Standing Height and its Estimation Utilizing Foot Length Measurements in Kosovan Adults: National Survey

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ABSTRACT
The purpose of this research is to examine standing height in both Kosovan genders as well as its association with foot length, as an alternative to estimating standing height. A total of 1623 individuals (830 male and 793 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. Then a linear regression analysis was carried out to examine extent to which foot length can reliably predict standing height. Results displayed that Kosovan male are 179.52±5.96 cm tall and have a foot length of 26.22±1.19 cm, while Kosovan female are 165.72±4.93 cm tall and have a foot length of 23.52±1.01 cm. The results have shown that both genders made Kosovans a tall nation but not even close to be in top tallest nations. Moreover, the foot length reliably predicts standing height in both genders; but, not reliably enough as arm span.

KEYWORDS Prediction, Measurement, Stature, Foot Length, Kosovo
INTRODUCTION

There are lots of scientific findings that confirms the measurement of standing height is a vitally important variable when assessing nutritional status [cited in 5], 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 [8, 9, 16, 27]. However, according to Quanjer and his collaborators [22], 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 [cited in 7, 17]. 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 [16], 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 [10]. Lastly, it is important to be stated that this knowledge finds its importance in sport since the standing height represents an significant factor that influence the success in various sport disciplines.

As stated above, it is suggested to find the benefit of using various body indicators in estimating standing height in the Kosovan population. Additionally, couple of 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 one in adults [10, 11, 16, 27], 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 [cited in 24]. On the other hand, the relationship of long bones and standing height was found to vary in different ethnic and racial groups [1, 2, 19, 20, 21, 23, 25] and 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 prediction too, mostly due to the reason the Dinaric Alps populations has specific body composition [18]. Even though many studies with this essence are available on worldwide populations, only narrow data is available on Kosovan subjects. Considering rather sparse recent scientific literature, the purpose of this research was to examine the standing height in both Kosovan genders and its association with foot length.

METHODS

The nature of this research gave extension to 1623 last year high-school students (830 male and 793 female) from Kosovo to be subjects. Two reasons qualified the selected individuals, 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 18.26±0.45 years old (range 18-20 years), while the average age of the female subject was 18.24±0.43 years
old (range 18-20 years). It is important to underline that the researchers have excluded from the data analysis the individuals with physical deformities as well as those without informed consent. The exclusion criterion was also being non-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 [13]. 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”. Lasty, the age of the each subject was reached directly from the birthdays.

The analysis was performed 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 was carried out to examine the extent to which the foot length can reliably predict standing height. Statistical significance was set at p<0.05.

**STATISTICAL RESULTS**

A summary of the anthropometric measurements in both genders is shown in Table 1. The mean of the standing height for male was 179.52±5.96 centimeters and foot length was 26.22±1.19 centimeters, while for female the standing height was 165.72±4.93 centimeters and foot length was 23.52±1.01 centimeters. The sex difference between standing height and foot length measurements was statistically significant (standing height: t=50.685; p<.000, and foot length: t=48.906; p<.000).

| Subjects | Body Height Range (Mean±SD) | Foot Length Range (Mean±SD) |
|----------|-----------------------------|-----------------------------|
| Male     | 161.4-198.8 (179.52±5.96)   | 22.10-30.10 (26.22±1.19)    |
| Female   | 153.3-185.0 (165.72±4.93)   | 20.80-28.30 (23.52±1.01)    |

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: 0.669; female: 0.625).
Table 2. Correlation between Body Height and Foot Length of the Study Subjects

| Subjects | Correlation Coefficient | 95% confidence interval | Significance p-value |
|----------|--------------------------|-------------------------|----------------------|
| Male     | 0.669                    | 0.618–0.720             | <0.000               |
| Female   | 0.625                    | 0.570–0.679             | <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: 0.669; female: 0.625) signify that foot length notably predicts standing height in both Kosovan genders (male: t=25.90, p<0.000; female: t=22.49, p<0.000), which confirms the R-square (%) for the male (44.8) as well as for the female (39.0).

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     | 0.669                  | 4.432               | 44.8         | 25.90   | 0.000   |
| Female   | 0.625                  | 3.855               | 39.0         | 22.49   | 0.000   |

The associations between foot length measurements and standing height among the above models is sketched as a scatter diagram (Figure 1).

Figure 1. 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 [16, 27], while foot length is was very close [12, 24, 28]. 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 [cited in 1]. This fact confirms the study conducted by Chinese authors who confirmed a very high linear correlation between standing height and foot length in both genders [4], as well as in another study that confirmed that foot length can explain 77% variations in standing height [cited in 28], while the research study conducted by Uhrova and her collaborators [28] shows significant correlation between standing height and all measure anthropometric parameters in both genders of Slovak population, while the highest correlation coefficient 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. However, some recent studies confirmed the regional differences between among the same ethnic groups too [3, 14, 15, 29], which cause the need for additional caution. Therefore, the main goal of this research was to test the hypothesis if above-mentioned facts are true for the Kosovans. Hence, in the present research it was remarked that the foot length/standing height ratio in Kosovan male is quite low (male: 44.8%; female: 38.6%) contrasting 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 Kosovan genders, the foot length measure therefore seems to be a reliable indirect anthropometric indicator for estimating standing height in both genders of Kosovan population. Even though these relations are similar, the estimation equations, which are obtained in the Kosovans, considerably differ from other populations.

The results of this study confirm the necessity for developing separate standing height models for both genders in Kosovo at large; however, the researchers must underline 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 is based on the fact that entire Kosovo doesn’t fall into Dinaric Alps racial classification. Next to this issue, the obvious constraint of this research might 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, P., personal communication, 2016; Jurak, G., personal communication, 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 [6,
7], Poland [30] and Hungary [26]. On the other hand, this wasn’t the truth in Montenegro [18]. Hence, some further studies might confirm if this is the truth in Kosovo or not as we don’t have available student population to test this assumption. The obvious limitation of this study is 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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