NC2001: Estimation of stature from forearm length in Thai children

Kannika Song-in [1*], Suda Riengrojpitak [1,2*], Montip Tiensuwan [3]
[1]Forensic Science Graduate Programme, [2]Department of Pathobiology, [3]Department of Mathematics, Faculty of Science, Mahidol University
272 Rama 6 Road, Ratchathewi, Bangkok 10400

Abstract

In cases where only incomplete human remains of an unknown person are recovered from the crime scene, the estimation of stature from these remains is particularly important in personal identification. The estimated stature may be used to narrow down the search in missing person databases. The present study aims to set appropriate regression equations to estimate stature from percutaneous forearm length for Thai school-age children (45 males and 45 females) ages between 5 and 19 years in the central region of Thailand. All subjects were healthy and had no physical deformities. Stature and forearm length were measured by using a stadiometer and a digital caliper. All measurements were recorded to the nearest millimeter. The data was analyzed using SPSS version 18.0 for Windows. Descriptive statistics, paired samples t-test, Pearson's correlation analysis, linear Regressions, and multiple regression analysis were used. The results in the present study showed that the correlation coefficients between stature and forearm (ulna and radius) length are high and significant in both sexes ($r = 0.988 - 0.992$, $p < 0.01$). In Thai school-age children, forearm lengths (radial length) are highly correlated with stature (standard error of estimation range from ±2.7464 cm to ±3.1190 cm). The Multiple regression equations provide slightly better results than the linear regression equations. Therefore, the equations derived in the present study will be useful for stature estimation from forearm length in Thai children.

Keywords: Stature estimation, Forearm length, Thai children, Regression equation

*Kannika Song-in
Cell: 091-003-1789
E-mail: mootako1117@gmail.com, Suda.rie@mahidol.ac.th

1. Introduction

Stature has definite and proportional biological relationship with each part of the human body. The most commonly used bones for stature estimation of incomplete remains are the long bones such as femur, tibia, fibula, humerus, ulna, and radius because they are strong, large and easy to find. Estimation of stature, especially from bones, is a tedious and time consuming process which involves cleaning and preparation of bones. Due to this reason, forensic pathologists are using percutaneous measurements instead of direct measurements of the bone.

Many researchers in several countries have developed regression formulae to estimate stature from long bones and other bones such as skull, hand, foot. Some studies have also used forearm bones and percutaneous measurement of forearm to predict stature. The equations produced for one population do not always give accurate results for another due to differences in diet, environment and lifestyle of each country.

There are a few studies about stature estimation in the Thai population. (Mahakkanukrauh, Khanpetch, Prasitwattanseree, Vichairat, & Case, 2011) Previous studies on the estimation of stature from long bones and other bones have been conducted in many adult populations. However, Thai children have not been studied before. The formula derived for adults does not provide accurate results for children. Therefore, it is necessary to develop regression equations for estimation of stature for Thai children, and this study uses forearm length (ulna and radial) for stature estimation of Thai children.

2. Objectives

This study aims to find the relationship between stature and forearm lengths and set regression equations for estimation of stature from radius and ulna length for Thai school-age children

3. Materials and Methods

The subjects of this study were 90 students (45 males and 45 females) in the central region of Thailand of ages between 5 and 19 years. All subjects were healthy and had no physical deformities.

Stature of the subjects was measured using a standard stadiometer. Each subject was instructed to stand up in an anatomical position (stand up straight and look straight ahead). The subject's head was positioned in the Frankfort Horizontal Plane

The forearm measurements were taken using a sliding caliper. The ulna length was measured as the distance from the distal tip of olecranon process to the tip of ulna styloid process (the elbow to the wrist of forearm) and the radial length was measured as the distance from the distal tip of ulna head to the tip of radial styloid process. The subject's elbow was flexed at 90° to 110° with fingers extended in the direction of the long axis of the forearm. (AD, JEL, KC, & RM, 1988). All measurements were recorded to the nearest millimeter.

The data was analyzed using SPSS for Windows version 18.0. Descriptive statistics of stature and forearm (ulna and radial) measurements were calculated for both males and females. T-test was utilized to examine statistical significance in bilateral asymmetry in forearm measurements of males and females. Statistical significance was considered at P-value < 0.05. The Pearson's correlation coefficient was calculated. Simple linear and multiple regression analyses were performed to derive regression equations for estimation of stature from forearm measurements for males and females.

4. Results

4.1 Descriptive statistics

The descriptive statistics for stature and forearm measurements in males and females (the minimum values, maximum values, means, and standard deviations) are shown in Table 1

Table 1 Descriptive statistics for stature and forearm measurements in males and females (n = 90)

Measurenents	Side	male (n = 45)				female (n = 45)			
		Min	Max	Mean	SD	Min	Max	Mean	SD
Age		5	19	12	4.369	5	19	12	4.369
Height		109.9	178.4	145.013	21.6908	106.3	169.8	142.8	18.7983
Ulna Length	Left	15.00	29.85	22.6589	4.52871	15.00	29.85	22.6589	4.52871
	Right	15.20	29.90	22.6533	4.50797	15. .0	29.90	22.6533	4.50797
Radial Length	Left	15.35	29.90	22.7878	4.49394	15.35	29.90	22.7878	4.49394
	Right	15.20	29.80	22.7133	4.53389	15.20	29.80	22.7133	4.53389

4.2 Bilateral asymmetry

Table 2 presents the results of paired samples t-tests; the statistical significance of bilaterally asymmetry in forearm lengths of both sexes is represented by t and p values.

Table 2 Bilateral differences in forearm measurements in males and females (n = 90)

Measurement	Male (n = 45)				Female (n = 45)			
	Mean diff. (Left - Right)	SD	t-value	p-value	Mean diff. (Left - Right)	SD	t-value	p-value
Ulna length	0.00556	0.16349	0.228	0.821	-0.01333	0.22948	-0.39	0.699
Radial length	0.07444	0.18998	2.629	0.012	0.05667	0.19673	1.932	0.06

It is observed that bilateral asymmetry in the right and left ulna length of both sexes is not statistically significant. Similarly, the bilateral asymmetry in radial length of females is not statistically significant. On the other hand, bilateral asymmetry in radial length of males is statistically significant

4.3 Pearson's correlation coefficients

The results of the correlation coefficients between stature and forearm measurements are shown in **Table 3.** All forearm measurements exhibit statistically significant correlation coefficients with stature (p-value < 0.001). The correlation coefficient between stature and forearm length(ulna and radial) was higher in the male group. For males, the highest correlation is exhibited by the right radial length (r = 0.992, SEE = ±2.8539), and the lowest by both sides of ulna length (r = 0.990, SEE = ±3.1190 cm for left side and SEE = ±3.0630 for right side). For females, the highest correlation is exhibited by the right radial length (r = 0.990, SEE = ±2.7464), and the lowest by both sides of ulna length (r = 0.988, SEE = ±2.9535 cm for left side and SEE = ±2.9053 for right side) and the left radial length (r = 0.988, SEE = ±2.9451).

Table 3 Pearson's correlation coefficient between stature and forearm length

Measurement	Side	Male (n = 45)		Female (n = 45)	
		R	P	R	P
Ulna Length	Left	0.990*	0.000	0.988*	0.000
	Right	0.990*	0.000	0.988*	0.000
Radial Length	Left	0.991*	0.000	0.988*	0.000
	Right	0.992*	0.000	0.990*	0.000

*Significant at p-value < 0.001

4.3 Simple linear regression equations

The results of linear regression equations of different parameters were obtained as follows:

For males:
Stature (cm) = 37.588 + (4.741 × LUL*) (cm)
Stature (cm) = 37.080 + (4.765 × RUL**) (cm)
Stature (cm) = 36.065 + (4.781 × LRL***) (cm)
Stature (cm) = 37.273 + (4.744 × RRL****) (cm)

For females:
Stature (cm) = 36.724 + (4.783 × LUL*) (cm)
Stature (cm) = 33.251 + (4.937 × RUL**) (cm)
Stature (cm) = 35.685 + (4.792 × LRL***) (cm)
Stature (cm) = 33.608 + (4.897 × RRL****) (cm)

LUL = Left ulna length*, RUL = Right ulna length**, LRL = Left radial length***
RRL = Right radial length****

In the present study, regression equations have been formulated with the standard error of estimate (SEE) ranging from ±2.7464 cm to ±3.1190 cm.

For males, the highest standard error of the estimation is observed in left ulna length (SEE = ±3.1190 cm), and the lowest in right radial length (SEE = ±2.8539 cm).

For females, the highest standard error of the estimation is observed in left ulna length (SEE = ±2.9538 cm), and the lowest in right radial length (SEE = ±2.7464 cm).

4.4 Multiple regression equations

The multiple regression equations for estimation of stature from different combinations of forearm measurements for males and females are presented in Table 4

Table 4 Multiple regression equations for stature estimation from forearm measurements in cm (n = 90)

Sex	Side	Equations	r	R^2	SEE
Male	Left	S = 36.462 + (1.525×LUL) + (3.247×LRL)	0.991	0.982	3.0150
	Right	S = 37.185 + (0.771×RUL) + (3.979×RRL)	0.992	0.983	2.8792
Female	Left	S = 36.014 + (2.344×LUL) + (2.452×LRL)	0.989	0.978	2.8808
	Right	S = 33.435 + (1.140×RUL) + (3.771×RRL)	0.990	0.979	2.7626

It is observed that the correlation coefficients, the coefficients of determination, and standard errors of the estimate of the multiple regression equations are better than those of the linear regression equations.

For males, the right side of forearm measurements shows the highest correlation coefficient with stature (r = 0.992) and the lowest standard error of the estimate (SEE = ±2.8792 cm).

For females, the right side of forearm measurements exhibits the highest correlation coefficient with stature (r = 0.990) and the lowest standard error of the estimate (SEE = ±2.7626 cm).

5. Discussion

In this study, stature and forearm lengths were measured from a total of 90 (45 males and 45 females) children in the central region of Thailand. The results show that the mean stature and all forearm lengths of males are higher than those of females; similar findings were observed in previous studies (Amit, A.K., & A.K.; Ebite et al., 2008; Ilayperuma & Nanayakkara, 2010).

The results of paired samples t- tests show no significant bilateral asymmetry in ulna length in both sexes (mean difference = 0.00556, p-value = 0.821 for males and mean difference = -0.01333, p-value = 0.699 for females). Similarly, no significant bilateral asymmetry in radial length is observed in females (mean difference = 0.05667, p-value = 0.060). This result is supported by the study of Arun Kumar Agnihotri (2009) that showed no significant bilateral asymmetry in forearm bones of Indo Mauritian populations. Therefore, we can use either side of ulna for both sexes and either side of radius for females in constructing models. This is supported by another study on limb bilateral asymmetry (Freedman, Edwards, Willems, & Meals, 1998). On the other hand, bilateral asymmetry in radial length of males was significant (mean difference = 0.07444, p-value = 0.012), which may be due to the regularly use of both left and right side of forearms. However, the results in the present study were obtained from children age between 5 and 19 years, so the maturation or growth of the body and the bones are not static in both sexes. Growth usually indicates physical changes in height, weight and other limbs of the body. It means the increase and enlargement of the body or different parts of the body making it heavier and larger.

Linear regression equations and multiple regression equations show highly significant correlation between stature and forearm length and low standard error of the estimate, which are similar to previous studies in many populations. For linear regression equations, the correlation coefficients range from 0.990 to 0.992 in males and 0.988 to 0.990 in females. The right radial length shows the highest correlation coefficients in both sexes. Multiple regression equations show higher values of correlation coefficients than those of linear regression equations, which are similar to other studies. For the equations to be applicable, it is important that the independent variables, i.e. radial length and ulna length, fall within the minimum and maximum values used in deriving those equations.

When compared to previous studies, the correlation coefficients of this study are higher (Agnihotri, Kachhwaha, Jowaheer, & Singh, 2009; Ilayperuma & Nanayakkara, 2010; Leanne M Gauld, 2004; Mohanty, Babu, & Nair, 2001; Osman Celbis, 2006). The study by Athawl (Athwale, 1963) showed that stature could be reliable estimated from forearm length. This is supported by Chikhalkar, Mangaonkar and Nanandkar et.al (2009) that the forearm length showed the highest degree of correlation (r = 0.6558) in the region of Mumbai. Similar results were also shown in the present study.

Variety of factors such as age, race, gender and nutritional status affect human development and growth. Therefore, different equations may be required for different populations.

6. Conclusion

In Thai school-age children, forearm lengths are highly correlated with stature with the accuracy of stature estimation from forearm lengths ranges from ±2.74[illegible]1 cm to ±3.1190 cm. The highest correlation coefficient between forearm length and stature was found in the radial length. The Multiple regression equations provide slightly better results than the linear regression equations. The results in the present study indicate that the length of forearm can be efficiently used for stature estimation.

7. Limitations and suggestions

As the samples were collected from children in the central region of Thailand. Therefore, the equations from the present study are specific for Thai children. If the equations derived from this study were applied to others countries, it would present higher values of error from stature estimation. In further study, the estimation of stature from different anthropometric measurements should be used such as standing or sitting in case of the patients cannot stand due to disability.

References

AD, M., JEL, C., KC, H., & RM, M. (1988). *Anthropometric standardization reference manual.*

Agnihotri, A. K., Kachhwaha, S., Jowaheer, V., & Singh, A. P. (2009). Estimating stature from percutaneous length of tibia and ulna in Indo-Mauritian population *Forensic Science International, 187*(109), e1-109e103.

Amit, K., A.K., S., & A.K., V. estimation of stature by percutaneous measurements of distal half of the upper limb (forearms&hands). *J Indian Acad Forensic Med, 32*(4), 325-328.

Athwale. (1963). Anthropological study of height from length of forearm bones. A study of one hundred Maharashtrian male adults of age between 25 to 30years. *American Journal of Physical Anthropology, 21*, 105-112.

Ebite, L. E., Ozoko, T. C., Eweka, A. O., Otuaga, P. O., Oni, A. O., & F.A.E.Om'Iniabohs. (2008). Height: Ulna Ratio: A Method of Stature Estimation In A Rural Community in Edo State, Nigeria. *The Internet Journal of Forensic Science, 3*(1).

Freedman, D. M., Edwards, G. S. J., Willems, M. J. B., & Meals, R. A. (1998). Right Versus Left Symmetry of Ulnar Variance: A Radiographic Assessment. *Clinical Orthopaedics & Related Research, 354*, 153-158.

Ilayperuma, I., & Nanayakkara, G. (2010). A model for the Estimation of Personal Stature from the Length of Forearm. *Int. J. Morphol, 28*(4), 1081-1086.

Leanne M Gauld, J. K., John B Carlin, Colin F Robertson. (2004). Height prediction from ulna length. *Decelopmental Medicine&Child Neurology, 46*, 475-480.

Mahakkanukrauh, P., Khanpetch, P., Prasitwattanseree, S., Vichairat, K., & Case, D. T. (2011). Stature estimation from long bone lengths in a Thai population. *Forensic Science International, 210*, 279.e271-279.e277.

Mohanty, S., Babu, S. S., & Nair, N. S. (2001). The use of arm span as a predictor of height: A study of South Indian women. *Journal of Orthopaedic Surgery, 9*(1), 19-23.

Osman Celbis, H. A. (2006). Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. *Forensic Science Internat. nal, 158*, 135-139.

Authors

Kannika Song-in Forensic Science Graduate Programme, Faculty of Science, Mahidol University, 272 Rama VI Road, Ratchathewi District, Bangkok 10400 mootako1117@gmail.com

Suda Riengrojpitak Department of Pathobiology, Faculty of Science, Mahidol University, 272 Rama VI Road, Ratchathewi District, Bangkok 10400 suda.rie@mahidol.ac.th

Montip Tiensuwan Department of Mathematics, Faculty of Science, Mahidol University, 272 Rama VI Road, Ratchathewi District, Bangkok 10400 montip.tie@mahidol.ac.th