

Stature Estimation Using Foot and Shoeprint Length of Malaysian Population

M. Khairulmazidah, A. B. Nurul Nadiah, and A. R. Rumiza

Abstract—Formulation of biological profile is one of the modern roles of forensic anthropologist. The present study was conducted to estimate height using foot and shoeprint length of Malaysian population. The present work can be very useful information in the process of identification of individual in forensic cases based on shoeprint evidence. It can help to narrow down suspects and ease the police investigation. Besides, stature is important parameters in determining the partial identify of unidentified and mutilated bodies. Thus, this study can help the problem encountered in cases of mass disaster, massacre, explosions and assault cases. This is because it is very hard to identify parts of bodies in these cases where people are dismembered and become unrecognizable. Samples in this research were collected from 200 Malaysian adults (100 males and 100 females) with age ranging from 20 to 45 years old. In this research, shoeprint length were measured based on the print of the shoes made from the flat shoes. Other information like gender, foot length and height of subject were also recorded. The data was analyzed using IBM® SPSS Statistics 19 software. Results indicated that, foot length has a strong correlation with stature than shoeprint length for both sides of the feet. However, in the unknown, where the gender was undetermined have shown a better correlation in foot length and shoeprint length parameter compared to males and females analyzed separately. In addition, prediction equations are developed to estimate the stature using linear regression analysis of foot length and shoeprint length. However, foot lengths give better prediction than shoeprint length.

Keywords—Forensic anthropology, foot length, shoeprints, stature estimation.

I. INTRODUCTION

FORENSIC anthropology is the application of the study of humans to situations of modern legal or public concern. This typically takes the form of collecting and analyzing human skeletal remains to help identify victims and reconstruct the events surrounding their deaths [1]. However, the scope of forensic anthropologists nowadays has evolved as they do not only examine dead remains but also the living. Anthropometric standards are commonly accepted as vary among different populations and have to be constantly renewed to cope with temporal change [2]. Many parts of

human body have been studied by forensic anthropologists in the progression to formulate biological profile. Parts of body [3]-[9], bones [2], [4]-[14] and radiographic materials [15] were used to estimate stature and determine sex of the remains from various dimensions.

It has been estimated that more than 30% of all burglaries provide usable shoeprints that can be recovered from the crime scene [16]. Foot and shoe prints' relationship to the stature also have been previously studied in the previous literature [17]-[23] as it provides invaluable tool in forensic investigation. It can be used as an aid in criminal investigation in order to develop biological profile to find suspects or to associate with witness' statement.

The purpose of the current study is to evaluate the anthropometric relationship between shoeprint and foot length with stature in regards to Malaysian population. In order to estimate stature, regression formulae are being devised for this purpose using foot and shoeprint length as the known parameter.

II. MATERIALS AND METHODS

A. Samples Selection and Collection

200 Malaysian adult consisting of 100 males and 100 females were randomly selected throughout Malaysia for this study with age ranging from 20 to 45 years old. Subjects were randomly selected based on the shoe they were wearing during the sample collection. Only subjects with flat shoes were chosen during the sample collection. This is to standardize the type of shoe worn in order to minimize error during the height estimation.

Both foot length and shoeprint were recorded during the sample collection. Foot lengths were recorded directly after measurements were made using an osteometric board. Shoeprint were recorded using an oil-based ink. Apart from that, statures were also recorded using a portable stadiometer. Subjects were asked for their consent before their feet were measured and their shoeprints were recorded.

B. Sample Measurements

Maximum foot lengths were measured for foot length measurement. It was measured from behind the heel to the longest part of the foot; usually either the first toe or the second toe. Parallel measurement was made for the foot length measurement and osteometric board was used for the foot length measurement. Shoeprints that was printed using oil-based ink were measured using parallel measurement for its length. And finally for stature measurement, stadiometer was

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used to measure the height and the subjects were ensured to place their head in Frankfurt horizontal plane during which the measurements were made. Both left and right side were measured for foot and shoeprint length.

C. Data Analysis

The data collected from the measurements were analyzed for its general descriptive statistics, correlation between two parameters and resultant formulae for each pair of parameters of interest were derived for future use. For correlation analysis, scatterplot graph was plotted to see the distribution of the samples. This pattern of distribution can be used to determine whether there exists a correlation between the two parameters of interest and whether the relationship is positive or negative. Simple linear regression method was used for the stature estimation equations. Standard error of estimate (SEE) was also calculated to measure the accuracy of the predictions equations. All the data analysis in this study was done using statistical software IBM® SPSS Statistics 19.

III. RESULTS AND DISCUSSION

A. Descriptive Statistics

The descriptive statistical analysis of foot length, shoeprint length and stature of all measurements in male and female groups were shown in Tables I and II. These tables show the range of heights, foot and shoeprint length and also their means and standard deviations. The standard deviations of male subjects are higher than female subjects indicating more variation in male subjects compared to females.

TABLE I
DESCRIPTIVE STATISTICS FOR MALE SUBJECTS

Variables	Male (n=100)			
	Minimum	Maximum	Mean	*SD
Stature	152.0	185.0	166.567	6.850
*RFL	21.5	29.5	24.663	1.439
*LFL	22.2	30.0	24.814	1.518
*RSL	24.0	31.2	27.769	1.319
*LSL	23.9	31.0	27.822	1.325

*SD, Standard deviation, *RFL, right foot length, *LFL, left foot length, *RSL, right shoeprint length, *LSL, left shoeprint length.

TABLE II
DESCRIPTIVE STATISTICS FOR FEMALE SUBJECTS

Variable	Female (n=100)			
	Minimum	Maximum	Mean	*SD
Stature	140.2	168.9	156.086	5.835
*RFL	19.4	25.3	22.325	1.208
*LFL	19.4	25.6	22.330	1.203
*RSL	21.3	27.9	24.569	1.357
*LSL	21.3	27.8	24.605	1.375

*SD, Standard deviation, *RFL, right foot length, *LFL, left foot length, *RSL, right shoeprint length, *LSL, left shoeprint length. Correlation between variables

B. Correlation between Variables

The subjects in this study are classified into three groups, two groups with gender discrimination, namely male and female groups and one group without the gender discrimination, or unknown group. This is done to compare

which type of group gives better prediction in the simple linear regression formulation. The correlation graph or scatterplot of the stature with RFL, LFL, RSL and LSL for male group were plotted and are shown in Fig. 1. For female group, the scatterplot graphs are shown in Fig. 2 and for the unknown group, the graphs are shown in Fig. 3. This is done to make sure that there exists a relationship between the two variables of interest.

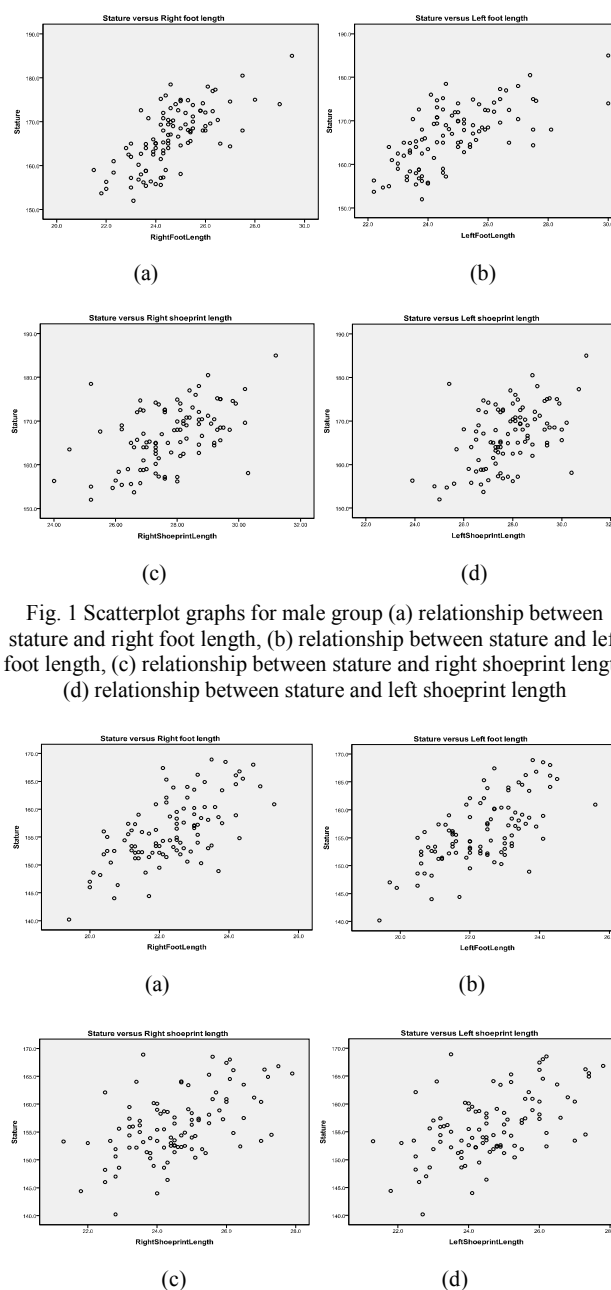


Fig. 1 Scatterplot graphs for male group (a) relationship between stature and right foot length, (b) relationship between stature and left foot length, (c) relationship between stature and right shoeprint length (d) relationship between stature and left shoeprint length

Fig. 2 Scatterplot graphs for female group (a) relationship between stature and right foot length, (b) relationship between stature and left foot length, (c) relationship between stature and right shoeprint length (d) relationship between stature and left shoeprint length

$$Y = a + bX \pm SEE$$

where, stature is denoted as 'Y', 'a' is a constant and 'b' is the regression coefficient of each independent variable while 'X' is the individual variable. Table IV summarizes the stature prediction equations using different variables studied in this research.

TABLE IV

LINEAR REGRESSION EQUATIONS FOR STATURE ESTIMATION IN MALE, FEMALE AND UNKNOWN GROUPS

Gender	Variable	Equation	*SEE (cm)
Males (n=100)	*RFL	$Y = 84.663 + 3.321(X)$	4.936
	*LFL	$Y = 92.819 + 2.972(X)$	5.182
	*RSL	$Y = 93.182 + 2.643(X)$	5.972
	*LSL	$Y = 94.972 + 2.573(X)$	5.928
Females (n=100)	*RFL	$Y = 86.554 + 3.115(X)$	4.483
	*LFL	$Y = 84.325 + 3.214(X)$	4.394
	*RSL	$Y = 100.609 + 2.258(X)$	4.991
	*LSL	$Y = 101.294 + 2.227(X)$	4.991
Unknown (n=200)	*RFL	$Y = 72.446 + 3.783(X)$	4.819
	*LFL	$Y = 76.726 + 3.589(X)$	4.899
	*RSL	$Y = 84.495 + 2.936(X)$	5.525
	*LSL	$Y = 85.186 + 2.904(X)$	5.562

*SEE, standard error of estimate, *RFL, right foot length, *LFL, left foot length, *RSL, right shoeprint length, *LSL, left shoeprint length

As shown in Table IV, the SEE for estimation of stature using foot length is lower compared to prediction of stature using shoeprint length. This shows that estimation of stature using foot length is more accurate than shoeprint length. Prediction of height using the unknown group prediction equation is also recommended compared to male or female groups separately as it gives better accuracy for height estimation.

The correlation coefficient results in this study when compared to another study in Turkey [18] showed that the present study generally shows a better correlation of foot and shoeprint length of male and female groups. In another study in India where foot length was used for stature estimation [21], their result gives a better accuracy for stature estimation compared to this study. However, since different population may have their own differences, this present result may be used to estimate stature using both foot and shoeprint length in Malaysian population in the future.

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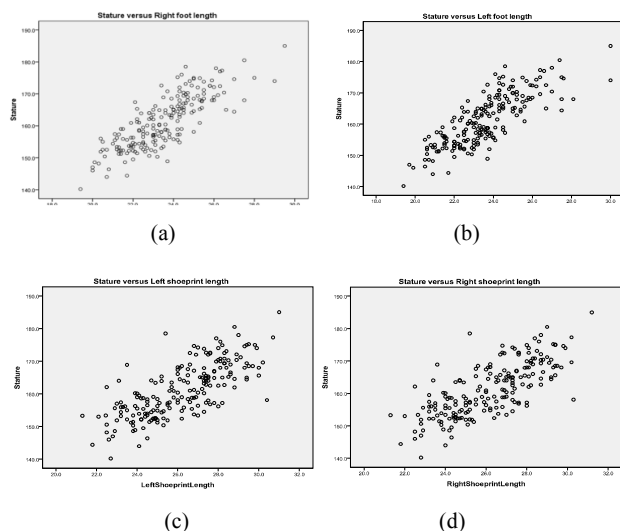


Fig. 3 Scatterplot graphs for unknown group (a) relationship between stature and right foot length, (b) relationship between stature and left foot length, (c) relationship between stature and right shoeprint length (d) relationship between stature and left shoeprint length

As presented in Figs. 1-3, there exists a correlation between stature and foot and shoeprint length. And they are positive correlation between the two variables. From the scatterplot graphs pattern, it can be indicated that the unknown group gives a better correlation between stature and other variables analyzed in this study. The correlation coefficient or r value between stature and other variables are tabulated in Table III.

TABLE III

CORRELATION COEFFICIENT (R) BETWEEN STATURE AND OTHER VARIABLES

Variables	Male	Female	Unknown
*RFL	0.697**	0.645**	0.812**
*LFL	0.659**	0.662**	0.805**
*RSL	0.509**	0.525**	0.743**
*LSL	0.498**	0.525**	0.739**

** Correlation is significant at the 0.01 level

*RFL, right foot length, *LFL, left foot length, *RSL, right shoeprint length, *LSL, left shoeprint length

As shown in Table III, all variables have significant correlation with stature. However, it is evident that foot length shows a better correlation to stature compared to shoeprint length. The unknown group shows better correlation of stature with other variables compared to male and female groups separately. This result, where the unknown group gives better correlation is same with another study done using footprint length in Malaysia [24].

C. Linear Regression Equations

As all the correlations of stature with other variables in this study are statistically significant, formulae for stature estimation using right foot length, left foot length, right shoeprint length and left shoeprint length are derived. The linear regression equation, which is obtained from this study, uses the following format:

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