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A COMPARATIVE STUDY OF FOOT MEASUREMENTS USING RECEIVER OPERATING CHARACTERISTICS (ROC) APPROACH.

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ABSTRACT

The objective of this research was to assess the reliability of the foot measurements by comparing the male and female foot measurements, to know if there is correlation between the male and female foot measurements using the standard set by Landis and Koch (1977), and also to identity the true positive rate and false positive rate of both male and female individuals using Receiver Operating Characteristics. The foot measurements for both male and female individuals were obtained from University of Port Harcourt Teaching Hospital (UPTH) Rivers State Nigeria. We investigated the influence of the data structure as a Multivariate analysis using Statistical software (SPSS 17). The receiver operating curve was done to compare the foot measurements of male and female individuals considering the ages of 18-19yrs, 20-21yrs, 22-23yrs and 24yrs and above. The results show that there seem to be a positive correlation between the male and female foot measurements. The Hotteling's T^2 statistic shows that the foot measurements differ.

Key words: Correlation, Receiver Operating Characteristics, Hotellings T^2

INTRODUCTION

A foot is a non System International (S.I) unit of length in a number of different systems including English units, Imperial units, and United States customary units. Its size can vary from system to system, but in each is around a quarter to a third of a meter. The dimensions of the foot can be used for the determination of sex and stature of an individual in forensic investigations [Moudgil et al (2008)]. Also, sex determination remains a critical aspect of human identification from skeletal remains in forensic cases as it reduces the number of possible matches by 50 percent, whilst jointly serving as baseline data for identification procedures such as facial reconstruction (Loth and Isçan, 2000).

The most commonly used foot measurement today is the International foot. Consequently, the International foot is defined to be equal to exactly (30.48cm)[www.wikipedia]. Historical records of foot measurement definitions and research works on foot measurement exist. An investigation by Bidmos and Dayal (2003) is based upon anthropometric study of 60 males and 60 female's crania and mandibles of indigenous South Africans whose age at death ranged from 25 to 70 years old were randomly selected from Raymond Dart collection. They concluded that by using discriminant analysis, the level of average accuracy of sex classification was 80% to 82% for the univariate method and 81% to 85% for the direct method. The research study carried out by

Zeybek (2008) on the estimation of stature and gender through foot measurements using 249 subjects who were attending medical faculty of Dokuz Eylul University and school of physical therapy and rehabilitation in Turkey showed that stature and foot measurements were higher in males than in females and that the difference between the average measures were significant. The study carried out by Bob-Manuel and Didia (2009) on sexual dimorphism in foot dimensions among adult Nigerians using 477 subjects (249 males and 28 females) resident in Port Harcourt Nigeria with ages 18 years and above showed that males had significantly higher values of foot length and foot breadth than females.

However, this research objectives are to assess the reliability of the foot measurements by comparing the male and female foot measurements, to know if the correlation between the male and female foot measurements are slight, fair, moderate, substantial or almost perfect and to identity the true positive rate and false positive rate of both male and female individuals using Receiver Operating Characteristics.

METHODS AND ANALYSIS

For the purpose of this research, a secondary data was collected which constitutes 300 subjects (150 Males and 150 Females) which include the Left Foot Length (LFL), the Right Foot Length (RFL), the Left Foot Breadth (LFB) and the Right Foot Breadth (RFL) for both male/Female individuals between the ages range of 18-35years. This data was obtained from the University of Port Harcourt Teaching Hospital (UPTH). The mean age of the three hundred participants was estimated to lie between $21.5 \pm 1.8 years$ old.

The data obtained was analyzed with a statistical software (SPSS 17) using the following statistical methods: the correlation, Receiver operating characteristics (ROC) analysis and Multivariate approach (Hotelling T^2 statistics).

The Pearson correlation co-efficient was calculated to characterize the foot measurements with the aim of identifying significant difference at $\alpha = 0.01$ and 0.05 level. Comparison of the foot measurements was done, using the Pearson correlation coefficient for both sexes (RFL/LFL, LFB/LFL, RFB/LFL, LFB/REL, RFB/RFL and RFB/LFB) to attain the level of reliability. The level of reliability of the Pearson correlation was classified using the characterizations reported by Landis and Koch (1977). These characterizations range from 0.00 to 0.20 (Slight), 0.21 to 0.40 (Fair), 0.41 to 0.60 (moderate), 0.61 to 0.80 (substantial) 0.81 to 1.00 (almost perfect).

Although Spearman's correlation is a well accepted measure of reliability, it is difficult to interpret Spearman's correlation values since they are dependent of the variability of the groups being assessed (because of the age range) and may not be transferred to different subject populations.

A receiver operating characteristics (ROC) is a graphical plot of the sensitivity or true positive rate (TPR), versus false positive rate (FPR) (1-specificity or 1- true negative rate). It is also known as a relative operating characteristics curve, because it is a comparison of two operating characteristics (TPR and FPR) as the criterion changes. ROC analysis provides tools to select possibly models and to discard suboptimal ones independently from the cost context or the class distribution. The diagnostic performance of test or accuracy of a test is to discriminate diseased cases from normal cases when evaluating using receiver operating characteristics (Metz 1978). In a receiver operating characteristics (ROC) curve, the true positive rate (sensitivity) is a plotted function of the positive rate (100-specificity) for different cut off points. Each point on the ROC plot represents a sensitivity/specificity pair corresponding to a particular decision threshold. A test with perfect discrimination (no over lap in

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the two distributions) has a ROC plot that passes through upper left corner (100% sensitivity, 100% specificity). Therefore the closer the ROC plot is to the upper left corner, the higher the overall accuracy of the test (Zweig and Campbell, 1993).

Hotelling T^2 statistics is a generalization of the students' t statistics used in multivariate hypothesis testing. In this study, it is used to test the average foot measurements of both sexes to know whether the foot measurements differ.

Correlation Matrix/Means (Males)

$$\begin{array}{cc} & \begin{array}{cccc} LFL & RFL & LFB & RFB \end{array} \\ \begin{array}{c} LFL \\ RFL \\ LFB \\ RFB \end{array} & \begin{pmatrix} 1 & 0.922^{**} & 0.626^{**} & 0.609^{**} \\ 0.922^{**} & 1 & 0.609^{**} & 0.637^{**} \\ 0.626^{**} & 0.609^{**} & 1 & 0.872^{**} \\ 0.609^{**} & 0.637^{**} & 0.872^{**} & 1 \end{pmatrix} \end{array} \quad \begin{array}{c} \text{Means} \\ \begin{pmatrix} 26.7587 \\ 26.6493 \\ 10.2133 \\ 10.2367 \end{pmatrix} \end{array}$$

Figure 1: Correlation Coefficients of Male Foot Measurements
**Correlation is significant at the 0.01 and 0.05 Level.

Correlation Matrix/Means (Females)

$$\begin{array}{cc} & \begin{array}{cccc} LFL & RFL & LFB & RFB \end{array} \\ \begin{array}{c} LFL \\ RFL \\ LFB \\ RFB \end{array} & \begin{pmatrix} 1 & 0.895^{**} & 0.464^{**} & 0.458^{**} \\ 0.895^{**} & 1 & 0.513^{**} & 0.535^{**} \\ 0.464^{**} & 0.513^{**} & 1 & 0.779^{**} \\ 0.458^{**} & 0.535^{**} & 0.779^{**} & 1 \end{pmatrix} \end{array} \quad \begin{array}{c} \text{Means} \\ \begin{pmatrix} 24.6093 \\ 24.6507 \\ 9.2833 \\ 9.3047 \end{pmatrix} \end{array}$$

Figure 2: Correlation Coefficients of Female Foot Measurements
**Correlation is significant at the 0.01 and 0.05 Level.

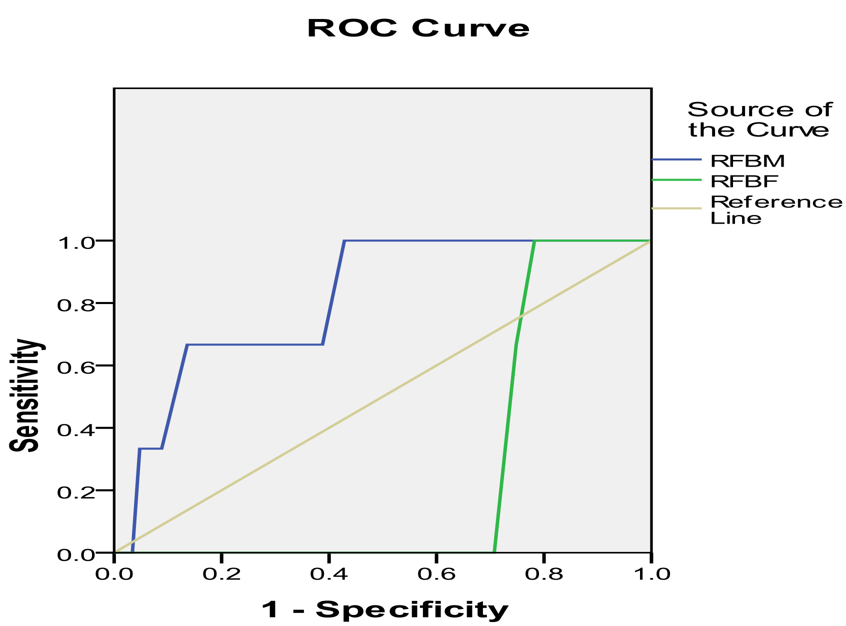
Table 1: Comparison of Foot Measurements Using Pearson Correlation Coefficient

Foot measurement	Male	Female	Level of reliability		Remark
RFL/LFL	0.922	0.895	Almost perfect	Almost perfect	Both are similar
LFB/LFL	0.626	0.464	substantial	Moderate	Male
RFB/LFL	0.609	0.458	Substantial	Moderate	Male
LFB/RFL	0.609	0.513	Substantial	Moderate	Male
RFB/RFL	0.637	0.535	Substantial	Moderate	Male
RFB/LFB	0.872	0.779	Almost perfect	Substantial	Male

Table 2: ROC Area Estimation for Both Sexes

Foot Measurement (CM)	Age Range With % Of Area On The Curve			
	18-19	20-21	22-23	24 and above
LFLM LFLF	0.753 (66.5) 0.379 (33.5)	0.577 (54.7) 0.477 (45.3)	0.461 (47.8) 0.504 (52.2)	0.376 (45.4) 0.453 (54.6)
RFLM RFLF	0.819 (68.4) 0.378 (31.6)	0.596 (55.6) 0475 (44.4)	0.464 (47.3) 0.518 (52.7)	0.412 (48.4) 0.440 (51.6
LFBM LFBF	0.605 (55.2) 0.491 (44.8)	0.541 (55.4) 0.436 (44.6)	0400 (41.0) 0.575 (59.0)	0.478 (48.6) 0.506 (51.4)
RFBM RFBF	0.813 (75.8) 0.26 (24.2)	0.588 (54.6) 0.489 (45.4)	0.400 (41.0) 0.575 (59.0)	0.459 (47.6) 0.505 (52.4)

ROC CURVE



Diagonal segments are produced by ties.

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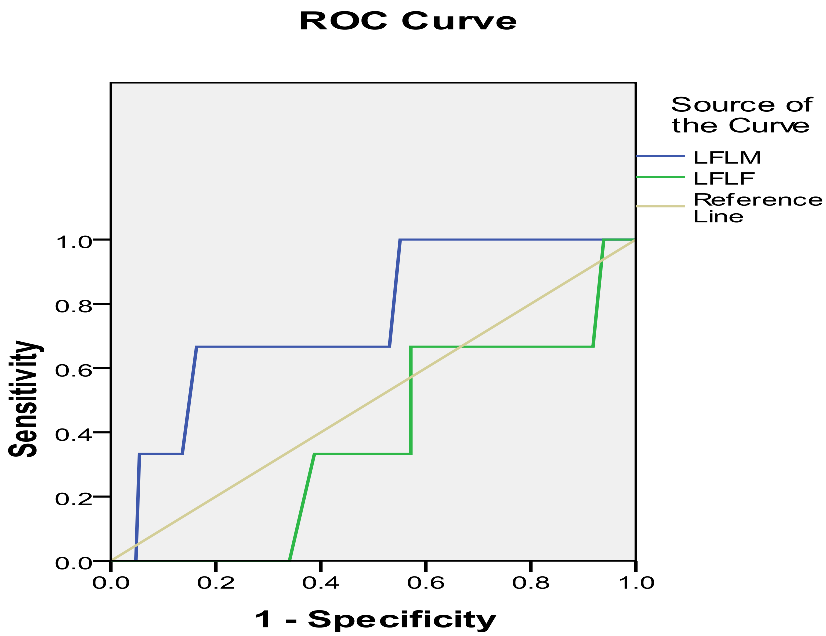

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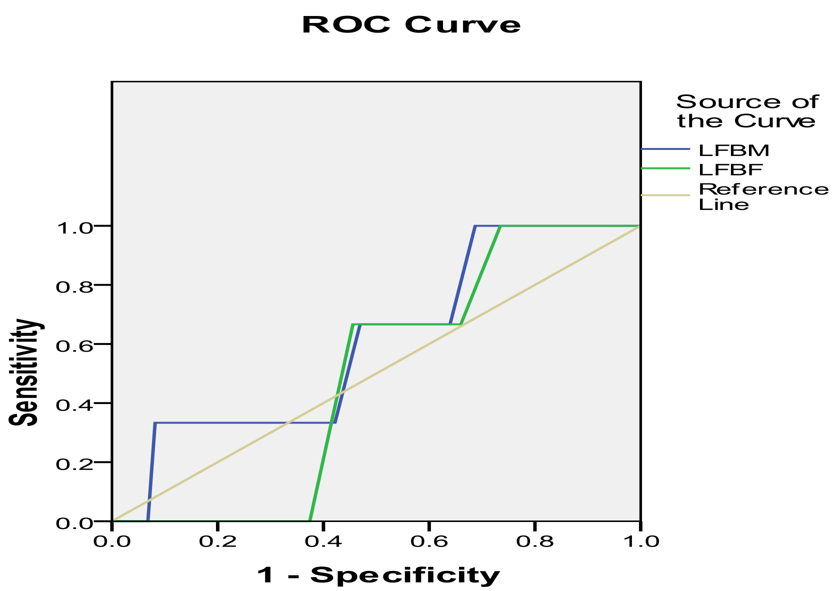

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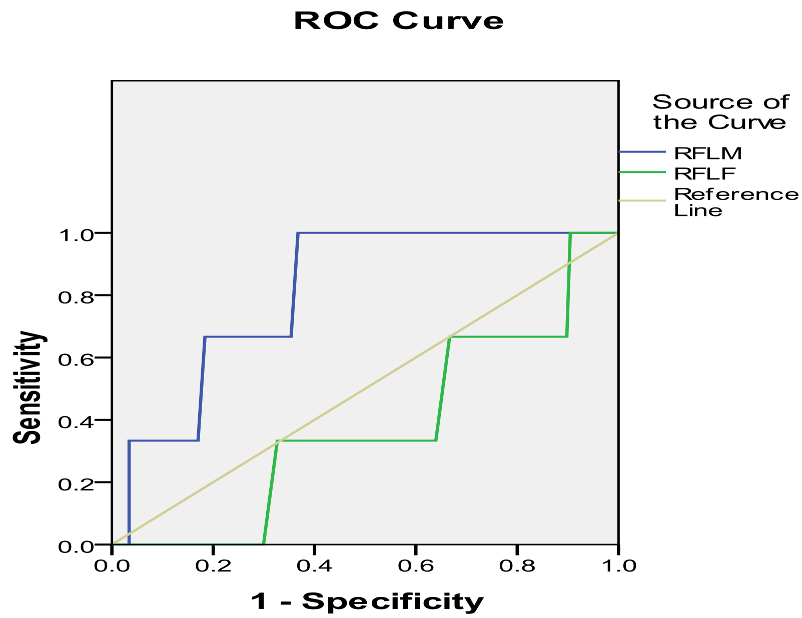

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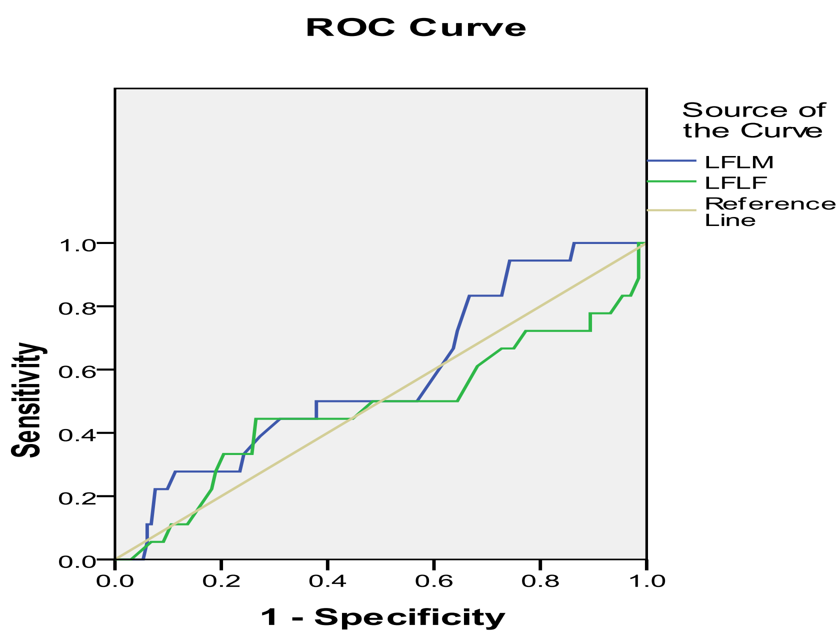

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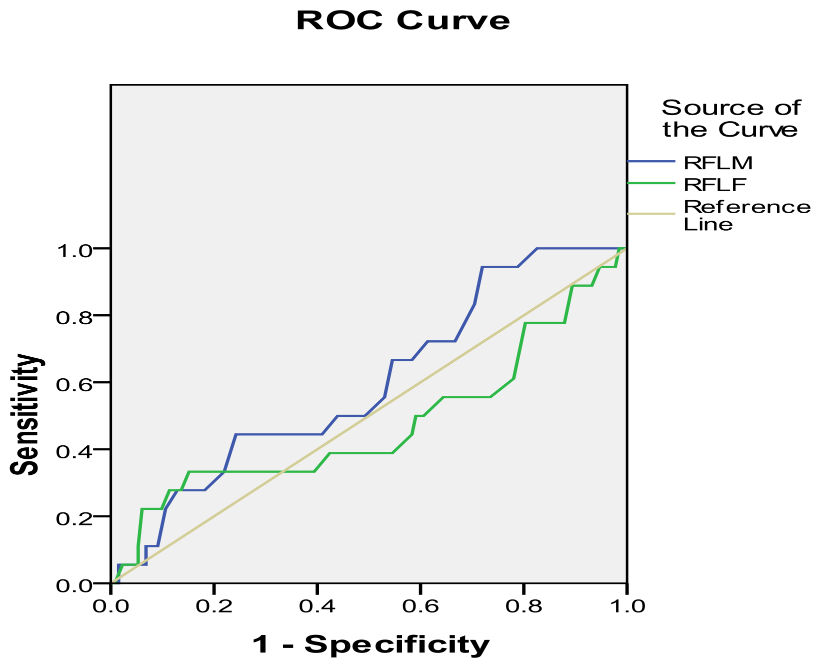

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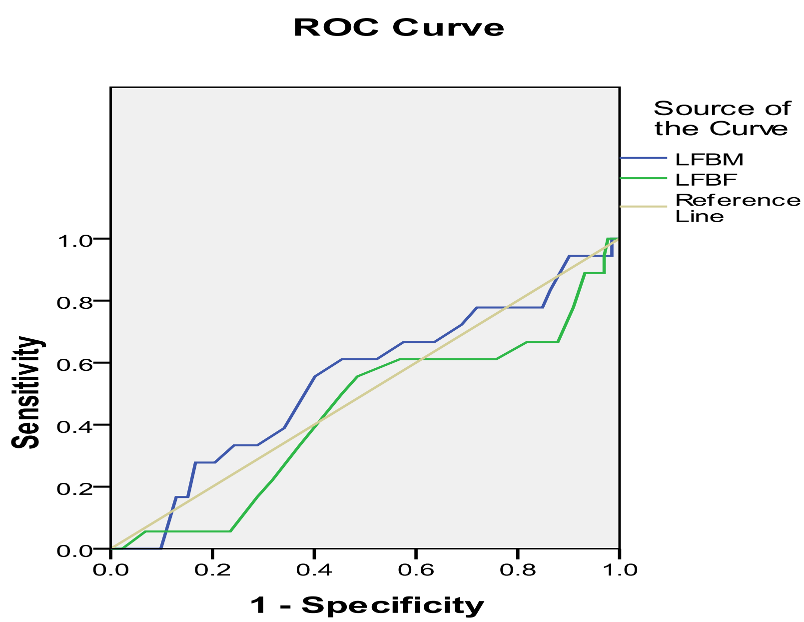

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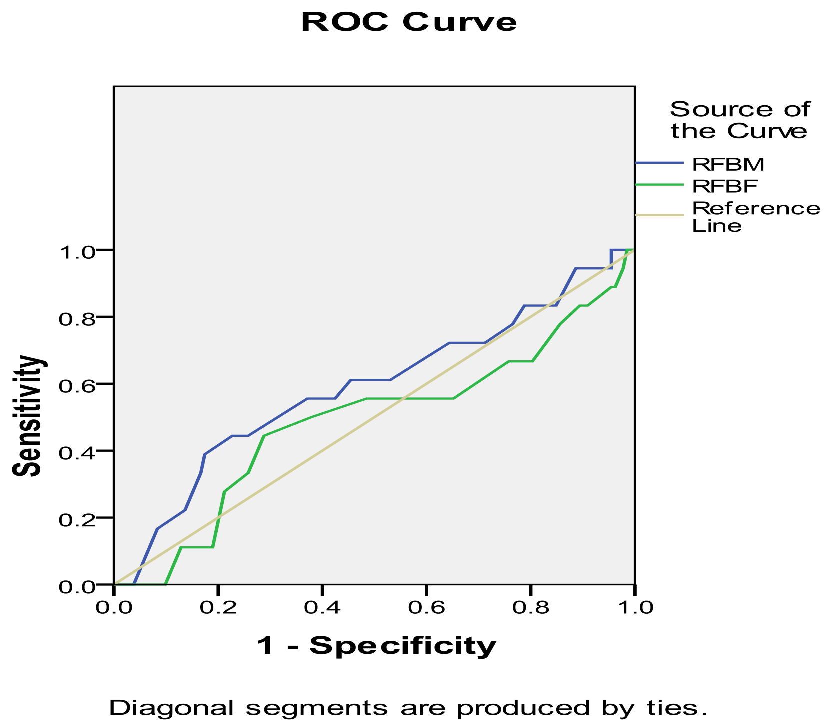
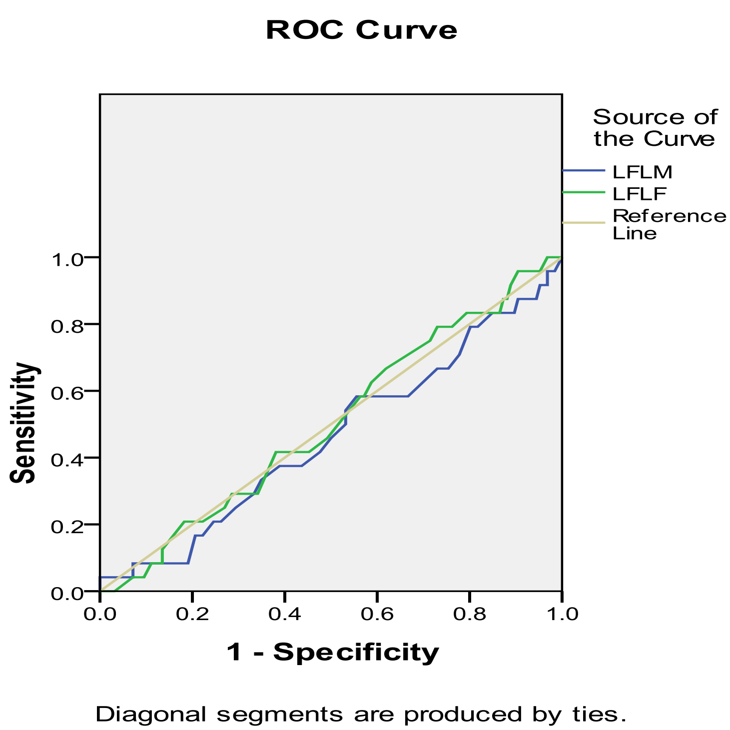

ROC Curve
Sensitivity
1 - Specificity
0.0
0.2
0.4
0.6
0.8
1.0
Source of the Curve
RFBM
RFBF
Reference Line
Diagonal segments are produced by ties.


ROC Curve
Sensitivity
1 - Specificity
0.0
0.2
0.4
0.6
0.8
1.0
Source of the Curve
LFLM
LFLF
Reference Line
Diagonal segments are produced by ties.

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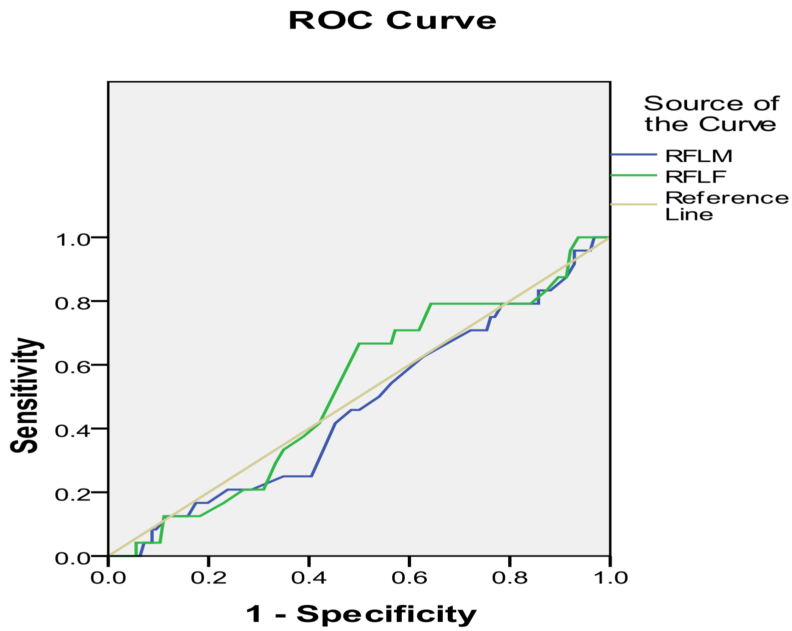

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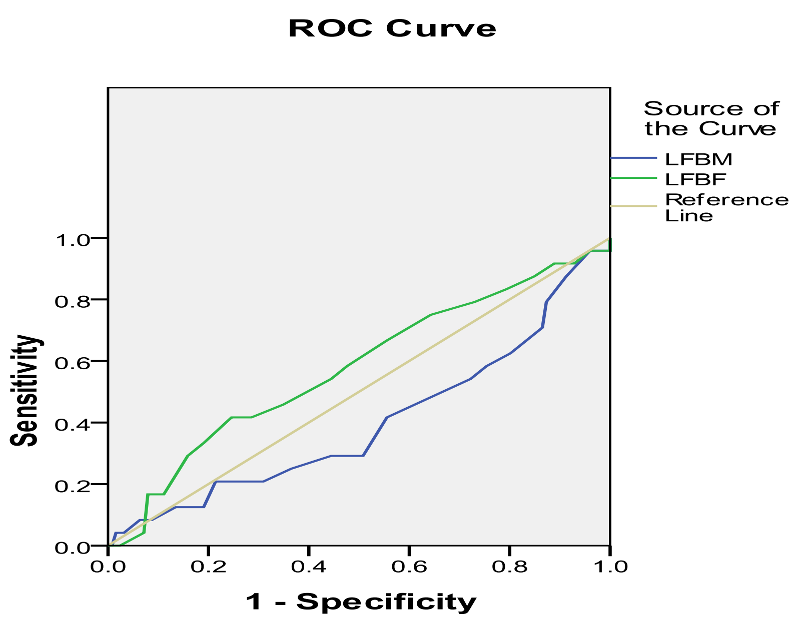

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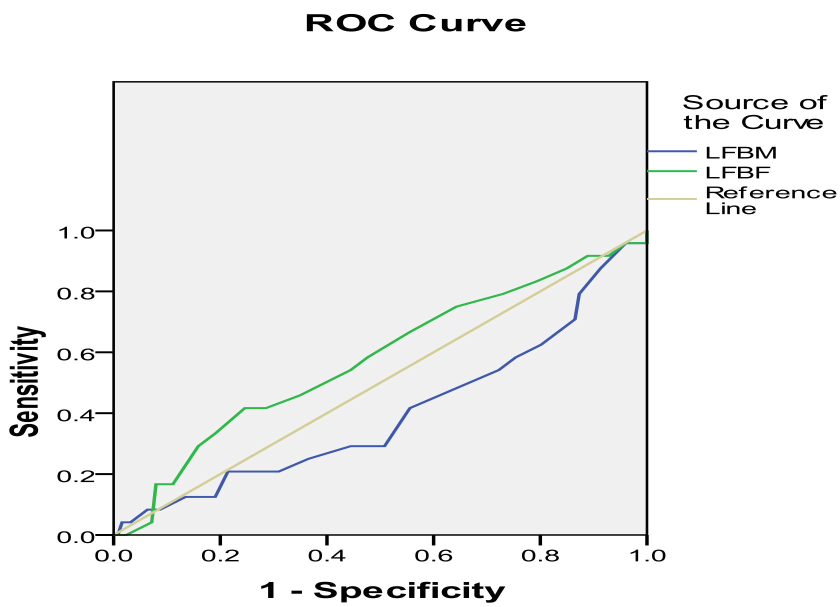

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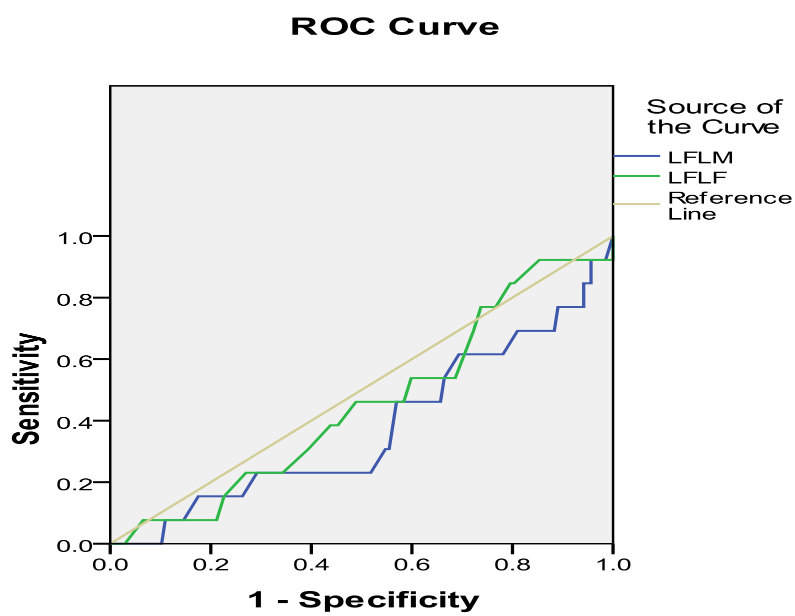

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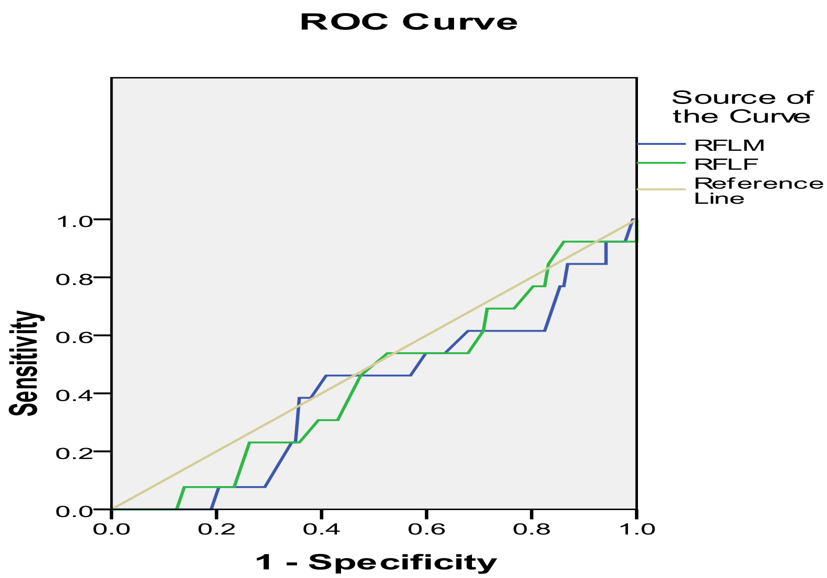

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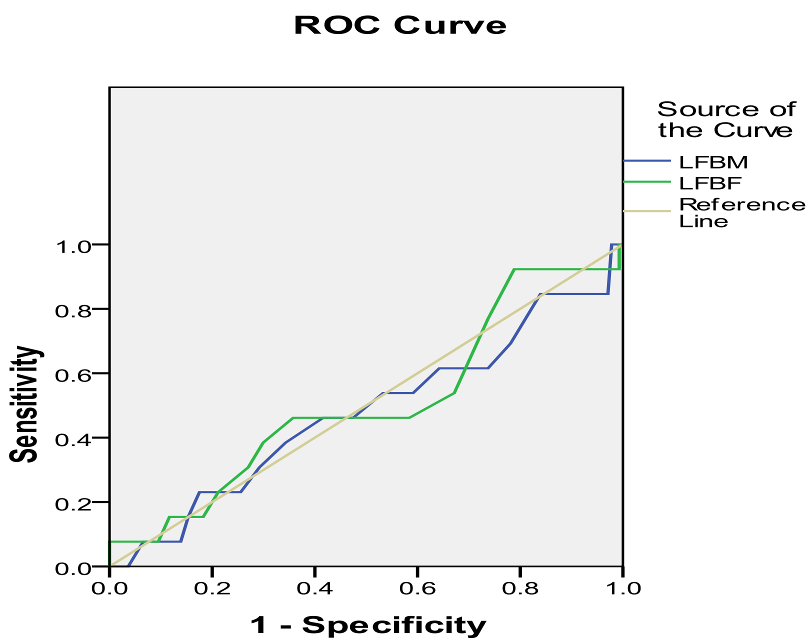

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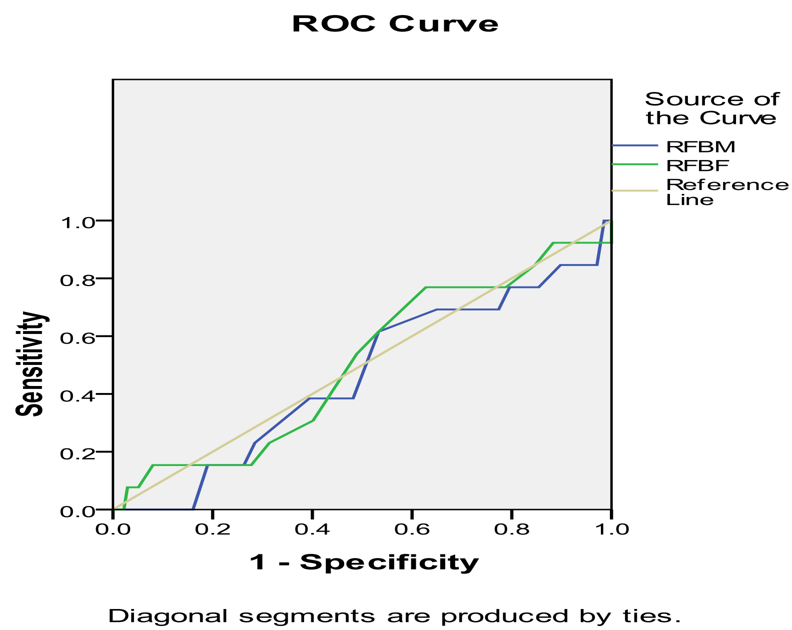

Figure 3: ROC Curve for Male and Female Foot Measurements (Age Range 18-19years, 20-21years, 22-23years and 24 & above).

DISCUSSION

Figures 1 and 2 show the correlation matrix and vector of means respectively of (LFL, RFL, LFB, RFB) male and female foot measurements. Table 1 shows the comparison of the foot measurements using the Pearson correlation coefficient which shows that LFL versus RFL are almost perfectly correlated for both sexes. Comparing LFB versus LFL, RFB versus LFL, LFB versus RFL and RFB versus RFL, the results show that the male foot measurements are substantially correlated. The female foot measurements are moderately correlated which indicate that the male foot measurements are larger than the females. On the other hand, the RFB versus LFB shows that the male foot measurements is almost perfectly correlated while the female foot measurement is substantially correlated which equally conclude that the male is also larger than the female. The result shows that there seems to be a positive correlation between both sexes, but the male foot measurements are bigger than the female.

Table 2 shows ROC Analysis curve estimation for the ages of both sexes with the percentage areas covered on the curve. The age range 18-19 yrs shows that the Left foot length for males cover 0.753 which achieve 66.5% foot dimension while the females Left foot length cover 0.379 with 33.5% foot dimension. In addition, the RFL for the males cover 68.4% while RFL for females cover 31.6% while LFB for males cover 55.2% while LFB for females cover 44.8% of ROC analysis curve.

Finally, the RFB for males cover 75.8% while the RFB for females cover 24.2% which indicate that at the age of 18-19 yrs, the males have larger foot dimension than the females.

Conversely for ages 20-21yrs implies that males have larger foot dimension while from 22-23 and 24 yrs above contradict the first two,

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indicating the female foot measurements is likely larger than the male.

The Hotelling T^2 Statistic, $T^2 = 138.228 > F_{tab} = 9.26$ and we conclude that the average lengths of foot measurements differ.

From the above analysis, Table 1 shows that there is a positive correlation between the foot measurements (male and female foot measurements). However, the ROC analysis and the Hotelling T^2 statistic show that the average foot measurements differ.

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