Research Article

Prediction of stature from radiographic study of foot and hand in modern Saudi at Baha Province

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Abstract

Background: Stature is necessary for medical and nutritional assessment in the living individual. Also, in Physical Anthropology and Forensic Medicine, determination of stature is an important parameter for personal identification along with others such as age and race.

Objective: The objective of this study was to investigate the relationship between stature and foot and hand variables in both sexes through anthropometric and radiographic means. At the same time, prediction equations for estimating stature from foot and hand parameters were developed.

Materials and Methods: Measurements of body weight, stature, foot length and breadth as well as hand length and breadth were taken from 400 randomly selected students in Al Baha University aged 19–22 years (290 male and 110 female). Plain X-ray for foot and hand was done for a subsample to measure the length and breadth of the metatarsals and metacarpals, respectively. Derived variables (body mass index, foot index, and stature/foot and hand ratios) were calculated from the measured variables.

Results: Significant correlations were found between stature and many foot parameters. Low correlations were found between stature and hand parameters. Predictive regression equations were computed to estimate stature from foot and hand parameters.

Conclusion: Predictive equations were computed to estimate stature from foot and hand variables. This would be useful in cases where stature cannot be measured in the living subjects or in cases of stature prediction in Physical Anthropology and Forensic Medicine.

KEY WORDS: Stature estimation, foot length and breadth, hand length and breadth, Anthropometry

Introduction

Stature depends on the length of various segments of the body including skull, spine, pelvis, and lower limbs.[1] Stature is considered to be one of the most important indicators of body size.[2]

Stature is necessary for medical and nutritional assessment.[3] Sometimes, stature is difficult or cannot be measured in the living, as a result regression equations have been developed to estimate it from other anthropometric variables that are easy to obtain and are closely related to stature.[4–7]

In Anthropology and Forensic Medicine, sometimes body parts, for example, a foot or a hand, are brought for postmortem examination.[8] The relationship between different body parts, especially the limbs, is being used to establish stature, which is a prerequisite to identification in forensic investigation.[9] Specifically, hand and foot have been used by some investigators to estimate stature.[10] Using radiographs of the hand and wrist to estimate stature by measuring the length of metacarpals and metatarsals was investigated by Karaman et al.[11]

The aim of the present study was to investigate the relationship between stature and foot and hand variables in both sexes through anthropometric and radiographic means. At the same time, prediction equations for estimating stature from foot and hand parameters were also developed.

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Materials and Methods

A random sample was drawn from a population of approximately 400 students aged 19–22 years (110 female, and 290 male) from Al-Baha University. The participation was voluntary and an informed consent was obtained. The students appeared healthy and without observed structural abnormalities particularly in the foot and hand. All the students were subjected to anthropometric measurements and subsample (50 students, 25 in both sex) and were subjected further to radiographic measurements.

Anthropometry

Anthropometric measurements of stature, body weight, foot length, and foot breadth were taken from each student by standard anthropometric methods.[12,13,] The measurements were done by one observer at the same time to avoid interpersonal error.[14] Also, the measurements were taken at fixed time between 8 and 10 a.m. to eliminate the discrepancies due to diurnal variation in stature. For each variable, two measurements were taken and the mean value was recorded.

Foot

Anthropometric foot measurements: Foot length was measured as the direct distance from the most prominent point of the back of the heel to the tip of the big toe or to the tip of second toe, when the second toe was larger than the big toe, by a sliding caliper (in centimeters).[15]

Foot breadth was measured as the distance between the most medially prominent point on the head of the first metatarsal bone and the most laterally prominent point on the head of the fifth metatarsal bone when the foot was fully during standing by the sliding caliper.[13,15]

Derived foot measurements: Foot/stature ratio is calculated by dividing the foot length by stature.[16] Foot index is calculated using the following formula: (Foot length/Foot breadth) × 100.[16,17]

Hand

Anthropometric hand measurements: Hand length was calculated by measuring the distance between the midpoint of the proximal skin crease of the wrist and foremost point of the middle finger.[11,18]

Hand breadth was calculated by measuring the distance between the metacarpophalangeal joints of second and fifth fingers.[11,18]

Derived hand measurements: Hand/stature ratio is calculated using the following formula: Hand length/Stature.[16]

Radiography

Radiographs study of left foot and left hand were obtained from a subsample of the study population (50 students).

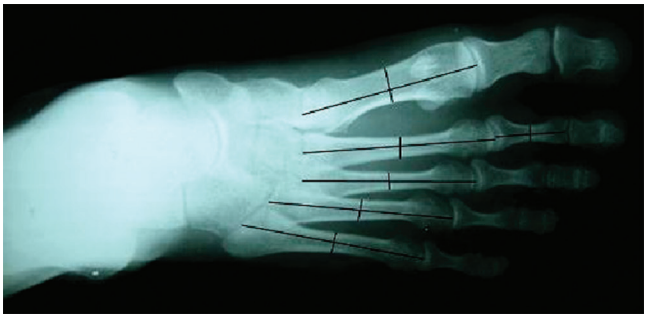

Figure 1: Plain X-ray of the foot showing the length (*L*) and breadth (*B*) of the metatarsals and proximal phalanx of the second toe.

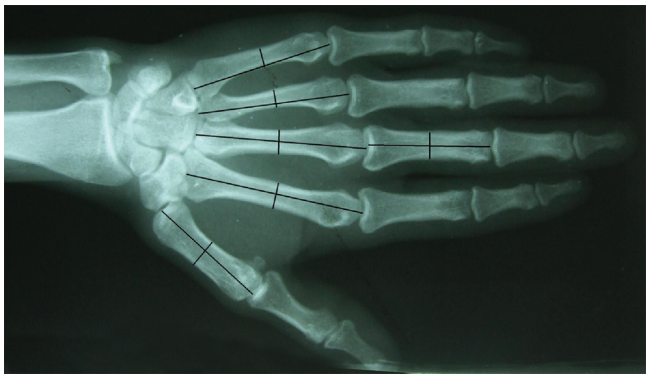

Figure 2: Plain X-ray of the hand showing the length (*L*) and breadth (*B*) of the metacarpals and proximal phalanx of the middle finger.

X-rays of left wrists were taken from a distance of 155 cm in P-A (postero-anterior) projection. All cases were imaged by a unified device (parameters of device suitable for X-ray foot and hand are 1,9 MAS and 48 kW) with the same technician.

Radiographic measurements

The foot and wrist X-rays taken were imaged with a digital camera according to scale and were recorded to be exported to a suitable computer program. Measurements were taken from the X-rays exported to a computer using Konica 2006 Merge eMED program. This program allows the user to take the anthropometric measurements of normal hand and metacarpal bones of the individuals with millimetric precision on the radiograms.[11]

Foot: The length of the each metatarsal was measured as the distance between the most prominent point of the metatarsal and midpoint of the line in the tarsometatarsal space [Figure 1]. The breadth of each metatarsal was measured at the level of the midpoint of the metatarsal length.[11] The length of the proximal phalanx of the second toe was measured as the distance between the most prominent point of the proximal phalanx and midpoint of the line in the metatarsophalangeal space.[11] The breadth of the proximal phalanx of the second toe was measured at the level of the midpoint of its length.[11]

Table 1: Means and standard deviations of foot measurements

Foot variables	Mean	SD
Foot length (cm)	25.7	1.38
Foot breadth (cm)	9.96	0.86
MT1 L (cm)	6.7	0.4
MT2 L (cm)	7	0.5
MT3 L (cm)	6.8	0.4
MT4 L (cm)	7	0.4
MT5 L (cm)	7	0.4
TPH L (cm)	2.8	0.3
MT1 B (cm)	1.5	0.11
MT2 B (cm)	0.9	0.1
MT3 B (cm)	0.8	0.1
MT4 B (cm)	0.8	0.1
MT5 B (cm)	0.8	0.1
TPHB (cm)	0.6	0.1
Derived variable		
BMI	23.2	4.8
Foot index	38	1.9
SFR	0.165	0.06

MT L, length of metatarsals; MT B, breadth of metatarsals; TPH L, length of proximal phalanx of second toe; TPHB, breadth of proximal phalanx of second toe; BMI, body mass index; SFR, stature/foot ratio

Hand: The length of each metacarpal was measured as the distance between the most prominent point of the metacarpal and midpoint of the line in the carpometacarpal space [Figure 2].[11] The breadth of each metacarpal was measured at the level of the midpoint of the metacarpal length.[11] The length of the proximal phalanx of the middle finger was measured as the distance between the most prominent point of the proximal phalanx and midpoint of the line in the metacarpophalangeal space. The breadth of the proximal phalanx of the middle finger was measured at the level of the midpoint of its length.

Statistical Analysis

Data were expressed as means±standard deviation (SD). Relationship between stature and foot measurements was obtained using Pearson correlation coefficient. Regression analysis was used to generate predictive equations of stature from foot and hand variables.

Results

Anthropometric Measurements

Weight, stature, and BMI in both male and female groups

In our study, 110 of 400 (27.5%) cases were women and 54 (72.5%) were men, and there were no statistically significant differences between the groups as regards to gender ($p < 0.05$). Although the average age of women was 20.1±1.123 years and that of men was 20.821±1.2, the average of the entire group was 20±0.435 years. The youngest being 19 years of age and the oldest being 22.

The mean body weight (kg) for male was 72±15.3 and of stature, it was 172.5±6.6. while both of these parameters in female group were 78±16.8, and of stature and of length 166.5±6.6. The average body mass index (BMI), measured as Weight in kg/(Height in meters)^2, of the male group was found to be 23.2±4.8, minimum being 16.50 and maximum 32.30 whereas in female group, it was 25.43±2.6 with minimum of 15.6 and maximum of 38.2.

Foot

Male group's measurements: The mean foot length for male group (cm) was 25.7±1.38 and 24.8±1.33. The mean length and standard variation of metatarsal bones were as follow: 1st = 6.7±0.4; 2nd = 7±0.5; 3rd = 6.8±0.4; 4th and 5th = 7±0.4; and the length of proximal phalanx of second toe was 2.8±0.3. The mean and standard deviations of breadth of metatarsals were as follow: 1st = 1.5±0.11; 2nd = 0.9±0.1; and 3rd, 4th, and 5th = 0.8±0.1. The mean and slandered deviation of breadth of proximal phalanx of the second toe was 0.6±0.1. The mean and slandered deviation for foot index was 38±1.9 and for stature to foot ratio was 0.165±0.06. All these figures are summarized in Table 1.

Female group's measurements: The mean foot length and breadth for female group (cm) was 24.8±1.33 and 8.93±0.82. The mean length and standard variation of metatarsal bones were as follow: 1st = 6.2±0.3, 2nd = 6.3±0.4, 3rd = 6.2±0.3, 4th = 6.4±0.4, and 5th = 6.3±0.4; length of proximal phalanx of second toe 2.5±0.3 cm. The mean and standard deviations of breadth of metatarsals were as follow: 1st = 1.3±0.11; 2nd = 0.8±0.1, 3rd, 4th = 0.7±0.7; and 5th = 0.7±0.1. The mean and slandered deviation of breadth of proximal phalanx of second toe was 0.5±0.1. The mean and slandered deviation for foot index was 36±1.6 and for stature to foot ratio was 0.155±0.06. All these figures are summarized in Table 2 and Graphs 3 and 4.

Hand

Male group's measurements: The mean hand length for male and female groups (cm) was 18.78±0.87 and 17.7±0.80, respectively. The mean length and standard variation of hand breadth was 8.1±0.77. The mean length and standard variation of metacarpal bones were as follow: 1st = 4.8±0.4, 2nd = 7±0.4, 3rd = 6.8±0.4, 4th = 6.2±0.5, and 5th = 5.7±0.38; length of proximal phalanx of third finger was 4.5±0.3 cm. The mean and standard deviations of breadth of metacarpals were as follow: 1st = 1.2±0.1, 2nd = 1±0.1, 3rd = 0.9±0.1, 4th = 0.7±1, and 5th = 0.8±0.1. The mean and slandered deviation of breadth of proximal phalanx of the third finger was 0.9±0.1. The mean and slandered deviation for stature to foot ratio was 0.115±0.06. All these figures are summarized in Table 3 and Graphs 5 and 6 (Figures 3–6).

Female group's measurements. The mean hand length for female group (cm) was 17.7±0.80. The mean length and

Table 2: Means and standard deviations of foot measurements

Foot variables	Mean	SD
Foot length (cm)	24.8	1.33
Foot breadth (cm)	8.93	0.82
MT1 L (cm)	6.2	0.3
MT2 L (cm)	6.3	0.4
MT3 L (cm)	6.2	0.3
MT4 L (cm)	6.4	0.4
MT5 L (cm)	6.3	0.4
TPH L (cm)	2.5	0.3
MT1 B (cm)	1.3	0.11
MT2 B (cm)	0.8	0.1
MT3 B (cm)	0.7	0.7
MT4 B (cm)	0.7	0.7
MT5 B (cm)	0.7	0.1
TPHB (cm)	0.5	0.1
Derived variable		
BMI	25.43	2.6
Foot index	36	1.6
SFR	0.155	0.06

MT L, length of metatarsals; MT B, breadth of metatarsals; TPH L, length of proximal phalanx of second toe; TPHB, breadth of proximal phalanx of second toe; BMI, body mass index; SFR, stature/foot ratio

Table 3: Descriptive statistics of the hand parameters for male group

Hand variables	Mean	SD
Hand length (cm)	18.78	0.87
Hand breadth (cm)	8.10	0.77
MC1L (cm)	4.8	0.4
MC2L (cm)	7	0.4
MC3L (cm)	6.8	0.4
MC4L (cm)	6.2	0.5
MC5L (cm)	5.7	0.38
CPHL (cm)	4.5	0.3
MC1B (cm)	1.2	0.1
MC2B (cm)	1	0.1
MC3B (cm)	0.9	0.1
MC4B (cm)	0.7	0.1
MC5B (cm)	0.8	0.1
CPHB (cm)	0.9	0.1
Derived variable		
SHR	0.115	0.06

MC L, length of metacarpals; MC B, breadth of metacarpals; CPHL, length of proximal phalanx of third finger; CPHB, breadth of proximal phalanx of third finger; SHR, stature/hand ratio

standard variation of hand breadth was 8.0±0.72. The mean length and standard variation of metacarpal bones were as follow: 1st = 4.2±0.4, 2nd = 6.8±0.4, 3rd = 6.6±0.3, 4th = 6.1±0.4, and 5th = 5.2 ± 0.36; length of proximal phalanx of the third finger was 4.3±0.3. The mean and standard deviations of breadth of metacarpals were as follow: 1st = 1.1±0.1, 2nd = 0.9±0.1, 3rd = 0.8±0.1, 4th = 0.6±1, and 5th = 0.7±0.1. The mean and slandered deviation of breadth of proximal phalanx of the third finger was 0.8±0.1. The mean and slandered deviation for stature/foot ratio was 0.110±0.06. All these figures are summarized in Table 4 and Graphs 5 and 6.

Correlation

Regression equation that predicts stature from various variables is: $Y = a + bX$, where Y = dependent variable (=stature), a = intercept (constant), b = slope (β coefficient), and X = independent variable (e.g., foot length).

In the male group, correlation of stature, weight, and BMI revealed a significant correlation between stature and body weight (r = 0.305) and BMI (0.927). In female group, the correlation was highly significant between stature and body weight (r = 0.298) and BMI (r = 916).

Foot measurements

A significant correlation was found between the stature and foot length in both male and female groups (r = 0.408 and r = 0.40). In the male group, there were significant correlations between stature and length of first metatarsal (r = 0.323), length of second metatarsal (r = 0.304), length of fifth metatarsal (r = 0.306), and length of fifth metatarsal (r = 0.633). For the breadth of metatarsals, a significant correlation was found between stature and breadth of third metatarsal (r = 0.279) and breadth of fourth metatarsal (r = 0.293).

For the female group, there were significant correlations between stature and length of first metatarsal (r = 0.316), length of second metatarsal (r = 0.296), length of fifth metatarsal (r = 0.299), and length of fifth metatarsal (r = 0.623). For the breadth of metatarsals, a significant correlation was found between stature and breadth of the third metatarsal (r = 0.268) and breadth of the fourth metatarsal (r = 0.283).

Hand measurements: There was no correlation between stature and all hand parameters in both male and female groups.

Discussion

In this study, the age of the subjects ranged from 19 to 22 years. This age range ensures completion of skeletal maturity.

Foot Measurements

In this study, significant correlations were found between stature and foot length for foot measurements. There was no correlation between stature and foot breadth. Also, regression equations that predict and estimate stature from the length and breadth of the foot were developed in the studied group. In agreement with the present work, Charnalia[19] showed a significant correlation between stature and foot length. Similarly, Qamra et al.[20] derived a regression equation between foot length and stature. In schoolchildren aged 12 years, Griva and Mihas[21] reported that there was a correlation between foot length and stature.

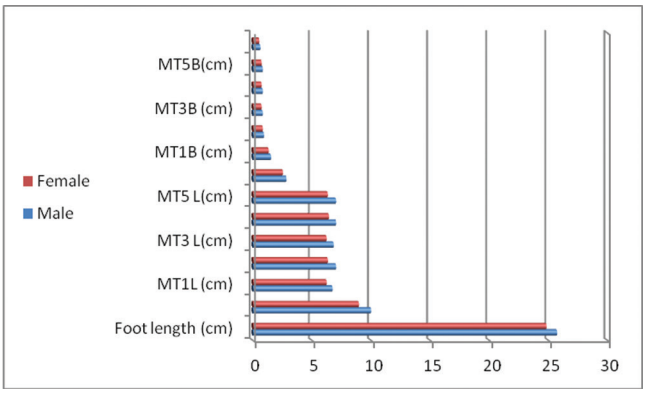

Figure 3: Means and standard deviations of foot measurements in both male and female groups.

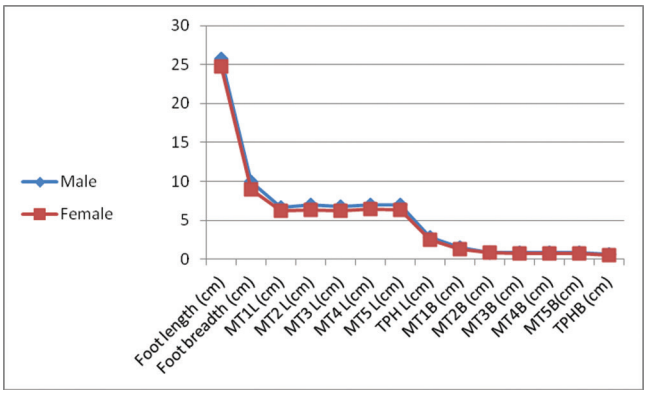

Figure 4: Linear graph showing foot parameters in both male and female groups.

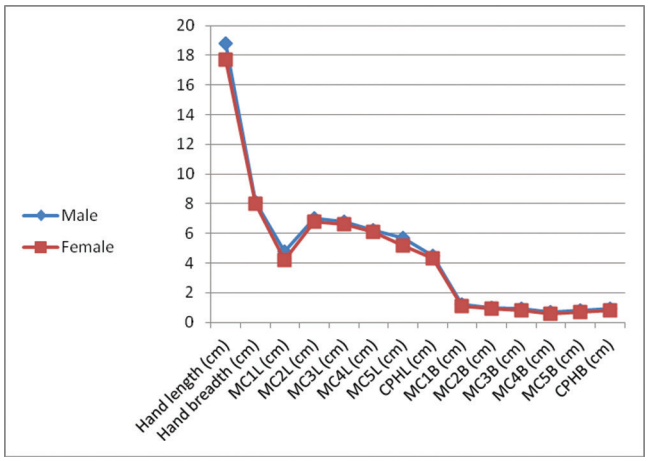

Figure 5: Hand parameters in both male and female groups.

Development of regression equations that predict stature from the lengths of the metatarsals also coincides with a study conducted by Hasan and Mahmoud[12] who studied the correlations between stature and foot length and

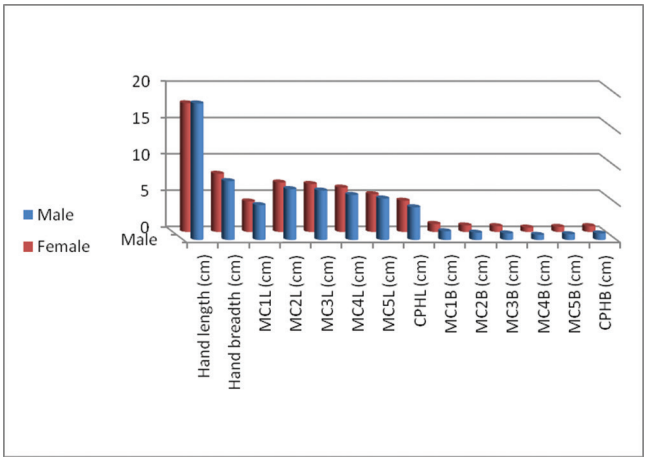

Figure 6: Hand measurements in both male and female groups.

Table 4: Descriptive statistics of the hand parameters for female group

Hand variables	Mean	SD
Hand length (cm)	17.70	0.80
Hand breadth (cm)	8	0.72
MC1L (cm)	4.2	0.4
MC2L (cm)	6.8	0.4
MC3L (cm)	6.6	0.3
MC4L (cm)	6.1	0.4
MC5L (cm)	5.2	0.36
CPHL (cm)	4.3	0.3
MC1B (cm)	1.1	0.1
MC2B (cm)	0.9	0.1
MC3B (cm)	0.8	0.1
MC4B (cm)	0.6	0.1
MC5B (cm)	0.7	0.1
CPHB (cm)	0.8	0.1
Derived variable		
SHR	0.110	0.06

MC L, length of metacarpals; MC B, breadth of metacarpals; CPHL, length of proximal phalanx of third finger; CPHB, breadth of proximal phalanx of third finger; SHR, stature/hand ratio

breadth in modern Egyptians. They developed a new predictive equation to estimate stature from foot length and breadth and found significant correlations between stature and first, second, and fifth metatarsal lengths. For the breadth of metatarsals, significant correlation was found between stature and breadths of third and fourth metatarsals. The authors also found a significant correlation between stature and breadth of the first metatarsal. They provided equations that enable the prediction of stature for adult people using breadth of the first metatarsal.

In the present study, no significant correlation was found between stature and length and breadth of proximal phalanx of the second toe despite of development of predictive

regression equation that predict stature from the length of the proximal phalanx of the second toe. This is partially in agreement with the study conducted by Hasan and Mahmoud[12] who reported a significant correlation between stature and length of proximal phalanx of the second toe whereas a nonsignificant correlation was found between stature and breadth of proximal phalanx of the second toe.

Hand measurements

In this study, poor correlations were found between stature and hand length. Similarly, low correlations were found between stature and hand breadth. Predictive regression equations that forecast stature from the hand length and breadth were computed in the studied group. In agreement, Hasan and Mahmud[12] investigated the relationship between stature and hand length and breadth. They found no significant correlation between stature and hand length and breadth. They provided equations that predict stature from both hand length and breadth. On contrary, Abdel-Malek et al.,[10] Agnihotri et al.,[22] and Danborno and Elukpo[16] investigated the relationship between stature and hand length and breadth. They found a significant correlation between stature and hand length and breadth and developed equations that predict stature from both hand length and breadth.

As regards metacarpal lengths, the highest correlation without significance was found between stature and length of the first metacarpal. As regards metacarpal breadths, the highest correlation without significance was between stature and the second metacarpal. Karaman et al.[11] studied the relationship of stature and hand measurements using anthropometric and radiological evaluation. Also, they developed equations that predict stature from the radiographic lengths and breadths of the second and third metacarpal bones. Hasan and Mahmoud[12] found significant correlations between stature and lengths of the first, third, fourth, and fifth metacarpals. They developed equations that predict stature from the radiographic lengths of these metacarpals.

In this study, a low correlation without significance was found between stature and length of proximal phalanx of middle finger. In agreement, Hasan and Mahmoud[12] reported in their study that there was a insignificant correlation between stature and length and breadth of proximal phalanx of the middle finger.

Conclusion

Stature was found to be significantly correlated with some of the foot anthropometric and radiographic variables. Stature was insignificant with hand anthropometric and radiographic variables. As a result, predictive regression equations were computed to estimate stature from foot and hand lengths and breadths. This would be useful in cases where stature cannot be measured in the living subjects. Similarly, these equations could be useful in stature prediction in Physical Anthropologic and Forensic Medical examination in cases of personal identification.

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