Optimization and Analysis of Female Foot Anthropometry

Stella I. Monye[1**] ; *Sunday* A. Afolalu1[2]; *Joseph* F. Kayode[2]; *Sunday* L. Lawal[2], *Moses* E. Emetere[3]

[1]Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado-Ekiti, 360101, Nigeria
[2]Department of Mechanical Engineering Science, University of Johannesburg, 2092, South Africa
[3]Department of Physics. Bowen University. Iwo. Nigeria

Abstract. The dynamic nature of the population makes it necessary to have reliable and updated data on the human foot dimensions. Many factors are responsible for the different forms and structures of the human foot, such as age, gender, nutrition, and genetic composition, among others. This study was carried out to optimize and analyse the various foot dimensions of the female subjects. A total of 200 female subjects participated willingly in the study, and 27-foot measurements were obtained. The results revealed the mean foot length to be 24.7cm with an SD of 1.2 while the mean foot breadth was obtained as 9.3cm having an SD of 0.6cm. The mean obtained was 58.7kg having a standard deviation of 12.5. From the findings, it can be concluded that a statistically significant correlation exists between foot length and body weight ($p<0.001$), with the value being $r = 0.48$ and also that for foot breadth and body weight being($r = 0.49$). These findings were compared to those from other studies, and it was concluded that the variation in the values could be due to environmental, ethnic, and racial differences.

1. Introduction

1.1 Foot Anthropometry

Foot anthropometry is basically the measurement of the size as well as dimensions of the foot. The human foot is a complex structure Igbigbi *et al*. [1], Ante *et al.* [2]. Foot breadth and foot length are the parameters that are frequently measured. Knowledge of foot anthropometry is key to the manufacturing of conveniently satisfying and serviceable footwear. The foot is known to be a very intricate framework comprising many bones and joints Manganaro *et al.* [3]. Foot anthropometry enables the optimization of products by providing statistical data on the distribution of foot measurements in the target population.

Many factors are taken into consideration during the measurement of human foot which invariably affect the overall data obtained. The dynamic characteristics of a human foot are: Eversion: Tuning of the foot outward, Dorsiflexion: Rising the foot in the upwards direction,

* Corresponding Author: monyeis@abuad.edu.ng

Energy Return: Energy storage and return ability of the foot, Impact absorption: Ability of the foot to absorb shock: Torsion: Twisting of the foot due to exertion of forces. Software was developed for testing the performance of the various gait modalities [4]

Also, Witana *et al*. [5] recommended a procedure to automatic foot measurement employing three dimensional (3D) scanned data. Eighteen (18) measurements of the foot were computed from scanned data. Each participant's foot was measured twice manually by two operators. They concluded that, there were no significant differences between simulated and manual measurements for seventeen of the eighteen foot measurements and heel width dimension was the exception. They also established that replicable information can also be obtained from automatic measurement with scanned data. However, [6] developed a method employing a 3-D digitizing device, which measures structural characteristics, shape and foot dimension, A total of twenty three (23) variables were obtained from the coordinates of twenty six (26) digitized points on the foot and leg. In another work done by Krauss et al. [7], the contrast existing between female feet and last design were investigated and they concluded that width differences between foot types and lasts differ significantly greatly (0-9mm). Also Wang (2010) defined a fitness function to ascertain the ideal shoe last among respective options in order to establish a procedure for the most befitting shoe last for human foot which is the purpose of the study. The research was based on Reverse Engineering technology. This involved scanning the human foot surface together with shoe lasts in stereo lithography (STL) pattern, this constructed the dimensions: joint circumference, waist circumference and instep circumference. The membership functions of these circumference dimensions between the shoe last and human foot were analyzed and built using fuzzy theory, also the weighting functions for each girth in order to find out the fitness function in the whole databases of the shoe last for the foot was decided by applying the analytical hierarchy process (AHP), from where three (3) case studies were applied to obtain the ranking of ten (10) shoe lasts in the database. He concluded that the research can be employed as a benchmark in the design and making of shoes. Since it defines the correlation between human foot and shoe last. Concerning the aspect of gender differences. Fritz et al. [8] established that static foot measurements can be utilized as fundamental design standards for footwear.

1.2Application of Foot Anthropometry

1.2.1 Medical Rehabilitation

Foot anthropometry is employed in the construction of medical rehabilitation equipment such as prosthetics which are artificial devices that substitute a body part that is missing either due to birth abnormality or disease. The aim of these prostheses is to recreate the typical functions of the missing body part. Some studies were carried out on this which include those by Albert and Ahmed [9] who constructed a lower extremity that can be adjusted for use in Baghdad, Iraq. This developed device aided the amputees in different aspects of movement involving kneeling and standing. Ekezie [10] also established foot anthropometry of the Igbos in South Eastern Nigeria which would be valuable in the stature reconstruction in situations requiring prosthetic and orthotic foot designs.

1.2.2 Forensic Science

The forensic anthropologist makes use of foot anthropometric dimensions to determine gender, age, race and stature of the evidence available in a crime scene. However, Singla et al. [11] reported that in events of natural disasters and terror strikes, recovery of body in developed phase of decomposition and incapacitated state, the height and gender from foot dimension can be helpful in the identification process.

1.2.3 Footwear Design

Footwear designers and manufacturers must use anthropometric foot measurement in order to avoid cases of misfit which may result in pain, injury and in severe cases deformity. This was supported by the study done by Baxter [12] who collected standard foot anthropometric data from New Zealand army personnel for the purpose of better footwear design and manufacture which in turn minimizes the occurrence of injury or damage. In addition, Buldt and Menz [13] examined the relationship between improper footwear, foot abnormalities, foot pain as well as frequent use of unsuitable footwear. Their study concluded that improper footwear was connected to foot pain and disorders also that a large segment of the population put on incorrect footwear.

The present study therefore seeks to optimize and analyze the female foot anthropometric dimensions for optimal results which can be applied by researchers, podiatrists, industrialists among others.

.

2. Materials and Method

2.1. The steps taken in carrying out this study will be fully explained. The procedure is encapsulated as follows in Figure 2.1:

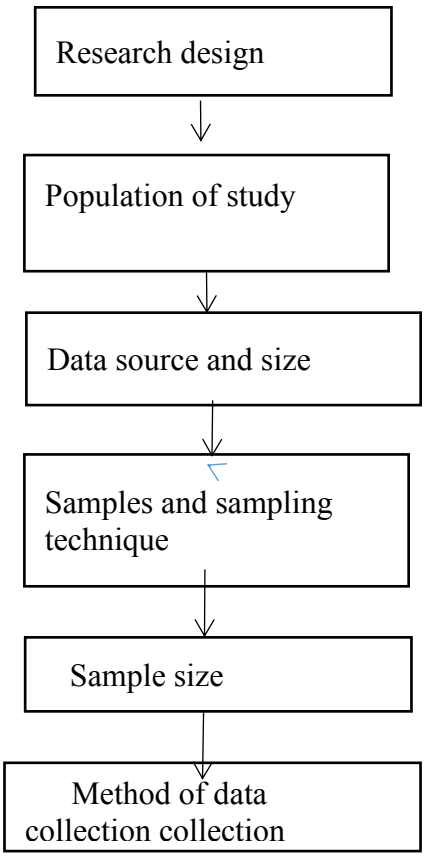

Figure 2.1: Flow chart for foot anthropometry

2.1.1 Research Design

An extensive survey of literature was carried out in order to extract the decisive variables that play pivotal role in female foot anthropometry. From the literature review, a total of thirty-six (36) variables were obtained. Questionnaires were skillfully produced with the thirty-six identified variables. Data were obtained from the Ugbowo community of Benin, Benin- City, Edo State for the female gender. These set of data were analyzed using Descriptive statistics, Correlation and Regression analysis, Eigen value and Eigen vector computation. The corresponding results, were presented as well as discussed, conclusions and recommendations were drawn.

2.1.2 Population of the Study

By the population of the study, it is meant the number of subjects that participated in the study. A total number of two hundred (200) subjects participated which were drawn from the different geo political zones. The subjects were all female.

2.1.3 Data Source and Size

The source of the data for the study was from the Ugbowo community in Benin-City, Edo State. The Ugbowo community of Benin-City is ideally located and has a sizeable portion of the population of interest. The dimensions are the demographic and measured dimensions. Twenty – seven foot anthropometric measurements were made excluding. These measurements were from 200 female participants.

The dimensions are listed below and some of the individual foot diagrams depicting them are; Age, Weight, Stature, Waist height, Waist thigh length, Thigh Circumference, Crotch height, Knee height, Knee Circumference, Calf height, Calf girth, Outer ankle height, Inner ankle height, Ankle girth, Foot length, Foot breadth, Heel height, Heel girth, Bimalleolar breadth (BMB), Heel breadth, ball Circumference, Foot waist Circumference, Instep Circumference, Instep height, Instep length, Ball height, Toe length, Toe height, Toe Circumference.

2.1.4 Samples and Sampling Technique

Sampling is a process of selecting a part of the population for the intended study. A sample is referred to as a cross section of people, objects or items taken from a larger target population for measurement. Simple random sampling technique was employed for this study from the various sampling techniques available.

2.1.5 Sample Size

Figure 2.2 is a scree plot depicting the determination of sample size from the cumulative standard deviation of the stature and the population. The sample size was obtained at the point where the curve became stable..

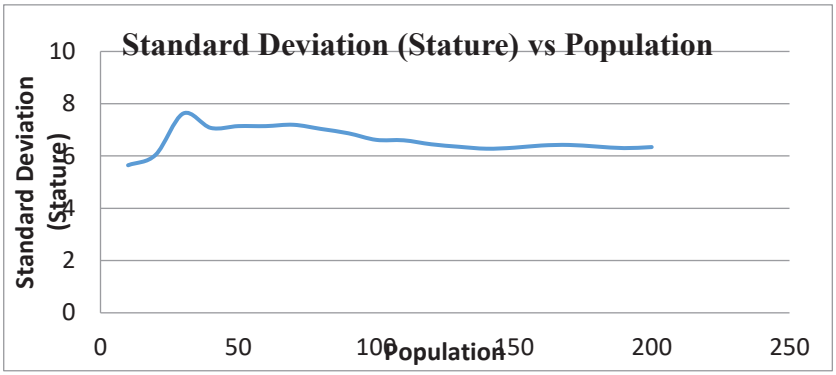

Figure 2.2: Screen Plot to Determine Sample Size

2.1.6 Method of Data Collection

The participants were willing to take part in the study by giving permission to be measured so as to get the appropriate data. They were also required to take off their footwear. In order to avoid diurnal error, the measurements were made at specific period of the day from the period of 9: 00am to 3:00pm. Duration of measurement for each participant was about 30 minutes which later reduced to 20 minutes with subsequent measurement.

2.1.7 Measurement Method and Equipment

In order to obtain accurate and reasonable foot anthropometric measurements as shown in Figure 2.3, dependable and trustworthy equipment are required. They should be well calibrated and of good quality for correct readings. Such equipment employed to attain the anthropometric measurements include: Weighing scale: which was used to measure the weight of the participants to the nearest 0.1kg, large digital sliding calliper as shown in Figure 2.4: was employed in taking length measurements, small sliding calliper: measured the width dimensions to the nearest 0.1cm, adjustable rule: was used to measure height to the nearest 0.1cm and the soft metric tape: this measured the girth/circumference dimensions.

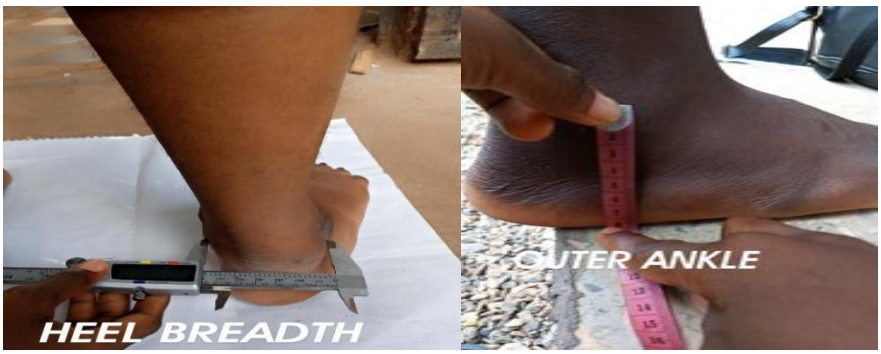

Figure 2.3: Foot anthropometric measurements

Figure 2.4: Measuring instrument-Vernier Calliper

3.0 RESULTS AND DISCUSSION

3.1 Results

Table 3.1 Descriptive statistics of females

					Percentiles				
MEASUREMENTS (Female)	**MEAN**	**SD**	**MIN**	**MAX**	**5th**	**25th**	**50th**	**75th**	**95th**
AGE	24.7	7.4	18.0	55.0	18.0	20.0	23.0	27.0	44.9
WEIGHT	58.7	12.5	40.0	120.0	43. 1	50.0	56.5	64.0	80.0
STATURE	164.6	6.3	150.0	182.0	154.5	160.0	164.0	168.2	176.7
WAIST HEIGHT	103.9	5.1	94.2	119.0	97.0	100.0	104.0	107.2	112.4
WAIST THIGH LENGTH	25.4	3.9	17.0	38.0	20.0	22.0	25.0	28.0	32.0
THIGH GIRTH	56.7	7.8	42.5	92.0	46. 1	51.5	55.0	61.0	71.0
CROTCH HEIGHT	77. 1	4.7	65.5	88.5	70.5	73.2	77.0	79.5	85.5
KNEE HEIGHT	48.4	3.2	35.5	59.9	44.5	46.6	48.5	50.0	52.5
KNEE CIRCUMFERENCE	38. 1	4.1	24.5	55.0	32.5	35.1	38.0	40.5	45.5
CALF HEIGHT	34.8	2.9	29.0	43.0	30.0	33.0	34.5	36.5	40.5
CALF CIRCUMFERENCE	35.1	3.5	26.0	48.5	30.0	32.5	35.0	37.5	40.9
OUTER ANKLE HEIGHT	6.8	0.7	5.5	8.0	5.8	6.2	6.9	7.3	8.0
INNER ANKLE HEIGHT	7.8	0.7	6.4	9.4	6.5	7.2	7.8	8.2	9.0
ANKLE CIRCUMFERENCE	26.4	2.3	21.5	36.5	23.5	25.0	26.0	27.5	30.0
FOOT LENGTH	24.7	1.2	21.5	28.4	22.7	23. 1	24.9	25.5	27.2
FOOT BREADTH	9.3	0.6	7.7	10.9	8.2	9.0	9.3	9.7	10.3
HEEL HEIGHT	5.2	0.7	3.5	7.4	4.0	4.8	5.2	5.7	6.4

HEEL CIRCUMFERENCE	33.2	1.8	28.0	38.0	30.0	32.5	33.0	34.5	36.2
BIMOLLEOLAR BREADTH (BMB)	6.5	0.4	5.4	7.7	5.7	6.2	6.5	6.8	7.2
HEEL BREADTH	5.6	0.5	4.1	6.9	4.6	5.2	5.6	5.9	6.5
JOINT/BALL GIRTH	23. 1	1.4	19.7	27.0	20.8	22.2	23.0	23.7	25.5
FOOT WAIST GIRTH	22.8	1.4	19.3	27.0	20.5	21.8	22.8	23.5	25.8
INSTEP GIRTH	24.0	1.5	19.5	28.5	21.5	23.0	24.0	25.0	26.5
INSTEP HEIGHT	4.2	0.5	2.5	5.8	3.3	3.8	4.2	4.5	5.0
INSTEP LENGTH	18.7	1.1	16.5	22.0	17.0	18.0	18.5	19.3	20.5
BALL HEIGHT	3.11	0.4	2.2	4.2	2.6	2.9	3.0	3.4	3.8
TOE LENGTH	7.1	0.6	6.0	9.0	6.2	6.5	7.0	7.3	8.0
TOE HEIGHT	1.9	0.2	1.5	3.0	1.6	1.8	2.0	2.0	2.3

Group 1

Table 3.2: Females Correlation wielding meritorious and substantial Correlation coefficients

Coefficient	Dimension 1	Dimension 2
$r_{2,6} = 0.829$	Weight	Thigh girth
$r_{2,9} = 0.811$	Weight	Knee circumference
$r_{2,11} = 0.831$	Weight	Calf circumference
$r_{2,21} = 0.659$	Weight	Joint girth
$r_{2,22} = 0.683$	Weight	Foot waist girth
$r_{3,4} = 0.844$	Stature	Waist height
$r_{3,7} = 0.742$	Stature	Crotch height
$r_{3,15} = 0.697$	Stature	Foot length
$r_{6,9} = 0.742$	Thigh girth	Knee circumference
$r_{6,11} = 0.699$	Thigh girth	Calf circumference
$r_{9,11} = 0.802$	Knee circumference	Calf circumference
$r_{11,21} = 0.658$	Calls circumference	Joint girth
$r_{11,22} = 0.73$	Calls circumference	Foot waist girth
$r_{15,18} = 0.678$	Foot length	Knee circumference
$r_{15,25} = 0.761$	Foot length	Instep length
$r_{16,21} = 0.812$	Foot breath	Joint girth
$r_{16,22} = 0.708$	Foot breath	Foot waist girth

$r_{21,22}=0.915$	Joint girth	Foot waist girth
$r_{21,23}=0.866$	Joint girth	Instep girth
$r_{22,23}=0.905$	Foot waist girth	Instep girth

Group 2

Table 3.3: Female Correlation wielding weak correlation coefficients

Coefficient	Dimension 1	Dimension 2
$r_{1,2}=0.051$	Age	Weight
$r_{1,17}=0.093$	Age	Heel height
$r_{2,12}=0.177$	Weight	Outer ankle height
$r_{3,26}=0.071$	Stature	Ball height
$r_{4,28}=0.029$	Waist height	Toe height
$r_{14,17}=0.227$	Ankle circumference	Heel height
$r_{15,24}=0.262$	Foot length	Instep height
$r_{19,27}=0.162$	BMB	Length
$r_{21,28}=0.24$	Joint girth	Toe height
$r_{10,20}=0.115$	Calf height	Heel breadth

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	1																												
2	0.05	1																											
3	0.21	0.39	1																										
4	0.19	0.26	0.84	1																									
5	0.01	0.18	0.08	0.3	1																								
6	0.01	0.83	0.22	0.1	0.02	1																							
7	0.14	0.21	0.74	0.68	0.22	0.14	1																						
8	0.12	0.15	0.63	0.6	0.05	0.1	0.56	1																					
9	0.01	0.81	0.29	0.2	0.21	0.74	0.12	0.28	1																				
10	0.16	0.2	0.61	0.54	0.01	0.15	0.46	0.5	0.16	1																			
11	0.21	0.83	0.26	0.16	0.24	0.7	0.06	0.11	0.8	0.21	1																		
12	0.16	0.18	0.26	0.2	0.07	0.15	0.03	0	0.14	0.16	0.16	1																	
13	0.06	0.29	0.27	0.28	0.14	0.07	0.03	0.04	0.19	0.06	0.3	0.48	1																
14	0.17	0.46	0.39	0.6	0.16	0.38	0.25	0.27	0.52	0.17	0.49	0.05	0.16	1															
15	0.45	0.48	0.7	0.6	0.07	0.31	0.55	0.38	0.35	0.45	0.39	0.13	0.26	0.37	1														
16	0.18	0.49	0.26	0.18	0.11	0.35	0.19	0.16	0.4	0.18	0.51	0.02	0.23	0.31	0.44	1													
17	0.1	0.31	0.17	0.22	0.28	0.11	0.05	0.2	0.32	0.1	0.4	0.03	0.15	0.23	0.37	0.29	1												
18	0.26	0.59	0.52	0.51	0.31	0.34	0.36	0.33	0.57	0.26	0.61	0.16	0.3	0.49	0.68	0.56	0.58	1											
19	0.27	0.44	0.41	0.35	0.32	0.26	0.12	0.25	0.47	0.27	0.5	0.02	0.17	0.39	0.5	0.39	0.41	0.57	1										
#	0.12	0.44	0.31	0.13	0.03	0.31	0.15	0.04	0.31	0.12	0.41	0.09	0.24	0.31	0.44	0.37	0.3	0.38	0.46	1									
21	0.26	0.66	0.35	0.28	0.16	0.44	0.2	0.08	0.5	0.26	0.66	0.18	0.4	0.33	0.55	0.81	0.39	0.65	0.5	0.49	1								
#	0.25	0.68	0.32	0.24	0.17	0.51	0.15	0.03	0.57	0.25	0.73	0.21	0.41	0.41	0.53	0.71	0.39	0.68	0.55	0.53	0.92	1							
#	0.27	0.61	0.35	0.3	0.17	0.39	0.21	0.06	0.51	0.27	0.65	0.2	0.37	0.36	0.53	0.63	0.38	0.67	0.56	0.49	0.87	0.91	1						
#	0.04	0.36	0.11	0.07	0.02	0.37	0.06	0.03	0.29	0.04	0.3	0.22	0.29	0.16	0.26	0.2	0.09	0.24	0.1	0.15	0.29	0.28	0.26	1					
#	0.34	0.49	0.6	0.52	0.15	0.33	0.39	0.3	0.34	0.34	0.36	0.19	0.27	0.31	0.76	0.35	0.44	0.57	0.46	0.42	0.43	0.41	0.37	0.28	1				
#	0.06	0.25	0.07	0.06	0.16	0.34	0.02	0.07	0.2	0.02	0.21	0.19	0.18	0.12	0.12	0.11	0.01	0.06	0.12	0.16	0.21	0.21	0.2	0.44	0.1	1			
#	0.24	0.38	0.42	0.34	0.02	0.33	0.37	0.23	0.24	0.24	0.27	0.1	0.19	0.15	0.51	0.41	0.1	0.35	0.16	0.17	0.44	0.43	0.29	0.23	0.41	0.2	1		
#	0.13	0.24	0.11	0.03	0.02	0.26	0	0.03	0.15	0.13	0.16	0.13	0.06	0.02	0.14	0.22	0.05	0.14	0.15	0.18	0.24	0.24	0.22	0.2	0.08	0.31	0.23	1	
#	0.05	0.42	0.15	0.13	0.12	0.3	0.03	0.14	0.34	0.14	0.49	0.38	0.42	0.26	0.39	0.43	0.2	0.47	0.34	0.41	0.56	0.61	0.57	0.27	0.28	0.23	0.21	0.32	1

Figure 3.1 :- Correlation Matrix of the Females Data

3.2 DISCUSSION

Table 3.1 depicts the descriptive statistics of foot dimensions of the female participants. The mean age was found to be 24.74 ± 7.43. The tables also showed that the mean weight obtained as 58.15 ± 13.29. Also, the mean of the stature was 164.59 ± 6.34. On the aspect of the foot dimensions, the mean foot length gave 24.71 ± 1.24 and the foot breadth also gave 9.3 ± 0.6. In the same table also, the 50th percentile was 164cm tall and the stature span was 32cm, between the range of 150cm and 182cm. Also, the age for the 50th percentile was 25years having a span of 37years from 18years to 55years. The 50th percentile gave a body weight of 56kg from 27kg to 120kg and a span of 93kg.. On the side of the foot measurements, the 50th percentile also gave a foot length of 24.88cm, which ranged from 21.54cm to 28.39cm and a span of 6.77cm.

The result for the correlation analysis was divided into two groups: the substantial and meritorious correlation coefficients as well as the weak ones. Table 3.2 shows the first group of inter play among the various foot dimensions. The various correlation coefficients were noted which also show those dimensions exhibiting substantial and meritorious relationships. The highest value of correlation coefficients ‘r’ was obtained for ball/joint girth and foot waist girth (0.915), foot waist girth and instep girth (0.905) in addition to ball/joint girth and instep girth. Table 3.3 gives the weak correlation coefficients with waist height and toe height having the least value (0.029). Also the correlation matrix was obtained for the foot dimensions as shown in Figure 3.1, this shows the detailed values of all the associations between the individual foot measurements. Generally, the use of shoes with inaccurate length

can result to foot injuries, Rodríguez-Sanz, *et al*. [15], Menz *et al*. [16], Castro *et al*. [17], the need therefore arises to match the foot with the correct shoe size using the right foot dimensions. Foot length of the female obtained, ranged from 21.5 cm to 28.4 cm having a Mean of 24.7 cm with a SD of 1.2. This result is in line with that of [18], Oommen *et al*. [19], Patel *et al* [20], Danborno *et al* [21] and Chikhalkar *et al* [22]. Foot breadth on the other hand, ranged from 7.7 cm to 10.9 cm having a Mean of 9.3cm with also a SD of 0.6. These findings in agreement with the works of Patel *et al.* (2012), Tandor *et al* [23] and Chikhalkar *et al*. [22] The Correlation coefficient 'r' obtained for foot length and weight was (r=0.48), this does not correspond with the study by [24], who obtained (r=0.227). The same is also applicable to the result of the study by Abiedu *et al.* [25] where they had the value of (r = 0.313). These variations in the values of the coefficient of correlation could be attributed to racial and ethnic differences.

4.0 CONCLUSION

The anthropometric data developed, will serve as a template for the Ugbowo community where the study was carried out. The findings from this work go further to prove that environmental as well as ethnic and racial factors have a huge impact on the foot anthropometric dimensions, therefore, it would be inept to apply the same result for different populations. The major standard for a comfortable footwear depends on how well it fits, therefore, information on the correlation between weight and foot length obtained from this study, will play a vital role in the design and manufacture of proper footwear. The result of this study will come in handy for footwear designers as well as further anthropometric studies and research.

Acknowledgment

The Authors acknowledged the financial support by Afe Babalola University in publication of this paper.

References

[1]. P.S Igbigbi, B, S. Ominde, C. F. Adibeli. Anthropometric dimensions of hand and foot as predictors of stature: a study of two ethnic groups in Nigeria. Alexandria journal of Medicine. Vol 54, Issue4, pp 611-617.(2018).

[2]. N. Ante,. T., Vasilije, M. Budimir. Foot anthropometry and morphology phenomena. Coll. Anthropol 30, 4. Pp 815 – 821. (2006).

[3]. D. Manganaro, B. Dollinger, Trevor A. Nezwek, Nazia M. Sadiq. Anatomy, Bony Pelvis and Lower Limb, Foot Joints. Statpearls Publishing LLC. National library of Medicine. National center for Biotechnology Information. (2022).

[4]. M. Strbac and D. B. Popovic. Software Tool for the Prosthetic Foot Modeling and Stiffness Optimization. Hindawi Publishing Corporation. Computation and Mathematical Methods in Medicine, Vol 12, Article ID 421796, 8 pages. (2012).

[5]. C. P. Witana, S. Xiong, J. Zhao, R. S. Goonetilleke. Foot measurements from three-Dimension (3D) scans: A comparison and evaluation of different methods. International Journal of Industrial Ergonomics. 36(9): pp 789-807. (2006).

[6]. W. Liu. Accuracy and reliability of a technique for quantifying foot shape, dimensions and structural characteristics. Ergonomics. Volume 42, Issue 2, pp 346-358. (2010).

[7]. Krauss, G. Valiant, T. Horstmann, S. Grau. Comparison of female foot morphology and last design in athletic footwear- are men's lasts appropriate for women? Res sports Med. 18(2): pp 140-156. (2010)
[8]. W. Chung-Shing. An Analysis and evaluation of fitness for Shoe lasts and human feet. Computers in Industry. Vol 61(6): pp 532-540. (2010).
[9]. I Fritz, T. Schmeltznfenning, C. Plank, T. Hein, S. Grau. Anthropometric influences on dynamic foot shape: measurements of plantar three- dimensional foot deformation. Vol 5, Issue 2, pp 121-129. (2013)
[10]. E.Y. Albert and A. S. Ahmed The design, development and construction of an adjustable lower extremity. IOSR Journal of Engineering. Vol 2, 10, pp 30 – 42. (2012).
[11]. J. Ekezie. Foot Anthropometry; A forensic and prosthetic application. International journal of science and research (IJSR), Vol. 4, issue 6, pp. 738 – 746. (2013).
[12]. R. Singla,, B. Minu, B. Mrinal. Sex estimation from foot anthropometry in Haryanvi jats and north Indian mixed population. J Punjab Acad Forensic Med Toxicol. 12 (1); pp 13-16. (2012).
[13]. M. L Baxter; D. G. Baxter. Anthropometric Characteristics of Feet of Soldiers in the New Zealand Army. Military Medicine, Vol 176. lssue 4. pp 438-445. (2011).
[14]. A. K. Buldt, H. Menz. Incorrectly fitted footwear, foot pain and foot disorders: A Systematic search and narrative review of the literature. Journal of Foot and Ankle Res. 11:43, pp 1-11. (2018).
[15]. A. Rodríguez-Sanz, N. Tovaruela-Carrión, D. López-López, P. Palomo-López, Romero-C. Morales, E. Navarro-Flores, C. Calvo-Lobo. Foot disorders in the elderly: A mini-review. Disease-a-Month, 64, pp 64–91. (2018).
[16]. H. B. Menz, E. Roddy, M. Marshall, T. Rathod, G. M. Peat, P. R. Croft. Epidemiology of shoe wearing patterns over time in older women: Associations with foot pain and hallux valgus. J. Gerontol. -Ser.A Biol. Sci. Med. Sci., 71, pp 1682–1687. (2016).
[17]. A. P. Castro, R. R. belatto, The relationship between wearing incorrectly sized shoes and foot dimensions, foot pain, and diabetes. J. Sport Rehabil, 19, 214–225. (2010).
[18]. E. N. Obikili and B. C. Didia. foot dimensions of a young adult Nigerian population. Anatomical Society of Eastern Nigeria, 1: pp. 22-24. (2006).
[19]. A. Oommen, A. Mainer and T. Oommen. A study of the correlation between hand length and foot length in humans. J. Anat. Soc. India, Vol 54 (2), pp. 55-57. (2005).
[20]. P.N. Patel, J.A. Tanna, S.D. Kalele. Correlation between hand length and various anthropometric parameters, Int. J. Med. Toxicol. Forensic Med. Vol 2 (2) pp 61–63. (2012)
[21]. B. Danboro, and A. Elukpo. sexual dimorphism in hand and foot length, indices, stature Ratio and relationship to height in Nigerians. The international Journal of forensic science, Vol 3(1). (2007)
[22]. G. Chikhalkar, A.A. Mangaonkar, S.D. Nanandkar, R.G. Peddawad. Estimation ofstature from measurements of long bones, hand and foot dimensions, J. IndianAcad. Forensic Med. Vol 32 (4), pp329–330. (2009).
[23]. R. Tandon, S. M. Yunas, N. A. Faruqi, A. Asghar. Measurements of hand and foot – a predictor of stature in adult human population of Uttar Pradesh. International journal of anatomy, Radiologyand Surgery. Vol 5 (1) pp12–15. (2006).
[24]. S. H. Charmode, H. S. Kadlimatti (2019), Correlation of foot dimensions with body weight- A study in young population of central India. Translational Research in Anatomy, Vol 16, 100043. (2019).
[25] J. K Abiedu, G. K. Abiedu, E. B Offei, E. M. Antwi. Estimation of stature and body weight from footprint dimensions among population in Ghana. Australian Journal of Forensic Sciences. Vol 48, Issue2, pp195-202. (2015).