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# Validity of Footprint Dimensions in the Estimation of Stature of Hausa Ethnic Group in Kano State, Nigeria

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## Abstract

*Footprints are of immense value in establishing the personal identity of individuals in forensic examinations and; identification of a person with the help of footprint analysis as an emerging biometric technique. The aim of this study was to estimate the stature of the Hausa ethnic group of Kano, using Footprints dimensions. The study was a cross-sectional survey conducted on 444 secondary pupils across selected LGAs in Kano. Their height was measured using a Stadiometer, and Footprint dimensions were measured from a plain sheet. Descriptive statistic was carried out to determine mean ±SD and correlation; regression analyses were carried out to establish the relationship and to derive predictive equations between the anthropometric parameters respectively. A statistically significant positive correlation between height and Footprint length was found to be r=0.640 for the population. A predictive equation H=4.23xFPL+55.47 obtained can be used successfully for the estimation of stature.*

**Keywords:** Estimation, Stature, Footprint dimensions, Hausa, Kano

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## INTRODUCTION

The human foot has been studied for a variety of reasons, i.e., for forensic as well as for non-forensic purposes by anatomists, forensic scientists, anthropologists, physicians, podiatrists, and numerous other groups (Krishan, 2007). Footprints are of immense value in establishing the personal identity of individuals in forensic examinations. They are found as a kind of evidence at the crime site and a potential link between the crime and the perpetrator (Sharma, 1990). The identification of a person with the help of footprint analysis is an emerging biometric technique (Kumar and Ramakrishnan, 2014). Footprints are the impressions which are left behind by a person when he walks and is a general term used for bare footprints (Naber, 2002). Usually, criminals remove their footwear to gain a better grip on climbing walls or to avoid noise (Tharmar *et al.*, 2011). Determination of the individuality of the human footprint shape for forensic identification purposes has been the subject of many studies (Borkowski, 2002; Kennedy *et al.*, 2005). Because, footprints are present at the locations of crimes, such as theft and murder; footprints can be found on mud, dust, cement, oil, and painted surfaces, as well as in blood during murder cases. Therefore, analyses of feet and footprints during stature estimation can be useful in the identification of criminals (Fawzy and Kamal, 2010; Hemy *et al.*, 2013; Abledu *et al.*, 2016).

It was reported that individual characteristics of a footprint recorded at a crime scene can help forensic investigators in establishing the identity of the person who deposited them or narrow down a long list of suspects (Robbins, 1978; Qamra *et al.*, 1980; Krishan, 2007). At a crime scene, footprints have the potential to leave behind forensic evidence in the form of marks or impressions on the contact surface, the placement and dimensions of which can be considered in terms of the overall shape, or morphology (Smerecki and Lovejoy, 1985; Mukhra *et al.*, 2018).

Moreover, footprints have a considerable value in forensic science, and they can be collected from the crime scene and can be utilized as a kind of evidence for estimation of body size, i.e., stature and body weight (Krishan, 2008). It was believed that stature, age and sex are primary characteristics used to establish the biological profile of an individual, but there are many other biometric identifiers used for the identification of an individual; fingerprints, voice, palm prints, hand geometry, iris patterns, retina characteristics, signatures, DNA types, keystroke dynamics and gait (Sharma, 2014).

So many other researches have been conducted using footprint dimensions in the estimation of stature (Krishan, 2008; Kanchan *et al.*, 2012; Hemy *et al.*, 2013). Analysis of footprints helps in the estimation of an individual's stature because of the existence of a strong positive correlation between one's stature and foot size (Kennedy *et al.*, 2005). Similarly, a relationship has been suggested between one's body weight and footprints (Robbins, 1986). Although footprints can be collected from almost every kind of crime scene, the possibility of their recovery at the scenes of sexual offences and homicides is relatively greater. Examination of barefoot impressions is important in developing countries where the majority of the rural population likes to walk barefooted because of socioeconomic and climatic reasons. The partial or complete footprints can be found on rain-covered surfaces, newly waxed floors, freshly cemented surfaces, moistened surfaces, in dust, mud, sand, oil, paint, and blood (Qamra *et al.*, 1980). Various methods are in use for the identification of an individual. Stature is one of the important parameters in identification and can be measured using various methods in fragmented bodies (Rastogi *et al.*, 2008).

Because, prints are present at the locations of crimes, such as theft and murder; footprints can be found on mud, dust, cement, oil, and painted surfaces, as well as in blood during murder

cases. Therefore, analyses of footprints during stature estimation can be useful in the identification of individuals (Fawzy and Kamal, 2010; Abledu *et al*., 2016). For these, research should be carried out among Hausa ethnic group using prints dimensions to identify individuals.

## Materials and Methods

Measuring tape (to the nearest 0.1 cm), questionnaire, Stadiometer (Holtain Ltd., Crymych, Dyfed, UK) to the nearest 0.1 cm, digital standing scales (Model DS-410, Seiko, Tokyo, Japan), to the nearest 0.1 kg, digital Vanier calliper (Starrett, 123 Series, U.S.A.)

## Anthropometry

I. **Footprint Length (FPL) in cm:** The maximum distance between the heel (pternion) and longest toe (akropodian).
II. **Footprint Breadth (FPB) in cm:** The distance between the most prominent point on the medial side of the foot to the most prominent point on the lateral side (which corresponds to the heads of the first to fifth metatarsals).
III. **Footprint Heel Breadth (FHB in cm:** The maximum distance from the most protruding point on the medial surface of the heel to the corresponding protrusion on the lateral surface of the heel.
IV. **Mid Footprint Width (MFW) in cm:** It is the narrowest distance of the middle of the plantar prints.

## Study Design and Location

The study was a cross-sectional survey that was carried out in selected secondary schools across selected LGAs in Kano.

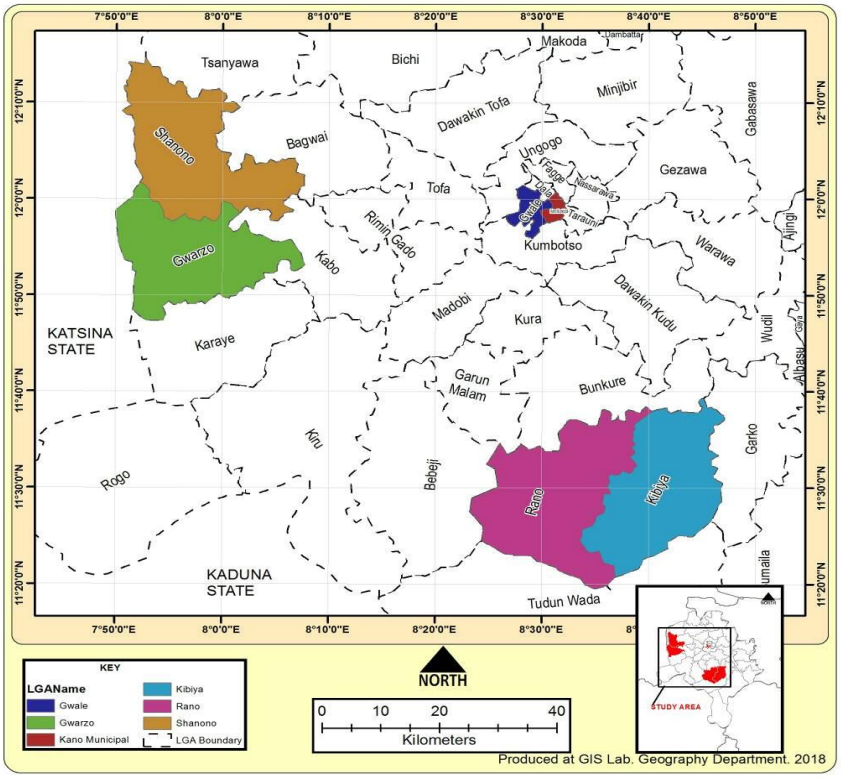


Figure: Map of Kano showing selected LGAs

**Selection Criteria**

**Inclusion Criteria**

- ✓ Healthy subjects
- ✓ Hausa of Kano up to the level of grandparents
- ✓ Secondary school pupils

**Exclusion Criteria**

- ✓ Any subjects outside the inclusion criteria

**Statistical Analyses**

The data was presented as mean ± SD. Independent sample t-test was used to test the difference between male and female subjects, while Pearson's correlation was used to measure the strength of the relationship between the variables and simple linear regression analysis was used for the estimation of height (stature). Data analysis was conducted using SPSS version 20 and a p-value < 0.05 was deemed to be statistically significant.

**RESULTS**

Table 1 presents descriptive statistics of the general population with the minimum, maximum and mean value of Age and Footprint dimensions of the Hausa ethnic group in Kano (n=444)

**Table 1: Descriptive statistic of the general population with the minimum, maximum and mean value of Age and Footprint dimensions of the Hausa ethnic group in Kano (n=444)**

| Variables | Minimum | Maximum | Mean±SD |
|---|---|---|---|
| Age (yrs) | 11.00 | 26.00 | 14.77±1.89 |
| Height (cm) | 121.00 | 177.00 | 148.78±11.33 |
| FPL(cm) | 16.10 | 27.00 | 22.06±1.71 |
| FPB(cm) | 4.10 | 11.00 | 7.89±0.91 |
| FPHB(cm) | 2.80 | 9.30 | 4.50±0.72 |
| MFPW(cm) | 0.30 | 7.00 | 2.31±1.04 |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width

Table 2 shows sexual dimorphism in Age, Height and Footprint dimensions among the Hausa ethnic group in Kano (n=444). It was observed that males have significantly higher values in all the variables with p-value <0.05

**Table 2: Sexual dimorphism in Age, Height and Footprint dimensions among Hausa ethnic group in Kano (n=444)**

| | Female | Male | | |
|---|---|---|---|---|
| Variables | Mean±SD | | t | p |
| Age(yrs) | 14.46±1.80 | 15.01±1.80 | -3.079 | 0.002 |
| Height**(cm)** | 148.07±10.84 | 149.38±11.70 | -1.207 | 0.002 |
| FPL**(cm)** | 21.65±1.33 | 22.39±1.91 | -4.662 | 0.001 |
| FPB**(cm)** | 7.59±0.70 | 8.14±0.99 | -6.605 | 0.001 |
| FPHB**(cm)** | 4.43±0.70 | 4.56±0.73 | -1.966 | 0.05 |
| MFPW**(cm)** | 2.03±0.87 | 2.53±1.11 | -5.275 | 0.001 |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width

Table 3 shows a correlation between the Height and Footprint dimensions of the Hausa ethnic group of Kano. It was observed that, in all the groups there was a significant relation between height and Footprint dimensions.

**Table 3: Correlation between Height and Footprint dimensions of the Hausa ethnic group of Kano**

| | All(n=444) | Female(n=199) | Male(n=245) |
|---|---|---|---|
| | Height | Height | Height |
| FPL(cm) | .639** | .395** | .783** |
| FPB(cm) | .510** | .288** | .646** |
| FPHB(cm) | .421** | .258** | .534** |
| MFPW(cm) | .190** | .147* | .204** |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width, ** Correlation is significant at the 0.01 level

Table 4 presents linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=444). It was observed that all the Footprint dimensions can be used to derive a predictive equation for the estimation of stature with the FPL having the highest r value of 0.640.

**Table 4: Linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=444)**

| Regression Equation | R | R^ | SEE | F | P |
|---|---|---|---|---|---|
| H=4.23xFPL+55.47 | 0.640 | 0.41 | 8.71 | 306.71 | 0.0001 |
| H=6.38xFPB+98.42 | 0.513 | 0.264 | 9.73 | 158.14 | 0.0001 |
| H=6.62xFPHB+118.95 | 0.422 | 0.178 | 10.28 | 95.72 | 0.0001 |
| H=0.39xFPI+134.89 | 0.096 | 0.009 | 11.29 | 4.09 | 0.044 |
| H=2.06xMFPW+144.06 | 0.190 | 0.036 | 11.14 | 16.391 | 0.001 |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width

**Table 5 presents linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=199).** It was observed that all the Footprint dimensions can be used to derive a predictive equation for the estimation of stature with the FPL having the highest r value of 0.397.

**Table 5: Linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=199)**

| Regression Equation | R | R^ | SEE | F | P |
|---|---|---|---|---|---|
| H=3.232xFPL+78.09 | 0.397 | 0.157 | 9.978 | 36.823 | 0.001 |
| H=4.657xFPB+112.71 | 0.296 | 0.088 | 10.384 | 18.921 | 0.001 |
| H=4.018xFPHB+130.27 | 0.260 | 0.068 | 10.496 | 14.338 | 0.001 |
| H=1.849xMFPW+144.44 | 0.147 | 0.022 | 10.772 | 4.329 | 0.04 |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width

Table 6 presents linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=245). It was observed that all the Footprint dimensions can be used to derive a predictive equation for the estimation of stature with the FPL having the highest r value of 0.783.

**Table 6: Linear regression equations for Height (Stature) estimation using measured Footprint dimensions of the Hausa ethnic group of Kano (n=245)**

| Regression Equation | R | R^ | SEE | F | P |
|---|---|---|---|---|---|
| H=4.792xFPL+42.04 | 0.783 | 0.612 | 7.292 | 383.94 | 0.001 |
| H=7.602xFPB+87.49 | 0.646 | 0.417 | 8.948 | 173.903 | 0.001 |
| H=8.527xFPHB+110.45 | 0.534 | 0.285 | 9.911 | 96.849 | 0.001 |
| H=2.145xMFPW+143.93 | 0.204 | 0.041 | 11.475 | 10.516 | 0.001 |

FPL=Footprint length, FPB=Footprint Breadth, FPHB=Footprint Heel Breadth, MFPW=Mid Footprint Width

## DISCUSSION

Footprints are of immense value in establishing the personal identity of individuals in forensic examinations. They are found as a kind of evidence at the crime site and a potential link between the crime and the perpetrator (Sharma, 1990).

In the present study, gender differences in footprint dimensions have been observed which agrees with the work done by Walia *et al.* (2016), footprint dimensions are higher in males than females. Also in the present study, a significant correlation was observed between footprint dimension (FPL with Height and FPB with height, 0.640 and 0.513 respectively) and body height in both sexes and is in agreement with work reported by Khan and Moorthy (2014).

It was also observed that there is a significant relation between footprint dimensions and body size (footprint length and height, r=0.640), and this agrees with work done by Devesh *et al.* (2006) and is consistent with what was reported by Krishan (2008) who found positive and significant correlation coefficient between body weight and measurements of footprints (r = 0.38–0.75) as such H=4.23xFPL+55.47 can be used to predict stature of both sexes, H=3.232xFPL+78.09 and H=4.792xFPL+42.04 for female and male subjects respectively as reported by Ukoha *et al.* (2013).

## CONCLUSION AND RECOMMENDATION

The present study established a correlation coefficient between body height and footprints dimensions with the significant relation between footprint dimensions and body size (footprint length r=0.640). The study also reported most of the footprint dimensions are sexually dimorphic specifically the footprint length can be used in discriminating the gender of an individual. Similar studies should be undertaken among various ethnic groups in Nigeria to establish a model for the estimation of stature from footprints.

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**Author's contributions:**

- ✓ **DS.:** Initial conceptualization of the work**,** Introduction and Discussion, **DSB.:** Results and Discussion, **TJA.:** Data analysis and Discussion, **TY.:** Methodology, **ALH.:** Data analysis and Results, **GA.:** Discussion and Conclusion, **I I.:** Introduction and Data analysis

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