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Estimation of stature and body weight in Slovak adults using static footprints: A preliminary study

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ABSTRACT

The stature and the body weight as part of the biological profile can aid the personal identification. The dimensions of the human foot, as well as the footprint, can be used for the prediction due to the existence of its positive correlation with the stature and body weight. Five diagonal axes and ball breadth of bilateral static footprints of 132 young Slovak adults were obtained. All diameters were larger in a male group than female group. No bilateral differences were found except the first diagonal axis and ball breadth. A positive correlations between the selected footprint diameters with the stature (r = 0.37–0.64) and the body weight (r = 0.29–0.71) were confirmed. The linear and multiple regression prediction equations were developed.

A stature prediction equation using the most lateral diameters (the fourth and fifth diagonal axis) exhibited the highest accuracy ranging from 4 to 7.5 cm. Similar results were found for the body weight estimation of the male and mixed group. In the female group, the most medial axis (first and second) exhibited the highest accuracy. The body weight estimation accuracy ranges from 9.09 to 11.09 kg.

The real and predicted stature and body weight were compared and found differences were lower than calculated SEEs. Thresholds and prediction trend of under- or overestimation was identified. The results of the present study show that selected measurements of static footprints could be used to predict stature and body weight but should be applied only for Slovaks due to population specificity.

1. Introduction

The body height and body weight are the basic characteristics often used to describe another person and they are part of a biological profile. Together with the sex and age, if estimated correctly, may aid a personal identification. Multiple publications exploring mainly the stature estimation from a dimension of the various body parts can be found, among which the lower extremities show high correlations [1,2,3].

Similarly to the direct foot measurements, the footprints attracted attention and can be used for the predictions [4–5]. An extensive research and development of the stature prediction equations from the footprints were conducted in the countries where barefoot walking is common, for instance in India. On the other hand, only a few studies focus on the estimation of the body weight from the footprints [4–8].

Footprints are found in the majority of crime scenes but may be overlooked or underestimated [6]. Considering their individuality, the stature and body weight footprint estimations could be particularly useful in the case of home violence. Alike the individual crease pattern of footprints [9], specific length and width measurements highlight their uniqueness [4,6–7]. Several quantitative footprint evaluation methods were developed utilizing the diagonal, parallel and horizontal measurements of the heel, ball, and toes or their combinations [10]. The positive correlations of the stature/body weight and various measurements of the footprint have been observed, but the population differences preclude the development of universal prediction equations [5–8,11].

Previously published literature confirmed the existence of the strong correlation between direct foot measurements and the stature of Slovak adults [12,13]. The presented research uses the diagonal footprint measurements based on Robbins [5] (five axes connecting the backmost point on the heel with the foremost point of each toe and breadth of the ball) to assess the footprint-stature and footprint-body weight correlations. The publication aims towards the development of the population-specific stature and body weight prediction equations, as they have not

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been developed for Slovak adults yet.

2. Materials and methods

The body weight and the stature of 132 young adults were measured, and a series of footprints were collected. The data collection was part of an anthropometric research project of young Slovak population conducted at the Faculty of Natural Sciences of Comenius University in Bratislava, Slovakia. All the participants received written instructions and details of the study explaining its aims, methods and expected involvement. Participation in the study was voluntarily and entirely based on a written informed consent, and each participant was ensured that he/she could withdraw from the study. All participants were measured approximately at the same time in the morning to avoid the diurnal variation in the stature [14,15].

Stature was measured using an anthropometer from the vertex to the floor in the anatomical position with the head oriented in the Frankfurt Plane by a single operator according to recommendations by [5]. The body weight was recorded using an analog body weight scale with a precision of 0.1 kg.

The collection of the bilateral static footprint was part of the gait pattern and dynamic footprint collection. Each participant applied an even layer of non-coloring cream on both feet. Participants were asked to stand up on a prepared recycled paper (5 m in length and 1 m in width). The first set of the static bilateral footprint was obtained. Then participants walked naturally towards the end of the prepared paper and stopped with a left and right foot next to each other. The set of dynamic footprints reflecting the gait pattern and the second set of static footprints were obtained. Each footprint was immediately traced by a pencil for better preservation.

Only bilateral static footprints were used for this study. Static (standing) footprints of 64 females (from 18 to 33 years old, with a mean age of 21.07 years old) and 68 males (from 18 to 25 years old, with a mean age of 20.59 years old) were collected. Six measurements comprising of five length diagonal dimensions and breadth of the ball were measured by a single operator. Firstly, the backmost point of the heel was identified (*Pternion*). Five diagonal axes connecting *Pternion* with the most anterior point of each toe was drawn according to [5]. The most lateral and medial points of the ball were used to obtain the ball breadth dimension (Fig. 1).

The left footprint measurements were designed as DA_1L, DA_2L, DA_3L, DA_4L, DA_5L, and Br_L. The right footprint measurements were designed as DA_1R, DA_2R, DA_3R, DA_4R, DA_5R, and Br_R (Fig. 1).

2.1. Statistic evaluation

Data were statistically evaluated in SPSS Statistics 19.0. Shapiro-Wilk test confirmed a normal distribution of data (p-value > 0.05). Intersexual differences were tested by two-sample *t*-test and bilateral differences by paired *t*-test. Pearson correlation coefficient was employed to assess the stature-measurements and body weight-measurements correlations. An analysis of covariance (using GLM, general linear model) was done to test whether sex has an impact on the relationship between diagonal axes and body weight or stature.

Prediction equations for stature and body weight were derived by linear regression analysis and multiple regression analyses [16].

Developed prediction equations were tested. Body weight and stature were calculated using every linear prediction equation in male, female and mixed group. Statistical differences between the measured and calculated data were verified by a two-sample *t*-test. Differences between the measured and calculated stature and body weight were calculated and the Pearson correlation coefficient was used to assess the relationship between the calculated difference and the stature or body weight and BMI.

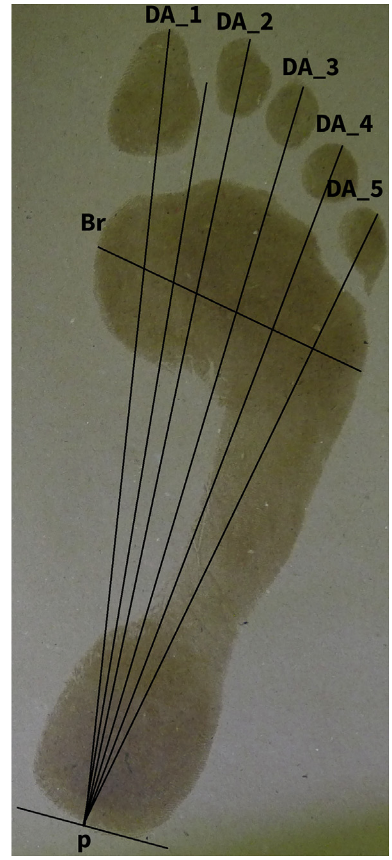

Fig. 1. Five diagonal axes of the footprint. p – the backmost point of the heel; DA_1 - DA_5 – diagonal axes, Br – ball breadth.

3. Results

Descriptive statistical analysis (mean, standard deviation, minimum, maximum) of stature, body weight, breadth of the ball and all diagonal axes of static footprints are shown in Table 1. Mean values of all measurements were found to be significantly larger in males than in females (p-value < 0.05). Statistically significant bilateral differences (p-value < 0.05) were only observed for the breadth of the ball and the diagonal axis of the first toe of females and males (Table 1). The results of the analysis of covariance confirmed the influence of sex on the relationship between stature and diagonal axes of static footprints (p-value < 0.05). Therefore, the results of the regression analysis are presented separately by sex as well as by side since it is possible to visually distinguish laterality of a footprint. The mixed group (males + females) is presented as well.

3.1. Stature

Correlation coefficients for the stature and static footprint measurements are shown in Table 2. All diagonal axes (p-value < 0.01) and ball breadth (p-value < 0.05) exhibited statistically significant correlation with the stature. In males, the highest correlation coefficient was between the stature and the fourth diagonal axis of the left footprint ($r = 0.64$). The lowest correlation coefficient was observed with the ball breadth of the right footprint ($r = 0.37$). In females, the fifth diagonal axis of the left footprint resulted in the highest correlation coefficient ($r = 0.69$), while the ball breadth of the left footprint showed the lowest correlation with the stature ($r = 0.27$). In the mixed group, the highest correlation coefficient was between the stature and the fourth diagonal axis of the left footprint ($r = 0.84$), and the lowest with the ball breadth of the left footprint ($r = 0.60$). Table 2 shows that