Journal of Forensic and Legal Medicine 53 (2018) 35–45

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/yjflm

Estimation of stature from hand and handprint measurements in Iban population in Sarawak, Malaysia and its applications in forensic investigation

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ARTICLE INFO

Keywords:
Forensic anthropology population data
Stature estimation
Hand and handprint measurements
Iban population
Malaysia

ABSTRACT

Handprints and dismembered hands are commonly found during crime scene investigations and disaster victim identifications, respectively. It has been indicated that the accuracy of handprint and hand measurements for estimating stature maybe population specific. Since Iban is the largest ethnic population in Sarawak, Malaysia and because the application of anthropometry of hand and handprint within this population as well as other populations within the Southeast Asian countries remain unreported, this present study that investigated the reliability and accuracy of these two anthropometric aspects acquires forensic significance. Upon measuring the height, 21 measurements were recorded on each hand and the corresponding handprint of 50 male and 52 female consented adult Iban subjects. Using univariate statistics as well as simple and multiple regression analyses, interpretation of the measurements examined here was attempted. Results revealed that lengths of hand and handprint are the more reliable traits for estimating stature in both the male and female Iban subjects ($p < 0.05$) with correlation strength ranging from 0.60 to 0.76. Comparable to the established skeletal standards for hand, the stature prediction accuracy using hand and handprint measurements investigated in this research ranged between 4.29 and 5.78 cm. Hence, this research provided the first forensic standard for estimation of stature among the Iban population in Sarawak that may prove useful for crime scene investigations and disaster victim identifications in Malaysia.

1. Introduction

Forensic anthropologist mainly deals with human bones to solve criminal cases.[1,2] Recently, the role of forensic anthropologist has expanded to cover a larger spectrum of forensic applications such as the analysis of living individuals as well as human remains associated with natural disasters or acts of terrorism.[2] Considering common discovery of hand as well as handprints and footprints at crime scenes, the use of several anthropometric parameters on these evidence for suggesting human traits especially stature and sex has been suggested.[3,4] Being a trait describing the natural standing height of an individual, stature forms an important part of human identification and profiling[5] by narrowing down the pool of suspects, which later can be positively identified using traditional markers such as DNA.[6]

While variations in the access for adequate nutrition and health services that may affect human stature[7] would occur across different populations worldwide and since genetic is a factor in human growth,[8] generalizing mathematical algorithms derived from a particular population to estimate stature from hands and handprints for other populations may lead to erroneous interpretations. Review of literature reveals a number of studies focusing on the use of hand[3,9–15] as well as hand and handprints[2,16] for estimating stature among various populations. To date, specific studies on this aspect covering different ethnic populations within the Southeast Asian countries including Malaysia remain unreported hence, limiting its applicability for forensic investigation in these countries.

Since Iban is the majority ethnic group (about 600,000 people) in Sarawak (Department of Statistics Malaysia, 2010, unpublished data)

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https://doi.org/10.1016/j.jflm.2017.10.011
Received 8 November 2016; Received in revised form 8 October 2017; Accepted 30 October 2017
Available online 31 October 2017

i.e. the largest state in Malaysia, separated by the South China Sea from the peninsular mainland, this present study that aimed at providing empirical data on the possible use of hand and handprint for estimating stature for this particular population acquires forensic significance. This aspect can potentially be useful when complete and/or partial handprints as well as dismembered hands are found during crime scene investigations and disaster victim identification, respectively.

2. Materials and methods

2.1. Experimental design

Ethical clearance (USM/JEPeM/16020091) was obtained from the Research Ethics Committee (Human) of Universiti Sains Malaysia. The sample size was calculated by considering the total population of Iban in Sarawak, power level (0.80), level of significance (0.05) and medium size effect (0.15). This study involved 102 consented healthy adult Iban subjects (50 males and 52 females) aged between 18 and 60 years old (mean ± standard deviation: 38.65 ± 9.66) with at least three lineages of pure Iban, residing in Sarawak. The exclusion criteria considered in this research that included pregnancy, present of any diseases and/or injuries that may affect stature and hand morphology, as well as metabolic and/or developmental disorders were examined by our third author. Subjects were provided with the information sheet and requested to sign a consent form, prior to conducting the measurement. In addition, the basic demographic data (i.e. sex, age and ethnicity) were obtained by asking each subject to answer a questionnaire. Upon completion, the stature as well as hand measurements and handprints of each subject were obtained. None of the subjects participating in the study was coerced in any way or rewarded for their involvement. To ensure the confidentiality of the data, the crude data as well as responses from the questionnaire were destroyed upon completion of this research.

2.2. Measurements of height and hands as well as acquisition of handprints

Following the protocol prescribed by Gordon and colleagues,[17] the living height (stature) of each subject was measured using a stadiometer (Seca 213) (Seca, China). Each subject was asked to stand barefooted on the flat platform of the stadiometer with heels placed together, touching the base of the vertical board. While in standing position with arms on the side of the thighs, each subject was asked to keep his/her head positioned in the Frankfort Horizontal plane against the vertical board. By aligning the horizontal sliding bar on the contact point of the vertex of the head, the stature of the subjects was recorded to the nearest centimetres. In each subject, 21 anthropometric measurements (Table 1, Figs. 1 and 2) were recorded on each hand using a vernier calliper and (whenever required) a measuring tape. Using a clean plain glass (8 mm of thickness), the quick drying black duplicating ink 4746 (Kores) was uniformly smeared using a paint roller. The subject was instructed to place his/her hand on the inked glass plate, followed by placing the inked hand on a plain white A4 paper. Following the same procedure for hand, the 21 anthropometric measurements of the handprints from both hands were recorded. In this present research inter-observer error was eliminated by categorically assigning one analyst to measure specific measurement i.e. one specific analyst each for measuring stature, hands and handprints. For assessing the intra-observer error, the relative technical error of measurement (rTEM) as well as coefficient of reliability (R) were calculated. Measurements of hands and handprints from four subjects were made at four different 24 h intervals, and the standard deviations among the repeated measurements on each subject were calculated for providing the technical error of measurement (TEM). Upon obtaining the variable average value, the TEM was then converted into rTEM. Following the standard prescribed by Ishak et al.,[2] the intra-observer errors observed here ($R > 0.90$ and $rTEM < 5\%$.) were acceptable. Because diurnal rhythm and the day activity after waking up may lead to variations in lengths of hands and height, the time for performing all measurements was standardized between 10 a.m. and 6 p.m.

2.3. Statistical analyses

Using the IBM SPSS software version 20.0, statistical analyses of the data (descriptive statistics, t-tests, Pearson correlation, linear and multiple regressions) were performed. While paired samples *t*-test was used for comparing the bilateral asymmetry as well as differences between hand and handprints, the independent samples *t*-test was used for comparing the measurements between the male and female subjects. The sex-specific linear regression analysis was utilised for exploring the association between stature and all the 21 measurements on hands and handprints; standard errors of the estimate (SEE) was used for reporting the accuracy of the stature prediction. Using a series of stepwise multiple regression analysis, improvement in the accuracy of prediction following the use of multiple measurements was evaluated. For defining the strength of correlation coefficient, the categorical definition (very high: 0.90–1.00; high: 0.70–0.89; moderate: 0.50–0.69; low: 0.26–0.49; little: 0.00–0.25) suggested by Munro[18] was used.

3. Results

3.1. Descriptive statistics, bilateral asymmetry and comparisons between hand and handprint measurements

Results of this research revealed that the male subjects (mean: 160.28 ± 7.52 cm, range: 144.50–176.00 cm) had significantly higher stature (independent sample *t*-test, $p < 0.05$) than that of female (mean: 151.17 ± 5.99 cm, range: 136.30–168.00 cm) subjects. In general, significantly larger measurements of hand and handprint were

Table 1
Definition of hand and handprint measurements (Jee & Yun, 2015[16]).

Hand dimension and designated labeling	Definition
Hand Length (HL)	The distance from the middle of inter stylion to the tip of middle finger
Hand Breadth (HB)[a]	The distance from the most lateral point on the head of the 2D metacarpal to the most medial point on the head of 5D metacarpal
Thumb (A); Index (B); Middle (C); Ring (D); Little (E) finger length	The distance from the proximal flexion crease of the finger to the tip of the respected finger
Thumb (A1); index (B1); middle (C1); ring (D1); little (E1) finger distal phalange length	The distance from the most forwarding projecting point on the tip of each finger to distal interphalangeal joint crease of each finger
Index (B2); middle (C2); ring (D2); little (E2) finger middle phalange length	The distance from the distal interphalangeal joint crease to the proximal interphalangeal joint crease
Thumb (A3); Index (B3); middle (C3); ring (D3); little (E3) finger proximal phalange length	The distance from the proximal interphalangeal joint crease to metacarpophalangeal joint crease of each finger

[a] Manual palpation of hand for locating the required bony anatomy is necessary.

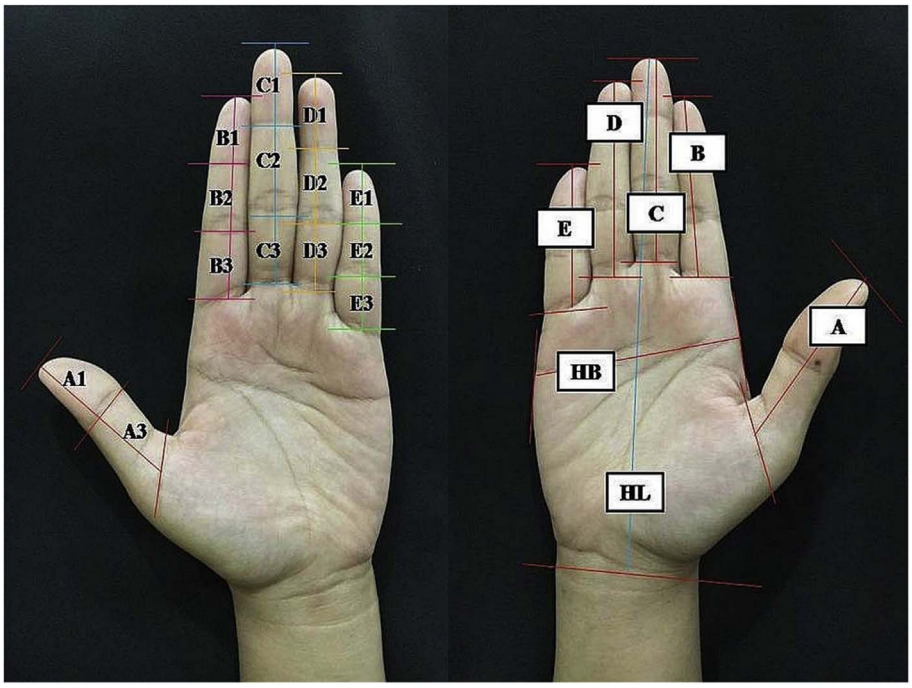

Fig. 1. Measurements of hand: hand length (HL); hand breadth (HB); thumb finger length (A); index finger length (B); middle finger length (C); ring finger length (D); little finger length (E); thumb distal phalange length (A1); thumb proximal phalange length (A3); index distal phalange length (B1); index middle phalange length (B2); index proximal phalange length (B3); middle distal phalange length (C1); middle middle phalange length (C2); middle proximal phalange length (C3); ring distal phalange length (D1); ring middle phalange length (D2); ring proximal phalange length (D3); little distal phalange length (E1); little middle phalange length (E2); little proximal phalange length (E3).

observed in the males ($p < 0.05$) when compared with that of female subjects (Table 2a–b). Although significant associations ($p < 0.05$) in the majority of the measurements of hand and handprint (for both hands) with that of stature were observed, the strongest strengths of correlation coefficients prevailed for the lengths of both hands (r: 0.70–0.76) as well as handprints (r: 0.60–0.68) for male and female subjects (Table 3a–b).

In view of bilateral asymmetry (Table 4a), paired sample *t*-test revealed significant differences ($p < 0.05$) in several measurements between the left and right hands (i.e. thumb fingers, ring fingers, thumb proximal phalanges and ring medial phalanges) among the male subjects. Significant differences ($p < 0.05$) in several measurements for the left and right hands (i.e. hand length, hand breadth, thumb fingers, middle fingers, thumb proximal phalanges and middle medial phalanges) were also observed among the female subjects (Table 4a). While the little medial phalanges alone differed significantly ($p < 0.05$) between the left and right handprints of the male subjects, the female subjects demonstrated significant differences ($p < 0.05$) in the breadth, index fingers as well as thumb distal and index distal phalanges for both sides of handprints (Table 4b).

Comparisons between the left hands and handprints for the male Iban subjects revealed significant differences ($p < 0.05$) in all the measurements except for index proximal, little medial and little proximal phalanges; insignificant differences ($p > 0.05$) for right hands and handprints were observed for middle proximal and little proximal phalanges (Table 5a). Similarly, significant differences ($p < 0.05$) in all the hand and handprint measurements were observed for the female Iban subjects, except for index proximal and little proximal phalanges for the left sides, as well as middle proximal and little proximal phalanges for the right sides (Table 5b).

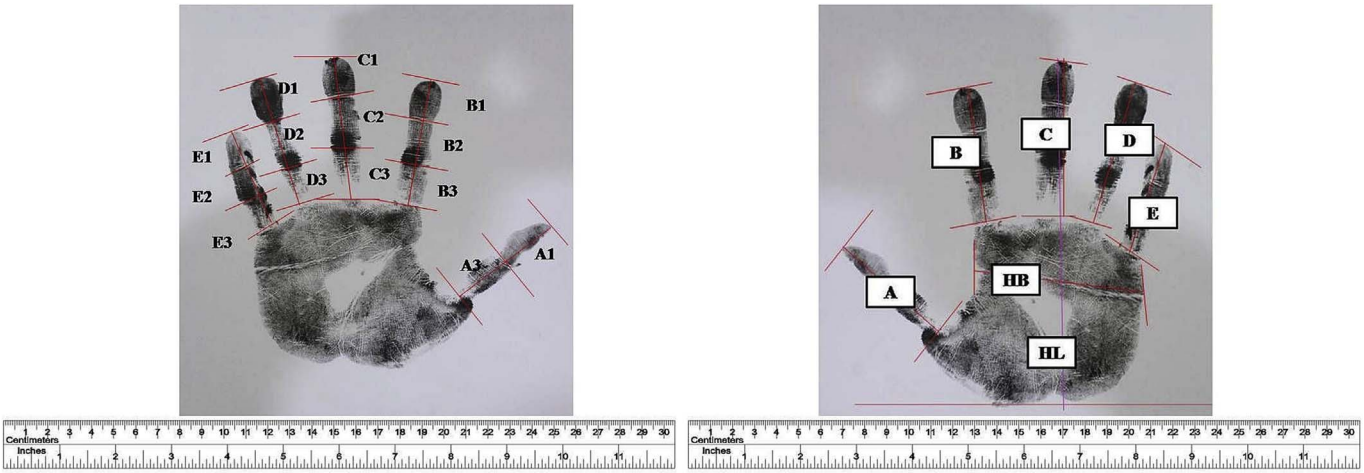

Fig. 2. Measurements of handprint: hand length (HL); hand breadth (HB); thumb finger length (A); index finger length (B); middle finger length (C); ring finger length (D); little finger length (E); thumb distal phalange length (A1); thumb proximal phalange length (A3); index distal phalange length (B1); index middle phalange length (B2); index proximal phalange length (B3); middle distal phalange length (C1); middle middle phalange length (C2); middle proximal phalange length (C3); ring distal phalange length (D1); ring middle phalange length (D2); ring proximal phalange length (D3); little distal phalange length (E1); little middle phalange length (E2); little proximal phalange length (E3).

Table 2
Means with standard deviations (SD) for hand (a) and handprint (b) measurements of male and female Iban subjects.

Measurements	Left Hand			Right Hand		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Male (n = 50)	Female (n = 52)		Male (n = 50)	Female (n = 52)	
(a) hand						
Hand Length	18.54 ± 0.99	17.48 ± 0.80	HS	18.51 ± 0.94	17.30 ± 0.82	HS
Hand Breadth	7.71 ± 0.51	7.11 ± 0.34	HS	7.83 ± 0.56	7.25 ± 0.37	HS
Thumbs Finger	6.21 ± 0.44	5.73 ± 0.41	HS	6.06 ± 0.48	5.63 ± 0.38	HS
Index Finger	6.96 ± 0.44	6.51 ± 0.40	HS	6.91 ± 0.43	6.52 ± 0.43	HS
Middle Finger	7.64 ± 0.47	7.19 ± 0.42	HS	7.60 ± 0.49	7.13 ± 0.41	HS
Ring Finger	7.16 ± 0.42	6.61 ± 0.48	HS	7.09 ± 0.47	6.66 ± 0.41	HS
Little Finger	5.77 ± 0.40	5.30 ± 0.45	HS	5.73 ± 0.39	5.30 ± 0.42	HS
Thumbs Distal Phalange	3.34 ± 0.25	3.06 ± 0.21	HS	3.32 ± 0.27	3.01 ± 0.24	HS
Thumbs Proximal Phalange	3.20 ± 0.38	2.98 ± 0.30	S	3.08 ± 0.41	2.89 ± 0.26	S
Index Distal Phalange	2.66 ± 0.26	2.40 ± 0.18	HS	2.65 ± 0.20	2.40 ± 0.20	HS
Index Medial Phalange	2.34 ± 0.22	2.24 ± 0.21	S	2.37 ± 0.32	2.23 ± 0.20	S
Index Proximal Phalange	2.36 ± 0.25	2.25 ± 0.22	S	2.36 ± 0.24	2.27 ± 0.22	S
Middle Distal Phalange	2.72 ± 0.20	2.47 ± 0.19	HS	2.71 ± 0.17	2.45 ± 0.19	HS
Middle Medial Phalange	2.72 ± 0.27	2.63 ± 0.21	NS	2.69 ± 0.27	2.56 ± 0.20	S
Middle Proximal Phalange	2.63 ± 0.24	2.58 ± 0.22	NS	2.65 ± 0.23	2.57 ± 0.20	NS
Ring Distal Phalange	2.68 ± 0.22	2.42 ± 0.22	HS	2.49 ± 0.23	2.43 ± 0.20	HS
Ring Medial Phalange	2.58 ± 0.26	2.39 ± 0.24	HS	2.33 ± 0.27	2.41 ± 0.20	NS
Ring Proximal Phalange	2.38 ± 0.24	2.30 ± 0.22	NS	2.34 ± 0.27	2.32 ± 0.20	NS
Little Distal Phalange	2.43 ± 0.21	2.20 ± 0.21	HS	2.42 ± 0.17	2.23 ± 0.20	HS
Little Medial Phalange	1.85 ± 0.24	1.70 ± 0.20	S	1.79 ± 0.21	1.68 ± 0.19	S
Little Proximal Phalange	1.86 ± 0.22	1.77 ± 0.18	S	1.89 ± 0.19	1.80 ± 0.17	S
(b) Handprint						
Hand Length	17.68 ± 0.89	16.59 ± 0.73	HS	17.63 ± 0.89	16.59 ± 0.85	HS
Hand Breadth	8.12 ± 0.48	7.58 ± 0.46	HS	8.20 ± 0.58	7.69 ± 0.43	HS
Thumbs Finger	5.77 ± 0.42	5.24 ± 0.43	HS	5.82 ± 0.48	5.37 ± 0.43	HS
Index Finger	6.94 ± 0.43	6.47 ± 0.44	HS	6.94 ± 0.48	6.56 ± 0.41	HS
Middle Finger	7.89 ± 0.52	7.30 ± 0.42	HS	7.86 ± 0.51	7.29 ± 0.44	HS
Ring Finger	7.38 ± 0.52	6.81 ± 0.38	HS	7.32 ± 0.54	6.82 ± 0.46	HS
Little Finger	5.94 ± 0.45	5.38 ± 0.43	HS	5.88 ± 0.43	5.39 ± 0.47	HS
Thumbs Distal Phalange	2.94 ± 0.23	2.65 ± 0.26	HS	3.02 ± 0.25	2.78 ± 0.24	HS
Thumbs Proximal Phalange	2.82 ± 0.33	2.63 ± 0.33	S	2.81 ± 0.34	2.57 ± 0.37	HS
Index Distal Phalange	2.38 ± 0.17	2.14 ± 0.18	HS	2.39 ± 0.17	2.18 ± 0.17	HS
Index Medial Phalange	2.20 ± 0.23	2.05 ± 0.22	S	2.21 ± 0.24	2.07 ± 0.23	S
Index Proximal Phalange	2.36 ± 0.22	2.29 ± 0.20	S	2.34 ± 0.23	2.33 ± 0.23	NS
Middle Distal Phalange	2.51 ± 0.18	2.24 ± 0.16	HS	2.47 ± 0.18	2.24 ± 0.21	HS
Middle Medial Phalange	2.62 ± 0.30	2.42 ± 0.23	HS	2.62 ± 0.27	2.40 ± 0.20	HS
Middle Proximal Phalange	2.74 ± 0.23	2.65 ± 0.21	NS	2.72 ± 0.30	2.62 ± 0.23	NS

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Table 2 (*continued*)

Measurements	Left Hand			Right Hand		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Male (n = 50)	Female (n = 52)		Male (n = 50)	Female (n = 52)	
Ring Distal Phalange	2.47 ± 0.19	2.23 ± 0.17	HS	2.47 ± 0.20	2.23 ± 0.17	HS
Ring Medial Phalange	2.46 ± 0.25	2.22 ± 0.22	HS	2.43 ± 0.21	2.23 ± 0.22	HS
Ring Proximal Phalange	2.44 ± 0.25	2.38 ± 0.24	NS	2.45 ± 0.34	2.35 ± 0.25	NS
Little Distal Phalange	2.27 ± 0.18	2.02 ± 0.19	HS	2.29 ± 0.18	2.03 ± 0.20	HS
Little Medial Phalange	1.78 ± 0.26	1.57 ± 0.19	HS	1.69 ± 0.24	1.55 ± 0.21	S
Little Proximal Phalange	1.90 ± 0.22	1.80 ± 0.20	S	1.90 ± 0.22	1.80 ± 0.20	S

Independent sample the *t*-test with level of significance of 0.05 was used. While HS and S represent highly significant ($P < 0.001$) and significant ($P < 0.05$), respectively, NS refers to no significance difference ($P > 0.05$).

Table 3
Descriptive statistics for the hand (a) and handprint (b) measurements (in cm) in male and female Iban subjects.

Measurements	Male (n = 50)				Female (n = 52)			
	Left		Right		Left		Right	
	Mean ± SD	r	Mean ± SD	r	Mean ± SD	r	Mean ± SD	r
(a) Hand								
Hand Length	18.54 ± 0.99	0.72[S]	18.51 ± 0.94	0.76[S]	17.48 ± 0.80	0.70[S]	17.30 ± 0.82	0.70[S]
Hand Breadth	7.71 ± 0.51	0.59[S]	7.83 ± 0.56	0.49[S]	7.11 ± 0.34	0.27[S]	7.25 ± 0.37	0.28[S]
Thumbs Finger	6.21 ± 0.44	0.43[S]	6.06 ± 0.48	0.51[S]	5.73 ± 0.41	0.39[S]	5.63 ± 0.38	0.43[S]
Index Finger	6.96 ± 0.44	0.53[S]	6.91 ± 0.43	0.57[S]	6.51 ± 0.40	0.61[S]	6.52 ± 0.43	0.63[S]
Middle Finger	7.64 ± 0.47	0.57[S]	7.60 ± 0.49	0.51[S]	7.19 ± 0.42	0.55[S]	7.13 ± 0.41	0.59[S]
Ring Finger	7.16 ± 0.42	0.53[S]	7.09 ± 0.47	0.53[S]	6.61 ± 0.48	0.54[S]	6.66 ± 0.41	0.50[S]
Little Finger	5.77 ± 0.40	0.51[S]	5.73 ± 0.39	0.36[S]	5.30 ± 0.45	0.50[S]	5.30 ± 0.42	0.46[S]
Thumbs Distal Phalange	3.34 ± 0.25	0.54[S]	3.32 ± 0.27	0.64[S]	3.06 ± 0.21	0.28[S]	3.01 ± 0.24	0.40[S]
Thumbs Proximal Phalange	3.20 ± 0.38	0.37[S]	3.08 ± 0.41	0.30	2.98 ± 0.30	0.09	2.89 ± 0.26	0.26
Index Distal Phalange	2.66 ± 0.26	0.30[S]	2.65 ± 0.20	0.47[S]	2.40 ± 0.18	0.32[S]	2.40 ± 0.20	0.43[S]
Index Medial Phalange	2.34 ± 0.22	0.40[S]	2.37 ± 0.32	0.43[S]	2.24 ± 0.21	0.39[S]	2.23 ± 0.20	0.44[S]
Index Proximal Phalange	2.36 ± 0.25	0.36[S]	2.36 ± 0.24	0.43[S]	2.25 ± 0.22	0.42[S]	2.27 ± 0.22	0.51[S]
Middle Distal Phalange	2.72 ± 0.20	0.24	2.71 ± 0.17	0.28	2.47 ± 0.19	0.25	2.45 ± 0.19	0.39[S]
Middle Medial Phalange	2.72 ± 0.27	0.38[S]	2.69 ± 0.27	0.48[S]	2.63 ± 0.21	0.48[S]	2.56 ± 0.20	0.53[S]
Middle Proximal Phalange	2.63 ± 0.24	0.42[S]	2.65 ± 0.23	0.43[S]	2.58 ± 0.22	0.37[S]	2.57 ± 0.20	0.25
Ring Distal Phalange	2.68 ± 0.22	0.17	2.49 ± 0.23	0.42[S]	2.42 ± 0.22	0.26	2.43 ± 0.20	0.37[S]
Ring Medial Phalange	2.58 ± 0.26	0.33[S]	2.33 ± 0.27	0.45[S]	2.39 ± 0.24	0.39[S]	2.41 ± 0.20	0.41[S]
Ring Proximal Phalange	2.38 ± 0.24	0.30[S]	2.34 ± 0.27	0.46[S]	2.30 ± 0.22	0.39[S]	2.32 ± 0.20	0.35[S]
Little Distal Phalange	2.43 ± 0.21	0.35[S]	2.42 ± 0.17	0.48[S]	2.20 ± 0.21	0.30[S]	2.23 ± 0.20	0.46[S]
Little Medial Phalange	1.85 ± 0.24	0.22	1.79 ± 0.21	0.35[S]	1.70 ± 0.20	0.38[S]	1.68 ± 0.19	0.39[S]
Little proximal Phalange	1.86 ± 0.22	0.29[S]	1.89 ± 0.19	0.21	1.77 ± 0.18	0.22	1.80 ± 0.17	0.24

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Table 3 (*continued*)

Measurements	Male (n = 50)				Female (n = 52)			
	Left		Right		Left		Right	
	Mean ± SD	r	Mean ± SD	r	Mean ± SD	r	Mean ± SD	r
(b) Handprint								
Hand Length	17.68 ± 0.89	0.65[S]	17.63 ± 0.89	0.68[S]	16.59 ± 0.73	0.60[S]	16.59 ± 0.85	0.64[S]
Hand Breadth	8.12 ± 0.48	0.38[S]	8.20 ± 0.58	0.52[S]	7.58 ± 0.46	0.19	7.69 ± 0.43	0.37[S]
Thumbs Finger	5.77 ± 0.42	0.29[S]	5.82 ± 0.48	0.60[S]	5.24 ± 0.43	0.29[S]	5.37 ± 0.43	0.42[S]
Index Finger	6.94 ± 0.43	0.58[S]	6.94 ± 0.48	0.54[S]	6.47 ± 0.44	0.52[S]	6.56 ± 0.41	0.59[S]
Middle Finger	7.89 ± 0.52	0.61[S]	7.86 ± 0.51	0.70[S]	7.30 ± 0.42	0.60[S]	7.29 ± 0.44	0.55[S]
Ring Finger	7.38 ± 0.52	0.57[S]	7.32 ± 0.54	0.60[S]	6.81 ± 0.38	0.37[S]	6.82 ± 0.46	0.43[S]
Little Finger	5.94 ± 0.45	0.63[S]	5.88 ± 0.43	0.46[S]	5.38 ± 0.43	0.52[S]	5.39 ± 0.47	0.44[S]
Thumbs Distal Phalange	2.94 ± 0.23	0.15	3.02 ± 0.25	0.38[S]	2.65 ± 0.26	0.29[S]	2.78 ± 0.24	0.26
Thumbs Proximal Phalange	2.82 ± 0.33	0.22	2.81 ± 0.34	0.56[S]	2.63 ± 0.33	0.15	2.57 ± 0.37	0.31[S]
Index Distal Phalange	2.38 ± 0.17	0.30[S]	2.39 ± 0.17	0.35[S]	2.14 ± 0.18	0.36[S]	2.18 ± 0.17	0.22
Index Medial Phalange	2.20 ± 0.23	0.48[S]	2.21 ± 0.24	0.56[S]	2.05 ± 0.22	0.42[S]	2.07 ± 0.23	0.44[S]
Index Proximal Phalange	2.36 ± 0.22	0.40[S]	2.34 ± 0.23	0.28	2.29 ± 0.20	0.35[S]	2.33 ± 0.23	0.45[S]
Middle Distal Phalange	2.51 ± 0.18	0.12	2.47 ± 0.18	0.44[S]	2.24 ± 0.16	0.32[S]	2.24 ± 0.21	0.33[S]
Middle Medial Phalange	2.62 ± 0.30	0.62[S]	2.62 ± 0.27	0.56[S]	2.42 ± 0.23	0.46[S]	2.40 ± 0.20	0.49[S]
Middle Proximal Phalange	2.74 ± 0.23	0.51[S]	2.72 ± 0.30	0.43[S]	2.65 ± 0.21	0.50[S]	2.62 ± 0.23	0.34[S]
Ring Distal Phalange	2.47 ± 0.19	0.33[S]	2.47 ± 0.20	0.45[S]	2.23 ± 0.17	0.17	2.23 ± 0.17	0.26
Ring Medial Phalange	2.46 ± 0.25	0.44[S]	2.43 ± 0.21	0.43[S]	2.22 ± 0.22	0.20	2.23 ± 0.22	0.21
Ring Proximal Phalange	2.44 ± 0.25	0.43[S]	2.45 ± 0.34	0.45[S]	2.38 ± 0.24	0.29[S]	2.35 ± 0.25	0.39[S]
Little Distal Phalange	2.27 ± 0.18	0.43[S]	2.29 ± 0.18	0.39[S]	2.02 ± 0.19	0.49[S]	2.03 ± 0.20	0.30[S]
Little Medial Phalange	1.78 ± 0.26	0.50[S]	1.69 ± 0.24	0.34[S]	1.57 ± 0.19	0.32[S]	1.55 ± 0.21	0.42[S]
Little proximal Phalange	1.90 ± 0.22	0.43[S]	1.90 ± 0.22	0.46[S]	1.80 ± 0.20	0.41[S]	1.80 ± 0.20	0.29[S]

[S]Pearson correlation coefficient is significant at 0.05 level of significance (2-tailed).

3.2. Simple linear regression

The bilateral regression equations obtained for hand and handprint measurements for all the male and female Iban subjects are provided in Tables 6(a – b) and 7 (a – b), respectively. Specifically, the range of SEE for measurements of the left and right hands of female subjects was lower (left hand: 4.36–6.04 cm; right hand: 4.44–5.88 cm) when compared with that of the male subjects (left hand: 5.30–7.50 cm; right hand: 4.97–7.38 cm) (Table 6a–b). Similarly, the female subjects demonstrated lower range of SEE for measurements of handprints (left hand: 4.91–6.00 cm; right hand: 4.67–5.92 cm) than that of the male subjects (left hand: 5.78–7.55 cm; right hand: 5.55–7.30 cm) (Table 7a–b).

3.3. Multiple regression

In an attempt to improve the accuracy of stature prediction using hand and handprint measurements, sex-specific bilateral multiple regression equations obtained using stepwise analysis for both the male and female Iban subjects presented in Table 8(a – b) were evaluated. In general, it was observed that the SEE for hand and handprint measurements ranged between 4.29 and 5.78 cm (Table 8a – b). Similar to the observation for simple linear regression analyses, results of multiple regression analyses also revealed that female Iban subjects had lower SEE for both the measurements of hands (range: 4.29–4.44 cm) (Table 8a) as well as handprint (range: 3.97–4.86) (Table 8b) than that of male Iban subjects. The ranges of SEE for hand and handprint measurements for the male Iban subject were 4.73–5.30 cm and 4.80–5.78 cm, respectively (Table 8a – b).

4. Discussion

While estimation of stature from body parts (e.g. hand) for profiling dismembered unknown human remains during mass disasters has been suggested,[2,19] the use of handprints for identifying suspects during crime investigations may possibly be useful as an early step for human identification.[20,21] Since such anthropological profiling may vary among different populations,[2,15,16,22] while no specific research focusing on the Southeast Asian populations has been reported, assessing the reliability and accuracy of utilizing hand and handprint

Table 4
Comparison in bilateral asymmetry for hand (a) as well as handprint (b) measurements for male and female Iban subjects.

Measurements	Male (n = 50)			Female (n = 52)		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Left	Right		Left	Right	
(a) Hand						
Hand Breadth	7.71 ± 0.51	7.83 ± 0.56	NS	7.11 ± 0.34	7.25 ± 0.37	HS
Thumbs Finger	6.21 ± 0.44	6.06 ± 0.48	HS	5.73 ± 0.41	5.63 ± 0.38	S
Index Finger	6.96 ± 0.44	6.91 ± 0.43	NS	6.51 ± 0.40	6.52 ± 0.43	NS
Middle Finger	7.64 ± 0.47	7.60 ± 0.49	NS	7.19 ± 0.42	7.13 ± 0.41	S
Ring Finger	7.16 ± 0.42	7.09 ± 0.47	S	6.61 ± 0.48	6.66 ± 0.41	NS
Little Finger	5.77 ± 0.40	5.73 ± 0.39	NS	5.30 ± 0.45	5.30 ± 0.42	NS
Thumbs Distal Phalange	3.34 ± 0.25	3.32 ± 0.27	NS	3.06 ± 0.21	3.01 ± 0.24	NS
Thumbs Proximal Phalange	3.20 ± 0.38	3.08 ± 0.41	S	2.98 ± 0.30	2.89 ± 0.26	S
Index Distal Phalange	2.66 ± 0.26	2.65 ± 0.20	NS	2.40 ± 0.18	2.40 ± 0.20	NS
Index Medial Phalange	2.34 ± 0.22	2.37 ± 0.32	NS	2.24 ± 0.21	2.23 ± 0.20	NS
Index Proximal Phalange	2.36 ± 0.25	2.36 ± 0.24	NS	2.25 ± 0.22	2.27 ± 0.22	NS
Middle Distal Phalange	2.72 ± 0.20	2.71 ± 0.17	NS	2.47 ± 0.19	2.45 ± 0.19	NS
Middle Medial Phalange	2.72 ± 0.27	2.69 ± 0.27	NS	2.63 ± 0.21	2.56 ± 0.20	S
Middle Proximal Phalange	2.63 ± 0.24	2.65 ± 0.23	NS	2.58 ± 0.22	2.57 ± 0.20	NS
Ring Distal Phalange	2.68 ± 0.22	2.49 ± 0.23	NS	2.42 ± 0.22	2.43 ± 0.20	NS
Ring Medial Phalange	2.58 ± 0.26	2.33 ± 0.27	S	2.39 ± 0.24	2.41 ± 0.20	NS
Ring Proximal Phalange	2.38 ± 0.24	2.34 ± 0.27	NS	2.30 ± 0.22	2.32 ± 0.20	NS
Little Distal Phalange	2.43 ± 0.21	2.42 ± 0.17	NS	2.20 ± 0.21	2.23 ± 0.20	NS
Little Medial Phalange	1.85 ± 0.24	1.79 ± 0.21	NS	1.70 ± 0.20	1.68 ± 0.19	NS
Little proximal Phalange	1.86 ± 0.22	1.89 ± 0.19	NS	1.77 ± 0.18	1.80 ± 0.17	NS
(b) Handprint						
Hand Length	17.68 ± 0.89	17.63 ± 0.89	NS	16.59 ± 0.73	16.59 ± 0.85	NS
Hand Breadth	8.12 ± 0.48	8.20 ± 0.58	NS	7.58 ± 0.46	7.69 ± 0.43	S
Thumbs Finger	5.77 ± 0.42	5.82 ± 0.48	NS	5.24 ± 0.43	5.37 ± 0.43	NS
Index Finger	6.94 ± 0.43	6.94 ± 0.48	NS	6.47 ± 0.44	6.56 ± 0.41	S
Middle Finger	7.89 ± 0.52	7.86 ± 0.51	NS	7.30 ± 0.42	7.29 ± 0.44	NS
Ring Finger	7.38 ± 0.52	7.32 ± 0.54	NS	6.81 ± 0.38	6.82 ± 0.46	NS
Little Finger	5.94 ± 0.45	5.88 ± 0.43	NS	5.38 ± 0.43	5.39 ± 0.47	NS
Thumbs Distal Phalange	2.94 ± 0.23	3.02 ± 0.25	NS	2.65 ± 0.26	2.78 ± 0.24	S
Thumbs Proximal Phalange	2.82 ± 0.33	2.81 ± 0.34	NS	2.63 ± 0.33	2.57 ± 0.37	NS
Index Distal Phalange	2.38 ± 0.17	2.39 ± 0.17	NS	2.14 ± 0.18	2.18 ± 0.17	S
Index Medial Phalange	2.20 ± 0.23	2.21 ± 0.24	NS	2.05 ± 0.22	2.07 ± 0.23	NS
Index Proximal Phalange	2.36 ± 0.22	2.34 ± 0.23	NS	2.29 ± 0.20	2.33 ± 0.23	NS
Middle Distal Phalange	2.51 ± 0.18	2.47 ± 0.18	NS	2.24 ± 0.16	2.24 ± 0.21	NS
Middle Medial Phalange	2.62 ± 0.30	2.62 ± 0.27	NS	2.42 ± 0.23	2.40 ± 0.20	NS
Middle Proximal Phalange	2.74 ± 0.23	2.72 ± 0.30	NS	2.65 ± 0.21	2.62 ± 0.23	NS
Ring Distal Phalange	2.47 ± 0.19	2.47 ± 0.20	NS	2.23 ± 0.17	2.23 ± 0.17	NS
Ring Medial Phalange	2.46 ± 0.25	2.43 ± 0.21	NS	2.22 ± 0.22	2.23 ± 0.22	NS
Ring Proximal Phalange	2.44 ± 0.25	2.45 ± 0.34	NS	2.38 ± 0.24	2.35 ± 0.25	NS

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Table 4 (*continued*)

Measurements	Male (n = 50)			Female (n = 52)		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Left	Right		Left	Right	
Little Distal Phalange	2.27 ± 0.18	2.29 ± 0.18	NS	2.02 ± 0.19	2.03 ± 0.20	NS
Little Medial Phalange	1.78 ± 0.26	1.69 ± 0.24	S	1.57 ± 0.19	1.55 ± 0.21	NS
Little proximal Phalange	1.90 ± 0.22	1.90 ± 0.22	NS	1.80 ± 0.20	1.80 ± 0.20	NS

Paired sample the *t*-test with level of significance of 0.05 was used. While HS and S represent highly significant ($P < 0.001$) and significant ($P < 0.05$), respectively, NS refers to no significance difference ($P > 0.05$).

Table 5
Comparison of hand and handprints measurement for male (a) and female (b) Iban subjects.

Hand Measurements	Left			Right		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Hand	Handprint		Hand	Handprint	
(a) Male subjects (n = 50)						
Hand Length	18.54 ± 0.99	17.68 ± 0.89	HS	18.51 ± 0.94	17.63 ± 0.89	HS
Hand Breadth	7.71 ± 0.51	8.12 ± 0.48	HS	7.83 ± 0.56	8.20 ± 0.58	HS
Thumbs Finger	6.21 ± 0.44	5.77 ± 0.42	HS	6.06 ± 0.48	5.82 ± 0.48	HS
Index Finger	6.96 ± 0.44	6.94 ± 0.43	NS	6.91 ± 0.43	6.94 ± 0.48	NS
Middle Finger	7.64 ± 0.47	7.89 ± 0.52	HS	7.60 ± 0.49	7.86 ± 0.51	HS
Ring Finger	7.16 ± 0.42	7.38 ± 0.52	HS	7.09 ± 0.47	7.32 ± 0.54	HS
Little Finger	5.77 ± 0.40	5.94 ± 0.45	HS	5.73 ± 0.39	5.88 ± 0.43	S
Thumbs Distal Phalange	3.34 ± 0.25	2.94 ± 0.23	HS	3.32 ± 0.27	3.02 ± 0.25	HS
Thumbs Proximal Phalange	3.20 ± 0.38	2.82 ± 0.33	HS	3.08 ± 0.41	2.81 ± 0.34	HS
Index Distal Phalange	2.66 ± 0.26	2.38 ± 0.17	HS	2.65 ± 0.20	2.39 ± 0.17	HS
Index Medial Phalange	2.34 ± 0.22	2.20 ± 0.23	HS	2.37 ± 0.32	2.21 ± 0.24	HS
Index Proximal Phalange	2.36 ± 0.25	2.36 ± 0.22	NS	2.36 ± 0.24	2.34 ± 0.23	NS
Middle Distal Phalange	2.72 ± 0.20	2.51 ± 0.18	HS	2.71 ± 0.17	2.47 ± 0.18	HS
Middle Medial Phalange	2.72 ± 0.27	2.62 ± 0.30	S	2.69 ± 0.27	2.62 ± 0.27	S
Middle Proximal Phalange	2.63 ± 0.24	2.74 ± 0.23	S	2.65 ± 0.23	2.72 ± 0.30	NS
Ring Distal Phalange	2.68 ± 0.22	2.47 ± 0.19	HS	2.49 ± 0.23	2.47 ± 0.20	HS
Ring Medial Phalange	2.58 ± 0.26	2.46 ± 0.25	HS	2.33 ± 0.27	2.43 ± 0.21	NS
Ring Proximal Phalange	2.38 ± 0.24	2.44 ± 0.25	NS	2.34 ± 0.27	2.45 ± 0.34	S
Little Distal Phalange	2.43 ± 0.21	2.27 ± 0.18	HS	2.42 ± 0.17	2.29 ± 0.18	HS
Little Medial Phalange	1.85 ± 0.24	1.78 ± 0.26	NS	1.79 ± 0.21	1.69 ± 0.24	S
Little Proximal Phalange	1.86 ± 0.22	1.90 ± 0.22	NS	1.89 ± 0.19	1.90 ± 0.22	NS
(b) Female subjects (n = 52)						
Hand Length	17.48 ± 0.80	16.59 ± 0.73	HS	17.30 ± 0.82	16.59 ± 0.85	HS
Hand Breadth	7.11 ± 0.34	7.58 ± 0.46	HS	7.25 ± 0.37	7.69 ± 0.43	HS
Thumbs Finger	5.73 ± 0.41	5.24 ± 0.43	HS	5.63 ± 0.38	5.37 ± 0.43	HS
Index Finger	6.51 ± 0.40	6.47 ± 0.44	NS	6.52 ± 0.43	6.56 ± 0.41	NS
Middle Finger	7.19 ± 0.42	7.30 ± 0.42	HS	7.13 ± 0.41	7.29 ± 0.44	HS
Ring Finger	6.61 ± 0.48	6.81 ± 0.38	HS	6.66 ± 0.41	6.82 ± 0.46	HS
Little Finger	5.30 ± 0.45	5.38 ± 0.43	S	5.30 ± 0.42	5.39 ± 0.47	S
Thumbs Distal Phalange	3.06 ± 0.21	2.65 ± 0.26	HS	3.01 ± 0.24	2.78 ± 0.24	HS
Thumbs Proximal Phalange	2.98 ± 0.30	2.63 ± 0.33	HS	2.89 ± 0.26	2.57 ± 0.37	HS

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Table 5 (*continued*)

Hand Measurements	Left			Right		
	Mean ± SD		Statistical significance	Mean ± SD		Statistical significance
	Hand	Handprint		Hand	Handprint	
Index Distal Phalange	2.40 ± 0.18	2.14 ± 0.18	HS	2.40 ± 0.20	2.18 ± 0.17	HS
Index Medial Phalange	2.24 ± 0.21	2.05 ± 0.22	HS	2.23 ± 0.20	2.07 ± 0.23	HS
Index Proximal Phalange	2.25 ± 0.22	2.29 ± 0.20	NS	2.27 ± 0.22	2.33 ± 0.23	S
Middle Distal Phalange	2.47 ± 0.19	2.24 ± 0.16	HS	2.45 ± 0.19	2.24 ± 0.21	HS
Middle Medial Phalange	2.63 ± 0.21	2.42 ± 0.23	HS	2.56 ± 0.20	2.40 ± 0.20	HS
Middle Proximal Phalange	2.58 ± 0.22	2.65 ± 0.21	S	2.57 ± 0.20	2.62 ± 0.23	NS
Ring Distal Phalange	2.42 ± 0.22	2.23 ± 0.17	HS	2.43 ± 0.20	2.23 ± 0.17	HS
Ring Medial Phalange	2.39 ± 0.24	2.22 ± 0.22	HS	2.41 ± 0.20	2.23 ± 0.22	HS
Ring Proximal Phalange	2.30 ± 0.22	2.38 ± 0.24	S	2.32 ± 0.20	2.35 ± 0.25	NS
Little Distal Phalange	2.20 ± 0.21	2.02 ± 0.19	HS	2.23 ± 0.20	2.03 ± 0.20	HS
Little Medial Phalange	1.70 ± 0.20	1.57 ± 0.19	HS	1.68 ± 0.19	1.55 ± 0.21	HS
Little Proximal Phalange	1.77 ± 0.18	1.80 ± 0.20	NS	1.80 ± 0.17	1.80 ± 0.20	NS

Paired sample the *t*-test with level of significance of 0.05 was used. While HS and S represent highly significant ($P < 0.001$) and significant ($P < 0.05$), respectively, NS refers to no significance difference ($P > 0.05$).

measurements for estimating stature for such populations becomes forensically pertinent. In view of such application, the use of simple linear and multiple regressions for suggesting suitable mathematical equations has been proposed, taking into account the values of SEE as a means for assigning the accuracy of such equations. Considering that Iban is one of the major ethnic groups in the East Malaysia and the fact that the data on utilization of hand and handprint measurements for estimating stature remain lacking in this country, the purpose of this present research appears justifiable.

It was observed that male subjects had significantly higher stature as well as hand dimensions when compared with that of the female subjects. Similar observations have also been indicated among the different populations,[2,11,14–16,22] attributable to factors such as genetic[11] and age of puberty.[10] Such a finding necessitates the need for having sex-specific algorithms for estimating stature. In view of bilateral asymmetry, previous studies have reported about significant differences in measurements between the left and right hands[2,10,11] as well as handprints[2] in male and female subjects among various populations However, statistical comparison between the measurements of hands with that of corresponding handprints for estimating stature has not been reported so far. Consistent with the findings reported by the previous studies, significant differences in several measurements of the left and right hands as well as handprints in the male and female Iban subjects were also observed in this present research. Moreover, significant differences in several measurements between hands and the corresponding handprints also prevailed. The significant differences observed in measurements of the left and right hands as well as handprints may partially be due to the handedness of the subjects.[11]

For suggesting a credible mathematical equation, the strength of correlation coefficient must be at least high ($r > 0.69$).[18] The simple linear regression analysis revealed that hand length was highly correlated (r: 0.70–0.76) with that of stature, indicating the reliability of such anthropometric trait for estimating stature in both the male and female Iban subjects. While moderate correlation coefficient was observed between the handprint lengths and stature (r: 0.60–0.68), the correlation coefficients for other traits of hand and handprint with that of stature remained little – low (r: 0.08–0.24). In this context it is pertinent to indicate that review of literature reveals no similar studies ever reported for the different populations within Malaysia as well as from the surrounding Southeast Asian countries, rendering difficulties in making suitable comparisons. However, the finding reported here was found to be in agreement with anthropological data reported for the Northern and Southern Indian,[10] Australian,[2] Egyptian,[20] Slovakian,[22] Korean[16] and Chinese[15] populations. Interestingly, results of this research on simple linear regression further revealed that the values of SEE for the lengths of hands (4.36–4.44 cm) and handprints (4.67–4.91 cm) were lower among the female than that of the male subjects (hand: 4.97–5.30 cm; handprint: 5.50–5.78 cm), suggesting better degree of prediction accuracy in estimating the stature following the use of such anthropometric traits among the female subjects. Although similar observation (i.e. lower SEE values in female subjects) among different populations has been indicated in literature,[10,13] suitable explanation for that phenomenon has yet to be offered.

In concordance with the simple linear regression analysis, the SEE values of the multiple regression analysis for hand (4.29–4.44 cm) and handprint (3.97–4.86 cm) measurements were lower among the females than that of the male subjects (hand: 4.73–5.30 cm; handprint: 4.80–5.78 cm). Hence, the data obtained in this research supported the use of multiple stepwise regression analysis for improving the prediction accuracy for estimating stature from hand and handprint measurements for both the male and female Iban subjects. Such findings were consistent with the findings reported by previous researchers.[2,3,10,11,13,15,16,20,22,23]

Table 6
Linear regression formulae with standard error of the estimate (SEE) for estimating stature (in cm) from measurements of left (a) and right (b) hands of Iban subjects.

Male (n = 50)			Female (n = 52)		
Equation	SEE	r	Equation	SEE	r
(a) Left hand					
S = 5.469HL + 58.899	5.30	0.72	S = 5.242HL + 59.533	4.36	0.70
S = 8.720HB + 93.030	6.13	0.59	S = 4.775HB + 117.244	5.83	0.27
S = 7.384A + 114.360	6.86	0.43	S = 5.697A + 118.510	5.59	0.39
S = 9.031B + 97.470	6.44	0.53	S = 9.048B + 92.247	4.82	0.61
S = 9.193C + 90.049	6.23	0.57	S = 7.896C + 94.377	5.06	0.55
S = 9.399D + 92.984	6.46	0.53	S = 6.768D = 106.460	5.11	0.54
S = 9.556E + 105.148	6.55	0.51	S = 6.677E + 115.749	5.24	0.50
S = 16.013A1 + 106.796	6.39	0.54	S = 7.925A1 + 126.938	5.81	0.28
S = 7.408A3 + 136.603	7.05	0.37	S = 1.727A3 + 146.031	6.04	0.09
S = 8.705B1 + 137.109	7.25	0.30	S = 10.658B1 + 125.617	5.74	0.32
S = 13.399B2 + 128.974	6.97	0.40	S = 11.309B2 + 125.819	5.58	0.39
S = 10.755B3 + 134.942	7.11	0.36	S = 11.490B3 + 125.347	5.50	0.42
S = 8.986C1 + 135.807	7.38	0.24	S = 7.807C1 + 131.919	5.86	0.25
S = 10.708C2 + 131.185	7.03	0.38	S = 13.679C2 + 115.186	5.30	0.48
S = 13.082C3 + 125.805	6.91	0.42	S = 10.126C3 + 125.066	5.63	0.37
S = 5.850D1 + 144.606	7.49	0.17	S = 7.102D1 + 133.952	5.86	0.26
S = 10.572D2 + 132.984	7.17	0.33	S = 9.688D2 + 128.020	5.58	0.39
S = 9.191D3 + 138.370	7.26	0.30	S = 10.456D3 + 127.145	5.58	0.39
S = 12.600E1 + 129.671	7.12	0.35	S = 8.703E1 + 131.996	5.77	0.30
S = 6.910E2 + 147.475	7.41	0.22	S = 11.100E2 + 132.292	5.61	0.38
S = 9.850E3 + 141.924	7.27	0.29	S = 7.471E3 + 137.971	5.91	0.22
(b) Right hand					
S = 6.030HL + 48.653	4.97	0.76	S = 4.955HL + 65.455	4.44	0.68
S = 6.537HB + 109.125	6.64	0.49	S = 4.529HB + 118.313	5.82	0.28
S = 8.053A + 111.448	6.53	0.51	S = 6.815A + 112.771	5.47	0.43
S = 10.127B + 90.288	6.23	0.57	S = 8.894B + 93.192	4.70	0.63
S = 7.939C + 99.960	6.52	0.51	S = 8.592C + 89.945	4.88	0.59
S = 8.390D + 100.794	6.46	0.53	S = 7.333D + 102.302	5.25	0.50
S = 6.858E + 120.979	7.11	0.36	S = 6.578E + 116.286	5.38	0.46
S = 17.932A1 + 100.754	5.87	0.64	S = 10.153A1 + 120.621	5.54	0.40
S = 4.361A3 + 146.818	7.38	0.24	S = 5.967A3 + 133.940	5.85	0.26
S = 17.882B1 + 112.869	6.69	0.47	S = 13.033B1 + 119.919	5.48	0.43
S = 10.208B2 + 136.105	6.86	0.43	S = 12.917B2 + 122.307	5.46	0.44
S = 13.137B3 + 129.282	6.88	0.43	S = 14.255B3 + 118.824	5.21	0.51
S = 11.889C1 + 128.037	7.31	0.28	S = 12.039C1 + 121.674	5.58	0.39
S = 13.601C2 + 123.633	6.67	0.48	S = 15.796C2 + 110.705	5.13	0.53
S = 13.814C3 + 123.659	6.88	0.43	S = 7.302C3 + 132.371	5.87	0.25
S = 18.169D1 + 111.443	6.88	0.42	S = 11.089D1 + 124.132	5.62	0.37
S = 14.607D2 + 123.948	6.78	0.45	S = 12.546D2 + 120.994	5.52	0.41
S = 12.734D3 + 130.487	6.75	0.46	S = 10.451D3 + 126.911	5.68	0.35
S = 21.793E1 + 107.530	6.67	0.48	S = 13.996E1 + 119.994	5.38	0.46
S = 12.490E2 + 137.988	7.11	0.35	S = 12.369E2 + 130.386	5.58	0.39
S = 7.958E3 + 145.269	7.44	0.21	S = 8.404E3 + 136.065	5.88	0.24

Table 7
Linear regression formulae with standard error of the estimate (SEE) for estimating stature (in cm) from measurements of left (a) and right (b) handprints of Iban subjects.

Male (n = 50)			Female (n = 52)		
Equation	SEE	r	Equation	SEE	r
(a) Left hand					
S = 5.506HLP + 62.953	5.78	0.65	S = 4.828HLP + 71.074	4.91	0.59
S = 5.997HBP + 111.585	7.02	0.38	S = 2.452HBP + 132.573	5.95	0.19
S = 5.153AP + 130.570	7.28	0.29	S = 3.980AP + 130.299	5.81	0.29
S = 10.059BP + 90.450	6.19	0.58	S = 7.130BP + 105.073	5.16	0.52
S = 8.800CP + 90.888	6.03	0.61	S = 8.454CP + 89.424	4.86	0.60
S = 8.517DP + 97.459	6.25	0.57	S = 5.766DP + 111.914	5.64	0.37
S = 10.501EP + 97.886	5.92	0.63	S = 7.215EP + 112.322	5.19	0.52
S = 4.998A1P + 145.598	7.51	0.15	S = 6.563A1P + 133.801	5.80	0.29
S = 5.167A3P + 145.732	7.41	0.23	S = 2.699A3P + 144.070	5.99	0.15
S = 12.858B1P + 129.628	7.26	0.30	S = 12.189B1P + 125.103	5.66	0.36
S = 15.977B2P + 125.165	6.65	0.48	S = 11.594B2P + 127.402	5.49	0.42
S = 13.843B3P + 127.668	6.97	0.40	S = 10.414B3P + 127.297	5.68	0.35
S = 4.959C1P + 147.844	7.55	0.12	S = 11.898C1P + 124.490	5.74	0.32
S = 15.711C2P + 119.087	5.97	0.62	S = 12.061C2P + 121.945	5.40	0.46
S = 16.332C3P + 16.332	6.55	0.51	S = 14.324C3P + 113.156	5.25	0.50
S = 13.068D1P + 128.031	7.19	0.33	S = 6.080D1P + 137.616	5.97	0.17
S = 13.586D2P + 126.832	6.81	0.44	S = 5.450D2P + 139.053	5.94	0.20
S = 12.975D3P + 128.597	6.86	0.43	S = 7.197D3P + 134.049	5.80	0.29
S = 17.472E1P + 120.551	6.87	0.43	S = 15.877E1P + 119.110	5.28	0.49
S = 14.062E2P + 135.252	6.60	0.50	S = 10.128E2P + 135.256	5.75	0.32
S = 14.408E3P + 132.849	6.87	0.43	S = 12.215E3P + 12.215	5.53	0.41
(b) Right hand					
S = 5.809HLP + 57.873	5.55	0.68	S = 4.506HLP + 76.392	4.67	0.64
S = 6.735HBP + 105.014	6.50	0.52	S = 5.219HBP + 111.039	5.62	0.37
S = 9.319AP + 106.048	6.08	0.60	S = 5.623AP + 120.966	5.54	0.41
S = 9.391BP + 95.128	6.38	0.54	S = 8.734BP + 93.863	4.88	0.59
S = 10.301CP + 79.359	5.42	0.70	S = 7.556CP + 96.055	5.06	0.55
S = 8.300DP + 99.543	6.09	0.60	S = 5.638DP + 112.701	5.46	0.43
S = 8.020EP + 113.125	6.74	0.46	S = 5.711EP + 120.393	5.44	0.44
S = 11.610A1P + 125.196	7.02	0.38	S = 6.357A1P + 133.383	5.86	0.26
S = 12.213A3P + 125.988	6.32	0.56	S = 4.988A3P + 138.335	5.77	0.31
S = 15.288B1P + 123.774	7.14	0.35	S = 7.779B1P + 134.234	5.91	0.22
S = 17.996B2P + 120.474	6.28	0.56	S = 11.638B2P + 127.132	5.44	0.44
S = 8.915B3P + 139.402	7.30	0.28	S = 11.814B3P + 123.588	5.40	0.45
S = 18.294C1P + 115.133	6.82	0.44	S = 9.599C1P + 129.627	5.72	0.33
S = 15.965C2P + 118.518	6.28	0.56	S = 14.783C2P + 115.690	5.30	0.49
S = 10.845C3P + 130.806	6.85	0.43	S = 8.592C3P + 128.631	5.71	0.34
S = 16.745D1P + 118.855	6.79	0.45	S = 9.491D1P + 129.998	5.85	0.26
S = 15.491D2P + 122.576	6.85	0.43	S = 5.755D2P + 138.342	5.92	0.21
S = 10.176D3P + 135.391	6.78	0.45	S = 9.251D3P + 129.412	5.58	0.39
S = 16.210E1P + 123.226	6.99	0.39	S = 8.741E1P + 133.385	5.79	0.30
S = 10.403E2P + 142.701	7.16	0.34	S = 11.842E2P + 132.814	5.51	0.42
S = 15.812E3P + 130.207	6.74	0.46	S = 8.755E3P + 135.410	5.81	0.29

5. Conclusion

In conclusion, the lengths of hand and handprint may prove to be reliable anthropometric traits for estimating the stature of male and female Iban subjects in Malaysia. The empirical data reported in this research would pave the way to the application of forensic anthropology in estimating stature of individuals using dismembered organ (i.e. hands) during mass disasters and handprints during crime scene investigation in Malaysia, as well as in the neighbouring Southeast Asian countries. Considering the ethnic diversities, investigation on the trustworthiness of using anthropometric measurements of hand and handprint covering different populations within the Southeast Asian countries should form an interesting and forensically important study.

6. Limitations

It has been indicated that after the age of 30, neck is prone to shorten, and the shortening of the intervertebral space may be shorter during later age.[24] Although no specific study about hand and handprint dimensions that changed with age has been reported, the fact this present study was aimed at using them as means for estimating stature, its use for older adults as well as elderly people must be made with care. In addition, since specific means for identifying gender and ethnicity from handprints are yet to be established, further exacerbated by mixed marriages, specific studies in these aspects would prove necessary for realizing its real potential in forensic investigations.

Table 8
Multiple regression formulae with standard error of the estimate (SEE) for estimating stature (in cm) from measurements of hands (a) and handprints (b) of Iban subjects.

Male (n = 50)			Female (n = 52)		
Equation	SEE	r	Equation	SEE	r
(a) Hand					
Left					
S = 58.899 + 5.469HL	5.30	0.72	S = 59.533 + 5.242HL	4.36	0.70
S = 50.247 + 4.299HL + 3.934HB	5.08	0.75			
Right					
S = 48.653 + 6.030HL	4.97	0.76	S = 65.455 + 4.955HL	4.44	0.68
S = 51.742 + 7.653HL + (−5.783) E	4.73	0.79	S = 64.691 + 4.118HL + 6.718B3	4.29	0.71
(b) Handprint					
Left					
S = 62.953 + 5.506HLP	5.78	0.65	S = 89.424 + 8.454C	4.86	0.60
S = 73.901 + 3.622HLP + 8.524C2P	5.51	0.97			
Right					
S = 79.359 + 10.301C	5.42	0.70	S = 76.392 + 4.506HL	4.67	0.64
S = 58.926 + 8.703C + 4.020HB	5.00	0.76	S = 71.995 + 3.912HL + 6.901B2	4.46	0.68
S = 59.775 + 7.201C + 3.556HB + 5.253A3	4.80	0.79	S = 68.617 + 4.965HL + 12.107B2 + (−11.148) D2	4.10	0.75
			S = 64.888 + 4.617HL + 9.416B2 + (−12.953) D2 + 7.953C2	3.97	0.77

Stepwise multiple regression analysis was used.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

We are thankful to the Universiti Teknologi Malaysia for providing Research University Grants (Q.J130000.2526.12H51 and Q.J130000.2526.16H92) for conducting this research project. Assistance provided by all the heads (Penghulu and Tuai Rumah) as well as members of long houses in Sarawak that participated in this research project is greatly appreciated.

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