

# Estimating actual foot size from a static bare footprint in a White British Population.

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# Use of bare footprints in forensic work.

- There has been increasing interest in the potential of bare footprints being an aid to identification (Vernon, 2015)
- Studies have demonstrated that bare footprints are highly individual because of differences in the foot dimensions of the people who created them (inter-subject variations), the potential for footprints to be amended through situational variables (intra-subject variations) is not fully understood.
- **This study considers how actual foot length can be estimated from a static inked foot print.**

# Use of bare footprints

- Bodziak (1999) found that there are three types of footprints that can be found at the scene of a crime: (1) the impression left in an insole of a shoe, (2) a true bare footprint, and (3) a foot that had a sock on.
- Bare footprint comparisons have been widely accepted as a method that can assist with the process of identification.
- According to Barker and Scheuer (1998), in the western world, there is a role for the bare footprint in forensic investigations. Crimes of a sexual nature can see the offender removing his or her clothing beforehand; other forensically aware offenders, who believe they know the system well, may remove their footwear prior to committing a crime because they believe that this would protect them from being caught.
- In areas such as India (Kanchan et al 2012), such considerations can have greater relevance because of the high proportion of the population who walk barefoot for a variety of socioeconomic, religious, or climatic reasons.

# The bare footprint (individual?)

- Kennedy (1996) considered the uniqueness of bare footprints as an aid to identification in a study which, at the time of publication, had utilized 6000 bilateral bare footprints from 3000 participants. Kennedy assessed these impressions by taking 38 measurements that were entered into a computer database. This database allowed individual footprints to be compared with all other footprints in the database. He concluded that footprints were individual.
- Krishan (2007)]considered the individuality of footprints in the Gujjar's population in North India, particularly considering shape, alignment, creases, size, cuts, cracks, and pits to determine whether these characteristics were individual. The study involved 1040 adult males between 18 and 30 years of age. The footprints were shown to be highly individual and showed a link with personal identity.
- Moorthy and Sulaiman (2015)]conducted a study that involved Malaysians (200 males and 200 females) between 18 and 60 years of age. Eight hundred bilateral prints were collected in total. Participants had to be healthy and free from symptomatic deformities of the foot to participate.

# Types of footprint.

- According to Vernon [2017], bare footprints can be static or dynamic.
- Static prints are associated with standing and dynamic prints with walking or running.

# What do we know about inked footprints and relationship to foot length?

- Bodziak (2000) reports that a difference exists between a footprint and actual foot length but did not suggest a measurement for this.
- Giles and Vallandigham (1991] pointed out that in Robbins study of height estimation, it was suggested that on average the difference between foot length and print length was around 14mm.
- Giles and Vallandigham (1991) wrote that Steggerda had established that the difference between the outline of the foot and foot length measured by callipers is from 2-3mm suggesting that the difference between footprint and foot length is around 1cm.
- Vernon (2017) reports a rule of thumb has been used to suggest the overall foot length implied by a complete two-dimensional footprint, in which 1.5 to 2 cm is added to the overall footprint length to suggest an implied overall foot length, an approximation only and should be used with care in evidence reports, if at all.

# Techniques for Analysis of Bare Footprints

- Vernon (2017) reports that multiple methods have been used as a way of measuring bare footprints to aid the identification process.
- These measurements include the Gunn method, the Optical Centre Method, The Overlay method, and the Reel method.
- As part of her Ph.D. Reel (2012) investigated the concurrent validity and reliability of Gunn, Optical Centre Method and Reel. Reel found the highest reliability occurred with her own Reel method and then the Gunn method.

# Study

- **Research question**
- Can you estimate actual foot size from a static bare foot print in a White British Population.



# Participation

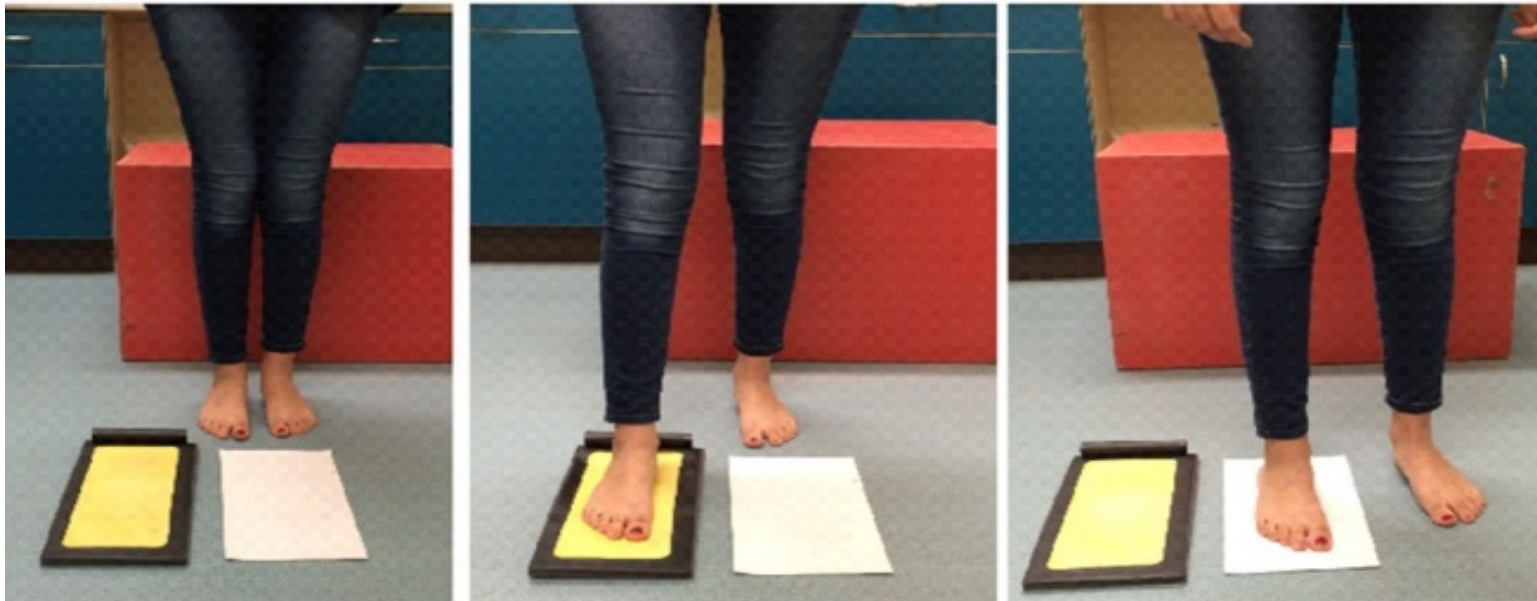
- An opportunistic sample of 146 participants were recruited from the student population of a University in the UK. The sample was made up from 73 males and 73 females from a White British population, ranging in age from 19 to 82 years (median 41 IQR 30-55 years).
- Ethical approval for the study was obtained from the Ethics Committee of the Faculty of Health and Society at the University of Northampton UK.
- Participants were fully informed of the study by two of the authors and each participant gave their consent to participate in the study.

# Inclusion and Exclusion criteria

- Participants aged over 18.
- White British ethnicity.
- Able to balance unaided with no self-reported history of falls.

# Obtaining a standing static footprint

- An inkless pad was placed on the floor. Participants placed their right foot onto the inkless mat in their natural stance position and held it for three seconds. They then transferred their foot onto the reactive paper next to the inkless mat in their natural stance, thus creating a two-dimensional static print.



# Measurement of actual foot length

Ward's® Osteometric board



# Footprint Analysis: Scanning GIMP and Reel Method

- Each static bare footprint was scanned using a HP Photosmart 5524 Scanner and saved as a JPEG file MacBook Air device. Each footprint was analysis using GNU Image Manipulation Program(GIMP) 2.8 software. Each footprint was uploaded into the GIMP software with the DPI (dots per inch) set at 150.
- Following the guidelines set out by Reel the central axis of the footprint was found and then the print was rotated until the central axis was vertical. A line was then drawn skimming the lowest heel pixel and crossing the central axis. The highest pixel of the most distal aspect of the foot, regardless to whether it represented the first or second toe as was marked. A line was then drawn from the central aspect of the calcaneus to the most distal part of the foot that had been marked and thus giving a measurement of longest possible footprint length.

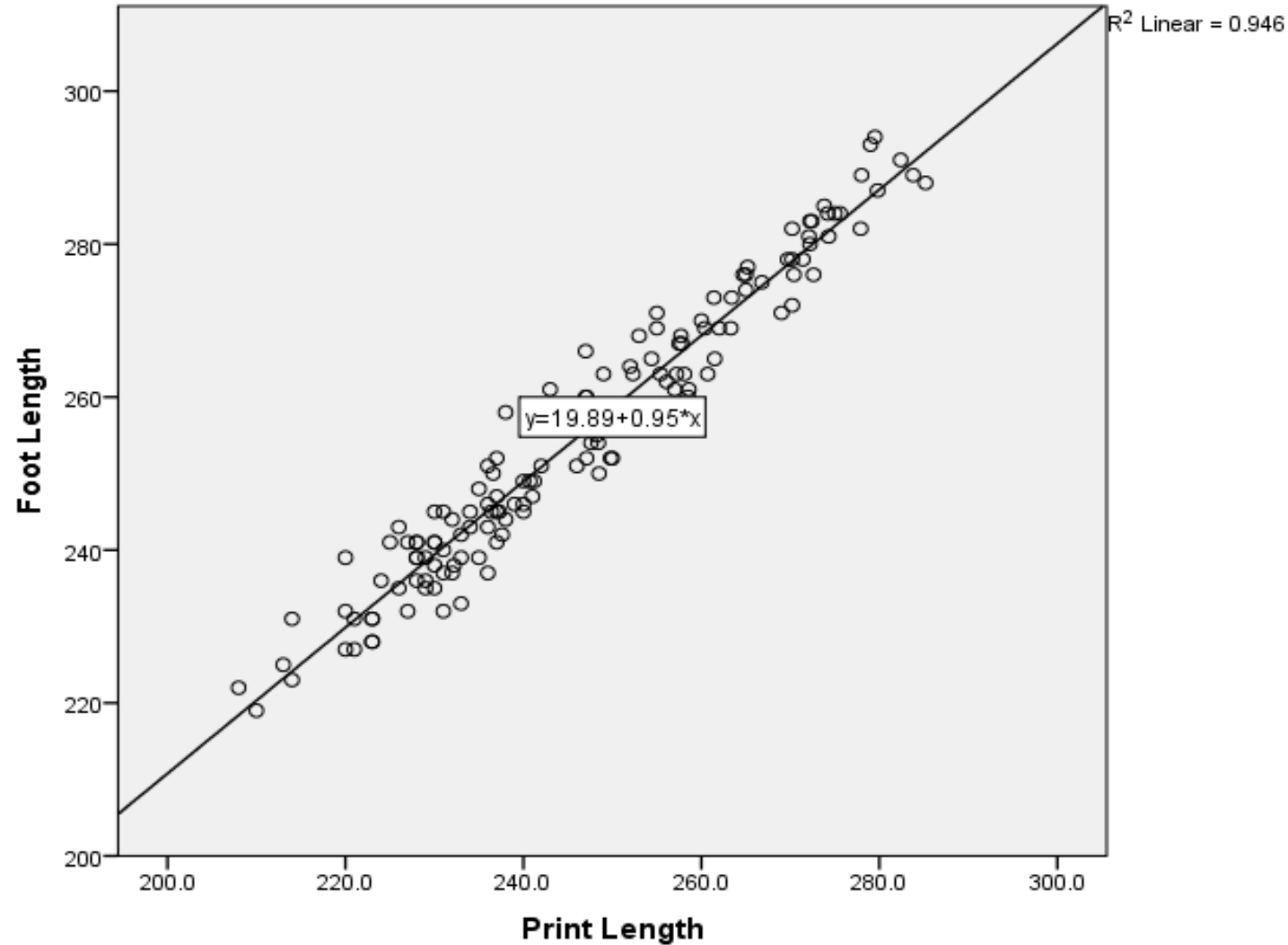
# Analysis

- Data were analysed using multiple regression (forced entry) with foot length as the dependent (outcome) variable and footprint length and gender as the independent variable/factor respectively.

# Findings explained

- There was a strong linear relationship between print length and foot length, justifying the assumption of linearity for the regression analysis.
- There were no outliers.
- The correlation coefficient,  $r = 0.973$ ;  $r^2 = 0.946$
- So 95% of variance in foot length can be explained by footprint length.

# Relationship between print length and foot length (mm)





# Regression analysis.

- The regression equation for the best estimate of the foot length is  **$19.89+0.954 \times \text{print length (in mm)}$** .
- The SD of the unstandardized residuals was 4.142, giving a 95% confidence interval for the predicted value (best estimate) of  $\pm 1.96 \times 4.142 = \pm 8.1$  mm.
- As an example, if the print length were measured as 228mm, then the best estimate of foot length =  $19.89+(0.95 \times 228) = 236.5$ mm. There is a 95% chance that the true length is between 228.4mm and 244.6 mm (calculated from  $236.5 \pm 8.1$ ).

# If you like statistics

- Post-analysis testing for assumptions found that 7 cases (4.8%) had standardised residuals in excess of  $\pm 1.96$  and 1 case (0.7%) had a standardised residual in excess of  $\pm 2.56$  which are in agreement with the expected percentages of 5% and 1% respectively. The residuals were normally distributed (K-S statistic= 0.046,  $p=0.200$ ).
- The maximum value of Cook's distance was 0.044 which indicates that no points exerted undue influence over the model. A plot of residuals v predicted values showed that the variance of the residuals did not vary with the magnitude of the predicted value (no heteroscedasticity).
- **All assumptions were therefore justified for regression analysis**

# Discussion

- The regression equation for the best estimate of the foot length is;
- **$19.89 + 0.954 \times \text{print length (in mm)}$ .**
- **The SD of the unstandardized residuals was 4.142, giving a 95% confidence interval for the predicted value (best estimate) of  $\pm 1.96 \times 4.142 = \pm 8.1$  mm.**
- Previous authors such as Bodziak , have suggested that a difference exists between actual foot length and inked print length but did not provide a figure for this.
- Giles and Vallandigham [10], suggest from two studies they have considered that this difference could range between 1cm and 1.4 cm.
- Vernon [8], suggested that adding 1.5 to 2cm to the total barefoot print length to get actual foot length is an approximation only and should be used with care in evidence reports, if at all.
- **In contrast to the findings and proposals of these authors, the findings from this study suggest the best estimate is 0.81 cm.**

# Conclusion

- This research suggests that it may be better to use a regression equation to estimate actual foot size from a static inked bare foot print rather than using an arbitrary length to add to inked footprints that vary greatly in size.
- White British Population ( New York study).
- Findings relates to the population studied.

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