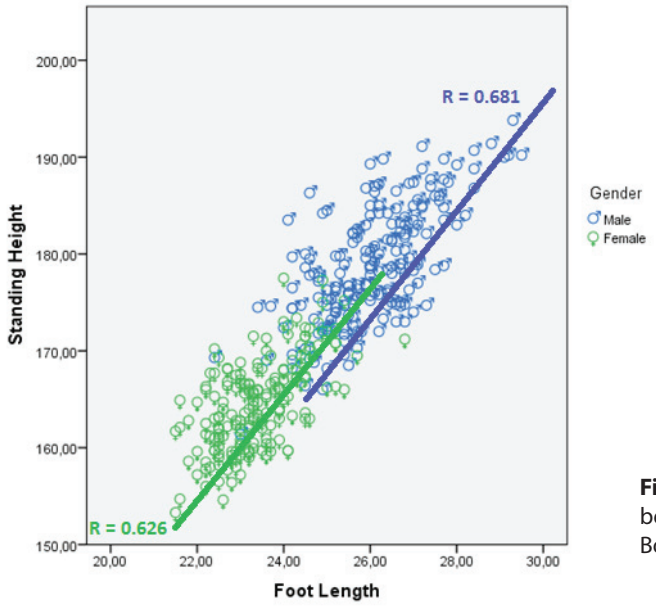

Figure 2. Scatter Diagram and Relationship between Foot Length Measurements and Body Height among Both Genders

Discussion

The assessment of standing height using various anthropometric measures is very typical from the past centuries and it has been attempted to be studied by many researchers. However, it is important to underline that the arm span has been obtained as the most reliable body indicator for predicting the standing height of an individual (Mohanty et al., 2001; Ter Goon et al., 2011), while foot length is was very close (Singh et al., 2012; Uhrova et al., 2015; Cheng et al., 1998). In parallel, it is important to emphasize that the individual and ethnic variations referring to standing height and its association with foot length might vary from ethnic group to ethnic group as well as race to race, because the racial and ethnic differences are affective on these measures and reduce the possibility of generalizing (Bjelica et al., 2012). This fact confirms the study conducted by Chinese authors (Cheng et al., 1998) who confirmed a very high linear correlation between standing height and foot length in both genders, as well as in another study which confirmed that foot length can explain up to 77% variations in standing height (Uhrova et al., 2015), while the research study conducted by Uhrova and her collaborators (2015) shows significant correlation between standing height and all measure anthropometric parameters in both genders of Slovak population. The highest correlation coefficient in this population was found for foot length in males (r=0.71) as well as in females (r=0.63).

All above-mentioned have confirmed the necessity for developing separate standing height models for each population on account of ethnic differences and the recent study conducted by Popovic and his collaborators (Popovic et al., 2017a; Popovic & Bjelica, 2017) who have analyzed the entire Kosovan population and have found specific correlation coefficient in Kosovan male (r=0.669) and female (r=0.625) population; however, some recent studies have also confirmed the regional differences between the same ethnic groups too (Arifi, 2013; Arifi et al., 2017b; Milasinovic et al., 2016a; Milasinovic et al., 2016b; Popovic et al., 2017b), which caused the need for additional caution, mostly due to the reason one of them was sampled by Western-Kosovans. Therefore, the main goal of this research was to test the hypothesis if above-mentioned facts are true for the Eastern-Kosovans, that is, for the one of five Kosovan regions. Hence, in the present research it was remarked that the foot length/standing height ratio in Eastern-Kosovan male is bigger (male: 46.4%; female: 39.2%) comparing to entire Kosovan (male: 44.3%; female: 38.6%) and Western-Kosovans (male: 40.2%; female: 39.4%) as well as smaller comparing to other available population that estimate over 70% each and more in male population, while female population is much more in parallel to previously measured populations. As the correlation between foot length and standing height was significant in both Eastern-Kosovan genders, the foot length measure therefore seems to be a reliable indirect anthropometric indicator for estimating standing height in both genders of Eastern-Kosovan population. Even though these relations are similar, the estimation equations, which are obtained in the Eastern-Kosovans, considerably differ from entire Kosovan, Western-Kosovans and other available populations.

The results of the study conducted by Popovic and his collaborators (Popovic et al., 2017a; Popovic & Bjelica, 2017) confirm the necessity for developing separate standing height models for both genders in Kosovo but the authors of the same study have recommended that further studies should consider dividing the population of this country to regional subsamples and analyze it separately, just to be sure there are no geographical differences (such as type of the soil) influencing the average standing height in both Kosovan genders as well as its association with foot length. This concern was based on the fact that entire Kosovo doesn't fall into Dinaric Alps racial classification. In parallel, this study confirms the assumption mentioned above and also confirms that it is necessary to develop separate standing height models for each population on account of regional variations in Kosovo.

Next to highlighted issue, the obvious constraint of this research might also be the composition of the measured sample that consisted of high school students. This limitation is based on the fact there are some studies which assumed the growth of an individual doesn't cease by this age (Grasgruber, 2016; Jurak, 2017). This assumption might be supported by the fact that university-educated individuals have been founded to be taller than the high school population in Bosnia and Herzegovina (Gardasevic et al., 2017; Grasgruber et al., 2017), Poland (Wronka & Pawlinska-Chmara, 2009) and Hungary (Szollosi, 1998). On the other hand, this wasn't the truth in Montenegro (Popovic, 2016) and comparing the average standing height measures of this study to the results of some study sampled by university students might give the science much precise conclusions. One more obvious limitation of this study is also the fact that both genders of Kosovo did not reach their full genetic potential yet, since various environmental factors controlled their development. Further continuous monitoring is necessary, mostly due to the reason it is expected the secular changes influencing standing height will ascend in the following two or three decades.

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Conflict of Interest
The authors declare there are no conflict of interest.

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