Can stature be predicted from fingerprint characteristics? Regression analysis of 200 participants

Beth McMurchie[1], George Torrens[2] Paul Kelly[1]

[1] Department of Chemistry, Loughborough University, Loughborough, United Kingdom
[2] Loughborough Design School, Loughborough University, Loughborough, United Kingdom

ABSTRACT

The study described in this report was part of a long-running programme to collect data of people's physical characteristics and their relationship with the interfaces through which they control their environment. The study aimed to establish if there is a correlation between fingerprints and stature, possibly providing a quick method of identifying the physical characteristics of an individual from a latent fingerprint. The aim of the specific study documented here was to define the relationship, and its significance between a latent fingerprint and the height and/or weight of the individual who deposited it. A standardised fingerprint from 200 participants (117 males, 83 females) was collected using a bespoke finger compliance meter, which applied a fixed force of 10N to each participant's fingertip and captured an image of the compressed print. Measurements of height and weight were also taken. Regression analysis was used to analyse the collected measurements. Whilst the results of regression analysis showed very little correlation between weight and fingerprint size, a significant ($p < 0.05$) correlation coefficient ($r = 0.61$) was established between height and fingerprint circumference. The post-processed results provided a formula for estimation of height from fingerprint size; a standard error value of ±15 cm for predicted height from a given print; and, an indication as to the viability of this form of biometric analysis applied in the field of forensic identification. The results contribute to the evidence already published about the correlations between body parts and stature.

KEYWORDS

Fingerprints; Forensic Anthropometry; Bertillonage.

Introduction

The study described in this paper is part of a long-running programme to collect data that contributes to our understanding of how we physically interact with interfaces through which we control and move through our environment (G E Torrens 1996; G. Torrens 1997; George E. Torrens, McDonagh-Philip, and Newman 2001; George E. Torrens, Campbell, and Tutton 2012). The current study focuses on the relationship between anthropometry and the latent print left, usually during a grip action within a task performance.

Every person's fingerprints are different; even identical twins possess unique fingerprints from each other (Srihari, Srinivasan, and Fang 2008). It is for this reason that fingerprints are so widely used

in the identification of perpetrators of crime and to identify victims of disasters. The use of fingerprints in identification currently focuses on the patterns of fingerprints, or on the composition of the residue left with a latent fingermark. The ongoing research described in this study is instead aiming to use the physical size of a fingerprint to identify the stature of the individual who deposited it. The study is the first step towards providing a way of reducing the number of potential suspects stopped in the proximity of a crime scene.

An extensive literature review was undertaken to find previous studies and relationships between a latent print and the physical characteristics documented. Academic journals, textbooks, professional journals and conference proceedings were reviewed to capture protocols and data that might inform a new study. There was no time limit placed on the date of publication as forms of physical identification of individuals predate most Journals.

Before fingerprinting was accepted as a form of personal identification, bertillonage anthropometry was used (Champod et al. 2004). Bertillonage was replaced by fingerprinting, as anthropometric measurements are not unique, and the differences in measurements recorded by different individuals made it a weak form of identification. However, more recently the possibility of using anthropometry to obtain pieces of information about an individual has been investigated. Zavala and Paley in 1975 attempted to predict anthropometric measurements from fingerprints (Zavala and Paley 1975). Whilst they showed a correlation between print and gender, they did not show a correlation between fingerprint detail and the height of an individual. The study was conducted over 40 years ago, and since then, the only research performed focussing specifically on the relationship between fingerprint size and anthropometric characteristics was conducted in 2005, with a small sample size of 17 (Edwards, Torrens, and Bhamra 2006).

Several studies to investigate how hand size compares to stature have been performed, (Paulis 2015; Jasuja and Singh 2004; Krishan and Sharma 2007; Jee and Yun 2015; Choksi, Babu, and Dahiya 2014; Pal et al. 2014) with some of these measuring hand length. Some also compared finger length and stature and even individual sections of the fingers. Whilst the length of the entire hand showed the most significant correlation with stature, every other measurement of the hand was also shown to have a significant relationship with stature except sections of the thumb and little finger (Paulis 2015). Each study also varies in the method used to collect measurements of the hand. Some simply physically measure the length of the hand, (Krishan and Sharma 2007; Jee and Yun 2015; Pal et al. 2014) whilst others ink or scan the hand and measure the resultant print (Paulis 2015; Jasuja and Singh 2004).

When using a fingerprint rather than the entire hand, the pressure used to deposit a print can considerably affect the size of the print. Theofanos *et al.,* (2008) found that the instruction given on how to deposit a fingerprint along with gender and age of the donor affected the pressure a participant used when depositing a fingerprint (Theofanos et al. 2008). The Reed-Stanton press rig (Reed et al. 2015) was established around the same time that Fieldhouse published an article describing the fingerprint sampler (Fieldhouse 2015). Both sets of equipment were established for the collection of standardised fingerprints. Fieldhouse found that using different amounts of force during fingerprint deposition significantly affected the length and width of a print up to 5N (Fieldhouse 2015).

To begin research into the physical characteristics of a fingerprint and their relationship to the height and weight of an individual, a bespoke finger compliance meter was utilised to collect standardised prints from participants. The following method describes a combination of

conventional measurements and post-processing which have been combined to establish the relationship between fingerprint size and stature.

Materials and Method

Ethical approval was obtained from the Ethics Approvals (Human Participants) Sub-Committee at Loughborough University in order to ask participants to take part in this study (reference: C16-15). 200 participants (117 males, 83 females) were recruited. All participants were over 18.

A stadiometer was used to measure the height of each participant. Participants were asked to remove their shoes and stand on the bottom plate of the stadiometer with their heels, buttocks, back, and the back of their head against the wall, whilst looking straight ahead (British Standards Institution 2012). Height was recorded in centimetres, to the nearest centimetre, three times and an average was calculated from these three measurements to reduce the chance of reading and recording errors. Weighing scales were used to record the weight of each participant. Participants were asked to remove their shoes and stand on the scales whilst their weight was recorded. To record the weight three times, participants were asked to step from the scales and back on twice. Participant weight was recorded in kilograms to the nearest kilogram and the average of the three measurements was calculated. Technical error measurement was considered; one investigator performed all measurements to avoid inter-observer error (Ulijaszek and Kerr 1999).

A photograph of the middle fingertip of the participant's dominant hand was collected using a bespoke finger compliance meter. Before collection of the photograph, the temperature of the skin on each participant's middle fingertip was recorded in degrees Celsius using a Type K Thermocouple digital thermometer. From previous studies it had been found that the fatty deposits within the ungual pulp were temperature sensitive, resulting in a harder or softer finger pad. Fingertip temperature was measured to ensure no extremes of variation in physical characteristics of the biomaterial. Participants were asked to wipe or wash their hands before using the compliance equipment. The removal of physical surface contaminants and excess sweat further standardised the skin prior to print deposition.

The middle finger on the dominant hand was used throughout the study, this was decided as the middle finger is usually the largest finger, and several studies agree that the middle finger gives the most significant correlation when compared with stature (Paulis 2015; Jasuja and Singh 2004; Jee and Yun 2015). Also the middle finger is known to be involved in most commonly defined grip patterns (Napier 1980). The finger compliance meter was set up to apply 10N of force to the fingertip for 5 seconds. The same time was used across all participants to ensure hysteresis in the proximal ungual pulp due to fluid dissipation was consistent. The pad on the dorsal aspect of the fingertip was used to distribute the applied pressure on the nail bed and avoid discomfort to the participant. 10N was chosen to avoid causing discomfort to the participant (G. Torrens 1997) and also because it was already established that the size of the fingerprint collected did not vary when using >5N compression (Fieldhouse 2015). The configuration of the finger compliance equipment is shown in
Figure 1.

Once the participant selected 'start' on the remote control the compression arm moved slowly down until it came into contact with the participant's finger (

Figure 2). Once in contact, the equipment applied 10N of force for 5 seconds before releasing. During these 5 seconds, a digital photograph of the compressed fingertip was taken and the image file stored. Examples of the fingerprint photographs collected are shown in Figure 3. Two light sources were used in the camera unit; one injects light parallel to the surface and the second injects at a shallow angle into the lower face of the surface. The image of the fingerprint can be seen due to frustrated total internal reflection (FTIR).

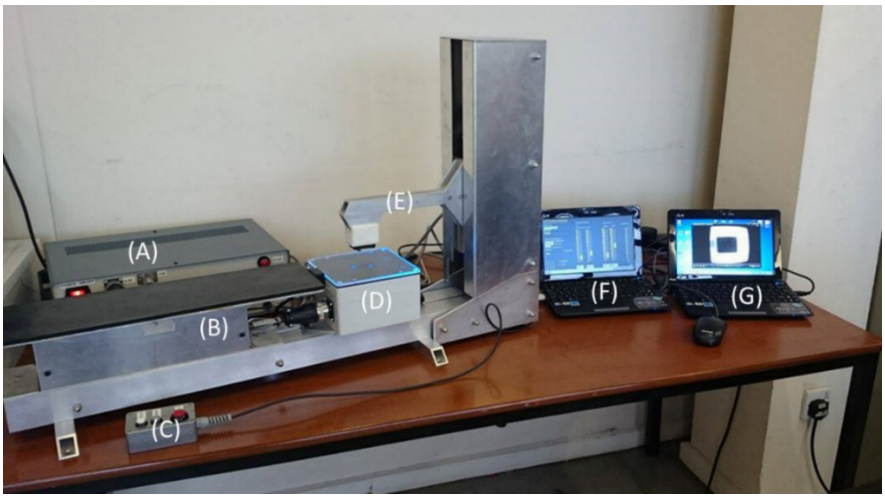

Figure 1: The setup of the finger compliance meter showing **(A)** the power unit, **(B)** the arm rest, **(C)** the participant accessible remote control (as shown, arranged for a left handed participant), **(D)** the camera unit, **(E)** the compression arm, **(F)** the control computer and **(G)** the visualisation computer showing the camera output.

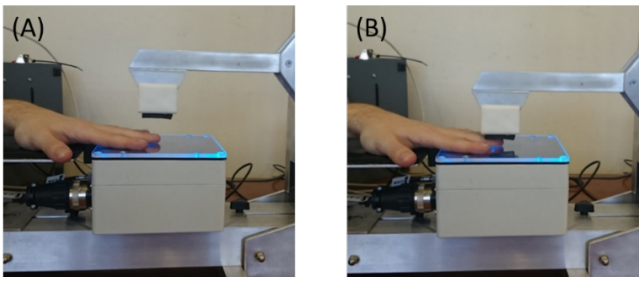

Figure 2: The position of participant's hand above the camera unit and below the compression arm **(A)** before and **(B)** during compression.

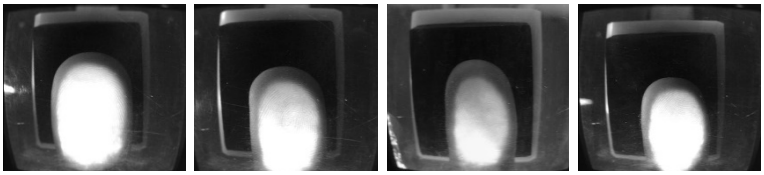

Figure 3 – Four of the fingerprint photographs collected using the finger compliance equipment.

To measure the size of the collected fingerprint photographs, the software 'IC Measure' by Imaging Source was used, which allows a personalised scale to be set and saved, reducing the error from calibration between measurements. The length, width, circumference and area of each fingerprint

was measured in millimetres and recorded to the nearest 0.1 mm. A standardised number of nodes (20) were used to establish the outline of the fingerprint and to maintain consistency between measurements. The collected data was analysed using IBM SPSS statistics software, version 22.

Results

The full data set of the 200 participants is available for review (McMurchie, 2019). The temperature recorded for participant's fingertips varied between 22 – 35°C, with 31°C being the most common. A linear regression between height, weight and the various measurements of the fingerprint were established using SPSS. All the correlation results are shown in Table 1. A graphical representation of the relationship between height and fingerprint circumference is shown in Figure 4. The circumference of the fingerprint gave the highest correlation with height (r = 0.61). The equations were established to estimate height of an individual from various fingerprint measurements; these are shown in Table 2. The standard error of the estimate (SEE) showed the possible deviation between the estimated and actual height. The SEE was lowest (7.54 cm) when using circumference of a fingerprint. Therefore, using the circumference of a fingerprint to estimate height of an individual will give the estimate to within ± 15 cm. Multiple regression analysis (stepwise) was also performed using SPSS to predict height and weight from the combined circumference, area, length and width of a fingerprint. The correlation coefficients and equations to calculate height and weight were calculated, these are shown in

Table 3: The stepwise regression equations used to estimate height from (C) Circumference, (A) area, (L) length and (W) width of the fingerprint, including correlation coefficient (R), the coefficient of determination (R^2) and the standard error of the estimate (SEE).

	R	**R^2**	**Equation**	**SSE**
Height	0.62	0.38	Height = 78.48 + (1.91C) – (0.14A) + (0.25L) + (1.11W)	7.55
Weight	0.51	0.26	Weight = – 26.96 – (0.13C) – (0.13A) + (2.15L) + (6.9W)	12.94

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Table 1: The correlation coefficient (R) and the coefficient of determination (R^2) found between the height/weight of an individual and the length, width, circumference or area of the individual's fingerprint.

		Participant's:			
		Height		**Weight**	
		R	**R^2**	**R**	**R^2**
Fingerprint:	**Length**	0.57	0.33	0.36	0.13
	Width	0.50	0.25	0.50	0.25
	Circumference	0.61	0.37	0.43	0.18
	Area	0.59	0.35	0.46	0.21

Table 2: The linear regression equations used to estimate height from various measurements of the fingerprint, including the standard error of the estimate (SEE) and the p values, indicating the significance of the result.

x	Equation	SEE	P
Circumference in mm	height in cm = 1.090x + 111.51	7.54	0.00
Area in mm^2	height in cm = 0.129x + 142.94	7.66	0.00
Length in mm	height in cm = 2.666x + 118.88	7.82	0.00
Width in mm	height in cm = 3.230x + 129.61	8.24	0.00

$P < 0.05$ is significant.

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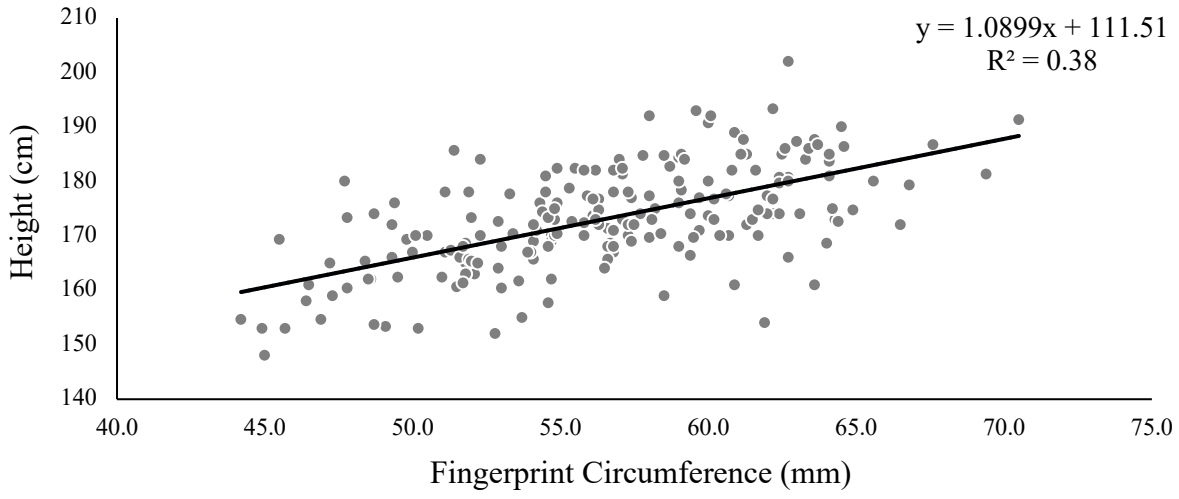

Figure 4: The correlation between Height and Fingerprint Circumference showing a regression line ($R^2 = 0.37$), and the equation of this line.

Discussion

The highest R^2 value for weight was 0.25, found using the width of the fingerprint. One explanation for this weak correlation is that a person's weight is likely to fluctuate. Unless a large amount of

weight was gained or lost, it would be unlikely to see a change in hand size, and therefore finger and fingerprint size. The consistency of a person's height may be the reason that better results were found between height and fingerprint size. The results collected from the 200 participants show that a positive significant correlation exists between fingerprint size and height. Both height and weight see a small increase in correlation coefficient when using all fingerprint measurements; however, no decrease in SEE is found when calculating height using either only circumference, or the combination of all fingerprint measurements. The SEE of 7.5 found using circumference, means that heights estimated would be accurate to within ± 15 cm, limiting the usability of such a correlation. Height estimations of individuals of average height would encompass a large proportion of the population but would still discount certain individuals as suspects.

While several studies comparing stature with other anthropometric measurements separated male and female results to establish a correlation, (Paulis 2015; Pal et al. 2014) it was decided that throughout this study and during data analysis, male and female measurements would be grouped together. The correlation coefficient found for this study when both genders were combined was much higher than either male ($r = 0.36$) or female ($r = 0.26$) when separated. This result benefits a realistic situation, as it may not be possible to tell immediately whether a fingermark was left by a male or female individual. The correlation coefficient between fingerprint circumference and height ($r = 0.61$), was found to be similar or higher than those already reported for the top section of the middle finger. Paulis found the same correlation coefficient between height and middle finger tip length for males ($r = 0.61$); however for females, the correlation coefficient was much lower ($r = 0.12$). Paulis (2015) and Jee and Yun (2015) found lower correlation coefficients for both males ($r = 0.28$) and females ($r = 0.33$); however, these correlations were found using physical measurements of the hand, which would not necessarily match the size of a deposited fingermark. The image of the fingermark (
Figure 3) shows the bright highlighted sections of fingerprint touching the surface, but also shows the dark areas of the finger that do not come into contact with the surface when touching it.

This study ensured that the photographed print highlighted only the area of the fingertip that was in contact with the surface. The bright white image of the fingerprint area was easy to measure and highlighted only the area of the fingertip that was in contact with the surface. This gives a print size similar to that of a developed or visible fingermark, providing measurements that are more accurate than simply measuring the length of a fingertip, as not the entire finger comes into contact with a surface when touching it. The most crucial variable controlled throughout the study was the pressure used to compress the finger during photograph collection. It is known that a fingerprint deposited with any pressure over 5N will give the same size print (Fieldhouse 2015) and it is only fingerprints deposited with minimal force (< 5N) that any variation in size is seen. Pressure was controlled in this study to establish whether under these artificial conditions, a correlation could be established, before moving onto the usability of any correlation found.

Whilst this correlation between fingerprint size and stature has been established, there are still several variables that would need investigating to establish whether this relationship could be utilised as a method for crime scene officers to estimate height from a fingerprint. This relationship has been established using intentional fingerprints, whilst natural fingerprints would likely be less perfect. For example, the collected fingerprints are complete, whereas partial prints, smudged prints or overlapping prints are often found. Prints found on uneven surfaces would add further complexity to any predictive formula and the practicalities of recording for reliable image processing. Similarly, the photographed prints were very easy to measure, whilst developed

fingermarks may be harder to measure without the same level of contrast. These variables will need investigating in order for the usability of the correlation in identification to be fully assessed. However, this initial investigation offers a possibility for a further use of fingerprints.

Conclusion

The results from this study of 200 participants has shown that a positive, significant correlation exists between height and middle fingerprint size. The best correlation coefficient was established between height and fingerprint circumference (0.61), and a similar correlation was established using all fingerprint measurements (0.62). A much weaker correlation was established between weight and fingerprint size. Regression equations were found for each fingerprint measurement and height, establishing that height could be estimated to within ±15 cm using fingerprint circumference.

This initial study has shown that a correlation does exist between fingerprints and stature, extending the known correlations between body parts and stature past hands and fingers, to as small as a fingerprint. The study has highlighted other areas for further research, such as variation in temperature, pressure applied and non-flat surfaces.

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