Original article

Development of a New Shoe Fitting for Obese Adults

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Abstract

Background: Standard fit as well as wide-fit footwear not currently being pertinent and comfortable for the obese adults. The biometric measurements of obese foot (such as foot length, foot width, heel girth, instep girth, waist girth, and ball girth,) significantly differ from healthy adults.

Aim: This study aims to develop a new shoe fitting for obese adults based on significant relationships among the relevant biometric parameters of the foot.

Method: These measurements of obese foot were determined using a Brannock device and measuring tape. All kinds of foot girth measurements were analyzed against scaling based on foot width or current fitting, BMI, foot length, heel girth, instep girth, waist girth and ball girth and compared these data with ANOVA.

Result: Results showed that responses of all kinds of girths against waist girth scaling provide best fitting prospects of obese adults than current standard fit as well as other parameters.

Conclusion: From the study and results, it can be concluded that shoe fitting based on waist girth can give more precise comfort and improve the ergonomic fitness of the product for obese users.

Keywords: Obesity; BMI; Foot girth; Shoe fitting.

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Introduction

Obesity is a term used to indicate the Body Mass Index (BMI) of ≥ 30 kg/m^2. In 2014, over 650 million adults from more than 1.9 billion overweight population were obese. Now it has been treated as a pandemic and can affect 10-30% of the adult population across the world.[1] The foot of an obese adult can vary in structure compared to the person with a normal weight due to changes in soft tissue, skeleton, morphology, and functionality.[2-3] The foot dimensions of an adult obese are blatant and having flatter morphology or lower longitudinal arch and greater foot girths.[4-6] Compared with the forefoot and rear foot, the midfoot had comparatively significant differences in height, width and circumferences due to increase of soft tissue thickness in the midfoot of obese adults.[6-9] The study showed that obese adults report ill-fitting and un-comforts about the standard fit footwear.[4] Comfort in footwear is defined mainly by the fit between the foot and the footwear. The poor fit between the foot and shoe affect foot function and may result in excessive foot pressure due to tightly fitting footwear or unnecessary friction due to loosely fit footwear.[10-11] In general, the fit is accomplished by fitting the foot to the footwear in terms of length, and width.[7] But they did not consider other important foot measurements, such as arch length, foot girths, and height. Many earlier studies found that foot length and foot width are not enough to define the foot.[12-13] There are different fittings available in the current shoe sizing system and most of those based on the ball width and a few of those were considered

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the ball girth of foot for determining the shoe fitting. These are also not accommodated and fit well in the foot of obese people.

This situation makes difficult for obese to choose a suitable footwear. In spite of having high frequency of fitting problems, there is no available study or research on the development of special footwear for the obese people. The aim of this study was to develop a versatile fitting system with considering the different foot girth measurements which provides an improved fit to the obese foot.

Materials and Methods

Participants and study locations

Thirty-eight normal obese men with average BMI 32.87 that ranges from greater than 30 to 40 were selected randomly for the experiment. The mean weight of these groups of participants was 98kg with a range of 85kg to 117kg.The age ranges of the participants were from 20 to 24 years with a mean of 21.55 years. All of the participants were the current students of Khulna University of Engineering & Technology come from different regions of Bangladesh. They have given their written consent about the data collection.

Data collection

Data for the six different parameters of the foot (foot width or current fitting, foot length, heel girth, instep girth, waist girth and ball girth) were taken from the participants using mainly two types of tools namely Brannock device and Measuring tape (Figure 1). Brannock device was used to take data for current fittings and shoe sizes while measuring tape was used for all kinds of girth measurements. All of the measurements were taken in a comfortable sitting condition with wearing a woolen sock and only their right feet were considered to ensure statistical freedom within the samples.

Statistical analysis

Seven categories of parameters related to obese foot including BMI were collected from the participants. Then a regular interval of scaling on those categories and their average collected values are shown in Table 2. According to these scales all the measured values of four girth’s i.e., Heel Girth (HG), Instep Girth (IG), Waist Girth (WG) and Ball Girth (BG) were analyzed against the seven categories of parameters. The one-way ANOVA was adopted to find out whether there is any statistically significant differences of girth values exist among the newly created scaling groups of seven variables. Sources of variation among between groups and within groups, F and F critical values and respective P values from the ANOVA are displayed in Table 3.

(a) (b) (c) (d) (e)

Figure 1. Data collection from the participants: (a) Fitting width, (b) Ball girth; (c) waist girth; (d) Instep girth, and (e) Heel girth, measurement.

Table 1. Categorization and scaling of parameters and their average group values

Categories	Scaling of parameters (mm except FW, BMI)	Average values of respective scaling groups (mm)			
		Ball Girth	Waist girth	Instep girth	Heel girth
FW	C	274.5	271.5	289.5	355.8
	D	265.6	267.3	286.7	359.0
	E	276.2	274.3	286.6	359.9
	EE	274.7	274.0	287.0	350.8
BMI	30-31	273.5	270.1	286.6	354.8
	32-33	267.9	271.5	285.4	357.4
	34-35	274.8	272.8	286.5	360.5
	36-37	280.7	277.0	295.3	373.7
	38-39	279.0	282.0	292.0	353.0
FL	6-6.5	250.0	257.0	255.0	359.0
	7-7.5	274.0	268.0	282.0	342.0
	8-8.5	266.0	272.3	290.5	356.3
	9-9.5	269.4	269.7	285.3	356.8
	10-10.5	278.7	271.5	287.9	355.1
	11-11.5	270.0	274.4	287.4	363.0
	12-12.5	284.3	281.0	294.7	365.3
	13-13.5	272.0	276.0	298.0	368.0
HG	320-329	253.0	257.0	274.0	324.0
	330-339	-	-	-	-
	340-349	275.8	271.6	287.3	343.4
	350-359	271.7	270.3	283.8	356.2
	360-369	267.9	270.0	287.9	366.3
	370-379	285.0	284.5	299.5	370.5
	380-389	277.0	278.0	294.0	385.0
	390-399	-	-	-	-
	400-409	288.0	294.0	310.0	401.0
IG	250-259	250.0	257.0	255.0	359.0
	260-269	-	-	-	-
	270-279	268.3	267.8	273.9	351.3
	280-289	270.5	268.5	285.0	355.4
	290-299	276.0	274.8	294.4	359.6
	300-309	282.0	286.0	306.3	375.3
WG	250-259	251.3	257.0	272.0	346.0
	260-269	270.2	266.3	285.0	355.8
	270-279	271.8	272.7	286.3	358.6
	280-289	286.7	283.7	296.7	358.2
	290-299	288.0	294.0	310.0	401.0
BG	250-259	252.7	263.8	279.2	350.3
	260-269	264.7	268.9	286.9	359.0
	270-279	274.6	272.2	286.9	359.1
	280-289	284.3	275.0	292.2	360.5
	290-299	294.3	285.3	293.0	357.0

FW = Foot Width; BMI = Body Mass Index; FL = Foot Length; HG = Heel Girth; IG = Instep Girth; WG = Waist Girth; BG = Ball Girth;

Table 2: F, F critical and P values of different girth measurements against seven categories of foot parameters

Grouping parameter	Analyzing Parameter	Source of variation (SS)		F value	P value	F critical
		Between Groups	Within Group			
FW	Ball Girth	835.5757	4525.6875	2.0925	0.1195	2.8826
	Waist Girth	378.6809	2178.6875	1.9699	0.1370	2.8826
	Instep girth	28.5833	4531.4167	0.0715	0.9748	2.8826
	Heel girth	394.0351	6219.3333	0.7180	0.5481	2.8826
BMI	Ball Girth	550.6881	4810.5750	0.9444	0.4507	2.6589
	Waist Girth	237.6229	2319.7455	0.8451	0.5068	2.6589
	Instep girth	271.1388	4288.8612	0.5216	0.7205	2.6589
	Heel girth	960.1542	5653.2142	1.4012	0.2552	2.6589
FL	Ball Girth	1639.4196	3721.8436	1.8878	0.1069	2.3343
	Waist Girth	598.1492	1959.2192	1.3084	0.2804	2.3343
	Instep girth	1441.4641	3118.5359	1.9810	0.0912	2.3343
	Heel girth	756.7441	5856.6244	0.5538	0.7867	2.3343
HG	Ball Girth	1239.4368	4121.8264	1.5536	0.1940	2.4094
	Waist Girth	1137.5559	1419.8125	4.1395	0.0036	2.4094
	Instep girth	1236.1111	3323.8889	1.9214	0.1086	2.4094
IG	Ball Girth	1140.7632	4220.5000	1.3965	0.2473	2.4094
	Waist Girth	1210.5113	1346.8571	4.6436	0.0018	2.4094
	Heel girth	1378.8565	5234.5119	1.3610	0.2611	2.4094
WG	Ball Girth	2862.5965	2498.6667	9.4516	0.0000	2.6589
	Instep girth	1821.6667	2738.3333	5.4883	0.0017	2.6589
	Heel girth	2344.3476	4269.0208	4.5305	0.0050	2.6589
BG	Waist Girth	1054.5738	1502.7946	5.7894	0.0012	2.6589
	Instep girth	636.5387	3923.4613	1.3385	0.2764	2.6589
	Heel girth	415.5976	6197.7708	0.5532	0.6980	2.6589

FW = Foot Width; BMI = Body Mass Index; FL = Foot Length; HG = Heel Girth; IG = Instep Girth; WG = Waist Girth; BG = Ball Girth;

Results

F statistics, F critical values and P values for the above seven categories of foot parameters were compared from the ANOVA test. Scaled values of girth measurements i.e., heel girth, instep girth, and waist girth except ball girth against FW showed larger variation within their own groups compared with the variation between the groups. Hence their F values are very much smaller than the F critical values are shown in Figure 2. Only for ball girth, F statistic is very close to F critical value. These lower F values are simply rejecting the alternative hypotheses and there is no significant relationships exist among the scaling groups of FW or current fitting for obese adults. The confidence level from the P values (>>0.05) also declined the hypothetical relationship among the groups. Scaling based on BMI and FL also showed larger variation within their own groups of all girth measurements than between groups, results very lower F than F critical values. The P values (>>0.05) of these two categories are also very larger than the standard α level.

Only for one parameter among the four girth's was found positive (P<0.05 and F>F critical) in cases of scaling based on HG, IG or BG. While in rest of the cases P>>0.05 and their F values are smaller than the F critical values. On the other hand, scaling based on WG gave maximum positive results against all the other girth measurements. Hence the variation of values within their own groups are very smaller than the between groups. F values for rest of girth measurements are larger than the F critical values.

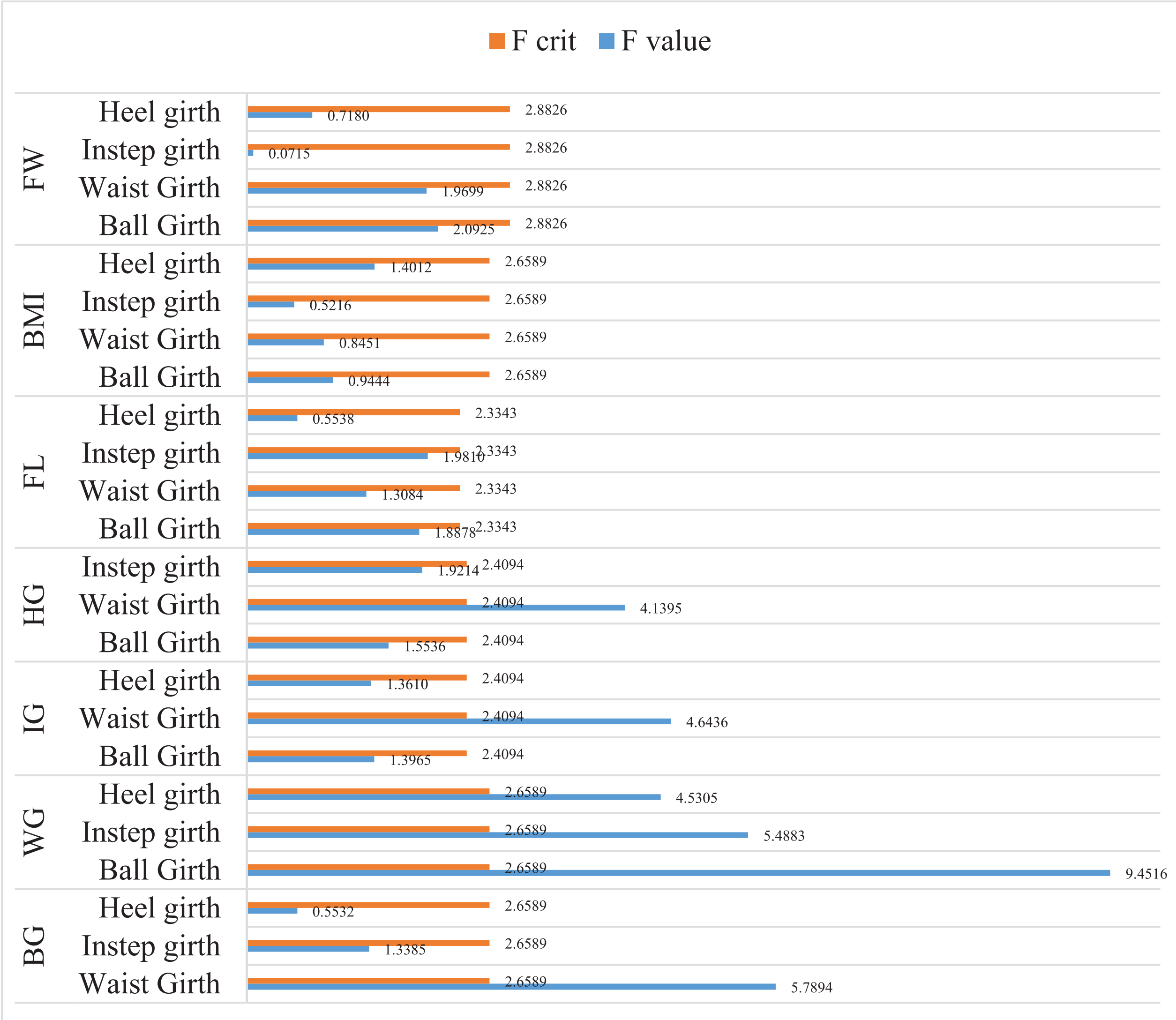

Figure 2. Comparison of F values with F Critical Values

These indicate the rejection of null hypothesis and explore the significance and strong relationship among the newly created scaling groups. Their P values (<0.05) also showed that there are higher levels of hypothetical relationship exist among the scaling groups based on waist girth.

Discussion

Previous study claims that the standard fit as well as wide-fit footwear comprises improper measurements of heights, width, and circumferences across areas of the foot.[8] Therefore, approximately seven parameters those are highly relevant with obese feet were studied for the shoe fitting of obese people. Among them parameters like FW, BG are being currently used as standard fit footwear. To find out their capabilities of being a suitable scale of shoe fitting for obese adults, few hypothesis tests were carried out on the collected data using ANOVA tools. To be a proper fitting shoe, the four circumstances of human foot such as heel girth, instep girth, waist girth and ball girth should accommodate maximum within each of the grouping scale.[8] In that case, sources of variation in sum of square (SS) within their own groups should be smaller than the between groups either with the next or the previous fitting group of the scale. Among seven categories in most of the cases the values of girth measurements showed higher variation within their own groups than between groups. Scaling based on FW of obese adults was provided quite closer result to satisfactory F (F is 27% smaller than F critical) and P (0.119>0.05) values only for ball girth

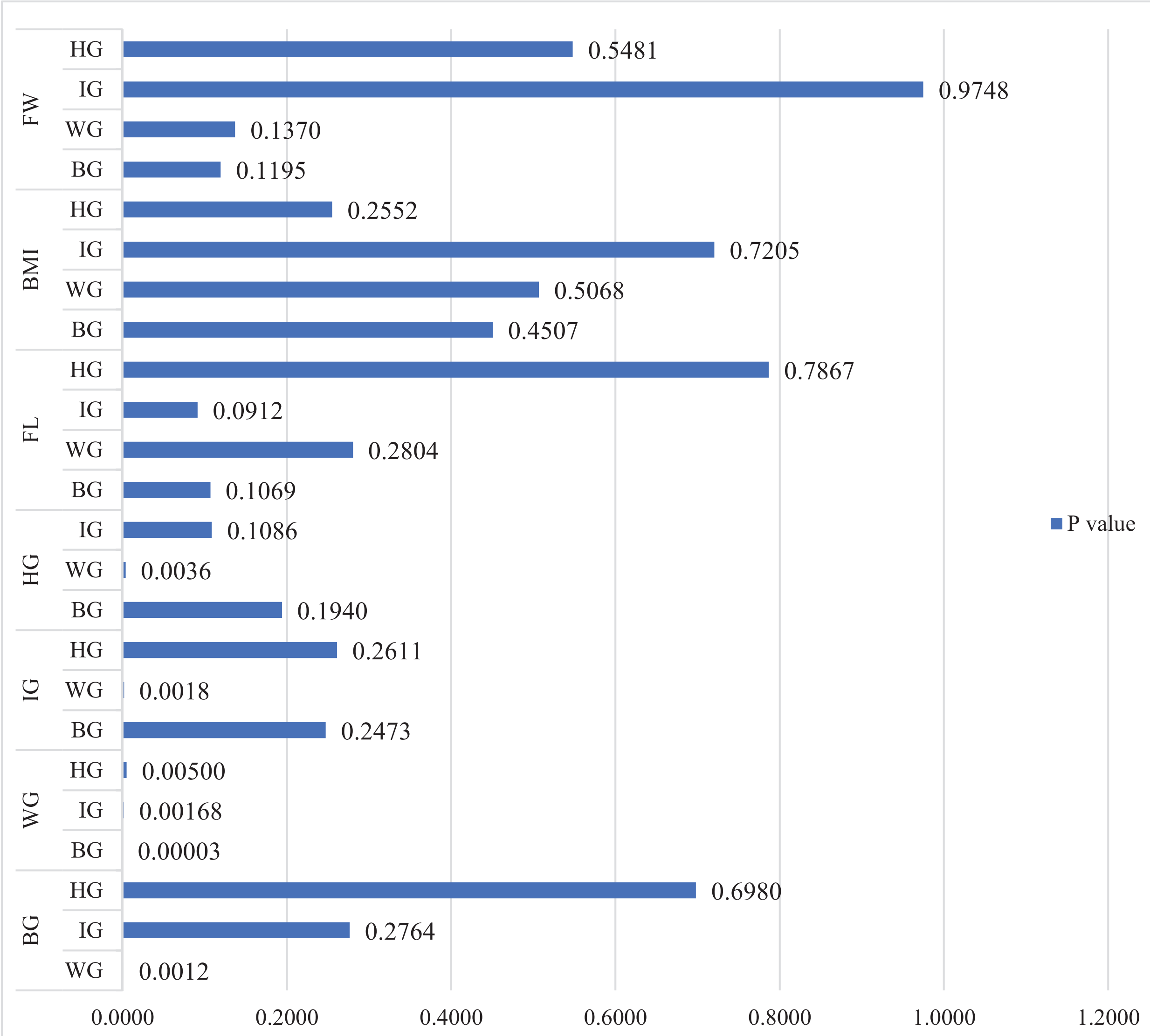

Figure 3. **Comparison of p values for different ANOVA test**

as FW used for scaling reference of this system. But for other parameters those values are far deviated from the acceptable range and their F values are up to 97% smaller than F critical value. F values of girth against BMI and FL showed minimum of 47% smaller to maximum of 80% smaller than F critical value. Their range of P values (>0.05) are from 0.255 to 0.720. Fitting scales were well laid out only for waist girth measurement in cases of HG, IG and BG scaling variables and their respective F values are 72%, 92% and 117% larger than F critical values shown in Figure 4. But for other girth measurements like heel girth, instep girth and ball girth, F values were smaller with a range of 20%-79% than F critical values and their subsequent p values are also greater than standard α level (p>0.05). This result indicates a meaningful thought about waist girth of obese participants. Surprisingly, scaling based on WG provide the maximum laid out of the girth measurements to the foot shape with respect to all other girths. In that case F values are 255%, 105% and 70% larger than F critical value respectively for heel girth, instep girth, and ball girth. Rationally there is very smaller variation within the groups than between groups. P values (<0.05) of these cases also showed higher levels of confidence for the rejection of null hypothesis. These results, consistent with the research output from Dowling & Steele that recommend to consider broader midfoot area to minimize foot discomfort from ill-fitting footwear.[14]

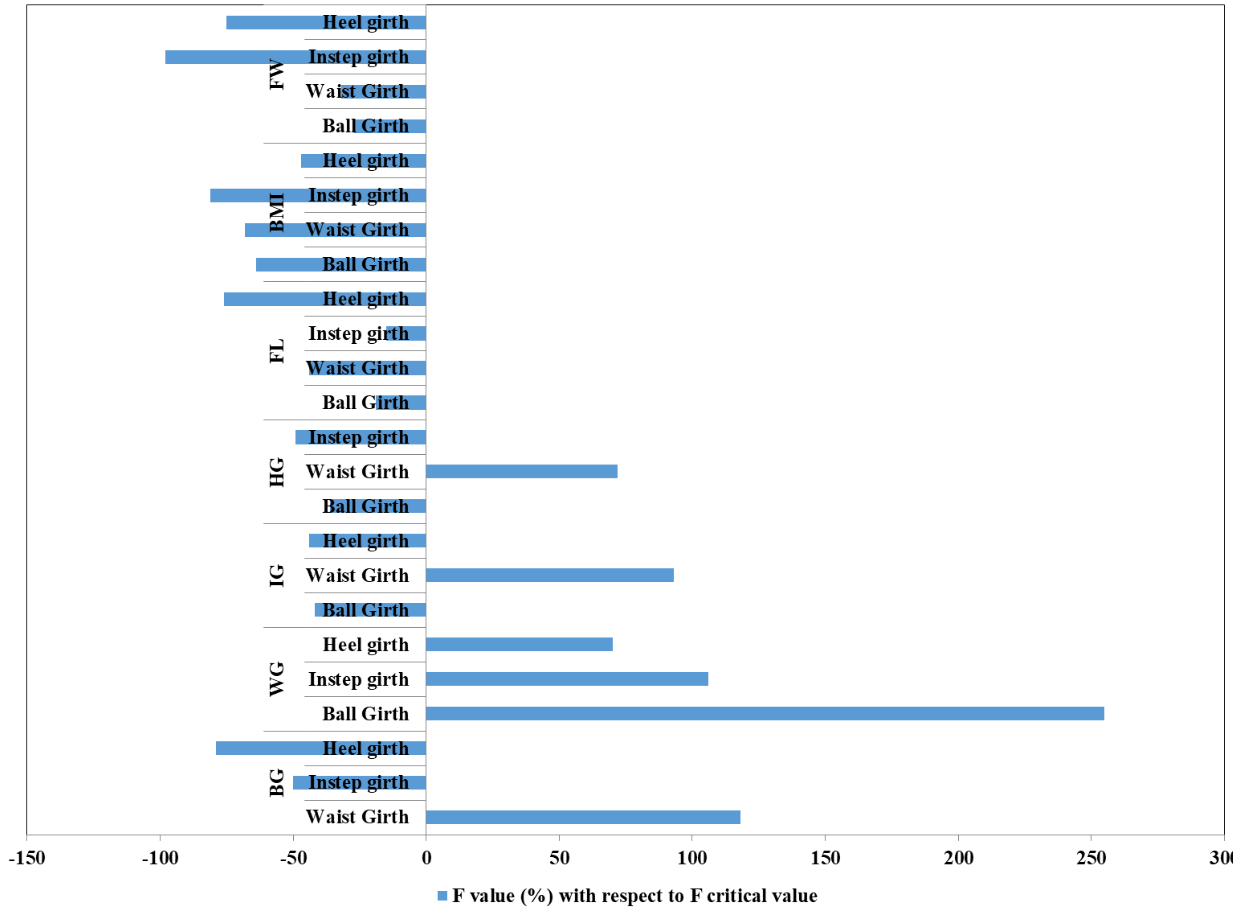

Figure 4. Comparison of percentage F values with respect to F critical values

Table 3. Proposed fitting chart for the obese adults based on waist girth measurement

Shoe size	Proposed Girth Fitting (mm)							
	WG-1	WG-2	WG-3	WG-4	WG-5	WG-6	WG-7	WG-8
8	255	265	275	285	295	305	315	325
9	255	265	275	285	295	305	315	325
10	255	265	275	285	295	305	315	325
11	255	265	275	285	295	305	315	325
12	255	265	275	285	295	305	315	325
13	255	265	275	285	295	305	315	325
14	255	265	275	285	295	305	315	325

In conventional fitting systems, most of the shoes are manufactured based on grading of foot width and joint girth.[15-16] Since differences are consistent in obese compared to normal adults, preferences for fit in specific foot regions vary within the shoe. Moreover, obese adult prefers to manage discrepancy by wearing a larger size. This could prompt misinterpretation of the toe room compared to the normal adults. This extra space inside the shoe may prompt improper footwear fit, abnormal frictional forces as well as foot defects like blisters.[17] Therefore, based on these statistical evaluation and evidence, a new fitting chart has been proposed and shown in Table 3. The ranges of this new fitting start from WG-1 to WG-8 with a regular interval of 10 mm around the waist circumference of the obese foot. Hence, obese customers with varying shoe size can find their suitable fitting on the basis of their waist girth measurements. This could help to overcome the difficulty to find an appropriate and comfortable footwear for obese adults claim in previous literatures.[18-19]

The present study is just only started to present statistical hypothesis. Some important issues have not been considered and completed with this initial research. Firstly, a greater number of participants would be helpful to get perfect results and outcome. Secondly, a consumer survey based on this new fitting chart would bring a more significant level of defense. Thirdly, some trials with the lesser intervals of scaling can provide more insights about the fitting. Finally, future investigations should expand on the current outcomes and explore additional aspects, such as link up with other relevant internal and external parameters of the obese foot.

Conclusion

This study has brought a solution to eradicate the fitting difficulty of obese people with a new shoe fitting development. To do that relevant parameters of obese foot was collated and studied with ANOVA. Comparison with the current standard fitting system as well as other relevant parameters, scaling based on waist girth provides statistically significant correlation with the obese foot shape. Based on this hypothetical calculation a new fitting chart is proposed for the manufacturers and users. Footwear selection based on this new fitting chart will enhance ergonomic fit and comfort of the product. Manufacturers can be able to produce different fitting grade for obese based on this proposed fitting chart. A consumer or obese customer can easily be able to choose their perfect shoe by their waist girth measurement.

Acknowledgement & conflicts of interest

The authors declare that they have no financial interests that could have appeared to influence the work reported in this paper. But we would like to express sincere gratitude to all the participants for their support in data collection.

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