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ABSOLUTE AND RELATIVE FOOT DIMENSIONS OF MALES AND FEMALES SCHOOL CHILDREN IN SOUTHWEST NIGERIA AGED 10 TO 18 YEARS.

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ABSTRACT

Absolute and relative foot dimensions are two classifications of anthropometric measures that are of important consideration when designing footwear for males and females. Besides, it can also be of benefit to the clinicians in determining foot types and deformities.

A localized, two-stage, stratified, Cross-sectional survey was conducted in 10 secondary schools involving male and female students with a total sample size of 518 (males: n= 235, 45.36% females: n 283, 54.63%) aged 10 to 18 years selected across different ethnic groups in public and private secondary schools in Ikeja, Lagos, Nigeria. The independent *t*-test conducted on the students population shows that the males' foot length were statistically significantly longer (left foot: 24.79±1.87cm; right foot: 24.77±1.89cm) than that of their females' counterpart (left foot: 23.38±1.39cm; right foot: 23.40±1.35cm), (left foot: t (518) =9.8190; right foot: t (518) = 9.6080), *p*=0.0000). The males' heel width were statistically significantly wider (left foot: 5.56±0.82cm; right foot: 5.63±0.84cm) than that of the females' heel width (left foot: 5.29±0.72cm; right foot: 5.29±0.71cm), (left foot: t (518) =3.9520; right foot: t (518) = 4.9894), *p*=0.0000). Similarly, the ball width of the male students was statistically significantly wider (left foot: 9.23±0.98cm; right foot: 9.31±0.97cm) than that of the female students ball width (left foot: 8.70±0.72cm; right foot: 8.66±0.76cm), (left foot: t (518) =7.1435; right foot: t (518) = 8.5605), *p*=0.0000). A one-way ANOVA conducted on the children's foot length, heel width and ball width at different age cohorts showed statistically significant difference between the four age groups. This study concluded that the absolute and relative foot dimensions of male children were larger than their female counterparts from the assessed parameters. The result also revealed statistically significant differences in foot dimensions at different age categories.

Keywords: Absolute and relative foot dimension, gender, school children.

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INTRODUCTION

Anthropometric foot dimension in children changes progressively because of active growth in their system. Many studies have been undertaken to determine children's anthropometric foot dimensions (Steenbekkers and Molenbroek, 1990; Kayis and Ozok, 1991; Wang *et al.,* 2002). It has a spectrum of benefits that can be used by clinicians to determine foot types such as flat feet (pes planus), high arch (pes cavus), hallux valgus etc. These differences in foot structure are thought to be associated with differences in foot function during movement. Through activities of living, overtime, the feet structures can change causing a reshaping of the feet. The reshaping process is more apparent particularly in cases of prolonged use of improperly fitting footwear which often results in several medical conditions like gait instability and deformities (Ledoux, 2003). It is also believed that systemic illnesses like blisters, calluses, ingrown toenails can also affect and change the feet which can limit daily activity and quality of life (Ledoux, 2003).

Anthropometric foot measures form the basis of forensic medicine (Saukko and Knight, 2016). The economic value is immense because anthropometric data is important in the children's footwear industry for the standardization of foot sizes in children (Vrdoljak *et al.,* 2017). The interest is also because the significant difference in foot morphology has been reported with patterning that varies across nationalities (Hawes, *et al.,* 1994; Hawes and Sovak, 1994). Notably from studies conducted in European countries, North America, and some Asian countries with African reports glaringly lacking.

Foot length has been observed as a reliable predicting factor for the estimation of body height (Rutishauser 1968). Since then, many attempts were made to discover other predicting factors to determine height with higher accuracy and reliability. The application of foot bones indices can be more valuable because maturation and ossification of these small bones occur earlier. Individual identification from foot and its segments becomes more significant in cases of mass disasters since there is the probability of recovering feet as it is enclosed in shoes (Dhaneria *et al.,* 2016).

There are indications that most static and dynamic foot characteristics change continually during growth and maturation that shows gender variability in foot shapes (Stavlas, *et al.,* 2005; Chen, *et al.,* 2009). These provide a basis for the assessment of absolute and relative foot dimensions amongst the student population which can be beneficial in their shoe production. According to an anthropometric study carried out on high school students to assess their foot profile, it was reported that differences in physical activities and nutrition were possible factors responsible for differences noted in the foot dimensions (Abdurrahman *et al.,* 2018).

The database of foot dimension for children in most African countries including Nigeria is lacking. The reason being lack of investment by the government in data collection and management to have a national database for children as well as insufficient funding for research and data collection initiatives in the area of foot measures of the children population. This study was therefore undertaken to assess the foot profile of children in southwestern Nigeria to know the anthropometric status of their foot dimensions. It can also lay basis for the establishment of the country's specific database which can be utilized by the children's footwear industry to produce comfortable shoes for Nigerians and Sub-Saharan Africans at Large.

MATERIALS AND METHODS

Study population and sample

A localized, two-stage, stratified, cross-sectional, and a descriptive survey was carried out in 10 secondary schools involving a total of 518 secondary school children of both boys and girls respondents across different ethnic groups aged between 10 and 18 years. A total of 235 boys (45.36%) and 283 girls (54.63%) randomly selected from both public and private secondary schools in Ikeja, Lagos, were recruited into the study. Cochran's method for sample size determination was used where the identified 518 students eligible to participate in the study were selected through a simple random sampling method. For each respondent, anthropometric measurements were collected and physically recorded into data tables before conversion to electronic data for statistical analysis. Ikeja, Lagos was selected as the geographic territory for the study due to its cosmopolitan nature and is home to diverse ethnic groups in Nigeria being one of the hubs of commercial activity within Lagos State. The demography elicited in the results was thus reflective and representative of the Nigerian population.

Sample inclusion and exclusion criteria

Criteria for selecting the subjects were:

(1) Students in secondary schools located within Ikeja, Lagos and

(2) Students with no reports of lower limb problems congenital or acquired

Exclusion Criteria:

1. Students with visible known foot deformities
2. Students with previous orthopedic corrective surgery.

Questionnaire and anthropometric measurement procedure

The questionnaire was designed following the study's objective protocol. The research questionnaire captured;

1. Demographic characteristics of the respondents (age, gender, ethnicity).
2. General Anthropometric measurements.
3. The measurements were recorded in the metric unit centimeters (cm).

Anthropometers used for this survey include the following:

a. Modified Harris Matts and Ink Pad
b. Stadiometer (Field Type)
c. Tape rule
d. Metal Rule

For each respondent, anthropometric measurements were collected and physically recorded into data tables before conversion to electronic data for statistical analysis. The demography elicited in the results is thus seen as reflective and representative of the Nigerian population.

Equipment Name	Manufacturer	Technical Specification	Protocols for standardization	Relevant Citation
Modified Harris Matts and Ink Pad	Diabetic Foot Care India Private Limited	Foot Imprinter Harris Mat Model FM1111 **Dimensions(mm):** 610 x 323 x 15.5 mm **Sensor area (mm):** 1440 x 440 mm	The individuals on the study team had all received written instruction and specific training on the operation of the instrument.	Coughlin MJ, Kaz A (2009). Correlation of Harris mats, physical examination, pictures, and radiographic measurements in adult flatfoot deformity. Foot Ankle Int. 30(7):604-12. DOI: 10.3113/FAI.2009.0604. PMID: 19589305. Park, Jeong Mee, Kim, Ki Wan, Lee, Young Hee, Kim, Sung Hoon (1998). A method of analyzing footprint using the Harris Mat for diabetic foot lesions. Journal of the Korean Academy of Rehabilitation Medicine. 22(2):339-345. https://www.e-arm.org/journal/view.php?number=2809
Tape rule	B. D. R. Products (India) Private Limited Sadar Bazaar, Delhi	Material PVC Size 20 mm X 150 cm	The individuals on the study team had all received written instruction and specific training on the operation of the instrument.	Leanda McKenna, Leon Straker & Anne Smith (2013). The inter-tester reliability of anthropometric measurement with portable tools. European Journal of Physiotherapy. 15(1): 34-41.
Metal rule	Sri Neelkanth Impex Private Limited, Punjab	Material Stainless Steel Size 20 cm	The individuals on the study team had all received written instruction and specific training on the operation of the instrument.	Carsley S, Parkin P.C, Pullenayegum K.T.E, Persaud N, Maguire J.L, Birken C.S (2019). Reliability of routinely collected anthropometric measurements in primary care. BMC Medical Research Methodology. 19(84) https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/s12874-019-0726-8

Procedure for the assessment of static foot dimensions

1. Each subject was asked to remove his or her shoes.
2. Foot to be assessed was cleaned with disposable wipes.
3. Foot being assessed was placed on the water-soluble ink mat to obtain an efficient volume of inking on the sole of the feet.
4. Foot being assessed is then placed on the modified mat that is graphed in centimeters.
5. Once complete ink is cleaned off with wipes.
6. Necessary dimension, assessment, and measurements can then be obtained from the impression taken.

In this study, the dimensions measured include the foot length (cm), heel width (cm), ball width (cm) obtained from the right and left foot of the participants. In the measurement of all dimensions except that of the girths, the full-body weight was on the measured foot while the other foot was rested on a 25cm raised platform. Length measurements were performed parallel to the long axis of the foot. Width measurements were made in the horizontal plane perpendicular to the long axis of the foot from the foot imprints. Modified Harris mats were used for each participant. All dimensions were measured by one operator while the other was recorded. The dimensions were assessed according to the protocols in previous studies (Hawes & Sovak, 1994; Goonetilleke *et al.,* 2009). The definition of standard foot measurements and the anatomic landmarks used to measure them are indicated below.

Parameter	Protocol and Landmark
Foot length (cm)	A measure of the distance from the heel to the longest toe of the foot, when the subject stands with the weight evenly distributed on both feet.
Heel width (cm)	The distance between the two widest points at the heel at 15% of the foot length from the heel to the toe.
Ball width (cm)	The distance between the most medial and most lateral projections of the first and fifth metatarsal projected on the horizontal plane The ball width is measured between the big toe joint and the small toe joint. The ball is the widest part of the foot, where the foot flex, and thus also where the shoe should be built to flex.

All measurements of foot dimensions were recorded to the nearest centimeter using standardized anthropometric measuring equipment and the mean actual data obtained.

Study consent and ethical approval

This study was carried out following the recommendations of the Declaration of Helsinki with written informed consent/assent obtained from all subjects under the following tenets; free and informed consent, respect for privacy and confidentiality, respect for justice and inclusiveness, and respect for vulnerable persons our study group in particular (children).

The study protocol was approved by the Lagos State University Health Research Ethics Committee. **LRC/ 06/10/1438**. Written permission to conduct the study was obtained from the Lagos State Government through the Ministry of Education District VI, Ideal Primary School, C/O, Apapa-Oshodi Express Way, Lagos. Written informed consent/assent was obtained having provided necessary identification and study documentation of each school for students, parents, school administration prior to the enrolment of their students to participate in the study.

Data analysis

The data collected was analyzed using STATA software version 14.0 and the results of the continuous measurements were presented on Mean ± SD. The findings on categorical variables were presented as number (%). A Chi-square test was used for assessing the statistical significance of associations at a 5% confidence level. This statistical tool was used because of its robustness pertaining distribution of the data, its ease of computation, the detailed information that can be derived from the test, its use in studies for which parametric assumptions cannot be met, and its flexibility in handling data from both two group and multiple group studies.

The independent t-test was carried out on the sample of 518 students to determine if there was a statistically significant difference in the means of their foot lengths based on their gender groups (i.e. male and female groups). However, ANOVA was used in cases were the means of different age groups were compared.

RESULTS

Comparison of foot lengths and weights of male and female secondary school students

The independent *t*-test was carried out on a sample of 518 students to determine if there was a statistically significant difference in the means of their foot lengths based on the gender groups (i.e. male and female groups). The first group consisted of 235 randomly assigned male students while the second group was made up of 283 female students that were randomly selected. The results of the independent t-test as presented in Table1a; reveals a slight difference in the foot length (left foot and right foot) of males as well as that of the females. The males foot length were statistically significantly longer (left foot: 24.79±1.87cm; right foot: 24.77±1.89cm) than that of the females counterpart (left foot: 23.38±1.39cm; right foot: 23.40±1.35cm), (left foot: t (518) =9.8190; right foot: t (518) = 9.6080), p=0.0000). The males heel width were statistically significantly wider (left foot: 5.56±0.82cm; right foot: 5.63±0.84cm) than that of the females heel width (left foot: 5.29±0.72cm; right foot: 5.29±0.71cm), (left foot: t (518) =3.9520; right foot: t (518) = 4.9894), p=0.0000). The ball width of the male students were statistically significantly wider (left foot: 9.23±0.98cm; right foot: 9.31±0.97cm) than that of the female students (left foot: 8.70±0.72cm; right foot: 8.66±0.76cm), (left foot: t (518) =7.1435; right foot: t (518) = 8.5605), p=0.0000).

Table 1a: presents the mean, standard deviation (SD) of the foot dimensions of students by gender.

(N=518)	Males (235)		Females (283)		*P*-val.
	Mean	SD	Mean	SD	
Left Foot					
Foot length (cm)	24.79	1.87	23.38	1.39	0.0000*
Heel width (cm)	5.56	0.82	5.29	0.72	0.0001*
Ball width (cm)	9.23	0.97	8.70	0.72	0.0000*
Right Foot					
Foot length (cm)	24.77	1.89	23.40	1.35	0.0000*
Heel width (cm)	5.63	0.84	5.29	0.71	0.0000*
Ball width (cm)	9.31	0.97	8.66	0.76	0.0000*

CI – confidence interval; SD - standard deviation; p-value - statistical *significance at p<0.05

Mean differences of students foot length in relation to gender

Table 1b, provides descriptive statistics of an independent t-test to determine if the mean difference of the students foot length between two groups (male and female) were statistically significantly different to zero.

Independent t-test was run on a sample of 518 students to determine if there were differences in foot lengths based on gender. The male group consist of 235 participants while the female group consist of 283 participants. The output provides useful descriptive information for the two groups (male and female) that was compared, including the mean and standard deviation and also the actual results from the independent t-test. The group means were significantly different as the *p*-value in the Pr (|T|>t) row (under Ha: diff! =0) is less than 0.05 (based on a 2-tailed significance level). The results revealed that respondents who were males had statistically significantly longer foot lengths (24.78±1.87cm) compared to their female counterparts (23.37±1.39cm) t (516) = 9.8190, *p* = 0.0000 (Fig. 1).

Table 1b. Mean differences of student's foot lengths for each gender category

Group	Mean	SD	Freq.	F	*t*	*P* -value
Male	24.78	1.87	235	9.8190	516	0.0000
Female	23.38	1.39	283			
Combined	24.02	1.77	518			
Diff	1.40					

Diff = mean (Male) – mean (Female). Ho: diff = 0

Ha: diff < 0	Ha: diff !=0	Ha: diff > 0
Pr(T<t)=1.0000	**Pr(|T|>|t|) =0.0000**	**Pr(T>t) =0.0000**

Note: SD – Standard Deviation; Freq. – Frequency; Diff – Difference; *significance at *p*<0.05

Mean differences of students' heel width in relation to gender

Independent t-test was also run on to determine if there were differences in heel widths of the students in relation to gender; consisting of both males (234 participants) and females (282 participants). The output provides useful descriptive information for the two genders that was compared, including the mean and standard deviation and also the actual results from the independent t-test. The group means were significantly different as the *p*-value in the Pr(|T|>t) row (under Ha: diff! =0) is less than 0.05 (for a 2-tailed level of significance). The results presented revealed that female participants had statistically significantly smaller heel width (5.29±0.73) compared to the males (5.56±0.82), t (514) = 3.9520, *p* = 0.000 (Table 1c and Fig. 2).

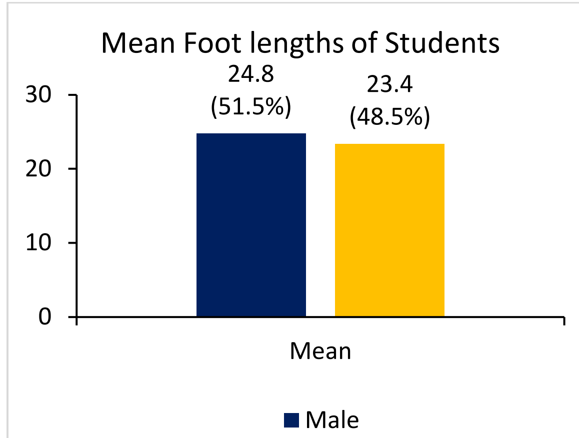

Fig. 1: Bar chart showing mean difference of students foot length in relation to gender

Table 1c. Mean differences of student's heel width for each gender category

Group	Mean	SD	Freq.	F	*T*	*P* –value
Male	5.56	0.82	234	3.9520	514	0.0001
Female	5.29	0.73	282			
Combined	5.41	0.78	516			
Diff	0.27					

Diff = mean (Male) – mean (Female)
Ho: diff = 0

Ha: diff < 0	Ha: diff !=0	Ha: diff > 0
Pr(T<t)=1.0000	**Pr(|T|>|t|) =0.0001**	**Pr(T>t) =0.0000**

Note: SD – Standard Deviation; Freq. – Frequency; Diff – Difference; *significance at *p*<0.05

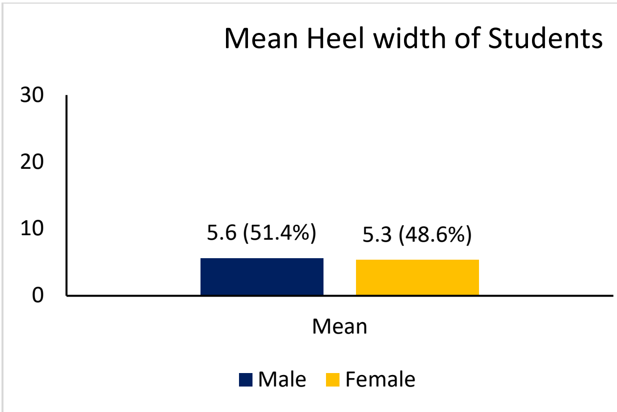

Fig. 2: Bar chart showing mean difference of students heel width in relation to gender

Table 1d. Mean differences of student's ball width for each gender category

Group	Mean	SD	Freq.	F	*T*	*P* – value
Male	9.32	0.97	234	7.1435	510	0.0000
Female	8.70	0.72	278			
Combined	8.94	0.89	512			
Diff	0.54					

Diff = mean (Male) – mean (Female)
Ho: diff = 0

Ha: diff < 0	**Ha: diff !=0**	**Ha: diff > 0**
Pr(T<t)=1.0000	**Pr(|T|>|t|) =0.0000**	**Pr(T>t) =0.0000**

Note: SD – Standard Deviation; Freq. – Frequency; Diff – Difference; *significance at $p<0.05$

Mean differences of students ball width in relation to gender

Independent t-test was run on a sample of 512 students to determine if there were differences in ball widths of students in relation to their gender. The output presents useful descriptive information for the two groups (male and female) that was compared, including the mean and standard deviation and also the actual results from the independent t-test. The group means were significantly different as the *p*-value in the Pr(|T|>t) row (under Ha: diff! =0) is less than 0.05 (for a 2-tailed level of significance). The results revealed that female participants had statistically significantly smaller ball width (8.70±0.72) compared to the males (59.23±0.97), t (510) = 7.1435, *p* = 0.0000 (Table 1d and Fig. 3).

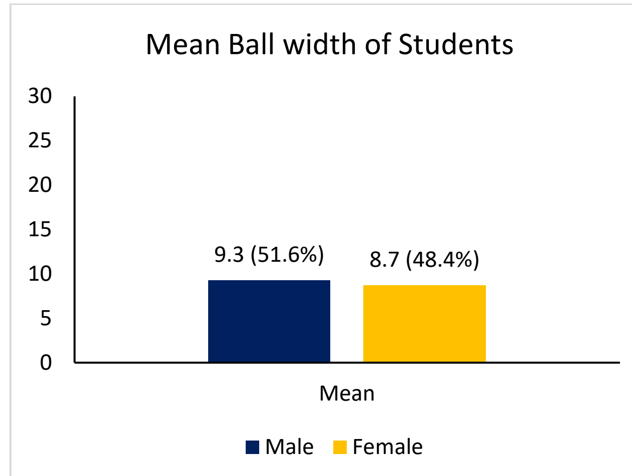

Figure 3: Bar chart showing mean difference of students ball width in relation to gender

Relationship between age categories of students and their foot length

The descriptive output, highlighted in Table 2a provides descriptive statistics, including the mean, standard deviation of the foot lengths for each age category of students (i.e., " 10-12 years", " 12-14 years", "15-17 years" and "18 years"), as well as for all groups combined (Total). The mean foot lengths for all groups of students age group combined (Total) is 24.01±1.77. The mean±SD foot length of students was highest (24.60±1.65 cm) for age group 15 – 17 years and was least (22.21±1.24 cm) for age group 10-12 years.

Table 2a. Descriptive statistics of Students Foot lengths for each Age Category.

Age Group	**Summary of Foot length**		
	Mean	SD	Freq.
10-12 years	22.21	1.24	28
12-14 years	23.58	1.70	200
15-17 years	24.60	1.65	247
18 years	23.67	1.68	38
Total	24.01	1.77	513

Note: SD – Standard Deviation; Freq. – Frequency.

A one-way ANOVA was conducted to determine if the students' foot lengths were different for the different age categories. The statistical analysis shows significant difference between the four age cohorts ($F (3,509) = 26.77$, $p = 0.000$). (Table 2b).

Table 2b. ANOVA showing the difference in the group means

Source	SS	Df	MS	F	Prob > F
Between groups	218.430132	3	72.8100441	26.77	0.0000
Within groups	1384.46566	509	2.71997182		
Total	1602.89579	512	3.13065584		

SS – Sum of squares; df – degree of freedom; MS – Mean Square; F – Calculated value; Prob>F (*p*-value)

Pairwise multiple comparisons for the Tukey post hoc test

Pairwise multiple comparisons result for the Tukey post hoc test is presented in Table 2c. A Tukey post-hoc test reveals no statistically significant differences in the foot lengths of students between the age group "18 years" and the group "12-14 years" (0.086±0.291, $p = 0.991$). However, there were statistically significant differences in the foot lengths of students between the age group "12-14 years" and group "10-12 years" (1.372±0.333cm, $p = 0.000$), or between the age group "15-17 years" and group "10-12 years" (2.392±0.328cm, $p = 0.000$), or between the age group "18 years" and group "10-12 years" (1.458±0.411cm, $p = 0.002$) or between age group "15-17 years" and group "12-14 years" (1.020±0.157cm, $p = 0.000$) or between the age group "18 years" and the group "15-17 years" (-0.934±0.287, $p = 0.007$).

Relationship between age categories of students and their heel widths

The descriptive output, highlighted in Table 3a, provides descriptive statistics, including the mean, standard deviation of the Heel widths for each age category of students (i.e., " 10-12 years", " 12-14 years", "15-17 years" and "18 years"), as well as for all groups combined (Total). The mean heel width for all groups of student's age group combined (Total) is 5.41±0.78. The mean±SD heel width of Students was highest (5.71±0.83cm) for age group 15 – 17 years and was least (4.90±0.63 cm) for age group 10-12 years.

Table 2c. Pairwise multiple comparisons result for the Tukey post hoc test

Age Group	Mean diff.	Std. Error.	*p-value*
12-14 years vs 10-12 years	1.371786	0. 3327788	0.000
15-17 years vs 10-12 years	2.39212	0. 3288676	0.000
18 years vs 10-12 years	1.457707	0. 4107555	0.002
18 years vs 12-14 years	0.0859211	0.2918528	0.991
18 years vs 15-17 years	-0.934413	0.2873852	0.007

*The mean difference is significant $p<0.05$

Table 3a. Descriptive statistics of Students Heel widths for each Age Category.

Age Group	Summary of Heel Width		
	Mean	SD	Freq.
10-12 years	4.90	0.63	28
12-14 years	5.14	0.59	200
15-17 years	5.71	0.83	245
18 years	5.21	0.66	38
Total	5.41	0.78	511

Note: SD – Standard Deviation; Freq. – Frequency

A one-way ANOVA was conducted to determine if the students' heel width was statistically different for the different age categories. The statistical analysis shows significant difference between the four age cohorts ($F (3,507) = 28.78$, $p = 0.000$). (Table 3b).

Table 3b. ANOVA showing the difference in the group means

Source	SS	Df	MS	F	Prob > F
Between groups	45.2002107	3	15.0667369	28.78	0.0000
Within groups	265.434427	507	0.523539304		
Total	310.634638	510	0.609087525		

SS – Sum of squares; df – degree of freedom; MS – Mean Square; F – Calculated value;
Prob>F (*p*-value).

Pairwise multiple comparisons for the Tukey post hoc test

Pairwise multiple comparisons result for the Tukey post hoc test is presented in Table 3c. A Tukey post-hoc test reveals statistically significant differences in the heel width of students between the age group "15-17 years" and the group "10-12 years" (0.807±0.144, p = 0.000) or between the age group "15-17 years" and the group "12-14 years" (0.569±0.069, p = 0.000) or between the age group "18 years" and the group " 15-17 years" (-0.500±0.126, p = 0.000). There were no statistically significant differences in the heel width of students between the age group "12-14 years" and group "10-12 years" (0.239±0.1463cm, p = 0.359), or between the age group "18 years" and group "10-12 years" (0.307±0.180cm, p = 0.323), or between the age group "18 years" and group "12-14 years" (0.068±0.128cm, p = 0.951).

Relationship between age categories of students and their ball width

The descriptive output, highlighted in Table 4a, provides descriptive statistics, including the mean, standard deviation of the ball width for each age category of students (i.e., " 10-12 years", " 12-14 years", "15-17 years" and "18 years"), as well as for all groups combined (Total). The mean ball widths for all age cohorts of students combined (total) is 8.93±0.88. The mean±SD of the ball width of Students was highest (9.20±0.86 cm) for the age group 15 – 17 years and was least (8.19±0.54 cm) for the age group 10-12 years.

Table 3c. Pairwise multiple comparisons result for the Tukey post hoc test

Age Group	Mean diff.	Std. Error.	*p-value*
12-14 years vs 10-12 years	0.2389286	0.1459984	0.359
15-17 years vs 10-12 years	0.807449	0.1443424	0.000
15-17 years vs 12-14 years	0.5685204	0.0689535	0.000
18 years vs 10-12 years	0.3069549	0.1802087	0.323
18 years vs 12-14 years	0.0680263	0.1280431	0.951
18 years vs 15-17 years	-0.5004941	0.1261517	0.000

*The mean difference is significant p<0.05

Table 4a. Descriptive statistics of Students Ball width for each Age Category.

Age Group	Summary of Ball width		
	Mean	SD	Freq.
10-12 years	8.19	0.54	28
12-14 years	8.71	0.82	199
15-17 years	9.20	0.86	242
18 years	8.92	0.95	38
Total	8.93	0.88	507

Note: SD – Standard Deviation; Freq. – Frequency

A one-way ANOVA was conducted to determine if the students' ball widths were different for the different age categories. There was a statistically significant difference between the four age cohorts as determined by one-way ANOVA (F (3,506) = 20.25, *p*= 0.000). (Table 4b).

Table 4b. ANOVA showing the difference in the group means

Source	SS	Df	MS	F	Prob > F
Between groups	42.4705601	3	14.1568534	20.25	0.0000
Within groups	351.640801	503	0.699087079		
Total	394.111361	506	0.778876207		

SS – Sum of squares; df – degree of freedom; MS – Mean Square; F – Calculated value;
Prob>F (*p*-value).

Pairwise multiple comparisons for the Tukey post hoc test

Pairwise multiple comparisons result for the Tukey post hoc test is presented in Table 4c. A Tukey post-hoc test reveals no statistically significant differences in the ball width of students between the age group "18 years" and the group "12-14 years" (0.203±0.148, *p* = 0.519) or between the age group "18 years" and the group "15-17 years" (-0.283±0.146, *p* = 0.211). However, there were statistically significant differences in the ball width of students between the age group "12-14 years" and group "10-12 years" (0.527±0.169cm, *p* = 0.010), or between the age group "15-17 years" and group "10-12 years" (1.013±0.167cm, *p* = 0.000), or between the age group "18 years" and group "10-12 years" (0.730±0.208cm, *p* = 0.003) or between age group "15-17 years" and group "12-14 years" (0.487±0.080cm, *p* = 0.000).

Table 4c. Pairwise multiple comparisons result for the Tukey post hoc test

Age Group	Mean diff.	Std. Error.	*p-value*
12-14 years vs 10-12 years	0.527351	0.1687614	0.010
15-17 years vs 10-12 years	1.013872	0.1669017	0.000
15-17 years vs 12-14 years	0.4865215	0.0800112	0.000
18 years vs 10-12 years	0.7300752	0.2082413	0.003
18 years vs 12-14 years	0.2027241	0.1480204	0.519
18 years vs 15-17 years	-0.2837973	0.1458966	0.211

*The mean difference is significant *p*<0.05

DISCUSSION

In this study, the absolute foot data indicates that males have a larger foot dimension than females. Similarly, relative foot dimension showed higher values for the males from the three assessed parameters. In this case, the female participants had statistically significantly smaller foot length, heel and ball widths. It has been established that from 10 years of age and above males tend to have a greater foot length and width than females (Morrison *et al.,* 2009; Ran *et al.,* 2011; Mbaka and Adelaja, 2021). These reports justify the present study findings because the age range conforms to the age class of the studied population. However, the absolute and relative foot dimensions are two different measures that may not correlate in both genders. It is known that the dimension of a foot is proportionate to the body size (Fessler *et al.,* 2005). More often, female gender exhibit smaller body size than their male counterpart hence their feet is usually smaller. For this purpose, the composite of the parameters that sum to absolute data of the foot often indicates a smaller value for the females. This was the observed trend from most population studies (Manna *et al.,* 2001; Ozden *et al.,* 2005;

Hajaghazadeh *et al.,* 2018). The result of this work also validates the observations. Although the relative foot dimensions, foot length, heel width and ball width of the males were respectively larger than their female counterpart in this study, females nonetheless have shown larger value in some dimensions based on research reports. Notably, the report of Gould *et al.,* (1990) on a population showed females to have a wider forefoot at the age of 9 years while the males exhibited wider forefoot width at age 10 and 12 years. Studies have also shown that in the same shorter foot length, females could have the larger value in some dimensions such as foot width and ball girth (Wunderlich and Cavanagh, 2001; Arora and Tyagi, 2018). It is therefore evident that female feet are not simply scaled-down versions of male feet. The variability of relative foot dimension is a function of several factors that include genetics, environmental, socioeconomic, lifestyle, and shoe-wearing which cause developmental changes in the foot in the direction of sexual dimorphism (Hawes *et al.,* 1994, Razeghi and Batt, 2002).

Usually, in the course of a child's growth, foot shape and proportions change progressively. In this study, growth changes were examined through one-way ANOVA analysis as well as using pairwise multiple comparisons for foot dimensions at four different age cohorts. A one-way ANOVA conducted on the children's foot length at different age cohorts indicates a statistically significant difference of foot length between the four age groups. Pairwise multiple comparison likewise revealed statistically significant difference in foot length between the four age cohorts. The mean±SD foot length of students was highest for age group 15 – 17 years and was least for age group 10-12 years. The remarkable difference could be due to significant changes occurring at those periods which conforms to the report that foot length shows a trend for a significant increase at varied age categories in both genders (Ran *et al.,* 2011). However, it was observed in this study that at age group 18 years the students exhibited decrease in foot length compared to their preceding age group. Nonetheless, it might not confer growth decrease since it was not the same set of students that were measured at different age cohorts. The conjecture was the likelihood that majority of the students population of age cohort 15-17 years may have by genetic predisposition had longer foot.

There was also a statistically significant difference between the heel width of the school children at four age cohorts as determined by one-way ANOVA in which highest (mean±SD) value was recorded at age cohort 15 – 17 years, and the least at age cohort 10-12 years. The pairwise multiple comparison only showed significant difference in heel width between age cohort with the highest mean value (15 – 17 years) and other age categories. The remarkable increase in heel width in the mid to late adolescence life was indicative that the foot has a dynamic and continuously changing shape even in adulthood. This corroborates the report of Xu *et al.,* (2019) who observed a significant increase in heel width in both genders at age cohorts 17-18 years. But the decrease observed at the age of 18 years may be due to similar factor that affected the foot length at the same age cohort.

The ball width equally exhibited a statistically significant difference between the four age cohorts as determined by one-way ANOVA in which case, it showed highest (mean±SD) value at age cohort 15 – 17 years, and least value at age cohort 10-12 years. The decrease in size of ball width at age 18 years suggests that the factor that affected the foot length and heel width may have inadvertently affected the ball width of the students. The pairwise multiple comparison of ball width at different age cohorts also exhibited similitude of variability observed in the heel width.

CONCLUSION

This study shows that the absolute and relative foot dimensions from the assessed parameters of foot length, heel width and ball width were larger in males than their females' counterpart. The result also reveals statistically significant differences in foot dimensions at different age groups.

Authors' contribution: The study was a collaborative work between all authors. Author GOM undertook the literature searches, partook in the statistical analysis, the write-up and final editing of the manuscript. Author MAA designed the experiment, and took part in the write-up and statistical analysis. All authors read and approved the final manuscript.

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