Original Research Report

DEVELOPMENT OF FORMULAE TO DETERMINE LIVING STATURE USING HANDPRINT ANTHROPOMETRY OF TAGALOG PEOPLE IN THE PHILIPPINES

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ABSTRACT

Forensic science plays a crucial role in the pursuit of justice, particularly through the identification of physical evidence found at crime scenes, such as human fingerprints and handprints. This study aimed to develop formulae for determining living stature using the handprint anthropometry of Tagalog people, an indigenous ethnic group in the Philippines. A total of 360 Tagalog volunteers, comprising 180 men and 180 women, were recruited. This study excluded subjects who had finger and hand-related diseases, injuries, or were under the age of 18 years. The materials used were a stadiometer for height measurement, a digital vernier caliper for handprint measurements, and a handprint kit to collect handprints. Five length measurements were collected for each handprint. The length measurement spanned the distance from the middle wrist crease to the tips of each of the five fingers. The data were analyzed statistically using regression analysis ($p<0.05$) in IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, N.Y., USA). The analysis results produced equations for determining stature using all the length measurements of the handprints. The study involved the calculation of correlation coefficients (r values) and standard deviations using the stature and handprint lengths of individuals of both genders. The results were presented in the form of tables and figures. The study concluded with the development of regression equations that may be utilized for determining stature based on various handprint length measurements of the Tagalog people. This study represents the first-ever anthropological study conducted on the Philippine Tagalog population within the scope of this research subject matter. The formulae can be applied to actual crime scenes for the purpose of personal identification.

Keywords: Forensic science; living stature; handprint; Tagalog people; medicine

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Highlights:
1. This is the first-ever anthropological study on Tagalog people in the Philippines that has established formulae for determining stature using handprint length measurements.
2. This study has generated formulae that are applicable for personal identification purposes within real crime scenes.

INTRODUCTION

The pursuit of justice, particularly in criminal cases, is a complex and multifaceted process that cannot be achieved through a single act. Resolving the cases within an hour, as often depicted in movies, can be a cumbersome task (Mishra 2020). Forensic science represents the intersection of science and law. The field of forensic science focuses on the examination and analysis of physical evidence found at crime scenes. This evidence may appear in either visible or latent forms, viz., impression evidence, which includes fingerprints, handprints, and footprints (Abderrahmane et al. 2021, Asadujjaman et al. 2021). However, other sorts of impression evidence may be helpful in a forensic investigation. Tool marks and tire marks are some other examples of impression evidence (Sharma et al. 2019, Usman et al. 2019, Sørensen et al. 2020). Different types of evidence may also be present at crime scenes, such as trace evidence. This type of evidence includes, but is not limited

to, hair, fiber, bloodstains, and handwriting (Stewart 2017, Singh 2020, Zhang et al. 2022). In a separate study carried out by (Kumar & Khaira 2018), another form of evidence was examined. The research revealed that charred documents found at crime scenes may help establish a link between criminal activities and the criminals involved in those crimes. Invisible or latent impressions can be visualized by applying various chemical powders for further analysis (Singh 2020).

In forensic examinations, the required vital factors for personal identification are the determination of stature, gender, age, and race. These factors are commonly referred to as the "Big Four" (Ubelaker & Khosrowshahi 2019, Dembosky et al. 2019). The inclusion of stature is essential in the construction of a biological profile. Assessment of stature based on different body parts and their impressions is an area of interest to forensic experts, anthropologists, and anatomists. Stature determination can be performed through several anatomical measurements, such as hand, handprint, foot, footprint, finger, fingerprint, orbital cavity, and external ear morphometry. This is feasible since a strong correlation exists between stature and human body parts (Srijith 2019; Antunes et al. 2021).

Anthropometry is a scientific technique used to measure human body parts or their impressions and to understand human physical variation for personal identification. Anthropometric studies are conducted to investigate the evolutionary significance of differences in body proportion between populations whose ancestors lived in different environments (Hemy et al. 2013). This study aimed to examine the relationship between living stature and handprint anthropometry among the Tagalog population in the Philippines and to develop formulae for stature estimation using handprints of the study population for forensic application. It is worth noting that this study represents the first-ever anthropological study of Tagalog people in the Philippines regarding this research subject matter.

MATERIALS AND METHODS

The sample collection was conducted in the Philippines, while the analysis was performed at Management and Science University (MSU), Shah Alam, Malaysia. The ethical clearance for this study was granted by the University Ethics Committee of Management and Science University with certificate No. MSU-RMC-02/FR01/05/L2/007 on 28/2/2020. This study recruited 360 Tagalog volunteers, consisting of 180 males and 180 females, who consented to be participants (Moorthy et al. 2014). All participants were born and resided in the Philippines, and their ages ranged between 18 and 55 years old. Subjects with any hand-related disease, physical impairment, injury, or disorder were excluded from the study. This study used several materials, including a portable stadiometer for height measurements, a fingerprint kit for handprint collection, a digital vernier caliper for handprint length measurements, writing equipment, and A4-size white papers.

The stature of all participants was recorded in cm using a body meter (Model 208, SECA, Germany) from the crown of the head to the sole touching the floor. The measurements were repeated until concordant values were achieved (Moorthy et al. 2014). The Grade "A" fingerprint slab ink (Tritech Forensics, USA) was smeared uniformly on a clean glass plate using a roller. A clean hand was placed on the inked plate with mild pressure. Afterwards, the inked hand was then lifted slowly and impressed on an A4-size white paper, resulting in the transfer of the handprint onto the paper. This process was repeated for all participants. A digital caliper with a length of 300 mm was utilized to get five measurements of length for each handprint. The length was measured from the baseline of the handprint to the tips of each finger, as shown in Figure 1. The measurements covered the distance between the middle wrist crease (LHP) and the tips of all fingers, viz., thumb (T), index finger (I), middle finger (M), ring finger (R), and little finger (L).

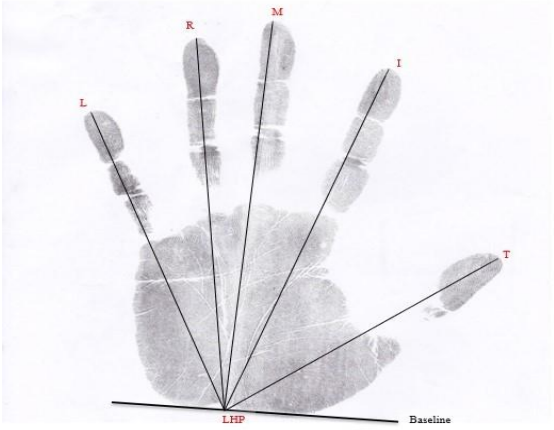

Figure 1. A print showing the various lengths of a participant's left handprint (Asadujjaman et al. 2021).

In order to avoid potential interobserver variability, Kaifi et al. (2019) recommended that all measurements be conducted by a single author (INLD). The data were analyzed statistically using regression analysis in IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk,

N.Y., USA). This analysis aimed to develop formulae that could be utilized for determining stature based on the lengths of handprints in both male and female samples. The threshold of statistical significance was set at $p<0.05$. The participants' stature measurements were organized in a tabular format, displaying the mean values and standard deviations (SD) to illustrate variation between sexes. The standard error of estimate (SEE) served as a measure to assess the accuracy of predictions, which was achieved when the values were between 2 and 6 cm (Moorthy et al. 2019). The presentation of the variance in stature by sex was depicted in graphical form. Similarly, the handprint length measurements from males and females were presented in different tables, along with the corresponding standard deviations. The developed formulae for determining stature based on handprints for males and females were also presented in tabular form. Additionally, the correlation coefficients (r values) that establish the relationship between stature and handprint lengths were calculated. When the r value exhibited a positive value, it indicated that the variables were correlated. The results were presented in the form of tables and figures.

RESULTS

Table 1 displays the recorded stature measurements for both male and female participants within the study samples. The mean stature of the male participants was found to be 163.04 cm, with a variation in height ranging from 147 cm to 184 cm. The mean stature of the female participants was found to be 151.57 cm, with a range of heights spanning from 135 cm to 163 cm. This study observed that the mean stature of males was higher than that of females, as determined by the standard deviation (SD). Figure 2 demonstrates the stature variation among the male and female participants.

Table 1. Stature measurements (cm) of the male and female Tagalog participants.

	Male (n=180)	Female (n=180)
Range	147-184	135-163
Mean	163.04	151.57
SD	6.81	5.16

Notes: n=Sample size; SD=Standard deviation.

Table 2 shows the five lengths on left handprints and the five lengths on right handprints among the male Tagalog participants. The mean handprint lengths with the middle finger were found to be longer, while the handprint lengths with the thumbs were shorter on both sides. In the left handprint, the length between the middle wrist crease and the middle finger (HPM) was the longest, followed by the lengths between the middle wrist crease and the ring finger (HPR), the index finger (HPI), the little finger (HPL), and lastly the thumb (HPT). Whereas, in the right handprint, the length between the middle wrist crease and the middle finger was the longest (HPM), followed by the lengths between the middle wrist crease and the index finger (HPI), the ring finger (HPR), the little finger (HPL), and the thumb (HPT), respectively. Interestingly, the result showed that the left handprint lengths and right handprint lengths were not similar, indicating variation in lengths, known as "bilateral asymmetry". The standard deviation values were very low compared to the height measurement values.

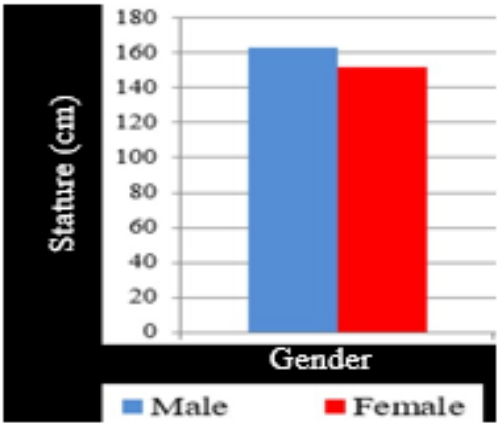

Figure 2. Stature variation by male and female sexes among the Tagalog participants.

Table 2. Handprint measurements (cm) among the male Tagalog participants.

Measurement	Left handprint			Right handprint		
	Range	Mean	SD	Range	Mean	SD
HPT	9.51-13.94	11.76	0.86	10.24-13.95	11.90	0.73
HPI	13.16-18.99	16.07	1.00	14.10-18.92	16.23	0.87
HPM	14.64-20.52	17.10	1.04	14.30-20.16	17.09	0.95
HPR	14.12-19.67	16.27	0.98	14.02-19.71	16.12	0.90
HPL	12.16-15.91	13.93	0.89	12.09-16.57	13.84	0.87

Notes: Handprint length is the distance between the middle wrist crease and the thumb (HPT), the index finger (HPI), the middle finger (HPM), the ring finger (HPR), and the little finger (HPL). SD=Standard deviation.

Table 3 presents the five lengths on left handprints and five lengths on right handprints among the female Tagalog participants. All handprint lengths of the male participants were comparatively longer than the female participants' handprint length measurements. As similarly observed in the male Tagalog participants, the mean handprint lengths measured from the middle finger (HPM) were

found to be longer. The handprint lengths measured from the thumb (HPT) on both the left and right sides were also shorter among the female participants. In the left handprint, the handprint measured from the middle finger (HPM) was the longest, followed by the lengths measured from the ring finger (HPR), the index finger (HPI), the little finger (HPL), and lastly the thumb (HPT). In the right handprint, the longest handprint was measured from the middle finger, followed by the index finger (HPI), the ring finger (HPR), the little finger (HPL), and the thumb (HPT). Similar to the measurement results among the female participants, the left and right handprint lengths among the female participants showed variation and bilateral asymmetry but were not significant. The standard deviation values were very low compared to the height measurement values.

Table 3. Handprint measurements (cm) among the female Tagalog participants.

Measurement	Left handprint			Right handprint		
	Range	Mean	SD	Range	Mean	SD
HPT	9.06-12.93	10.54	0.71	8.17-12.91	10.60	0.77
HPI	12.22-17.94	14.75	0.88	12.32-17.61	14.76	0.92
HPM	13.62-17.85	15.62	0.89	13.10-17.99	15.53	0.95
HPR	13.06-16.92	14.77	0.90	12.40-16.92	14.73	0.97
HPL	10.08-15.83	12.56	0.94	10.41-16.69	12.48	0.89

Notes: Handprint length is the distance between the middle wrist crease and the thumb (HPT), the index finger (HPI), the middle finger (HPM), the ring finger (HPR), and the little finger (HPL). SD=Standard deviation.

The important finding in the investigation was that the declining order of the male and female participants' handprint lengths reflects similarity on both the right-hand and left-hand sides of the study population. The presence of bilateral asymmetry in the handprint lengths of the male and female participants was not so significant, as shown in Figure 3. Hence, the left and right handprint lengths were combined as one side (i.e., HPT, HPI, HPM, HPR, and HPL). Five regression formulae were developed to determine stature using five lengths for male and female stature, as shown in Table 4 and Table 5.

Table 4. Regression formulae to determine stature (cm) using handprint length (cm) measurements of male Tagalogs.

Regression formulae	R	R^2	SEE
S=105.442+4.870HPT	0.52	0.27	5.85
S=83.094+4.951HPI	0.65	0.42	5.21
S=83.200+4.670HPM	0.66	0.43	5.16
S=87.475+4.665HPR	0.60	0.36	5.46
S=99.747+4.559HPL	0.55	0.31	5.69

Notes: S=Stature. Handprint length is the distance between the middle wrist crease and the thumb (HPT), the index finger (HPI), the middle finger (HPM), the ring finger (HPR), and the little finger (HPL). SD=Standard deviation. SEE=Standard error of estimate, ($p<0.001$).

The Pearson correlation coefficient (r) quantifies the extent of association between the variables of height and handprint length. All observed r values demonstrated a strong positive correlation. The r values were positive and statistically significant (<0.001).

Table 5. Regression formulae to determine stature (cm) from handprint length (cm) measurements of female Tagalogs.

Regression formulae	R	R^2	SEE
S=101.008+4.785HPT	0.59	0.35	4.16
S=89.625+4.199HPI	0.70	0.48	3.72
S=87.523+4.114HPM	0.69	0.48	3.75
S=94.035+3.901HPR	0.66	0.44	3.87
S=111.654+3.188HPL	0.51	0.26	4.46

Notes: S=Stature. Handprint length is the distance between the middle wrist crease and the thumb (HPT), the index finger (HPI), the middle finger (HPM), the ring finger (HPR), and the little finger (HPL). SD=Standard deviation. SEE=Standard error of estimate, ($p<0.001$).

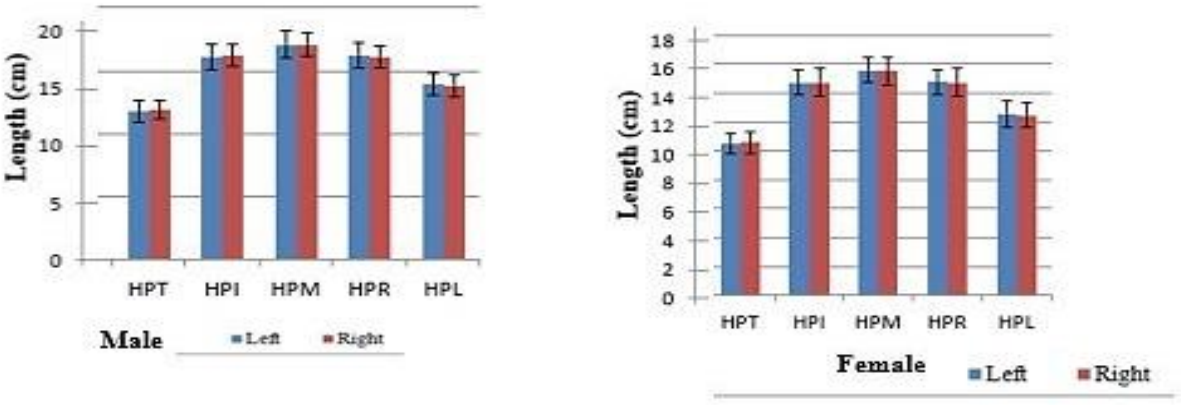

Figure 3. Various handprint lengths for both sexes as well as left-hand and right-hand sides.

The correlation coefficient (r) values were higher among the female samples (0.51–0.70) when compared with the male samples (0.52–0.66). The female participants exhibited a higher coefficient of determination (R^2), indicating higher predictive accuracy compared to the male participants. All measurements were positive and statistically significant for the stature estimation. The observed values in this study were small, indicating that the estimation of stature was achieved with enhanced accuracy.

DISCUSSION

The Philippines is a country characterized by its diverse ethnic composition, comprising around 120 distinct ethnic groups. Each of these ethnic groups has its own language and unique traditions. The Tagalog people are an indigenous ethnic group, with Tagalog being recognized as one of the two official languages in the Philippines (Talabis et al. 2013). In the current demography of the Philippines, it is observed that males constitute 50.1% of the total population, while females account for 49.9%. There is a considerable amount of research available on the topic of determining stature from footprints and shoeprints. On the contrary, studies on palm prints or handprints are rare due to a limited knowledge of the subject matter, particularly in the Philippines. In our prior experiences of crime scene investigation, it was frequently found that the perpetrators of the crimes would leave latent handprints at burglary scenes, whereas visibly stained prints were left behind at bloody murder scenes.

Crime scene professionals face challenges when attempting to estimate the stature of culprits using unidentified handprints found at the scenes of burglary, homicide, and sexual assault cases. In such cases, it is mandatory to determine the stature of the crime offenders based on the handprints found at the respective crime scenes. A practical alternative approach involves the development of novel formulae. Consequently, this work has undertaken the task of developing regression formulae for determining the stature based on the handprints of the Tagalog population. The formulae can be utilized to either include or exclude individuals under suspicion whenever they are brought to police stations (Vernon et al. 2020). The current state of research on handprints is notably scarce due to a reluctance among individuals to share their fingerprints or handprints with others, even when they are in a familial or friendly relationship.

Table 6 compares the stature measurements between the present study population and other populations, highlighting the observed ethnic variations. The data presented in the table demonstrates a consistent pattern of males having a larger average stature than females across all populations. This observation underlines the natural variation between the sexes within the analyzed samples. The comparison of the studies revealed that Western Australian males and Iraqi males have comparable stature (Hemy et al. 2013, Farhan et al. 2023). Western Australian males were found to have the tallest height (178.47 cm), while Iraqi males ranked second in terms of stature (177.71 cm). This was followed by Punjabis in Pakistan (173.42), UPites in Uttar Pradesh, India (173.20), Chinese Malaysians (171.50 cm), Saudi Arabians (170.80 cm), Malays in West Malaysia (168.70 cm), Ibans in East Malaysia (164.80 cm), Minangs in Indonesia (163.85 cm), and lastly Tagalogs (163.40 cm) of the present study, Kagay-anons (162.06 cm), and Visayans in the Philippines (161.57 cm) (Asif 2021, Elelemi et al. 2021, Mishra & Vardaini 2022).

Table 6. Comparison of Tagalog stature (cm) with other ethnic groups showing the ethnicity variation.

Ethnic Groups	Region/Country	Stature	
		Male	Female
Malays	West Malaysia	168.70	156.30
Chinese	West Malaysia	171.50	158.20
UPites	Uttar Pradesh, India	173.20	163.20
Saudi	Saudi Arabia	170.80	159.60
Punjabis	Pakistan	173.42	162.09
Minangs	Indonesia	163.85	152.39
Ibans	East Malaysia	164.80	153.50
Kagay-anons	Philippines	162.06	151.35
Visayans	Philippines	161.57	150.84
Western Australians	Australia	178.47	163.67
Iraqis	Iraq	177.71	161.79
Tagalogs (present study)	Philippines	163.40	151.57

Numerous studies have reported a significant correlation between the length of the middle finger and an individual's stature. A study conducted by Asha et al. (2012) found a strong correlation between the length of the middle finger and the stature of Indian adults. Similar findings were revealed in several studies conducted in other countries. One of which is a study carried out by Sanli et al. (2005) that found a moderate correlation between the length of the middle finger and the stature of Turkish individuals. However, it is important to note that these correlations may not universally apply to all populations. Additional variables, such as genetics, nutrition, and environmental factors, play a significant influence

on an individual's stature (Grasgruber et al. 2014). Forensic and anthropological studies on human stature, which involve diverse multicultural and multiethnic groups across different countries, play a pivotal role in establishing comprehensive databases that may be effectively used in actual forensic investigations.

Strength and limitations

Prior studies have developed formulae to estimate an individual's stature using the measurement of handprint length from a single hand. In this study, the development of formulae was achieved using five length measurements for each handprint in both male and female subjects. In many instances, only partial handprints are found at crime scenes, wherein only one handprint is left, either with the thumb or middle finger, and so on. The developed formulae from this study can be used for determining stature, even when partial handprints are present at crime scenes. However, it is important to acknowledge the limitations of this study. The derived equations are applicable only to the Tagalog population, rather than serving as general equations that can be applied to all populations in the world.

CONCLUSION

The regression formulae derived in this study can determine living stature by making use of handprint anthropometry, thus successfully achieving the research objective. It is recommended that future research attempts to investigate other populations and develop more extensive databases that may be useful in crime scene investigations.

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Conflict of interest

None.

Ethical consideration

The University Ethics Committee of Management and Science University, Shah Alam, Malaysia, approved this study with certificate No. MSU-RMC-02/FR01/05/L2/007 on 28/2/2020.

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None.

Author contribution

TNM designed the study, analyzed the data, and corrected the draft manuscript. INLD collected the samples in the Philippines, analyzed the data, and drafted the manuscript. MDA reviewed, revised, and submitted the manuscript.

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