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Prediction of Living Human Body Mass from 2D Foot Impressions among Malays in Peninsular Malaysia

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Abstract | **Original Research Article**

It is a well-known fact that foot impressions, either 2D or 3D, form a valuable silent witness found at crime scenes. In the initial stage of investigation, it is cumbersome to identify the person directly, but need to predict/determine stature, body mass and gender. This impression reflects the ethnic variation, and hence ethnicity should be considered whenever population specific research is initiated. Earlier researchers have conducted studies relating stature, body mass, and gender to foot impressions. But till now, no study has been conducted to determine living body mass from 2D foot impressions. Keeping this in mind, the present study is planned to predict living body mass from foot impression among the Malay population in Peninsular Malaysia. This study's supervisor and corresponding author (Herein, mentioned TN) approached adult Malay people and requested them to donate footprints to conduct this research, and they also accepted for the same. The study was carried out in Peninsular Malaysia, involving 400 Malaysian Malays (200 males and 200 females), ranging in age from 18 to 55 years. The body mass of the subjects was measured, and 800 bilateral footprints were collected using an inkless shoeprint kit following standard procedures. From each subject, a total of 10 anthropometric measurements were taken, viz., five from the left sides and five from the right sides and developed formulae for body weight determination.

Keywords: Forensic Science, 2D Foot impression, Living body weight, Malays, Malaysia.

INTRODUCTION

It is a well-known fact that foot impressions, either 2D or 3D, form a valuable silent witness found at crime scenes. In the initial stage of investigation, it is cumbersome to identify the person directly, but need to predict/determine stature (Fawzy *et al.,*2010), body mass (Hairunnisa and Nataraja, 2018) and gender (Nataraja Moorthy and Devina, 2021). Foot impressions are rarely found at crime scenes because of the habit of wearing footwear by even the villagers. Walking barefoot contributes significantly to the longevity of individuals, with walking being an integral part of their daily lives. In many countries, people are still walking barefoot, considering the importance of health conditions, as advised by the medical officers. The offenders also sometimes ignore the use of footwear to avoid noise during crime operations (Zoltan *et al.,*2023). Identification of an individual is a mainstay in any forensic investigation (Nataraja and Rina, 2007). Current researchers have shown that footprints are found in almost all crime scenes, and the investigator has to locate them to identify the offenders. (Nataraja and Hairunnisa, 2018). Footprints form valid and reliable physical evidence at crime scenes and can provide more information than fingerprints (Nirenberg, 2016). Foot impressions are found at the crime scenes in the form of 2D (Nataraja and Devina, 2021), 3D (Nataraja and Sangitha, 2021) and latent print (Lee, 2001). This study initiated the relationship between the living body mass and the 2D foot impression and developed formulae to predict body mass from foot impressions.

MATERIALS AND METHODS

The study was conducted in Peninsular Malaysia and included 400 volunteers, 200 males and 200 females, chosen randomly among the Malay population living in Peninsular Malaysia. The participants were informed of the purpose of the study and the sampling technique. Following the standard

procedure, the 2D-foot impressions were collected on A4size white paper by the inkless technique along with bodyweight measurements (Nataraja and Hairunnisa, 2017), and analysis was conducted at the Science University of Malaysia, Kelantan, Malaysia, Malaysia.

Figure 1: Illustrated example of length measurements on the left 2-D foot impression

There were ten measurements taken, five from the left foot and five from the right foot impression from each individual, as shown in Figure 1. The left foot impression length measurements are the distance between the posterior end of the heel (LH), the pternion and the anterior end of all toes, viz. V1(first toe or big toe), V2 (second toe), V3 (third toe), V4 (fourth toe) and V5 (fifth toe or little toe). The five left footprint lengths are abbreviated as LHV1, LHV2, LHV3, LHV4, and LHV5. The right foot impression length measurements are the distance between the posterior end of the heel (RH), the pternion and the anterior end of all toes, viz. V1(first toe or big toe), V2 (second toe), V3 (third toe), V4 (fourth toe) and V5 (fifth toe or little toe). The five right footprint lengths are abbreviated as RHV1, RHV2, RHV3, RHV4, and RHV5.

STATISTICAL ANALYSIS

The data were analysed using SPSS software version 29 and derived linear regression equations, separately for males and females, to determine body weight from various foot impression measurements. In males, the mean footprint length of the left is 22.409cm, while the right is 22.345 cm. In females, the mean footprint length of the left is 20.508 cm, while the right is 20.498 cm. The result showed that a significant positive correlation exists between the 2D footprint/impression lengths and body weight.

The correlation between footprint lengths and living body weight was analysed using the Pearson correlation coefficient (r), and the findings were presented in tables and figures. The correlation coefficient (r) values are found to be higher in males (0.336-0.390) than in females (0.111-0.227), and the standard deviation values are also low. The results were presented in the form of tables and figures.

RESULTS

Table 1 presents the frequency distribution of body weight in kilograms among the male and female Malay participants.

Table 1: Descriptive statistics of body weight in Malays in Peninsular Malaysia (in Kg)

Gender	N	Min	Max	Mean	SD
Male	200	40.8	135.2	68.570	1.57
Female	200	32.1	102.3	57.110	1.38

The living body weight of females ranged from 32.1 kg to 102.3 kg, while that of males ranged from 40.8 kg to 135.2 kg. The mean body weight of males is found to be higher (68.570 kg) than that of females (57.110 kg).

Table 2 presents the various two-dimensional foot impression length measurements of both the left and right sides of the study population. In males, the mean right foot impression lengths (20.09-23.62 cm) and left side lengths (20.12-23.65 cm) show slight variation but not significant. Thus, the bilateral asymmetry in foot impressions is insignificant. Similarly, in females, the mean right foot impression length (18.33-21.68 cm) and the left foot impression length (18.33 – 21.72 cm) show slight variation but not significant. Thus, both male and female footprints did not show significant bilateral asymmetry in both genders.

Table 2: Descriptive statistics of 2D-foot impression lengths in adult Malays (in cm)

Lengths	Male				Female			
	Min	Max	Mean	SD	Min	Max	Mean	SD
LHV1	20.93	26.70	23.45	1.049	19.61	24.28	21.67	0.910
LHV2	20.81	26.70	23.65	1.115	19.81	24.45	21.72	0.958
LHV3	19.81	25.81	22.88	1.105	18.90	23.62	20.90	0.932
LHV4	19.02	26.62	21.72	1.034	17.41	22.22	19.84	0.881
LHV5	17.73	22.63	20.12	0.946	16.30	20.50	18.33	0.829
RHV1	20.72	26.53	23.36	1.048	19.50	22.42	21.65	0.940
RHV2	20.62	26.93	23.62	1.117	19.60	24.32	21.68	1.002
RHV3	19.81	25.82	22.85	1.108	19.00	23.50	20.95	0.968
RHV4	19.01	24.62	21.69	0.933	18.00	22.12	19.85	0.886
RHV5	17.50	22.80	20.09	1.054	16.40	20.42	18.33	0.796

Based on the foot impression anthropometry and living body weight, linear regression equations were developed to determine body weight from footprint among Malays in Peninsular Malaysia.

Table 3: Descriptive statistics of missing toes in the study population

Gender	Missing toe	Number of subjects
Males	LHV5	11
	LHV2	1
	LHV4	2
	LHV5	12
Females	RHV2	2
	RHV5	10
	LHV2	1
	LHV4	1
	LHV5	11

Another important observation made during the development process of the footprint is that some toes of some subjects were found to be missing, i.e., did not make contact with the ground and were reflected as missing toes in the footprints. The non-contact of the toes is an important and valuable clue in crime scene investigation, and perpetrator identification is perfect in a scientific way. Table 3 shows the missing or noncontact of toes on the ground while walking or standing. Similar findings were observed and recorded by Reel *et al.,*2012; Kanchan *et al.,*2012 and Nataraja Moorthy *et al.,*2011. The present study indicated the existence of a statistically significant and positive correlation between foot impression lengths and living body weight among the Malay population in Peninsular Malaysia.

DISCUSSIONS

Malaysia is a country in Southeast Asia. It consists of 13 states and three federal territories. Peninsular Malaysia is on Mainland Southeast Asia, and East Malaysia is on the island of Borneo. Malays are Muslims, an Austronesian ethnoreligious group native to the Malay Peninsula and eastern Sumatra. Despite the widespread distribution of the Malay population throughout the Malay Archipelago, modern Malay nationalism was only significantly mobilised in the early twentieth century, in British Malaya, i.e. the Malay Peninsula (Ayu Nor *et al.,*2022). Malay cultures from within the country and from surrounding regions have greatly influenced the cuisine. Much of the influence comes from the Malay, Chinese, Thai, Javanese and Sumatran cultures (Mohd Nazri *et al.,*2017).

Table 5: Comparison of male foot impression lengths (in cm) of the present study with selected populations that reflected the ethnicity variation

Variables (cm)	Present study Malays	Chinese people (Nataraja *et al.*, 2014)	Indian Tamils (Nataraja *et al.*, 2014)	Bidayuh (Nataraja *et al.*, 2014)
LHV1	23.45	23.81	24.72	23.3
LHV2	23.65	24.06	24.63	23.5
LHV3	22.88	23.24	23.69	22.7
LHV4	21.72	22.05	22.41	21.5
LHV5	20.12	20.48	20.67	19.7
RHV1	23.36	23.86	24.62	23.3
RHV2	23.62	24.01	24.52	23.5
RHV3	22.85	23.18	23.60	22.7
RHV4	21.69	22.02	22.32	21.5
RHV5	20.09	20.43	20.59	19.7

Table 5 clearly shows the variation of foot impression lengths of the present Malay populations in Malaysia from other populations, viz. Chinese population in Malaysia, Tamil population in India, Bidayuh population in Borneo Island, East Malaysia. It is important to note that the regression equations derived for the Malay population cannot be applied to any other populations, either in Malaysia or any part of the world, to determine body weight from 2D foot impressions.

CONCLUSION

It is concluded that the present study derived linear regression equations to determine living body weight from 2D foot impressions among the Malay population in Malaysia. The study developed ten regression equations, and they can be applied even in the presence of partial or full footprints found at the crime scenes to estimate living body weight for person identification, without neglecting this valuable foot impression evidence.

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