



Research Paper

Estimation of stature from hand and foot dimensions in a Korean population

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ABSTRACT

The estimation of stature using foot and hand dimensions is essential in the process of personal identification. The shapes of feet and hands vary depending on races and gender, and it is of great importance to design an adequate equation in consideration of variances to estimate stature. This study is based on a total of 5,195 South Korean males and females, aged from 20 to 59 years. Body dimensions of stature, hand length, hand breadth, foot length, and foot breadth were measured according to standard anthropometric procedures. The independent t-test was performed in order to verify significant gender-induced differences and the results showed that there was significant difference between males and females for all the foot-hand dimensions ($p < 0.01$). All dimensions showed a positive and statistically significant relation with stature in both genders ($p < 0.01$). For both genders, the foot length showed highest correlation, whereas the hand breadth showed least correlation. The stepwise regression analysis was conducted, and the results showed that males had the highest prediction accuracy in the regression equation consisting of foot length and hand length ($R^2 = 0.532$), whereas females had the highest accuracy in the regression model consisting of foot length and hand breadth ($R^2 = 0.437$). The findings of this study indicated that hand and foot dimensions can be used to predict the stature of South Korean in the forensic science field.

1. Introduction

In forensic science, identifying one's gender, age, and stature is a key task to establish biological traits of a person.^{1,2} To precisely determine personal identification, studies relating to anthropometry have been actively conducted. In cases when bodies are dismembered or disfigured by crimes and/or disasters, identification of a body is more complex and difficult. Therefore, it is critical to develop a method that can estimate individuals' physical traits accurately. Human stature can be determined by combined length of the skull, vertebrae, pelvis, and lower limbs, and combinations of each part of the body.^{3,4} In this regards, many studies have been conducted on people of different races to identify correlation between stature and body parts including hands and feet. In these kinds of studies, regression analyses are usually used.⁵

Various studies have been conducted to improve the accuracy of regression equation models to estimate stature using measured values of feet and footprints.^{6–9} Zeybek et al. have used foot measurement dimensions of length, malleol height, breadth, and navicular height to estimate stature and gender of Turkish individuals.⁹ For the same population, Ozden, et al. have used foot breadth and length data to estimate stature.⁷ Hisham et al. estimated the stature of Malaysians through regression analyses using foot length and breadth as predictors.⁶ Uhrová et al. have used foot length and circumference to

estimate stature.¹⁰ Jakhar et al. have predicted the stature of an Indian population using foot length data.¹¹ In addition, foot length and breadth have been used to estimate stature of population of north Bengal, India in a study by Sen & Ghosh.⁸ Kanchan et al. have also used foot length and breadth data to predict the stature of them.¹² Therefore, foot length and breadth are major dimensions used to predict stature.

In the field of stature estimation using hand measurements, many studies have developed regression models for diverse races.^{13–16} Agnihotri et al. have predicted hand length and breadth to predict the stature of Mauritians.¹⁴ Rastogi et al. have used hand length and breadth data to predict stature of the population of northern and southern parts of India.¹⁶ For Egyptians, Abdel-Malek et al. have collected and used hand dimensions of length and breadth to predict stature.¹³ Ishak et al. have used hand dimensions and handprint data to predict stature of Australians.¹⁷ Hand dimensions used in their study were hand and palm length, hand breadth and four fingers' length including thumb, index, middle and ring finger. In Korea, Jee & Yun have estimated the stature of Koreans based on hand dimensions.¹⁸ They collected a total of 29 hand dimensions including measurements related to length, breadth, circumference, and thickness. Although they predicted stature using various dimensions measured from the hand, they did not proceed with the prediction in conjunction with foot data.

In previous studies, body parts have distinctive characteristics by

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ances due to genetic and environmental factors.^{16,19} However, a regression model deduced based on a certain race cannot be applied to different races or groups.²⁰ Thus, the objective of the present study was to determine correlations between hand-foot related dimensions and stature and deduce an equation to estimate the stature of Koreans. Findings of the study may be effectively used for personal identification of Korean people in forensic science.

2. Methods

2.1. Subjects

This study was conducted at SizeKorea, the national institute of technology standards in South Korea. A total of 5195 test subjects (2750 males and 2445 females) were measured. The average age of males was 41.6 years, while that of females was 38.6 years. Test subjects reside in widely different regions. Due to daily stature changes, almost all test subjects were simultaneously measured in the morning. Right hand and foot dimensions were measured using standard anthropometric procedures. Measurement values and statures were conducted in centimeter units following standard anthropometric procedures.

2.2. Measurement

Measurement dimensions used in this study and subsequent definitions are summarized in Table 1. Stature was measured as a vertical length from floor to vertex while subjects looked forward with heads fixed using an anthropometer (Fig. 1). Hand length was measured from distal wrist crease to distal tip of the longest finger (Fig. 2). Hand breadth was measured as a distance between Metacarpal V and Radial Styloid (Fig. 2). Foot length was measured from the rearmost point of the heel to the end of the longest toe. Foot breadth was measured as a distance between the straight line from Metatarsophalangeal V to Metatarsophalangeal I (Fig. 3). Measurement of each variable was conducted by one researcher. Measurement accuracy is the most critical factor in studies related to anthropometry. To eliminate intra-error due to measurement prior to the start of the measurement, each researcher conducted measurements twice at different times. Measurement errors for 20 subjects were then calculated. Measurement margin of error was calculated using relative technical error of measurement (rTEM) and coefficient of reliability (R).²¹ As a preliminary measurement, rTEM was less than 5% and R was higher than 0.91 in measurement variables. According to Uljiaszek,²¹ intra-observer error was regarded as an acceptable range for measurement variables.

2.3. Statistical analysis

SPSS 23.0 was used for all statistical analyses. T-test was conducted to verify differences by gender and each measurement dimension. Correlation analysis was conducted to identify correlation between stature and hand-foot measurement dimensions. Correlation was deduced using Pearson's coefficient. Previous studies on estimation of stature for a specified population have applied simple and multiple linear regression methodology to establish an estimation model with

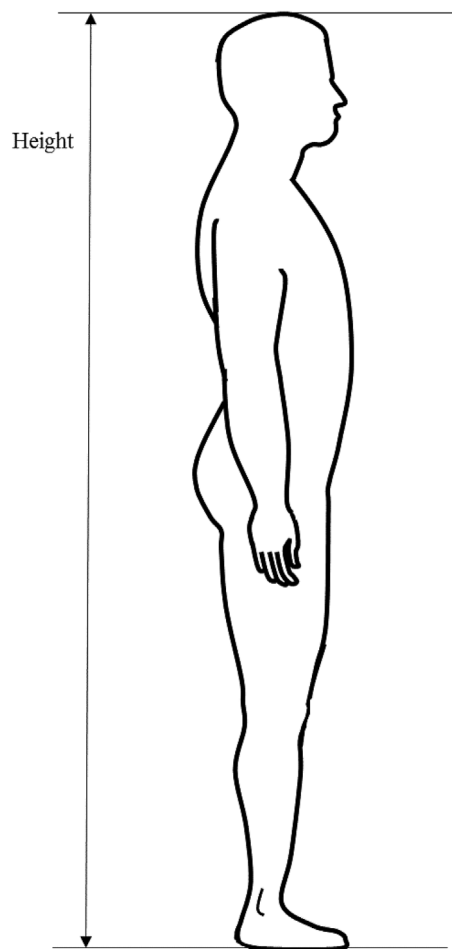


Fig. 1. Stature (S) for measurement.

foot,^{6,9} hand,^{14,17} or both^{20,22} as independent variables. In addition, Krishan et al. have compared range of error between multiplication factor and regression analysis when estimating stature²³ and demonstrated that regression analysis has better performance with lower range of error than multiplication factor. Therefore, simple and multiple linear regression analysis were used in this study to compute the equation of stature estimation using hand-foot measurement dimensions.

Based on existing studies to predict stature, hand dimensions including hand length and breadth and foot dimension with foot length and breadth were used in multiple linear regression in this study. For a combination of hand and foot parameters, stepwise multiple linear regression was used to extract significant variables when estimating the stature of Koreans. Linear regression analysis and stepwise multiple regression analysis were used to compute the equation for stature estimation using hand-foot measurement dimensions.

Table 1
Definition of hand and foot measurement in this research.

| Body parts | Dimension | Abbreviation | Definition |
|------------|--------------|--------------|---|
| Hand | Hand length | HL | The distance from the mid-point of distal crease of wrist joint to the tip of middle finger |
| | Hand breadth | HB | The distance from the radial side of the 2nd metacarpophalangeal joint to the ulnar side of the 5th metacarpophalangeal joint |
| Foot | Foot length | FL | The distance from the acropodian which is the most distal part of the longest toe of the foot to the pternion which is the most prominent part of the heel |
| | Foot breath | FB | The distance from the metatarsal tibiale which is the most prominent of the inner side of the foot to the metatarsal fibulare which is the most prominent of the outer side of the foot |

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