STATURE AND SEX ESTIMATE USING FOOT DIMENSIONS

Odhad telesnej výšky a pohlavia z rozmerov nohy

Petra Uhrová[1], Radoslav Beňuš[1], Soňa Masnicová[2], Eva Neščáková[1]

[1]Department of Anthropology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak republic

[2]Department of Criminalistics and Forensic Sciences, Academy of Police Force, Bratislava, Slovak republic

Abstract

The foot length and foot breadth are important in forensic field as they can be used as body height and weight predictors for an individual. The dimensions of foot can also be used for sex determination. The main aim of this study was to find the relation between stature and foot length and foot breadth. The second aim was to find out if the foot index is an appropriate tool for sex determination. We measured the stature and bilateral foot length and foot breadth of 71 volunteers (38 females and 33 males) ranging in age between 18 and 27 years. The foot index for both sexes was derived by dividing the foot breadth by foot length and multiplying it by hundred. The results revealed significant sex differences in foot length and foot breadth ($p < 0.001$). The highest significant and positive correlation coefficients with stature were observed for foot length in males ($r = 0.759$), in females ($r = 0.722$). Regression equations were computed separately, for each sex group, each side of foot and for each parameter. In the present study, the foot index is higher in males than in females but these differences are not statistically significant. Although foot length and foot breadth show significant sex differences, foot index can not be used in sex determination.

Key words: *forensic anthropology, stature estimation, foot length, foot breadth, foot index, Slovak population*

Introduction

Stature is one of the important parameters used in biological profiles as an indicator of identity. The anthropometry and anatomy of the foot has been examined for many years. Scientists have tried to expose its relationship with other body parts and it has been observed that the dimensions from the lower extremity have greater association with the body height than those of the upper extremity (Özaslan et al., 2003; Fessler et al., 2005). Stature has been estimated from footprints and foot outline (Barker, Scheuer, 1998; Fawzy, Kamal, 2010; Krishan, 2008; Robbins, 1986;), from footstep and stride length (Jasuja, Manjula, 1993; Jasuja et al., 1997; Straus, 1999) and from various foot measurements such as foot length, foot breadth, malleol and navicular height of foot (Agnihotri et al., 2007; Kanchan et al., 2008; Krishan, Sharma, 2007; Ozden et al., 2005; Přidalová et al., 2006; Riegerová et al., 2006; Sanli et al., 2005; Sen, Ghosh, 2008; Zeybek et al., 2008). Some studies have focused on sex estimation from various foot dimensions and foot indices (Agnihotri et al., 2007; Atamturk, Duyar, 2008; Bob-Manuel, Didia, 2009; Moudgil et al., 2008; Ozden et al., 2005; Zeybek et al., 2008), while others estimated stature or sex based on shoe dimensions (Atamturk, Duyar, 2008; Ozden et al., 2005; Straus, 1999). The present study has been conducted to find the relation between stature and foot length and foot breadth and to find out if the foot index is an appropriate tool for sex determination.

The morphology of human foot shows the variations due to the combined effects of heredity, lifestyle and climatic factors (Krishan, 2007; Robbins, 1978). Therefore, population-specific equations that can help to estimate stature from foot measurements among Slovaks are provided in this study.

Aims

- Verifying the association between stature and foot measurements – length and breadth and deriving regressionequations for stature estimation from foot dimensions.
- Determination of sex differences in foot measurements.
- Deriving foot index from foot length and foot breadth.
- Determination of sex differences in foot index.

Methodology

The research was carried out in the Department of Anthropology, Faculty of Natural Sciences, Comenius University, Slovakia.

Stature, right and left foot measurements (foot length and foot breadth) were obtained from 38 female and 33 male students aged between 18 and 27 years. These were common college students with normal gait and motion activity. Subjects with foot deformities or those who underwent a foot operation were excluded from the study. Decimal age was calculated for each subject (Weiner, Lourie, 1969) and the mean age was 22.73 for males and 23.70 for females. Measurements were recorded during period between April 2009 and January 2010 on barefoot subjects. Because of the diurnal variation in stature, all subjects were measured approximately at the same time in the morning.

Stature (S) was measured with an anthropometer and was taken from the vertex to the floor with the person standing barefoot in the anatomic position and with the head in Frankfurt Plane (Martin, Saller, 1957). Foot length (FL) was measured as the direct distance from the most posterior point of the heel *(pternion)* to the most anterior point of the longest toe – first or second *(acropodion)* (Fig. 1) (Martin, Saller, 1957). Foot breadth (FB) is defined as the distance between the surfaces of the first and fifth metatarsal bone heads (Fig. 2) (Martin, Saller, 1957). The foot index (FI) for both sexes was derived by dividing the foot breadth by foot length and multiplying it by hundred (17) – $FI = (FB/FL) \times 100$ (Klementa, 1987).

The obtained values were statistically analyzed using SPSS 17.0 for Windows. The comparisons of measurement values between sexes were compared by using one-way analysis of variance (ANOVA). The Pearson Correlation Analysis was used to determine the association between stature and foot measurements. The equations for stature estimation were calculated by Linear Regression Analysis as well as Multiple Regression Analysis for stature estimation. Foot index was derived in MS Office Excel 2003. T-test was used to compare the means of our measurements with other studies.

Figure 1. *Foot lenght*

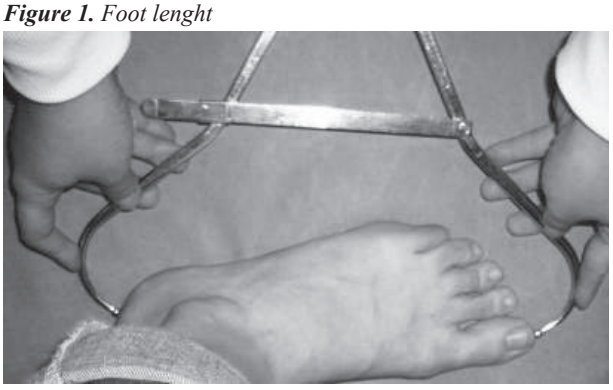

Figure 1. *Foot breadth*

Results and Discussion

Table 1 presents the descriptive statistics (mean, standard deviation, minimum, maximum) of foot length, foot breadth and foot index by sex. The foot measurement values are higher in males than in females and these sex differences are statistically significant (Table 2). Although the values of foot index are higher in males than in females these are not found to be statistically significant (Table 2).

Correlation between stature and foot measurements is determined by Pearson Correlation Analysis on the right and left side in males and females (Table 3). The foot measurements exhibit statistically significant correlation coefficients with stature. The highest correlation was observed for foot length in males (r = 0.759) and in females (r = 0.722). Table 4 illustrates the regression equations for stature estimation from foot length and foot breadth calculated by Linear Regression Analysis. Regression equations were computed separately for each sex group, each side of foot and for each foot parameter. Regression coefficients are statistically significant for all foot parameters. In addition, standard errors of estimate (SEE) are presented. A low value of SEE indicates greater reliability in the stature estimation. The foot length exhibits the lowest values on both sides in both sex groups. Thus, foot length provides optimal reliability for prediction of stature from tested measurements.

The results of the present study show that foot dimensions can be used as predictive values for stature estimation in forensic and medical investigations. However, one has to take into consideration that these results and the regression equations in particular can only be applied to the population from which the data have been obtained. When means of foot measurements were compared with other studies (Kanchan et al., 2008; Sen, Ghosh, 2008; Zeybek et al., 2008), differences were found between the underlying populations.

The foot index has been found to be higher in males than in females for both sides. Although there were found statistically significant sex differences in foot length and foot breadth, no statistically significant differences were found in foot index between males and females. Thus, foot index can not be used to determine sex. Our findings are in concordance with study of Moudgil et al. (2008) but in contrary with the study of Agnihotri et al. (2007).

In the present study statistically significant differences were found between sexes for all foot measurements. These findings are in concordance with several previous studies (Agnihotri et al., 2007; Fessler et al., 2005; Kanchan et al., 2008; Moudgil et al., 2008; Ozden et al., 2005; Sen, Ghosh, 2008; Zeybek et al., 2008).

In our study, foot length shows higher correlation coefficients with stature and also the lowest standard error estimate. Therefore, foot length can be considered as the best parameter for prediction of individual's stature.

Table 1. *Descriptive statistics of foot measurements and foot index in female and male groups*

	Females (n = 38)				Males (n = 33)			
	M	SD	MIN	MAX	M	SD	MIN	MAX
S	168.3	6.6	159.0	186.3	180.6	7.1	168.0	197.4
RFL (cm)	24.3	1.1	22.2	26.6	26.7	1.3	23.3	29.3
LFL (cm)	24.4	1.1	22.2	26.7	26.7	1.3	23.4	29.8
RFB (cm)	9.2	0.5	7.8	10.2	10.2	0.7	8.9	11.7
LFB (cm)	9.2	0.5	8.0	10.2	10.3	0.7	8.8	11.5
FI-r	38.4	2.3	34.8	43.8	37.9	1.7	34.4	41.2
FI-l	38.6	1.8	35.5	42.1	37.8	1.5	34.9	40.5

Note: S – stature; RFL – right foot length; LFL – left foot length; RFB – right foot breadth; LFB – left foot breadth; FI-r – foot index – right side; FI-l – foot index – left side.

Table 2. *Sex differences in foot measurements and foot index*

n = 71	Right side	Left side
FL	0.000***	0.000***
FB	0.000***	0.000***
FI	0.254***	0.061***

*Note: FL – foot length; FB – foot breadth; FI – foot index; ***significant at p ≤ 0.001.*

Table 2. *Correlations between stature and right-left measurements for all gender groups*

	Females (n = 38)	Males (n = 33)
RFL	0.722**	0.759**
LFL	0.704**	0.755**
RFB	0.486**	0.363*
LFB	0.550**	0.362*

*Note: RFL – right foot length; LFL – left foot length; RFB – right foot breadth; LFB – left foot breadth; *significant at p ≤ 0.05; **significant at p ≤ 0.01; ***significant at p ≤ 0.001.*

Table 4 . *Linear regression equations for estimation of stature (cm) from foot measurements on right and left side*

Females (n = 38)		Males (n = 33)	
Regression equations	SEE	Regression equations	SEE
59.825 + 4.473 RFL	4.66	68.563 + 4.200 RFL	4.69
64.454 + 4.262 LFL	4.78	67.720 + 4.227 LFL	4.73
112.359 + 6.092 RFB	5.88	143.731 + 3.601 RFB	6.71
99.228 + 7.501 LFB	5.62	141.432 + 3.806 LFB	6.72

Note: S – stature; RFL – right foot length; LFL – left foot length; RFB – right foot breadth; LFB – left foot breadth; SEE – standard error of estimate.

Conclusions

To sum up, even though sex differences were found to be statistically significant in foot measurements, the foot index can not be used as a tool for sex determination, because the differences in foot index between males and females were not significant.

Foot length and foot breadth are well correlated with stature in our sample comprised of 71 Slovak males and females aged between 18 to 27 years. Foot length shows the greatest association with stature in males and females. It can be said that a single foot dimension can help to estimate stature of an unknown person with a great accuracy and a small standard error of estimate.

In conclusion, population-specific regression equations for stature estimates based on foot length and foot breadth are presented for a Slovak sample of young adult males and females. Foot length and foot breadth show a comparatively high correlation with individual's stature. Our study also shows that it is not appropriate to use foot index to determine sex, even though sex differences were significant in foot measurements.

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Súhrn

Dĺžkové a šírkové nohy majú svoj význam aj vo forenznej oblasti, slúžia pri určení telesnej výšky a hmotnosti jedinca. Tieto rozmery môžu byť taktiež využité aj pri určení pohlavia jedinca. Hlavným cieľom tejto štúdie bolo zistiť, či existuje vzťah medzi telesnou výškou jedinca a dĺžkou a šírkou nohy. Taktiež sme zisťovali možnosť využitia indexu nohy pri určení pohlavia jedinca. Bola zmeraná telesná výška a bilaterálne rozmery dĺžky a šírky nohy u 71 jedincov (38 žien a 33 mužov) vo veku od 18 do 27 rokov. Index nohy, ktorý sa vypočíta ako podiel šírky nohy k dĺžke nohy a daná hodnota je vynásobená hodnotou sto, bol stanovený pre každé pohlavie a jednotlivca zvlášť. Výsledky odhalili signifikantné rozdiely medzi pohlaviami v dĺžke aj šírke nohy ($p < 0,001$). Najvyššie štatisticky významné a pozitívne korelačné koeficienty s telesnou výškou boli zistené u mužov ($r = 0,759$), u žien ($r = 0,722$). Regresné rovnice boli stanovené zvlášť pre jednotlivé pohlavie, lateralitu a parameter nohy. V našej štúdii je index nohy vyšší u mužov ako u žien, ale tieto rozdiely nie sú štatisticky signifikantné. Napriek tomu, že v dĺžke a šírke nohy boli zistené pohlavné rozdiely, nie je vhodné použiť index nohy pri určení pohlavia jedinca.

Kľúčové slová: *forenzná antropológia, určenie telesnej výšky, dĺžka nohy, šírka nohy, index nohy, slovenská populácia*

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