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A Study on the Correlation among Different Foot Parameters of Bangladeshi Male.

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Abstract

Human beings are considered to be bilaterally symmetrical but there is an asymmetry in the dimension of the feet. There are many differences between left and right foot length, width and girth but there was no data available in the previous literature showing the relationship between left and right foot length. This study was therefore undertaken to determine the correlation between the left foot length and right foot length and identify its acuteness. One hundred (100) male between the ages of 20 and 60 years with no obvious deformities or previous history of trauma to the feet were selected for the study. Furthermore, the study leads to conservation formulas which may emphasize not only last modeling but also augment comfort in footwear.

Keywords: Foot, Dimension, Correlation, Z-test, Regression equation

1. Introduction

The 'comfort of fit' characteristic has not been subjected to any great scientific scrutiny and has largely been left in the hands of the last master, a highly skilled model maker who relies on an artistic sense of shape, size and proportion. Comfort of fit is arguably the most important aspect of shoe design furthermore the most important aspect of footwear customization is to design a custom or better-fitting shoe-last. The shoe-last, a solid 3D mold around which a shoe is made, has relatively complex shape without any straight lines and is normally made of high-density polyethylene for footwear production. The fit of a shoe depends on the design, shape and volume of the shoe-last [1, 4]. Especially, the high incidence of metatarsal bone fractures can be explained by high medial and lateral forefoot loading. The type of footwear modifies in-shoe pressures substantially. This knowledge is important for improving foot comfort and injury prevention. Several techniques have been developed to study the morphology, architecture and kinematics of the foot. Both the kinematics and dynamic structural behaviors of the foot during gait, including development and validation of the 3D finite element model of the foot [2, 5]. The purpose of this study is to investigate the relationship between foot anthropometrical and biomechanical descriptors and derive usefulness regression equations for correlation between foot measurements. This is multiple regression analysis, in which various combinations of these variables were regressed against each other with physical explanation. Besides this paper describes the method of measurement and gives details of the correlation between foot length and joint girth and also provides information that booth of the human foots are not same in measurements and correlation between two foot. These measurements also vary from age to age, weight to weight and height to height. Including this two types of regression equation have been shown in this paper one for correlation between two foot length and another for foot length and joint girth. From the equation, if the length of the large foot (left or right) is known then the length of other foot & joint girth of that person can be determined. Null hypothesis & Z-test is also done for comparing the measurements. The determined regression equation is very much helpful in respect to footwear comfort. As the footwear shape derives from last shape, if the lasts are shaped through regression equation then the footwear will be more comfortable during long time wearing. The calculated value from the regression equation is closely accurate to the measured value hence it can be used.

A total number of 100 male were chosen by purpose sampling of study. Their foot length, width and joint girth measurement was taken through measuring tape and foot caliper(an instrument for measuring external dimensions of foot, having two hinged legs resembling a pair of compasses and in-turned or out-turned points.) similar to Ritz scale (having $\pm$1mm deviation from slide calipers). During taking the measurements ISO/TS 19408 was followed.

Abbreviations: MTP: Metatarsal Phalangeal, TS: technical specification, FL: Foot Length, FW: foot width, JG: Joint girth, LFL: Left foot length, RFL: Right foot length, LFW: left foot width, RFW: Right foot width, LFJG: Left foot joint girth, RFJG: Right foot joint girth, ISO: International Organization for Standardization, FHSQ: Foot Health Status Questionnaire, AVG: Average, STDEV: Standard deviation, HRQOL: health-related quality of life, OA: Osteoarthritis

2. Methodology

Several methods were developed for determination of foot length, width and joint girth. ISO/TS 19408 was prepared by Technical Committee ISO/TC 137 for "Footwear sizing designations and marking system" according to this

2.1. Foot length:

Maximum horizontal distance from the center of the back of the heel (maximum point of heel curve) to the end of the longest toe, which may be the first or second toe, measured along the inside tangent with the subject standing with the weight of the body equally distributed on both feet [7].

2.2. Foot width:

Perpendicular distance between the inside tangent at the first metatarsal head and the parallel line touching the fifth metatarsal head [7].

2.3. Joint girth:

The circumference of the foot in a vertical plane around the heads of the first and fifth metatarsal bones measured with the subject standing with the weight of the body equally distributed on both feet [7].

During data analyzing various methods were followed such as:

2.4. Regression equation:

A regression equation is used in stats to find out what relationship, if any, exists between sets of data. The regression line is represented by an equation. Regression is useful as it allows to make predictions about data [8].

A linear regression line has an equation of the form:

$$Y = a + bX \quad (1)$$

Where X is the explanatory variable and Y is the dependent variable. The slope of the line is ***b***, and ***a*** which indicates the intercept [9].

2.5. Z-test:

Z-test is a statistical test used to determine whether two population means are different when the variances are known and the sample size is large. The test statistic is assumed to have a normal distribution and nuisance parameters such as standard deviation should be known in order for an accurate z-test to be performed [10].

For two populations Z-test the formula is:

$$Z = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{\sigma_1^2}{n} + \frac{\sigma_2^2}{n}}} \quad (2)$$

Where,

σ_1 = Standard deviation for first sample, σ_2 = Standard deviation for second sample, $\bar{x}_1$ = Mean value of first sample, $\bar{x}_2$ = Mean value of first sample, n = Total population number

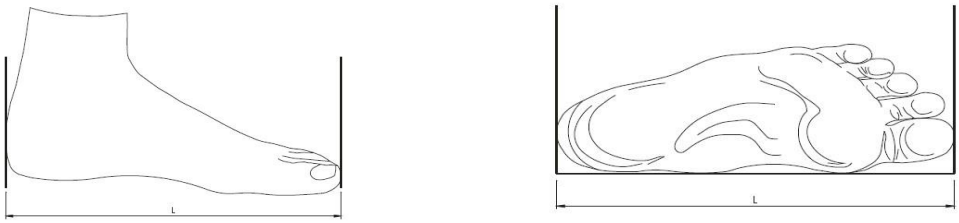

Fig. 2.1.1. Foot length measuring (according ISO/TS 19408)

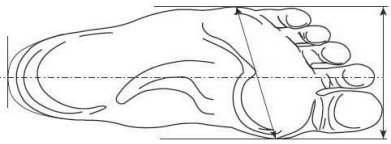

Fig.2.2.1. Foot width measuring (according ISO/TS 19408)

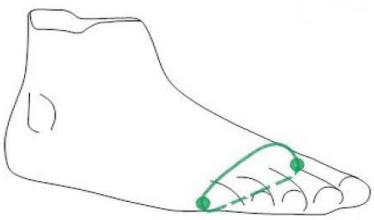

Fig.2.3.1. Foot joint girth measuring (according ISO/TS 19408)

3. Data analysis:

On the basis of analyzing 100 people foot parameters i.e. foot length, foot width and foot joint girth following declarations were made.

Table 1. Overview of collected data

Foot parameters	Foot Length (cm)		Foot Width (cm)		Foot Joint Girth (cm)	
	Right	Left	Right	Left	Right	Left
AVG.=	24.978	25.112	9.579	9.531	23.948	23.978
STDEV=	1.141555	1.11982	0.580368	0.629525	0.876112	0.878541

From the surveyed data it was also observed that the foot width, joint girth and foot length are not changing with respect to each other i.e. different foot lengths having same girth or the same foot length having different width and joint girth. Moreover it is also observer that Left foot is the longer foot for a large population.

Z-test was done to find whether there is any similarity between Left foot length to right foot length, left foot width to right foot width, left foot girth to right foot girth.

Table 2. Synchronization of data though Z-test

Parameters	Left foot length to Right foot length	Left foot width to Right foot width	Left foot joint girth to Right foot joint girth
Z-value =	0.838	0.561	0.242
From Z table[11], P=	0.402	0.575	0.81

P value obtained from above three cases is >0.05. So, null hypothesis can be accepted. Hence it can be declared that similarity exists between two foot lengths, widths and joint girths.

4. Result:

Plotting the left and right foot length of 100 male into the pie chart it was observed that 65% of populations having their left foot larger in length than right foot including this only 18% having their right foot longer in length and 17% having booth foot similar in length.

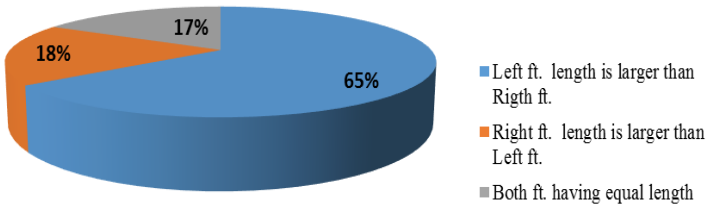

Fig: Foot length pie chart

As majority of population having left foot larger, all the correlation was determined based on left foot. However, people who are having right foot larger all the parameters can be considered against right foot and also who are having both foot length similar either foot can be chosen.

4.1. Regression equation result:

As Z-test reflects similarities between foot parameters, so an approach was made to develop conversation formula through regression analysis.
Three types of conversation formula were developed to get one foot parameter from another
1. Left foot length to Left foot Joint girth. 2. Left foot length to Right foot length. 3. Left foot Joint girth to right foot Joint girth.

4.2. Conversation between left foot length to right foot joint girth:

Considering Left foot Length as an independent variable and left foot joint girth as a dependent variable a linear equation y = 0.7746x + 4.5256 is obtained. Here blue dotted linear line indicates the actual measurement and the red dotted liner line indicates the predicted calculated value from the equation

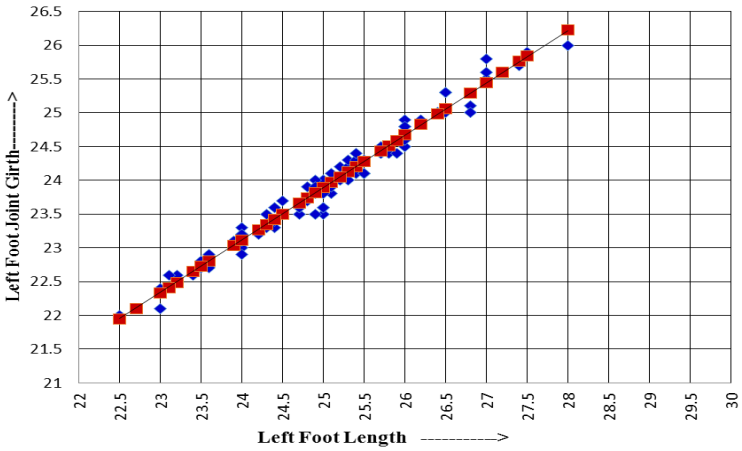

Fig 4.2.5.1.1: LFL vs. LFJG Plot

4.3. Conversation between left foot joint girth to right foot length:

Considering Left foot Length as an independent variable and Right foot length as a dependent variable a linear equation y = 0.9954x - 0.0189 is obtained. Here blue dotted linear line indicates the actual measurement and the red dotted liner line indicates the predicted calculated value from the equation

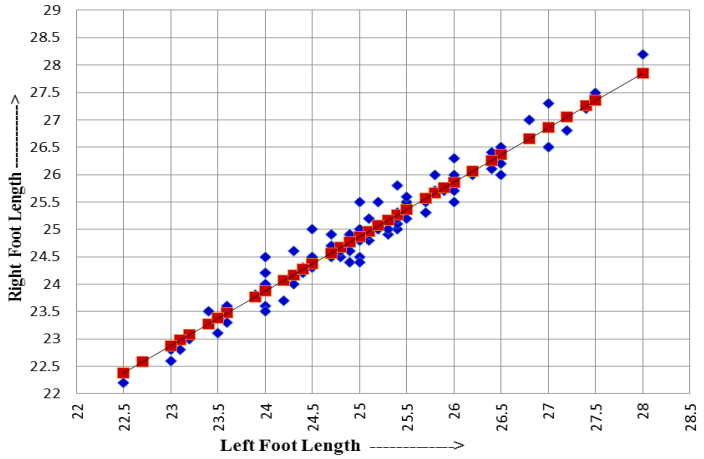

Fig 4.2.5.1.1: LFL vs. RFL Plot

4.4. Conversation between left foot joint girth to right foot joint girth:

Considering Left foot JG as an independent variable and Right foot JG as a dependent variable a linear equation y = 0.9478x + 1.2208 is obtained. Here blue dotted linear line indicates the actual measurement and the red dotted liner line indicates the predicted calculated value from the equation

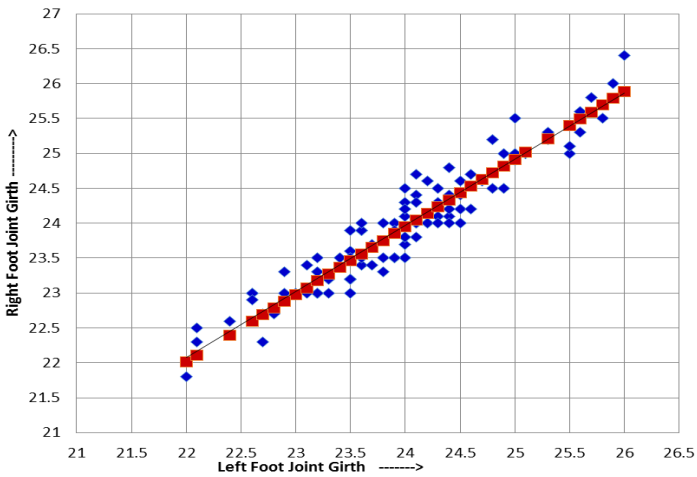

Fig 4.2.7.1.1: LFJG vs. RFJG Plot

5. Discussion:

Studies have demonstrated some variation in the results obtained from actual measurement using different techniques side by side Human measuring errors were eliminated [12,13]. The relation between foot length and foot girth in the male populations from collected data were similar to that in the present young adults from the data series, but many males had a extremely small foot girth for the same foot length. It is not known whether this is a characteristic of males or is rather caused by sampling bias, due to a lack of other comparative materials [14]. First MTP joint OA is recognized as a condition that commonly causes foot pain. However, no studies have comprehensively investigated the broad impact of this condition using HRQOL outcome measures. Therefore, the primary objective of this study was to compare the foot specific and general HRQOL of people with and without symptomatic first MTP joint OA. Foot-specific HRQOL was investigated using the FHSQ. All FHSQ domain scores (foot pain, foot function, footwear, and general foot health) were significantly lower in the case group, indicating that symptomatic first MTP joint OA is associated with reduced foot-specific HRQOL. Due to the wide range of shoes currently available, clinicians and researchers must be able to agree on their footwear assessments to enable valid comparisons to be drawn [15,16]. Subjects with foot pain, irrespective of its postural characteristics were found to have more foot problems than subjects with no pain. The higher the number of foot problems the more likely the presence of foot pain. In order to evaluate the independent association of specific foot abnormalities with pain, the variables describing leg foot dimensions were introduced as independent variables in a multiple logistic regression model where the dimension of right foot was considered as the dependent variable. In this model, we found a significant association between foot pain and the presence of calluses and corns [17].

However it was observed that in some cases left foot is larger in length than right foot but having smaller joint girth or width. So, human foot shapes differ from age to age, height to height and gender to gender and no regular increment or decrement was observed and so we can't declared that only one parameter is the main factor for fitting comfort hence combining all the parameters i.e. foot length, breadth. Joint girth comfort ability of foot wear is achieved. So further analysis i.e. Z-test was done to find out that is there is any similarities present between left and right foot measurement and side by side regression equation was applied for proposing conversation formulas between foot measurements

5.1. Overviewing Z-test & regression equation

From the z-test it can be declared that there is similarities between two foots lengths, in between two foot widths and between two foots joint girth as in all three cases $P>0.05$ where Statistical significance for hypothesis tests will be set at the conventional level of $\alpha = 0.05$.

Including this three types of conversation formula were developed through regression equation:

i. $y = 0.7746x + 4.5256$ (LFL vs. LFJG)
ii. $y = 0.9954x - 0.0189$ (LFL vs. RFL)
iii. $y = 0.9478x + 1.2208$ (LFJG vs. RFJG)

Construction of shoes must certainly be based on these essential differences between individuals and between populations. It was observed that foot breadth and ball girth are to be taken into consideration quite separately from foot length. This means that these three basic measurements are to be regarded as the significant procedures for the healthy shoe last manufacture. On the other hand, racial differences may play an important role in the structure of foot.

5.2. Outcome of study

- As shoe last is the base of shoe manufacturing and last dimension for both foots are equal hence the both foots in human are not equal which causes discomfort during wearing.
- All of these three conversations are trending with the comfortability of footwear and it's fitting property.

- So it can declared that for any known foot length or any predicted foot length, joint girth of that foot and length of the another foot can be determined by applying the conversation formulas.
- From these three equations for a particular foot dimension can be obtained which can enhance the last modeling**.**

6. Conclusion:

The most common reason for the discrepancy was having a difference between right and left foot sizes, necessitating the selection of a shoe to fit the larger foot. Several factors contributed to the allocation of a different sized shoe, such as participant preference, accommodation for orthosis and expected foot swelling, suggesting that foot dimensions alone cannot be used to select the optimum shoe size besides the shoe last was classified into different classes by considering various incremental intervals of the foot length[6]. The information which are provided in this work can be used as a guideline to evaluate and determine the feasible parameter for shoe last design and manufacturing, and especially, to develop the reasonable and comfortable shoe last and foot wear.

However during study in some cases during taking the measurements the servitor was not in proper weight bearing condition including this due to foot deformities some measurements were fluctuated this deformities were ignored and not mentioned in the thesis work also during data processing in some cases average value of Length, Girth and Width was considered but some people have the measurement of these parameters above or below the level of STDEV. Moreover no direct conversation formula was mentioned for those who have equal foot lengths**.**

To achieve the mass production's objective of mass production, it is necessary for us to set up the standard size specification system [3]. The method used in this research can be applied to other related anthropometric items in a wide variety of practical cases and provides a new approach for the architecture of mass-customization system for both style and fit [18]. The present method saved the processing time and labor, and made the processing of a large amount of data possible.

"The customer will judge their shoe fit by wearing the shoes, but at the factory used the "substitute" characteristic like length, width, and so on, to design, develop and produce their product". The use of the "error" metric can not only improve fit but will allow footwear manufacturers to design lasts that match a given population. Present thesis work involves determining the parameteres of feet and the development of parameters to quantify the shape of different feet so that the mapping from feet to shoes is straightforward.

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