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Ergonomics modeling of human height from stride length for adult population in South Western, Nigeria

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Abstract

The crime gauging in Nigeria have increased unexpectedly. The Identification of criminals has also constituted a great danger to the justice of the criminal acts. This study was conducted to appraise the relationship between Human heights (HH), Stride length (SL) and subsequently deduce models for the justice of criminals. A total of nine hundred and fifty six (956) participants, (486 males and 470 females) were assessed. The ages of the participants were between 25 years and 60 years. The human height and stride length of the participants were measured and recorded. The data obtained were analysed using SPSS 23.0 version software to establish the model equations for the HH. The result shows that male individuals possess higher mean value of HH and SL than female counterparts. The model equations obtained were validated with the direct measurement of HH. The present study has clearly demonstrated that SL can be used in the judgment of HH. The authors recommended further and elaborate research in other geo-political region of Nigeria, so as to build a database for Nigerian population.

Keywords: Human height, Stride length, South Western Nigeria, Criminals, Anthropometric

1. Introduction

Ergonomics is the science of designing and arranging things people use so that the people and things interact most efficiently and safely. One aspect of ergonomics is anthropometry, which is the study of human body measurements and proportions [1]. Human height (HH) is an important anthropometric measure that has a wide range of applications in fields such as medicine, sports, and forensic science [2] In Nigeria, there is a need for accurate and reliable models to estimate human height (HH) from readily available measurements, such as stride length, especially in forensic investigations [3].

Previous studies have investigated the relationship between human height and various body measurements, including stride length [4, 5]. In a study conducted in India, the researchers established a model to predict human height from foot length and step length [6]. Sometimes it becomes monotonous and exceedingly arduous to identify assailant with mere facial identification or name. There are lots of reported cases of kidnapping in Nigeria but the constrain of identification of the assailant human height (HH), body height (Bh) or stature (S) remain mirage. But assessment of assailant anthropometric body parts could help in the tracking of the attackers. Several researchers have reported the relationship of human height, body height or stature of the individual with different anthropometric body parts for forensic medico-legal cases [7-11].

Guest et al., researched into exploring the relationship between stride lengths, stature and hand size for forensic assessment [11]. It was known facts that forensic apparently relies on a combination of factuality or perfection recorded data and estimated measurement from body height given known data within an image and infrared [11]. Different segments of the body have shown magnitude correlation with body height in different climes using different anthropometric body parts which include knee length, tibia length, hand length, upper and lower limb length, foot length and foot print etc. [5, 9, 12-14].

Bickes performed the estimation of body height from percutaneous mean length of tibia in Debra Marko university students, North West Ethiopia. The percutaneous mean length of the tibia was a good predictor of body height for the students [15]. Vukotic also estimated body height employing the foot length measurement of adolescent [16]. The observed body height was reliably estimated. Musa et al., researched into the forensic appraisal of leg length (LL) as a predictor for determination of Nigerian student body height (Bh) using snowball sampling technique [7]. The study was conducted among 324 students (162 males and 162 females). The research concluded that the regression model equations developed to predict the body height is very useful and reliable in the forensic field.

Body height determination is a very essential and required when the biological depiction of the individual cannot be identified [9]. The discerning of body height will abet in the case of crime, mass disaster, missing person, kidnapping and amnesia individual. Stride length, foot length, footprint and finger print as well as footstep could be of great aid in the case of crime as physical evidences in the

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medico-legal cases. The physical evidence can be intent in forensic science towards the determination of body height to aid in the recognition processes [17]. But to achieve this, the correlation of the elements and the measured values are needed for the development of model equations for the body height using regression analysis [10, 17].

Musa et al. also studied and conducted research to investigate and determine the body height (Bh) from foot length (FL) [8]. Two hundred and sixty (260) adults of ages ranged between 24years and 55years in Abeokuta South West Nigeria participated. The study established regression models to intuit the body height (Bh) from foot length (FL). The study concluded that foot length was identified as a predictor of body height estimation. But few or no literature was found on the assessment of SL of an adult in South West Nigeria. The SL is described as the distance between successive points of initial contact of the same foot. The stride length of an individual is in gait pattern of fast or slow motion. An individual while walking or running make series of intuition and this is called gait pattern. This is initiated due to the motion of limbs during locomotion. Gait pattern is highly used in the verification of solving some certain crime. Evaluation and analyzing the gait pattern of individual is very useful and important because it helps in the determination of age, sex, height etc.

In Nigeria, few studies have investigated the relationship between human height and stride length. Therefore, there is a need for further research to develop accurate and reliable models for estimating human height from stride length for Nigerian population. This study aims to fill this gap by developing ergonomics models for estimating human height from stride length for adult population in South Western Nigeria.

In view of the studied literatures, the present study is to examine and evaluate the relationship between HH and SL of adult population in South Western Nigeria using regression analysis. The study might not be novel but it is an effort to contribute and build to body of forensic in the investigation of crimes in south-west Nigeria and also aid in the formation of database for the investigation of the relationship between HH and SL which is still lacking and inexistent in South Western Nigeria.

The motivation behind this study is to address the increasing crime rate in Nigeria and the challenges associated with identifying criminals. The study proposes a novel approach to estimating human height (HH), which is an important factor in criminal investigations. By using stride length (SL) as an indicator of human height (HH), the study aims to develop models that can be used to improve the justice system in Nigeria.

2. Materials and methods

2.1 Sample selection and measurement procedure

A total of nine hundred and fifty six (956) adults (486 males and 470 females) were randomly selected using snowball sampling techniques within Ogun State Central Senatorial District (Abeokuta South, Abeokuta North, Odeda, Obafemi-Owode, Ifo and Ewekoro local government respectively). The purposive, judgmental and selective sampling methods were also use along with the snowball techniques because it is the best when studying a particular set of groups that have traits that are rare to find due to the insecurity in Nigeria. The selected population was examined to determine their human height (HH) and stride length (SL). None of the participants had any deformity in their walking pattern or any part of the lower limbs. The individual having malformed limb(s) were exempted from participating in the study. The age span of the participants was between 25years and 60years old.

- The HH was measured using a stadiometer in a standing position bear footed with head in Frankfort plane and recorded.
- The SL is the walking pattern of the participant steps. The participant takes 10 steps on a smooth surface floor at their normal pace of walking, the distance is thereafter measured from the start to finish and divide by 10.

All the measurements were measured and recorded in centimetres (cm)

2.2 Data analysis

The obtained data were analyzed using statistical package for social sciences (SPSS) 23.0 version software to determine the socio-demographical characteristics such as average mean values and standard deviation (SD), Coefficient of determination (R^2), correlation of coefficient (R) and Standard error of estimates (SEE) were also determined. The linear regression analysis was also employed to determine the model equation for the determination of human height (HH) from the stride length (SL) and their relationships is presented in the scatter plot.

3. Results

A total of nine hundred and fifty six (956) adults (486 males and 470 females) were randomly assessed and evaluated using snowball sampling techniques within Ogun State.

Table 1 Socio-demographic characteristics of the participants (Male, Female and Both)

SEX	Anthropometric parts	N	Min (cm)	Max (cm)	Mean (cm)	SD (cm)
Male	Human height (HH)	486	144.5	183.0	164.2	6.90
	Stride length (SL)	486	58.1	76.0	69.1	2.88
Female	Human height (HH)	470	140.0	173.0	159.7	6.11
	Stride length (SL)	470	57.9	71.5	66.0	2.53
Both	Human height (HH)	956	140.0	183.0	162.6	6.91
	Stride length (SL)	956	57.9	76.0	63.4	2.92

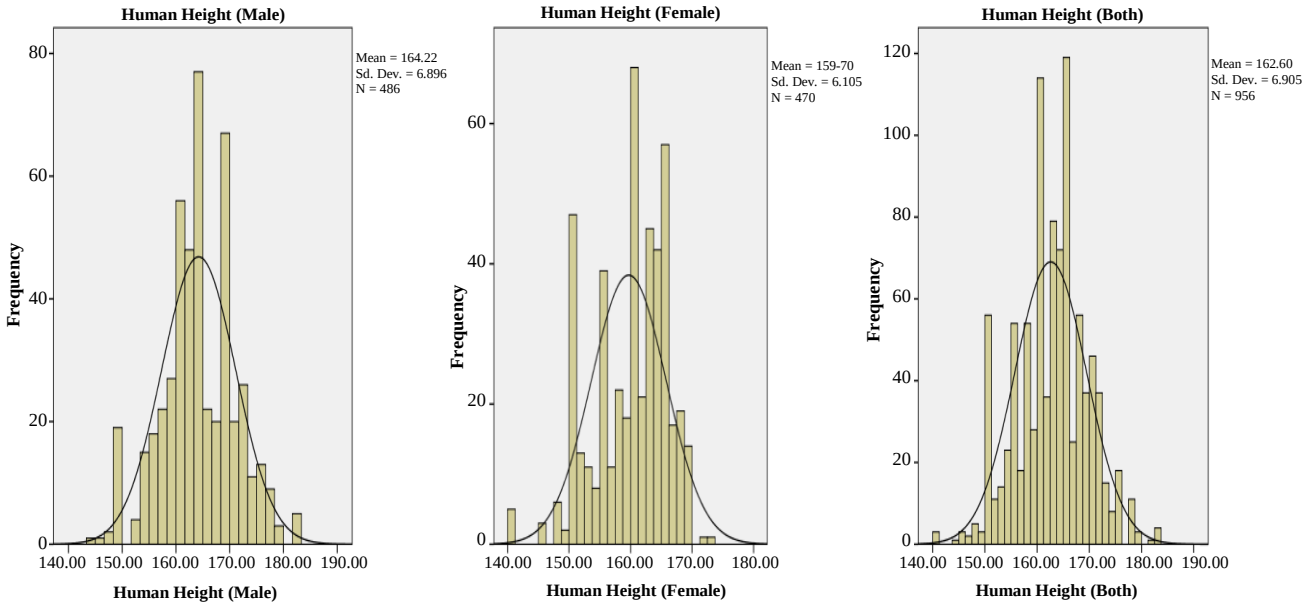

Figure 1 Histogram–Frequency curve distribution of HH

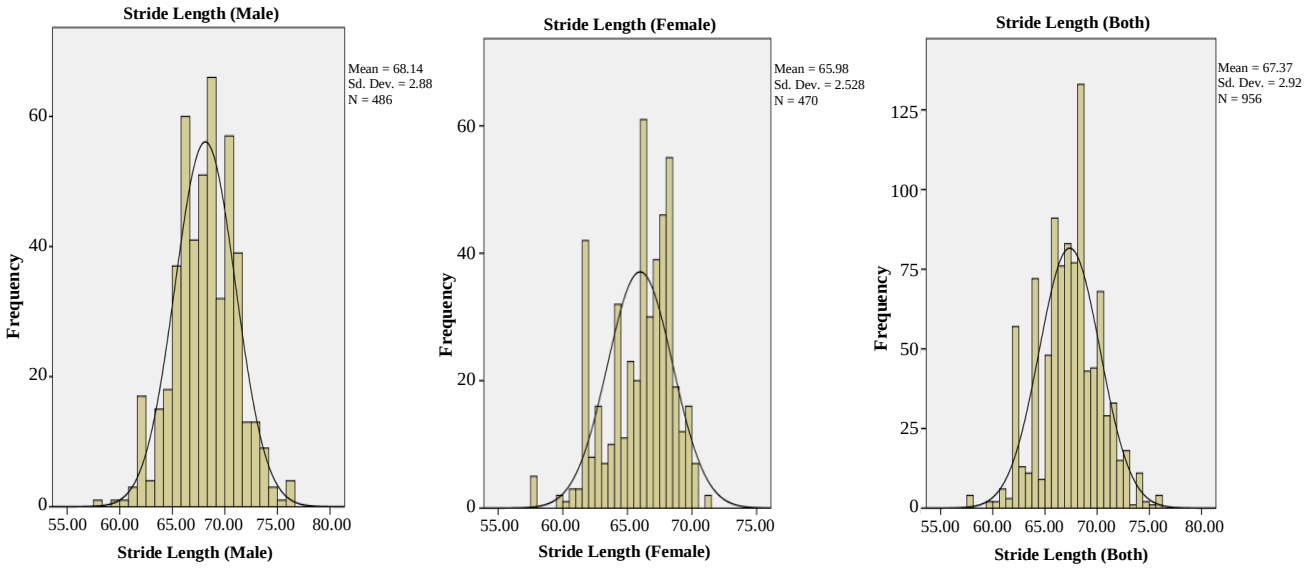

Figure 2 Histogram–Frequency curve distribution of SL

Table 1 shows the distribution statistics of the participants. The result shows significant differences between the male and female gender. The higher mean value of human height (HH) of 164.2 ± 6.90 cm existed in male compare to 159.7 ± 6.11 cm in female counterpart. This is due to the facts that duration of puberty growth is longer in male gender than female resulting in ossification of bone ceasing earlier in female than male to an appreciable increase in height of male individual than the other female counterpart [18]. The result also revealed the conspicuously higher SL of 69.1 ± 2.88 cm in male compared to the 66.0 ± 2.53 cm in female respectively. Hence, the two sexes were analysed together for combine data. The Human height (HH) and Stride length (SL) for both sexes are 162.6 ± 6.91 cm and 63.4 ± 2.92 cm respectively. A person length could be influence by several indicators such as race, body size, physiological variables, rate of growth, motivational status of the body and physical capacities [19]. Figure 1 and Figure 2 shows the histogram–frequency curve distribution statistic of HH and SL.

Table 2 Correlation and linear regression analysis

Anthropometric	R^2	R	S.E.E	P-value	Constant (k)	Bi
SL_{Male}	0.988	0.996	0.582	0.000	1.651	2.386
SL_{Female}	0.979	0.990	0.878	0.000	2.004	2.390
SL_{Both}	0.993	0.994	0.785	0.000	4.350	2.349

*Dependent - HH_{Male}; HH_{Female}: HH_{Both}
**Variables- SL_{male} SL_{female} SL_{Both}

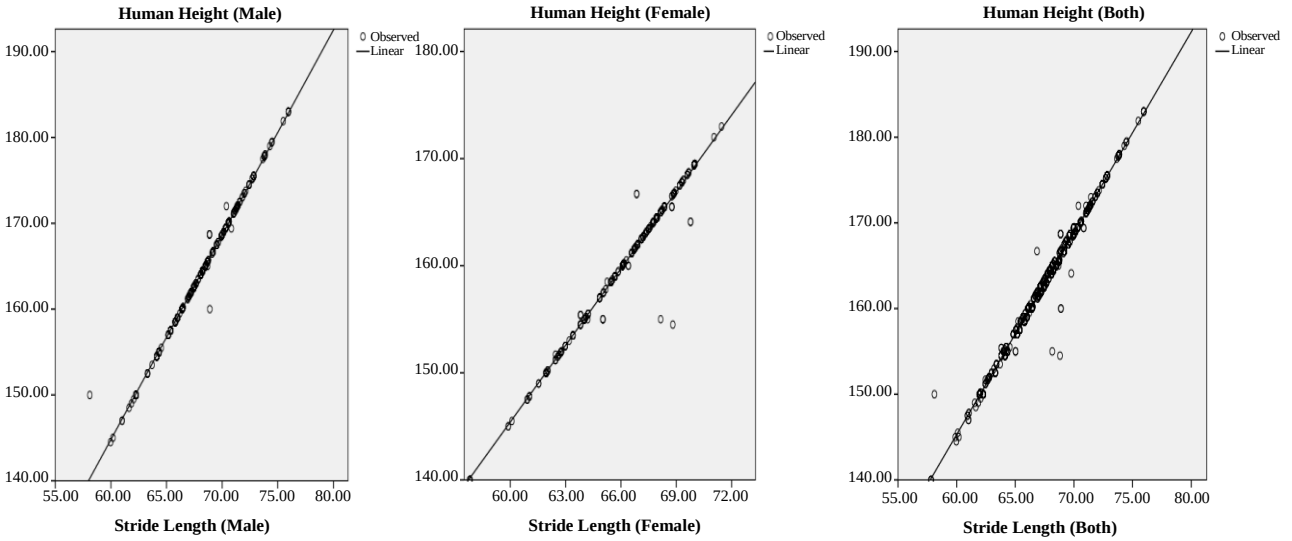

Figure 3 Scatter plot of HH against SL

Table 2 shows the correlation and regression analysis of the anthropometric body dimension. The result shows the coefficient of determination (R^2) as 0.988, 0.979 and 0.993 and coefficient correlation (R) as 0.996, 0.990 and 0.994 for $SL_{Male,}$ SL_{Female}, and SL_{Both} respectively. However, standard error of estimation (S.E.E) of 0.582, 0.878 and 0.785 also existed between the participants. The result also shows that there is no significant difference (P-value = 0.000). Figure 3 shows the scatter plots of HH against SL. The scatter plot shows a perfect positive correlation between HH and SL which mean that as HH are increasing, SL is also increasing.

The general formula for the regression model equation is

$$M = k + bf \quad (1)$$

Where M = Dependent variable (HH),
k = Constant,
f = predictor (SL)
Equation 1 is used to determine the values of HH for the regression model.

Table 3 Regression model equations and validation of the models

	Model Equation (M = k + bf)	Measured Mean (cm)	Determined Mean (cm)
1.	$HH_{Male} = 1.65 + 2.386SL_{Male}$	171.11	173.49
2.	$HH_{Female} = 2.00 + 2.39SL_{Female}$	165.81	165.74
3.	$HH_{Both} = 4.35 + 2.35SL_{Both}$	169.51	169.53

Table 3 shows the regression model equation of the anthropometric body dimension. The human height, HH_{Male}, HH_{Female}, HH_{Both} were determined respectively. Validation of the model was performed using the regression equation and compared with the measured values (Table 3).

4. Discussion

The criminal acts in Nigeria have increased unexpectedly, bringing the citizens to insecurity of life and properties. Nigeria is rated 17th among the least peaceful country in the world with high level of crime rate. In the justice of identifying faceless criminals, anthropometric parameters such as stride length, foot length, foot prints, etc. are employed to determine the case. Severally, the law enforcement agencies paraded criminals but identification of culprits could not be determined. The stride length can be ascertained by the investigators as physical evidence which can be used to determine the human height or stature of the criminals. Forensic investigators or experts and human factors engineers are needed after thorough analysis of the measured anthropometrics parameters. In presuming this analysis, linear regression or multiple regression analysis is employed for accurate, correct and exact equation or models. This present study uses linear regression analysis due to the variable obtained.

Ugochukwu et al and Jasuji et al. reported that stride length is relatively and correlatively to the height of an individual [20, 21]. Several researchers revealed that stride length of individual walking fast or normal walking pattern are nearly the same [20, 21]. In view of this, either the criminal decided to walk fast, run or normal walking pattern, the stride length is still possible and useful instrument to evaluate and determine the human height (HH). The human height of the adults was assessed and evaluated along with the stride length (SL). The result reveled that human height (HH) of the male adult is higher compared to the female counterparts. The stride length (SL) in male is conspicuously higher than in female respectively. The gender complimentary differences in human height of the sexes could be due to the hormones, chromosomes', genes and heredity [22].

Furthermore, coefficient of determination (R^2) and coefficient correlation (R) was also evaluated for $SL_{Male,}$ SL_{Female}, and SL_{Both} respectively (Table 2). The result shows that there is no significant relationship between human height and stride length (P>0.001). The R^2 and R correlated with human height as dependent variable and stride length as the predictor. The result shows that there is strong bond of correlation between these anthropometric parameters in male and female.

The values of R^2 and S.E.E was statistically used to determine the extent to which observed data match the values of expected data and the effectiveness of the statistical model in the evaluation of the models. Coefficient of determination R^2 measured the goodness of the regression model. However, higher R^2 indicates that the models are reliable and a good fit. To achieve a good fit, R^2 is expected to be 70% and above. Accuracy and reliable determination of human height from SL for forensic purposes is great importance to be achieved. The present study shows that R^2 are 98.7%, 97.9% and 99.3% for male, female and both sexes respectively which is a good indication that the values are reliable in the determination of human height of the individual.

Several researchers also established association between stature, stride length, lower limb, knee length, foot length, leg length etc. [7, 8, 20, 23]. The present model equations were validated (Table 3) to determine the human height of individuals by plunge-in the values of the stride length into the equation and the results was compared with the direct measured values. It was observed that human height shows a little difference of +2cm but the model equations are accurate, correct and exact for other.

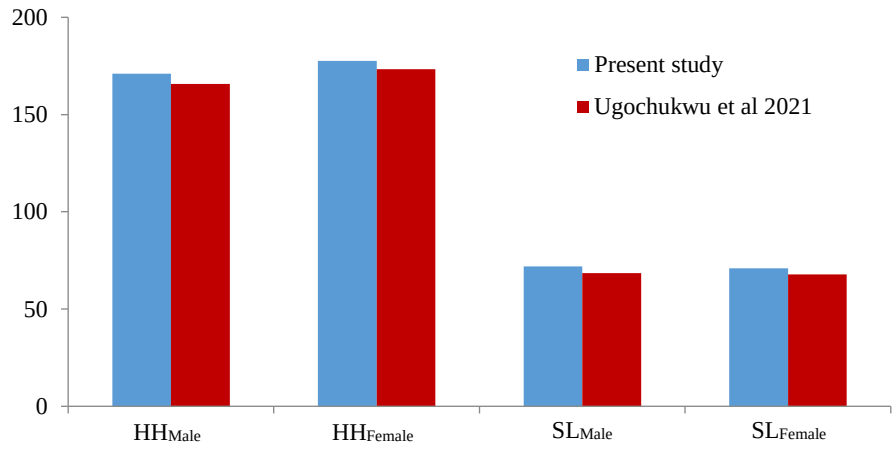

Figure 4 Comparison of present study to other study

Similarly, the present study was compared with similar study conducted in another geo-political region of South-South Nigeria (Figure 4). The average mean value of HH and SL obtained in Ogun State South western Nigeria was compared with the study in Cross River State South-South Nigeria. The result shows that there is a slight difference of HH of 162.8 ± 14.8 cm, 159.4 ± 14.0 cm and the SL of 62.6 ± 8.3 cm and 60.1 ± 7.7 cm for male and female respectively in the anthropometric parameter of South-South Nigeria compared to South Western Nigeria. This could be as a result of biological and tropical conditions of the region.

5. Conclusions

The study collected data from a significant number of participants, including both male and female individuals between the ages of 25 years and 60 years. By analyzing the data with advanced software tools, the study was able to establish model equations for human height (HH) that can be used to estimate the height of an individual based on their stride length (SL). The findings of the study shows that male individuals have a higher mean value of HH and SL than females. The model equations obtained were validated with direct measurements of human height, indicating their reliability and accuracy.

The present study clearly demonstrated that stride length can be used in the assessment and evaluation of human height. The coefficient of determination R^2 values obtained from the models was comparable with other study. Furthermore, the models were compared with direct measured human height. The novel dataset was used wherein data for human height and stride length captured for the South Western population of Nigeria. This allowed for unique modeling of the relationship between the elements. The present study was also compared with similar study conducted in South-South Nigeria.

Based on the results of this study, it can be concluded that there is a significant relationship between HH and SL among the adult population in South Western Nigeria. The study has extended the current knowledge by providing a new approach to estimating HH using SL, which is a simple and non-invasive method that can be easily implemented in different settings.

However, it is important to note some limitations of this study. First, the sample size used in this study may not be representative of the entire adult population in South Western Nigeria. Therefore, caution should be taken when generalizing the results of this study to the entire population. Second, the study only focused on the relationship between HH and SL and did not take into account other important factors that may influence height determination, such as age, sex, and body composition. Despite these limitations, this study has contributed to the growing body of literature on human height determination and ergonomics modeling.

The authors recommend further research to be conducted in other regions of Nigeria to build a comprehensive database of the Nigerian population. This will enable the development of more accurate and reliable models for estimating human height, which can aid in the identification of criminals and improve the justice system in Nigeria.

Further studies should be extended to the Sub-Saharan countries in African which literatures revealed that there are little or no studies on human height and stride length. The studies should also consider expanding the sample size and incorporating additional variables to enhance the accuracy of human height determination using stride length in different populations.

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