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Original article

Body Weight Determination from Foot Outline Length among the Iban Population in Malaysia

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Abstract

Foot impression measurements provide valuable information in estimating stature, weight, gender and age in crime scene investigation. In Asian countries, many people living in rural places walk without footwear. The aim of this research was to generate regression equations to estimate living body weight from foot outline length among the Iban population of Malaysia.

The study included 200 (100 males and 100 females) adult Ibans, mostly living in Sarawak, a state in Malaysia. Following the standard procedure, the foot outlines were collected followed by body weight measurements. The collected data were analysed with PASW 20 computer software. The correlation coefficient (R) between the foot outline lengths and body weight was determined for males, females and a pooled sample.

Based on the foot outline and body weight, 30 regression equations were generated, 10 for males, 10 for females and 10 for pooled samples/unknown gender. The correlation coefficient (R) values were positive and statistically significant.

It is concluded that the present investigations provided regression equations to determine body weight from foot outline anthropometry. These equations can be used to determine body weight even when partial foot impressions are available at crime scenes.

Keywords: Forensic Sciences, Body Weight, Foot Outline, Iban Population, Malaysia

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تحديد وزن الجسم من قياس طبعة القدم الأنثروبومترية بين سكان ايبان الماليزيين

المستخلص

تشكل انطباعات القدم دليلاً مادياً قيماً لحل الجريمة. وقد قدمت قياسات انطباع القدم معلومات قيمة في تقدير طول القامة والوزن

والجنس والعمر خلال التحقيق في مسرح الجريمة. ويمشي كثير من الناس في البلدان الآسيوية وخصوصاً الذين يعيشون في المناطق الريفية دون ارتداء الأحذية. وخلص الباحثون إلى أن انطباعات القدم يمكن أن توفر معلومات أكثر من بصمات الأصابع. والهدف من هذا البحث هو صياغة معادلات انحدار لتحديد وزن جسم الانسان الحي من خلال قياس طبعة القدم البشرية بين السكان في ايبان الماليزية.

وشملت الدراسة 200 شخص بالغ (100 من الذكور، 100 من الإناث) من سكان منطقة ايبان وافقوا على المشاركة في الدراسة، ومعظمهم يعيشون في ولاية ساراواك في ماليزيا. وبعد تحضير الإجراءات المعيارية، تم جمع طبعة القدم وتلاها قياس أوزن الجسم وتم تسجيلها بغرض عمل التحليل الرياضي للبيانات. وتم تحليل البيانات التي جمعت بواسطة برنامج الكمبيوتر المسمى باسو 20 (PASO 20). وحُدِّد معامل الارتباط (R) بين أطوال طبعات القدم ووزن الجسم للذكور والإناث وكذلك العينة المجموعة كلها.

وبناء على طبعة القدم ووزن الجسم الانثروبومتري بين سكان منطقة ايبان، تم صياغة 30 معادلة للانحدار منها 10 للذكور، و10 للإناث و10 للعينات المجموعة كلها حيث لم يحدد فيها جنس المشارك. كانت قيم معامل الارتباط (R) إيجابية وذات دلالة إحصائية.

وخلصت الدراسة إلى أن هذه البحث قد قدم صيغة لمعادلة الانحدار التي تحدد وزن الجسم من خلال طبعة القدم الانتروبومترية. ويمكن استخدام هذه المعادلات لتحديد وزن الجسم حتى لطبعات القدم الجزئية المتاحة في مسارح الجريمة.

الكلمات المفتاحية: علوم الأدلة الجنائية، وزن الجسم، طبعة القدم، سكان منطقة إيبان، ماليزيا

1. Introduction

During crime scene investigation, the field criminalist is searching for physical evidence for the purpose of identification. Physical evidence needs to express individual characteristics. In any crime scene investigation, it is important to establish a link between the accused and his/her crime involvement scientifically. Individual identification is mandatory in crime scenes such as burglary, murder, rape and assault. Researchers indicated that footprints can be used for identification like fingerprints [1]. Very detailed analysis of footprint impressions can provide useful information to establish personal identity and facilitate the crime investigation [2]. Forensic anthropologists are showing interest in footprint studies [3]. It is an established fact that there is a relationship between each part of the body and the whole body [4]. In Asian countries, some people in rural areas still walk without footwear [5]. Crime investigators are locating and collecting foot impressions found at crime scenes because sometimes the offenders avoid the use of footwear [6]. Generally, footprints (2D) are found on hard surfaces and foot outlines (3D) are left on soft surfaces [7]. Footprints can be recorded by using an ink or inkless footprint kit, while foot outlines are obtained by tracing the outline of the foot [8]. Analysis of footprints [9-12], foot outlines [7, 12-14] and feet [10, 15-17] are useful in determining stature during crime investigation. The literature review did not show a significant number of studies in living body weight determination from foot impressions [8,18-19]. Racial and ethnic aspects should be taken into account while conducting anthropological studies relating to body weight and foot impressions [20]. Hence, we are aiming to generate formulae to determine living body weight from the foot outline (3D) lengths in 200 (100 males and 100 females) adult Ibans, mostly living in the state of Sarawak in Malaysia.

2. Materials and Methods

2.1 Study area

The study was conducted in Sarawak, a state in east Malaysia as shown in Figure-1. The subjects were from colleges, universities and the general public. The Ibans are an indigenous population mostly living in this state. They were originally farmers and hunters.

Before starting the study, permission was obtained from the Sarawak state Chief Minister vide No. JKM.P/DEV/16/005/12 (44), for sample collection. Informed consent was also obtained from all participants and procedures were followed in accordance with the ethical standards of Universiti Sains Malaysia Human Research Ethic Committee (Ethical approval No. USMKK/ PPP/JEMPeM [247.4.(2.12]/Amend (01) dated 8th April 2012 of USM).

2.2 Sample collection

The study involved 200 Ibans with an equal number of males and females aged between 18 and 64 years old. Subjects with medical conditions like Pes Cavus, Pes Planus, onychocryptosis, RA, DM, any apparent foot-related disease, and pregnancy were excluded from the study. The weight of the subjects was collected by using a digital weighing scale at a fixed time in the evening to avoid weight changes [21].The foot outline was drawn using a sharp pencil by placing the foot on an A4 size white paper and marking the land marks, namely pternion (P) and toe (OT2) end [13-14]. An illustrative example of land marks on the left and right foot outline are presented in Figure-2.

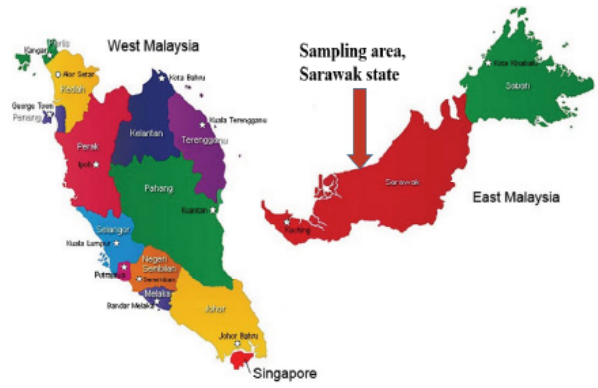

Figure 1- *Map of Malaysia showing the sampling area, Sarawak state, east Malaysia.*

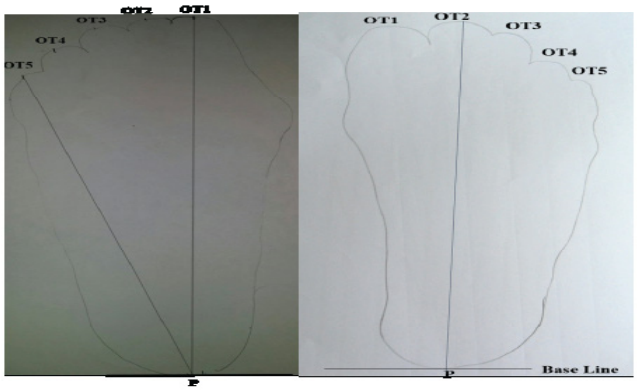

Figure 2- *Illustrative example showing the pternion (P) to the most anterior point of first and fifth toe (OT1 & OT5) on left and second toe (OT2) on right foot outline.*

Table 1- *Descriptive statistics of body weight in adult males, females and pooled sample of Ibans of east Malaysia.*

Variables	Male (n = 100)				Female (n = 100)				Pooled sample (n = 200)			
	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
Weight (kg)	40.0	66.0	55.6	6.1	44.1	64.6	52.2	5.7	40.0	66.0	53.9	6.1

Min, minimum; Max, maximum; n, sample size; S.D., Standard Deviation

The length measurements were taken using a ruler to avoid inter-observer error.

2.3 Statistical analysis

The collected data were analyzed using PASW Statistics version 20 (Predictive Analytic Software). Pearson's correlation coefficient (R) between various foot outline lengths and body weight was obtained. The linear regression analysis method was employed to derive regression equations to determine living body weight from various foot outline length measurements.

3. Results

Table-1 presents the descriptive statistics of body weights in males, females and a pooled sample (combined male and female subjects) among the Iban population. It is shown that the mean living body weight is comparatively higher (55.6 kg) in males than females (52.2 kg).

Table-2 recorded the various diagonal foot outline lengths between pternion and toe ends on both sides in the population. The male and female samples are put together to form a pooled sample (n = 200) in addition to separate males and females. Mostly, the gender of the foot impres-

Table 2- *Descriptive statistics of foot outline length measurements (cm) in males, females and pooled sample of adult Ibans of east Malaysia.*

Variable	Male (n = 100)				Female (n = 100)				Pooled sample (n = 200)			
	Min	Max	mean	S.D	Min	Max	mean	S.D.	Min	Max	mean	S.D.
LPOT1	21.3	27.2	24.41	1.1	20.0	25.3	22.71	0.9	20	27.2	23.56	1.3
LPOT2	20.6	26.4	24.19	1.1	19.9	24.8	22.43	1.0	19.9	26.4	23.31	1.4
LPOT3	19.9	26.1	23.33	1.1	19.1	24.1	21.64	1.0	19.1	26.1	22.49	1.4
LPOT4	18.9	25.0	22.16	1.1	18.2	23.0	20.60	1.0	18.2	25.0	21.38	1.3
LPOT5	17.8	23.5	20.61	1.0	17.0	21.1	19.09	0.9	17.0	23.5	19.85	1.2
RPOT1	20.8	26.9	24.49	1.1	21.1	25.5	22.82	0.9	20.8	26.9	23.65	1.3
RPOT2	21.0	26.4	24.19	1.1	20.3	25.1	22.49	1.0	20.3	26.4	23.34	1.3
RPOT3	19.9	26.0	23.29	1.1	19.7	24.3	21.65	1.0	19.7	26.0	22.47	1.3
RPOT4	18.9	25.2	22.10	1.1	18.8	23.0	20.56	0.9	18.8	25.2	21.33	1.3
RPOT5	17.8	23.4	20.49	1.0	17.5	21.5	19.02	0.9	17.5	23.4	19.76	1.2

Min, minimum; Max, maximum; LPOT1 to LPOT5, left foot outline lengths from anterior part of toes OT1- OT5 to mid-rear heel point P; RPOT1 to RPOT5, right foot outline lengths from anterior point of toes OT1-OT5 to mid-real heel point P; S.D., Standard Deviation; n, sample size.

Table 3- *Linear regression equations for body weight estimation from various foot outline length measurements (cm) on left and right sides among adult Iban males of east Malaysia.*

Variables	Regression Equations	SEE	R	ANOVA
LPOT1	34.846 + 0.851POT1	6.092	0.150	2.255(1, 98) ; $p = 0.136$
LPOT2	30.062 + 1.057POT2	6.046	0.193	3.779(1, 98) ; $p = 0.055$
LPOT3	25.604 + 1.287POT3	5.992	0.233	5.622(1, 98) ; $p = 0.020$
LPOT4	26.625 + 1.309POT4	5.994	0.231	5.546(1, 98) ; $p = 0.021$
LPOT5	34.950 +1.003POT5	6.079	0.163	2.664(1, 98) ; $p = 0.106$
RPOT1	36.771 + 0.770POT1	6.103	0.137	1.881(1, 98) ; $p = 0.173$
RPOT2	30.938 + 1.020PORT2	6.059	0.181	3.337(1, 98) ; $p = 0.071$
RPOT3	27.163 + 1.222PORT3	6.006	0.223	5.128(1, 98) ; $p = 0.026$
RPOT4	25.598 + 1.359PORT4	5.982	0.240	5.976(1, 98) ; $p = 0.016$
RPOT5	30.699 + 1.216PORT5	6.042	0.196	3.922(1, 98) ; $p = 0.050$

LPOT1 to LPOT5, left foot outline lengths from anterior part of toes OT1- OT5 to mid-rear heel point P; RPOT1 to RPOT5, right foot outline lengths from anterior point of toes OT1-OT5 to mid-rear heel point P; SEE, standard error of estimate; R, correlation coefficient.

sion at crime scene is unknown and hence pooled sample measurements are used to derive formulae to determine living body weight from foot outlines of unknown gender. The length measurements reflect the gender variation and asymmetry in size.

Tables-3, 4 and 5 depict the linear regression equations to determine living body weight in both sexes and the combined/pooled sample of adult Ibans from foot outline lengths along with ANOVA. The error of estimate (SEE) among females was (5.541-5.611), reflecting the lower value when compared to males (5.982-6.092) and pooled samples (5.786-5.883). The correlation coefficient (R) values are statistically significant (<0.001). The pooled sample R show a higher value (0.294-0.341) than males (0.137-0.240) and females (0.182-0.238) separately.

4. Discussion

The demographics of Malaysia are represented by multiple ethnic groups that exist in this country [22]. The Ibans are the largest of Sarawak's ethnic groups. Most of the Ibans are involved in agriculture and some are hunters [23]. The age range of the subjects is appropriate since 18 years is accepted as an indication of full adult growth [17-20]. The present study shows that the mean body weight of Iban

Table 4- *Linear regression equations for body weight estimation from different foot outline length measurements (cm) on left and right sides among adult Iban females of east Malaysia.*

Variables	Regression Equations	SEE	R	ANOVA
LPOT1	19.900 + 1.422POLT1	5.541	0.238	$5.871(1, 98)$; $p = 0.017$
LPOT2	26.472 + 1.146POLT2	5.582	0.206	$4.356(1, 98)$; $p = 0.039$
LPOT3	27.053 + 1.161POLT3	5.580	0.207	$4.405(1, 98)$; $p = 0.038$
LPOT4	28.294 + 1.160POLT4	5.591	0.198	$4.016(1, 98)$; $p = 0.048$
LPOT5	27.565 + 1.290POLT5	5.588	0.201	$4.124(1, 98)$; $p = 0.045$
RPOT1	27.215 + 1.094PORT1	5.611	0.180	$3.292(1, 98)$; $p = 0.073$
RPOT2	24.021 + 1.252PORT2	5.566	0.219	$4.925(1, 98)$; $p = 0.029$
RPOT3	25.441 + 1.235PORT3	5.568	0.217	$4.852(1, 98)$; $p = 0.030$
RPOT4	28.120 + 1.171PORT4	5.599	0.192	$3.734(1, 98)$; $p = 0.056$
RPOT5	26.385 + 1.356PORT5	5.578	0.209	$4.472(1, 98)$; $p = 0.037$

LPOT1 to LPOT5, left foot outline lengths from anterior part of toes OT1- OT5 to mid-rear heel point P; RPOT1 to RPOT5, right foot outline lengths from anterior point of toes OT1-OT5 to mid-rear heel point P; SEE, standard error of estimate; R, correlation coefficient.

males is 55.6 kg while the mean body weight of Melanau males living in Sarawak state is found to be 60.9 kg. But interestingly, the mean body weight of Iban and Melanau females are found to be 52.2 kg and 52.5, showing similarity in weight, unlike Melanau males. All the foot outline length measurements show significant gender asymmetry [24]. But insignificant bilateral asymmetry also exists in foot outline lengths. The interesting feature observed in this study is that the mean POT1 length is longer than other lengths on both sides and genders. This finding is consistent with the finding on the Melanau population in east Malaysia [25]. Regarding mean foot outline length measurements, Iban males have (Left: 20.61- 24.41cm; Right: 20.49-24-49 cm) shorter lengths than Lun Bawang male foot outline lengths (Left: 21.7-25.6 cm; Right 21.6-25.6 cm), an ethnic group residing in Sarawak state, east Malaysia. This result clearly indicated that ethnic variation can affect variation in foot size. It is unfortunate to note that only a very small number of studies have been recorded in the literature relating living body weight and foot outline lengths for forensic application. The possibility of finding 3D impressions at the crime scene is high and hence anthropological researchers are encouraged to undertake the study on populations of different racial and ethnic groups

Table 5- *Linear regression equations for body weight estimation from different foot outline length measurements (cm) on left and right sides among adult Iban pooled sample.*

Variables	Regression Equations	SEE	R	ANOVA
LPOT1	19.041 + 1.480POLT1	5.831	0.320	22.543(1, 198) ; $p < 0.001$
LPOT2	20.225 + 1.445POLT2	5.819	0.326	23.512(1, 198) ; $p < 0.001$
LPOT3	19.196 + 1.543POLT3	5.786	0.341	26.044(1, 198) ; $p < 0.001$
LPOT4	19.780 + 1.596POLT4	5.799	0.335	25.048(1, 198) ; $p < 0.001$
LPOT5	22.545 + 1.580POLT5	5.850	0.311	21.167(1, 198) ; $p < 0.001$
RPOT1	21.403 + 1.374PORT1	5.883	0.294	18.725(1, 198) ; $p < 0.001$
RPOT2	19.248 + 1.485PORT2	5.820	0.325	23.431(1, 198) ; $p < 0.001$
RPOT3	18.994 + 1.554PORT3	5.789	0.339	25.755(1, 198) ; $p < 0.001$
RPOT4	19.099 + 1.632PORT4	5.794	0.337	25.370(1, 198) ; $p < 0.001$
RPOT5	20.601 + 1.686OPRT5	5.818	0.326	23.557(1, 198) ; $p < 0.001$

LPOT1 to LPOT5, left foot outline lengths from anterior part of toes OT1- OT5 to mid-rear heel point P; RPOT1 to RPOT5, right foot outline lengths from anterior point of toes OT1-OT5 to mid-rear heel point P; SEE, standard error of estimate; R, correlation coefficient.

to assess the relationship between 3D foot impression and living body weight so as to record the ethnic variation forensically.

5. Conclusion

The present investigation successfully generated formulae to determine living body weight from various foot outline lengths of Malaysian Iban population through linear regression analysis. The regression formulae derived for the pooled sample can be used to estimate body weight when the gender of foot impression is unknown. If these formulae are used to any other populations to determine living body weight from foot outlines, it displays an error value.

Conflict of interest

The authors have no conflict of interest to declare.

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