Stature Estimation from Foot Measurements in Thais

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Abstract

Stature estimation is the important parameter in forensic identification work. It is advantage in deriving the biological profile especially in mass disaster and dismemberments case which incomplete remain usually found. The aim of this study is to develop regression equations for stature estimation using foot dimensions for Thai population. Stature, foot length, foot breadth, foot medial malleol height and foot navicular height were measured from 410 Thai adults (males and females, 205 each) aged 20 to 50 years. Foot length parameters of both gender groups had the highest correlation between stature and foot measurements at p - value less than 0.01, while foot navicular height parameter of all groups had the lowest at p –value less than 0.01 except RFNH and LFNH of male group at p – value less than 0.05. Stepwise multiple regression equation for stature estimation was fitted. The range of SEE values in the present study were from 4.06 – 4.27 cm and the R^2 value was all high (74% - 76%). The equation obtained from the present study will be helpful to derive approximate height of Thais individual using foot dimensions.

Keyword Stature estimation, foot measurements

Background

The difficulty for decease identification is the dismemberment or mass disaster case which mutilated or fragmentary remains usually found. Identification works in forensic flied: sex, age, stature, and race are commonly determined. Krishan (1) found that sex, age, race and stature of an individual correlate directly with anthropometric characteristics. Anthropometry can be subdivided into somatometry and osteometry (1). Osteometry is the measurements of the skeleton and its parts while somatometry is the measurements of the living person.

Statue is one of the important factors in identification. Anthropometric technique has been used to estimate stature for long time by using statistically formulae. Somatometry of various body parts had been used in stature estimation such as hand (2, 3), finger (3), leg (4), forearm (4-6), head and face (7, 8).

Stature can also be estimated from various measurement of foot dimensions such as foot length and foot breadth using statistical derived equation (9-15). Zeybek et al. (15) introduced additional parameters which are foot medial malleol height and foot navicular height in stature estimation from foot. All these studies concluded that there were correlation between foot dimensions and stature.

Different populations show variation of the anatomical structure of human foot which influenced by heredity, climatic factors, physical activities, nutrient conditions and lifestyle (9-12). Consequently, researchers in many countries conducted foot measurement data and developed stature estimation formulae for their population (9-16) since statistical derived formulae giving specific data for each population which may give imprecise results for others population.

Manoonpol et al. (17) reported about stature estimation from foot measurements in Thai. They measured foot length, foot breadth and stature in 630 Thai police cadets and university students. Eighteen estimation formulas were developed.

Physical activities and lifestyles influence on anatomical structure of foot have been mentioned earlier. Our interest is the study on the stature estimation in Thai population in various physical activities and lifestyles by using foot length, foot breadth and two additional parameters: foot medial malleol height and foot navicular height (9).

Materials and Methods

Subjects

Four hundred and ten Thai (males and females, 205 each) aged between 20 to 50 years were used in the present study.

Measurement data collection

Stature and foot dimensions were measured in all barefoot subjects during measurement. Regarding to the diurnal variation of stature (18), all subjects were measured in the afternoon period. Stature was measured with a steel tape while foot dimensions were measured with digital caliper. All measurements were taken by one observer to avoid inter-observer error and evaluated in centimeter.

Stature is taken from the vertex to the floor according to the anatomic position and Frankfurt plane.

The right (RFL) and the left foot length (LFL) are the maximum distance between most anterior and posterior points of foot. *The right (RFB) and the left foot Breadth (LFB)* are the distances between the surfaces of the first and the fifth metatarsal bone heads. *The right (RFMH) and the left foot medial malleol height (LFMH)* are distances between the lower bound

of tibial malleolar to the floor. *The right (RFNH) and left foot navicular height (LFNH)* are distances between the most superior projecting part of the navicular bone and the floor, the dorsal side of foot.

Table 1 Descriptive statistics of all measurement (cm) for each group

Parameter	Mix-gender (n = 410)		Male (n = 205)		Female (n = 205)		t-test	
	Mean	SD	Mean	SD	Mean	SD	t	p
LFL	24.23	1.53	25.27	1.23	23.18	1.00	18.86	0.000
LFB	9.75	0.69	10.21	0.56	9.28	0.46	18.42	0.000
LFNH	6.89	0.74	7.31	0.62	6.47	0.60	13.83	0.000
LFMH	8.19	0.73	8.62	0.63	7.75	0.55	14.86	0.000
RFL	24.19	1.49	25.20	1.18	23.17	0.99	18.88	0.000
RFB	9.76	0.70	10.21	0.56	9.30	0.50	17.41	0.000
RFNH	6.88	0.77	7.30	0.63	6.45	0.66	13.39	0.000
RFMH	8.17	0.72	8.59	0.63	7.75	0.53	14.68	0.000
Height	162.17	8.33	167.95	6.50	156.38	5.43	19.56	0.000

Statistical analysis

The descriptive statistics of all measurements were examined and compared between males and females using t-test. The relations between stature and foot measurements were determined by Pearson correlation. The fitted equations were developed by multiple regression analysis. All data were analyzed by using a statistical package SPSS for Windows version 18. The P-value less than 0.05 was set for the significant difference between groups.

Results, Discussion and Conclusions

Results

From 410 subjects, mean age of male and female was 33.48 and 32.68 years respectively.

The descriptive statistics analysis was shown in Table 1. According to independent samples t-test, mean value of all measurements of male group were significantly higher than those of female group at p-value less than 0.05.

The correlation (r) between stature and foot measurements were determine by Pearson correlation analysis as shown in Table 2. Foot length parameter of all groups showed the highest correlation between stature and foot measurements at p-value less than 0.01, while foot navicular height parameter of all groups showed the lowest at p-value less than 0.01 except RFNH and LFNH of male group at p-value less than 0.05. It was noticed that the relation of mix - gender group had preferable correlation.

Table 3 showed the stepwise multiple regression equations for stature on the right and left foot measurements of male, female and mix-gender groups. Some parameters were eliminated in fitting equation to avoiding the collinearity among variables. In consequence, the best equation from mix-gender, male and female group were obtained from foot length and foot medial malleol height of each foot side

Discussions

In present study, the right and left foot measurements were taken from 410 Thais (males and females 205 each). All measurements of male showed significantly greater than those from female at p-value less than 0.05. The means of stature, foot length and foot breadth were compared with those from the previous studies of other populations (9-16), there were

Table 2 Correlation between stature and foot measurements

Parameter	Stature		
	Group	r	p
LFL	Mix-gender	0.848**	0.000
	Male	0.738**	0.000
	Female	0.671**	0.000
LFB	Mix-gender	0.636**	0.000
	Male	0.309**	0.000
	Female	0.322**	0.000
LFNH	Mix-gender	0.488**	0.000
	Male	0.138*	0.048
	Female	0.188**	0.007
LFMH	Mix-gender	0.626**	0.000
	Male	0.435**	0.000
	Female	0.280**	0.000
RFL	Mix-gender	0.852**	0.000
	Male	0.749**	0.000
	Female	0.675**	0.000
RFB	Mix-gender	0.624**	0.000
	Male	0.309**	0.000
	Female	0.319**	0.000
RFNH	Mix-gender	0.487**	0.000
	Male	0.161*	0.021
	Female	0.188**	0.007
RFMH	Mix-gender	0.656**	0.000
	Male	0.508**	0.000
	Female	0.306**	0.000

**Significant at $p < 0.01$
* Significant at $p < 0.05$

Table 3 Stepwise multiple regression equation for stature estimation from foot measurements

Group	Equation	*R*	R^2%	SEE
Mix-gender (*n*=410)	Stature from right foot = 44.882 + 4.060(RFL) + 2.336(RFMH)	0.866	75.0	4.17
	Stature from left foot = 48.357 + 4.032(LFL) + 1.969(LFMH)	0.859	73.9	4.27
Male	Stature from right foot = 62.070 + 3.579(RFL) + 1.826(RFMH)	0.874	76.4	4.06
	Stature from left foot = 66.395 + 3.540(LFL) + 1.404(LFMH)	0.868	75.4	4.15
Female	Stature from right foot = 59.070 + 3.579(RFL) + 1.826(RFMH)	0.874	76.4	4.06
	Stature from left foot = 63.444 + 3.540(LFL) + 1.404(LFMH)	0.868	75.4	4.15

difference. Likewise previous studies pointed that there are variation of stature and foot dimensions between populations influenced by ethnical, physical activities, climatic factor, and lifestyles (9-12).

The results of the presents study were compared with those from Manoonpol et al (17). It was shown that the means of stature, foot length and foot breadth were difference, although they also studied on Thai population. It could be from the subjects (police cadets and university students) which had similar physical activities.

The correlations between stature and foot measurements were evaluated. It was shown that the stature is significantly correlated with foot dimensions. In the present study, the highest correlation was found in the foot length. The length of foot was greater correlation with the stature than with the foot breadth. Krishan and Sharma (15) also found length of foot was greater correlation with stature than foot breadth.

Sen and Ghosh (12) reported that the stature was more significantly correlated with foot length at r = 0.813 at p-value less than 0.01.

The lowest correlation was the foot navicular height of both foot sides. Zeybek et al. (9) introduced the foot navicular height to be used in stature estimation. In their study, some of the foot navicular height had good significant correlation with stature than other parameters.

The stepwise multiple regression equation for stature estimation from foot measurements were fitted. Stature estimation equations were derived from foot length and foot medial malleol height. The accuracy of regression equation was measured by low value of the standard error estimation (SEE) and high value of coefficient of determination (R^2).

Zeybek et al. (9) suggested that the stature estimation equation excluding the gender had better results. The SEE value from sex dependent stature estimation equations was 9 – 10 cm, while sex independent stature estimation was 4 cm. Sen and Ghosh (12) also reported the sex independent stature estimation was preferable. The similar results were also presented in the study by Sanli et al (10). Kanchan et al (11) discussed that the equations for mix- gender group were better because of a larger sample size by pooling of the sample.

The present study was trying fitted equations for each gender by adding gender, as dummy variable, into the equation. The result for each gender showed better than those from previous studies. The range of SEE values in the present study were from 4.06 – 4.27 cm and the R^2 value was all high (74% - 76%).

Conclusion

From present study, it has been concluded that stature significantly correlate with foot dimensions. Stature estimation equations were fitted and will be helpful to derive approximate height of Thais individual in case mutilated or fragmentary remains are found.

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References

1. K. Krishan. Anthropometry in Forensic Medicine and Forensic Science-'Forensic Anthropometry'. The Internet Journal of Forensic Science. 2007 Volume 2 Number 1
2. Agnihotri AK, Agnihotri S, Jeebun N, Googoolye K. Prediction of stature using hand dimensions. Journal of Forensic and Legal Medicine. 2008;15(8):479-82.
3. Habib SR, Kamal NN. Stature estimation from hand and phalanges lengths of Egyptians. Journal of Forensic and Legal Medicine. 2010(1);17(3):156-60.
4. Agnihotri AK, Kachhwaha S, Jowaheer V, Singh AP. Estimating stature from percutaneous length of tibia and ulna in Indo-Mauritian population. Forensic Science International. 2009;187(1-3):109.e1-.e3.
5. Celbis O, Agritmis H. Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. Forensic Science International. 2006;158(2-3):135-9.
6. İzzet D, Can P. Estimating body height from ulna length: need of a population-specific formula. Eurasian Journal of Anthropology. 2010;1(1):11–17.

7. Krishan K. Estimation of stature from cephalo-facial anthropometry in north Indian population. Forensic Science International. 2008;181(1-3):52.e1-.e6.
8. Sahni D, Sanjeev, Sharma P, Harjeet, Kaur G, Aggarwal A. Estimation of stature from facial measurements in northwest Indians. Leg Med. 2010;12(1):23-7.
9. Zeybek G, Ergur I, Demiroglu Z. Stature and gender estimation using foot measurements. Forensic Science International. 2008;181(1-3):54.e1-.e5.
10. Sanli SG, Kizilkanat ED, Boyan N, Ozsahin ET, Bozkir MG, Soames R, et al. Stature estimation based on hand length and foot length. Clin Anat. 2005;18(8):589-96.
11. Kanchan T, Menezes RG, Moudgil R, Kaur R, Kotian MS, Garg RK. Stature estimation from foot dimensions. Forensic Science International. 2008;179(2-3):241.e1-.e5.
12. Sen J, Ghosh S. Estimation of stature from foot length and foot breadth among the Rajbanshi: An indigenous population of North Bengal. Forensic Science International. 2008;181(1-3):55.e1-.e6.
13. Agnihotri A, Purwar B, Googoolye K, Agnihotri S, Jeebun N. Estimation of stature by foot length. Journal of Forensic and Legal Medicine. 2007;14(5):279-83.
14. Kanchan T, Krishan K, Sharma A, Menezes RG. A study of correlation of hand and foot dimensions for personal identification in mass disasters. Forensic Science International. 2010;199(1-3):112.e1-.e6.
15. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. Journal of Forensic and Legal Medicine. 2007;14(6):327-32.
16. Özaslan A, Iscan MY, Özaslan I, Tugcu H, Koç S. Estimation of stature from body parts. Forensic Science International. 2003; 132(1):40-5.
17. Manoonpol C, Sricharoenvej S, Soparat K, Saelim K. Correlations and Estimation Stature of Foot Size of Thai Adults. Siriraj medical journal. 2005;57(9): 382-386.
18. Krishan K, Vij K. Diurnal Variation of Stature in Three Adults and One Child. Anthropologist. 2007;9(2):113-117.