

Anthropometric Measurements of 2D Foot Impressions for Living Body Weight Determination among Tagalog Population in the Philippines

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Abstract**Original Research Article**

Person identification is the mainstay in any forensic investigation based on physical evidence found at crime scenes. Foot impressions/ footprints serve as vital evidence in crime scenes. Studies have indicated that foot impressions can be used to determine stature, gender and body weight and to narrow down the suspects and for identification. Anyhow it is important to consider ethnicity whenever dealing with the determination of stature and body weight, and if not, it may end with the wrong result. Hence the present research aimed to develop regression equations to determine living body weight from 2D foot impressions among the adult Tagalog population, an indigenous ethnic group in the Philippines. The study recruited 100 male and 100 female volunteers with ages ranging from 18 to 60 years, whose 2D foot impressions and body weight were collected. A total of 10 length measurements, five from the left and five from the right side of the participants were made and the length is the distance between the posterior end of the heel and the anterior end of all toes. The data were analysed statistically using SPSS software version 27 and developed linear regression equations separately for males and females. The result showed that a significant positive correlation exists between 2D footprint length and living body weight. 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 developed regression equations can be well used in real crime scenes to determine body weight from 2D-foot impressions among Tagalog people in the Philippines.

Keywords: Forensic Anthropology, 2D Foot impression, Living body weight, Tagalogs, Philippines.

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INTRODUCTION

Identification of an individual is a mainstay in any forensic investigation (Nataraja and Rina, 2007). Current researchers have shown that footprints are found almost in 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 and undeniable evidence found at crime scenes are usually left unintentionally by the perpetrators. (Nataraja and Siti, 2015) However, because of a lack of knowledge of footprint evidence, some crime scene investigators have simply neglected this evidence in the initial stage of the investigation itself and lost the chance to identify the culprits (Nataraja, 2017). 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 (Steve, 1993). In crime scenes, 2D impressions are found on hard surfaces while 3D impressions are found on soft surfaces. Both 2D and 3D foot impressions can be used to estimate stature (Nataraja *et al.*, 2014) body weight (Nataraja and Hairunnisa, 2017) and gender (Nataraja and Hairunnisa, 2020), considering ethnicity. Hence the present study aimed to investigate the relationship between 2D foot impression and living body weight among the Tagalog population in the Philippines and developed linear regression equations for use in crime scenes.

MATERIALS AND METHODS

The sample collection was conducted in the Philippines and analysed at Management and Science

University. This cross-sectional study consists of 200 volunteers including 100 males and 100 females, randomly chosen among the Tagalog population living in the Philippines. The participants were explained the purpose of the study and the sampling technique. The sample collection was conducted by the Co-author Mr Ivan Nikkimor. under my supervision. The corresponding author Prof. Nataraja (TN) had also

visited the Philippines, during the sample collection. Following the standard procedure, the 2D-foot impressions were collected on A4 size white paper by inking technique along with bodyweight measurements (Nataraja and Hairunnisa, 2017), and analysis was conducted at the Management and Science Laboratory, Malaysia.

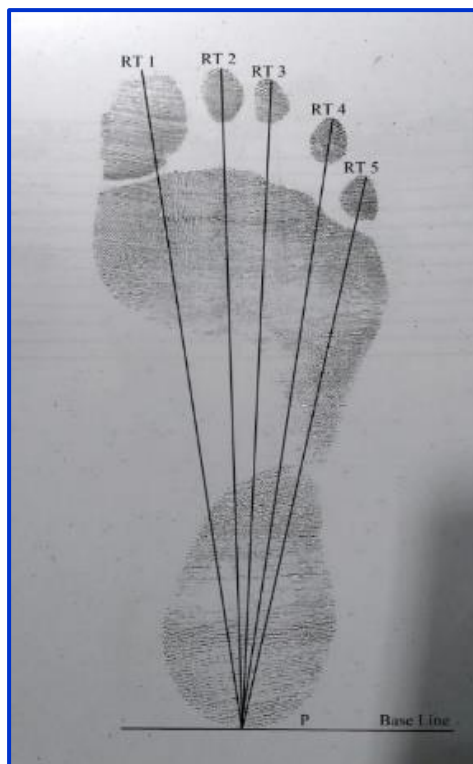


Figure 1: Illustrated example of length measurements of right (R) 2-D foot impression

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. Foot impression length measurements are the distance between the posterior end of the heel (P) the pternion and the anterior end of all toes viz. T1(first toe or big toe) T2 (second toe), T3 (third toe), T4 (fourth toe) and T5 (fifth toe or little toe). RT1 and LT1 indicated the right and left toe impressions, and accordingly marked other toes.

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 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 Philippine Tagalog participants. The living body weight of females ranged from 36.8 kg to 120.3 kg while males from 35.1 kg to 102.3 kg. The mean body weight of the male is found to be higher (63.46 kg) than females (58.17 kg)

Table 1: Descriptive statistics of body weight in adult Philippine Tagalogs (in Kg)

Gender	Min	Max	RD	Mean	SD
Female	36.8	120.3	83.5	58.172	1.46
Male	35.1	102.3	66.2	63.456	1.28

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 (19.67-23.14 cm) are slightly longer than the mean left side lengths (19.61-23.04 cm). Hence the mean right length and left length

are not similar thus showing the bilateral asymmetry in foot impressions. Similarly in females, the mean right foot impressions are longer (18.02-21.21 cm) than the left side (17.96 – 21.21 cm). Thus, both male and female footprints show bilateral asymmetry.

Table 2: Descriptive statistics of 2D-foot impression length measurements in adult Philippine Tagalogs (in cm)

Lengths (cm)	Female (N=100)					Male (N=100)				
	Min	Max	RD	Mean	SD	Min	Max	RD	Mean	SD
PLT1	17.8	23.5	5.7	21.206	0.9774	20.2	26.0	5.8	23.075	1.2118
PLT2	18.7	23.3	4.6	21.188	1.0003	20.1	25.5	5.4	23.040	1.1660
PLT3	18.1	22.7	4.6	20.439	0.9744	19.5	24.7	5.2	22.285	1.1407
PLT4	17.1	21.5	4.4	19.409	0.9243	18.2	23.4	5.2	21.137	1.1012
PLT5	15.5	19.8	4.3	17.964	0.8500	16.9	22.4	5.5	19.606	1.0170
PRT1	18.2	23.8	5.6	21.199	0.9176	19.8	26.3	6.5	23.140	1.2004
PRT2	18.6	23.7	9.1	21.211	0.9672	19.9	26.1	6.2	23.127	1.2261
PRT3	18.4	22.9	4.5	20.474	0.9424	19.2	25.4	6.2	22.350	1.1951
PRT4	17.3	22.0	4.7	19.483	0.9124	18.4	23.4	5.0	21.194	1.0899
PRT5	14.9	20.1	5.2	18.016	0.8841	17.0	22.0	5.0	19.673	1.0640

Tables 3 and 4 show the regression equations developed for body weight determination from various foot impression lengths, as abbreviated for the left sides as PLT1, PLT2, PLT3, PLT4, and PLT5 while the right

side as PRT1, PRT2, PRT3, PRT4, and PRT5. The tables show the correlation coefficient (r) between the various foot impression lengths and body weight is statistically significant.

Table 3: Linear regression equations to determine living body weight from 2D-foot impression lengths of left and right sides in adult female Philippine Tagalogs (N = 100)

Variables (cm)	Regression Equations	SEE	r	r ²	Adj.r ²
PLT1	20.330 + 0.015 PLT1	0.9576	0.223	0.050	0.040
PLT2	20.422 + 0.013 PLT2	0.9868	0.191	0.037	0.027
PLT3	19.702 + 0.012 PLT3	0.9607	0.186	0.035	0.025
PLT4	18.569 + 0.014 PLT4	0.9048	0.227	0.051	0.042
PLT5	17.254 + 0.012 PLT5	0.8382	0.208	0.043	0.034
PRT1	20.467 + 0.013 PRT1	0.9037	0.199	0.040	0.030
PRT2	20.747 + 0.009 PRT2	1.1545	0.111	0.012	0.002
PRT3	19.856 + 0.011 PRT3	0.9362	0.164	0.027	0.017
PRT4	18.837 + 0.011 PRT4	0.9021	0.177	0.031	0.021
PRT5	17.228 + 0.014 PRT5	0.8663	0.223	0.050	0.040

Table 4: Linear regression equations to determine living body weight from 2D-foot impression lengths of left and right sides in adult male Philippine Tagalogs (N = 100)

Variables (cm)	Regression Equations	SEE	r	r ²	Adj. r ²
PLT1	19.698 + 0.040 P-LT1	1.3340	0.388	0.150	0.146
PLT2	19.758 + 0.039 P-LT2	1.3243	0.378	0.143	0.139
PLT3	18.981 + 0.039 P-LT3	1.2989	0.388	0.150	0.146
PLT4	18.001 + 0.037 P-LT4	1.2311	0.390	0.152	0.148
PLT5	16.684 + 0.035 P-LT5	1.1518	0.386	0.149	0.145
PRT1	19.906 + 0.037 P-RT1	1.3502	0.359	0.129	0.125
PRT2	20.025 + 0.035 P-RT2	1.3799	0.336	0.113	0.108
PRT3	19.291 + 0.035 P-RT3	1.3453	0.340	0.116	0.111
PRT4	18.371 + 0.032 P-RT4	1.2431	0.341	0.117	0.112
PRT5	16.828 + 0.033 P-RT5	1.1983	0.360	0.130	0.125

Correlation coefficient (r) values are found to be higher in males (0.336-0.390) than in r values of females (0.111-0.227). The coefficient of determination (r²), the predictive accuracy is found to be comparatively higher in males than females. The adjusted coefficient of

determination (Adj. r²) was calculated to determine how much of the variance in the dependent variable could be explained by its relationship to the other variables. The present study indicated the existence of a statistically significant and positive correlation between foot

impression lengths and living body weight among the Tagalog population in the Philippines.

DISCUSSIONS

The Philippines is a multiracial and multi-ethnic country and the Tagalog people are the second largest ethnic group in the Philippines after the Visayan people and mostly practice Christianity (Andrew, 1998). Body weight can provide an important clue about the physiology of the perpetrator. It has been suggested that foot impressions recovered from a crime scene can reveal a deal about the body weight of the person (Naples and Miller, 2004). Based on the rich crime scene investigation experience of the corresponding author, (former Government Forensic Crime Scene Investigator in India for more than two decades) he had noticed foot impressions/prints at the scenes left by the criminals

unintentionally during their crime operations. The crime operators' foot impressions are used to identify the culprits (Nataraja *et al.*, 2021,2022). Researchers have shown that even partial foot and toe impressions (Nataraja and Nadiah, 2022) can be used to compare with suspects and to fix the offender since toe impressions show individual characteristics as fingerprints. Very limited studies were conducted on foot impression-based body weight estimation (Henry and Elaine, 2013), Hairunnisa and Nataraja, 2017), (Zusana *et al.*, 2018), (Hairunnisa and Nataraja, 2018). Population-specific linear regression equations were developed relating foot impression lengths and body weight in this study for crime scene application (Altman and Krywinski 2015). The shape and size of feet/ footprints show ethnic variation because people from different countries and regions are exposed to various environments, food habits and racial characteristics.

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

Variables (cm)	Tagalog (Present study)	Indian Tamil (Nataraja <i>et al.</i> , 2014)	Bidayuh (Nataraja <i>et al.</i> , 2017)	Egyptian (Fawzy <i>et al.</i> , 2010)
PLT1	23.1	24.7	23.3	25.3
PLT2	23.0	24.6	23.5	25.2
PLT3	22.3	23.7	22.7	24.3
PLT4	21.1	22.4	21.5	23.1
PLT5	19.6	20.7	19.7	21.5
PRT1	23.1	24.6	23.3	24.8
PRT2	23.1	24.5	23.5	24.7
PRT3	22.4	23.6	22.7	23.8
PRT4	21.2	22.3	21.5	22.7
PRT5	19.7	20.6	19.7	20.9

Table 5 clearly shows the variation of foot impression lengths of the present study from other populations viz. Tamil population in India, Bidayuh population in Borneo Island, East Malaysia and Egyptian population. It is cautioned that the regression equations derived for the Philippine Tagalog population cannot be applied to any other populations either in the Philippines or any part of the world to determine body weight from 2D foot impressions. Researchers are encouraged to continue similar research in various populations to understand forensically the effect of genetics and environment on human beings.

CONCLUSION

It is concluded that the present study derived linear regression equations to determine living body weight from 2D foot impressions among the Tagalog population in the Philippines. The study developed ten regression equations, and hence even the presence of partial or single foot or toe impressions in the crime scenes can be used to estimate body weight for person identification, without neglecting this valuable foot impression evidence.

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