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RELATIONSHIP BETWEEN TIBIA LENGTH MEASUREMENTS AND STANDING HEIGHT: A PROSPECTIVE REGIONAL STUDY AMONG ADOLESCENTS IN NORTHERN REGION OF KOSOVO

ABSTRACT: The purpose of this research is to examine standing height in Kosovan adolescents in the Northern Region as well as its association with tibia length, as an alternative to estimate standing height. A total of 177 individuals (87 boys and 90 girls) participated in this research. Anthropometric measurements were taken according to the protocol of ISAK. The relationship between standing height and tibia length was determined by using simple correlation coefficients at a ninety-five percent confidence interval. A comparison of means of standing height and tibia length between genders was performed using a t-test. After that a linear regression analysis was carried out to examine the extent to which tibia length can reliably predict standing height. Results displayed that Northern Kosovan boys are 180.28 ± 5.71 cm tall and have a tibia length of 40.59 ± 2.68 cm, while Northern Kosovan girls are 165.36 ± 4.56 cm tall and have a tibia length of 36.68 ± 2.05 cm. The results have shown that both sexes made Northern-Kosovans a tall group, a little bit taller than boys and a little bit shorter than girls of the general Kosovan population. It turned out that the tibia length reliably predicts standing height in adults. This study also aims to point out the necessity for developing separate height models for each region in Kosovo as the results from Northern-Kosovans don't correspond to the general values.

KEY WORDS: Prediction – Measurement – Stature – Tibia 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 tibia length measurements in adolescents in Northern region which contains seven municipalities (Leposavić, Mitrovica, North Mitrovica, Skenderaj, Vushtrri, Zubin Potok and Zvečan). This region (*Figure 1*) covers the area of 2,077 square kilometers and has a population of 272,247 inhabitants, while the average density per square kilometer is 110 inhabitants (Komunat, Kosovës 2013). Although Kosovo doesn't have too large a territory, it has a very varied relief that mostly belongs to Dinarides range and the author assumed that this fact might influence the main objective of this study, because of the type of the soil as well as the socio-economical and geographical characteristics that can be the potential influencing factors (Arifi 2017, Arifi *et al.* 2017b).

There are many scientific findings which confirm that the measurement of standing height is a vitally important variable when assessing nutritional status (cited in Arifi *et al.* 2017a; Datta Banik 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 physiological variables such as muscle strength, metabolic rate, lung volumes and glomerular filtration (Golshan *et al.* 2003, Golshan *et al.* 2007, Mohanty *et al.* 2001, Ter Goon *et al.* 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 estimation of the standing height has to be acquired from other reliable anthropometric indicators such as tibia length (Gardasevic *et al.* 2017, Popovic *et al.* 2017). Therefore, anthropometric indicators, which are used as an alternative to estimating 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

FIGURE 1: Geographical location of northern region in Kosovo.

people, is very difficult to be measured 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 chances of success are significantly influenced by the standing height factor in various sport disciplines (Popovic 2017).

Several researches have reported the benefits of using various body parameters in predicting standing height, and arm span happened to be one of the most reliable ones in adults (Hickson, Frost 2003, Ter Goon *et al.* 2011), while some authors (Singh *et al.* 2012) believe that 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 in the long bones and standing height could be more accurately predicted from foot measurement as compared to long bones during adolescent age. In addition, the relationship of long bones and standing height was found to vary in different ethnic and racial groups (Popovic *et al.* 2015) as well as various regions (Masanovic *et al.* 2018, Masanovic *et al.* 2019). 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 tibia length predictions too, mostly due to the fact that the Dinaric Alps population has specific body composition (Popovic 2017). Even though many studies with this essence are available in the neighboring countries as well as for the worldwide population, only limited data are available on Kosovan subjects, and one of them was conducted by Popovic *et al.* (2017), and Popovic and Bjelica (2017) that has covered the whole Kosovan population, and one regional analysis that confirmed Western-Kosovans have specific standing height/foot length ratio, comparing to general population in Kosovo (Popovic *et al.* 2017). Considering rather sparse recent scientific literature, the purpose of this research was to examine the standing height in both Northern-Kosovan sexes and its association with tibia length.

METHODS

The research took 177 high-school students last year (87 boys and 90 girls) from Northern Region of Kosovo to be the 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 subjects was 18.25 ± 0.46 years old (range 18-20 years), while the average age of the female subjects was 18.29 ± 0.46 years old (range 18–19 years). It is important to underline that the researchers have excluded the individuals with physical deformities as well as those without informed consent from the data analysis. The exclusion criterion was also being non-Northern Kosovan, anyone who was not born and lived in Northern Kosovo.

The anthropometric measurements, including standing height and tibia length, were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (Marfell-Jones *et al.* 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 each subject was calculated directly from their birthdates.

The analyses were performed by using the Statistical Package for Social Sciences (SPSS) version 23.0. Mean values and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of standing height and tibia length between sexes was performed using a *t-test*. The relationship between standing height and tibia length was determined by using simple correlation coefficients at ninety-five percent confidence interval. Then 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

A summary of the anthropometric measurements in both sexes is shown in *Table 1*. The mean of the standing height for boys was 180.28 ± 5.71 centimeters

TABLE 1: Anthropometric measurements of the study subjects.

Subjects	Standing height range (Mean±SD)	Tibia length range (Mean±SD)
Boys	167.90–197.30 (180.28±5.71)	35.10–48.60 (40.59±2.68)
Girls	158.70–182.00 (165.36±4.56)	31.60–43.20 (36.68±2.05)

and tibia length was 40.59 ± 2.68 centimeters, while the standing height for girls was 165.36 ± 4.56 centimeters and tibia length was 36.68 ± 2.05 centimeters. The sex difference between standing height and tibia length measurements was statistically significant (standing height: t=19.23; p<.00; and tibia length: t=10.89; p<.00).

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 tibia length were significant (p<0.00) and high in this sample, regardless of gender (boys: 0.63; girls: 0.54).

TABLE 2: Correlation between standing height and tibia length of the study subjects.

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Boys	0.63	0.47–0.80	<0.00
Girls	0.54	0.36–0.72	<0.00

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 (boys: 0.63; girls: 0.54) signify that tibia length notably predicts standing height in both Northern-Kosovan sexes (boys: t=7.58, p<0.00; girls: t=6.00, p<0.00), which confirms the R-square (%) for the boys (40.3) as well as for the girls (29.0).

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

DISCUSSION

The assessment of standing height using various anthropometric measures is very typical from the past

TABLE 3: Results of linear regression analysis where the tibia length predicts the standing height.

Subjects	Regression Coefficient	Standard Error (SE)	R-square (%)	t-value	p-value
Boys	0.63	4.44	40.3	7.58	0.00
Girls	0.54	3.86	29.0	6.00	0.00

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 tibia length is very close (Khatun *et al.* 2016, Kaore *et al.* 2012). In parallel, it is important to emphasize that the individual and ethnic variations referring to standing height and its association with tibia length might vary from ethnic group to ethnic group as well as from 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 authors (Agnihotri *et al.* 2009) who confirmed a very high linear correlation between standing height and tibia length in both genders, while the research study conducted by Khatun and her collaborators (2016) shows significant correlation between standing height and tibia length in both sexes of Indian population. The highest correlation coefficient in this population was found for tibia length in males (r=0.67) as well as in females (r=0.58). Similar results were obtained in this study.

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. However, some recent studies have also confirmed the regional differences between the same ethnic groups too (Arifi 2017, Arifi *et al.* 2017b, Popovic *et al.* 2017b, Milasinovic *et al.* 2016), which caused the need for additional caution, mostly due to the reason why 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 Northern-Kosovans, that is, for the one of five Kosovan regions. As the correlation between tibia length and standing height was significant in both Northern-Kosovan sexes, the tibia length measure therefore seems to be a reliable indirect anthropometric indicator for estimating standing height in both sexes of Northern-Kosovan population.

The results of the study conducted by Popovic and his collaborators (Popovic *et al.* 2017a, Popovic, Bjelica 2017, Masanovic 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
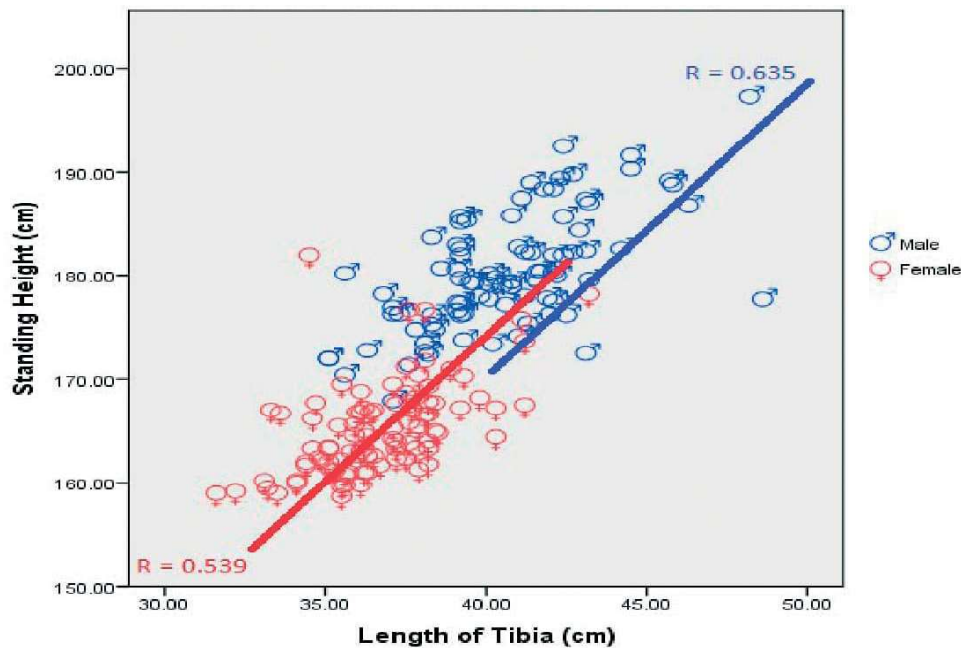
FIGURE 2: Scatter diagram and relationship between tibia length measurements and standing.

consider dividing the population of this country to regional subsamples and analyzing it separately, just to make sure that there are no geographical differences (such as type of the soil) influencing the average standing height in both Kosovan sexes as well as its association with tibia 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 this 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 (P. Grasgruber, personal communication 2016; G. Jurak personal communication 2017). This assumption might be supported by the fact that university-educated individuals are found to be taller than the high school population in Bosnia and Herzegovina (Grasgruber *et al.* 2017, Gardasevic *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 with 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 sexes 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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