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SIZE CHART FOR SOCKS FOR SCHOOL BOYS IN SRI LANKA

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ABSTRACT

The structure of the body of human depends on many factors. Hence the sizes and size charts for garments need to be developed for a specific nation/human group. This paper presents a size chart developed for socks for school boys in Sri Lanka. The foot and leg measurements of 2650 school boys in six different provinces of the country is used in the analysis in order to get a reasonable sample size as the foot and leg measurements may have many influences. Correlation between different foot measurements were analyzed and *k*- means clustering is used in segmenting data into five categories representing five different sock sizes.

KEYWORDS: anthropometry, socks, cluster analysis, size chart

INTRODUCTION

Although some product standards are accepted worldwide, the standard size charts for apparels may be country specific as the anthropometric measurements in different countries/nations vary widely. The manufacture of garments that fit the consumers properly, while retaining the aesthetical pleasing and comfort ability is challenging [1]. This is especially true for body fit garments where knowing the exact dimension/shape of the body is indispensable in developing a garment that fits well to the wearer. Body fit garments such as socks are usually manufactured using knitting as they allow fitting closely and comfortably [2].

Today the technology is available to knit garments to the exact shape and size. However, the shape and size of the body/leg measurements vastly differ from person to person. Although the business models used in mass customization can be used to customize the garments to individual customer, it is limited to special applications such as compression garments in the medical industry and high priced garments. The mass production of socks requires size charts.

According to Tsujisaka [3], the need for comfortable socks has grown. Special attention need to be paid to the fit of a sock by the consumers as the sock is a next to skin wear garment. Generally, the body fit garment measurements are somewhat smaller than the girth of the body part that touches the garment. This creates a pressure between the garment and the skin of the wearer. As the skin is very sensitive to the pressure applied by the garment, it is essential to determine correct dimensions of the garment based on the anthropometric data. These dimensions depend on the properties of the knitted structure as well. The research carried out among Japanese men on pressure applied by the elastic top of socks, Momota et al. [4] has found that men feel comfortable below a pressure of 10 mm Hg.

As per the Central bank reports between 2010 and 2015, the number of school children is over 375,000.00 and most of them wear socks every weekday, though the country has a standard for men's socks [5], which is outdated and needs revising. The size chart used in this existing standard is not based on the anthropometric data specially formulated for Sri Lankan community. Ariadurai et al. [6] states that the British size charts do not comply with the actual measurements of Sri Lankan school children. A study on American whites and Europeans (German and Czech) has revealed that the European adults have significantly wider heads with large head circumference, shorter and wider faces and a smaller mouth [7]. Therefore, making a standard size chart for sock wearers in Sri Lanka not only will benefit the customers, but also provides guidelines for the sock manufacturers to provide socks for the satisfaction of the customers.

This paper presents the size chart developed for Sri Lankan school boys.

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Anthropometric studies

The anthropometric measurements of the body depends on many factors in addition to the obvious differences exist between sex and age groups of any nation. The differences exist not only between sexes and ages, but also between different races and ethnic groups [8]. Although the most frequently recorded differences in the ethnic group is the body height, the differences exist in head circumference, face, height and the length of nose [9]. Therefore, the dimensions have to be established for a specific group when designing machinery, equipment, garments, furniture etc. The body measurements have not only used in the field of apparel, but also in many other fields such as medicine, nutrition, equipment and machine design, car design etc.[9].

The change in body dimensions are found to be affected by socioeconomic factors. The influence of the social class on the growth of children has been studied by many researches and different studies have used different bench marks and have reported different result [9]. The environmental factors such as mean annual temperature, humidity, degree of air pollution, severity of climate, altitude of the region found to have effects on the body measurements. However, it is difficult to establish body measurements based on the above factors as the interacting factors of genetic and ethnic groups, socioeconomic level of parents, nutrition levels and the length of exposure to the environmental factors have influenced on the growth of a human. Due to these, some studies have reported contradictory results [9].

Since these data may vary with the time, a study even for a specific group will not be valid after few years. The change of anthropometric data with time has been studied and has reported that differences exist and all anthropometric date published 20 years before is outdated [10]. Thus the data for any selected group has to be updated in defined intervals and new anthropometric data is needed to suit for today's culture [11].

Anthropometric data for Sri Lankans

Patel et al. [12] has derived a regression formula between foot length and height of Indians. According to his study, a +0.65 correlation has been observed with foot length and height of a man. This was statistically highly significant [12]. Patel el al. [12] have developed a regression equation for males as follows; $Y = 75.45 + 3.64X$ (Where Y = Total height and X = Foot length). There is a difference in anthropometry in people of Sri Lanka and India due to the geographical and genetic factors. The relationship between human height and foot length of Sri Lankan people have slight variation with regression equation and correlation coefficient compared to what Patel el al. [12] has derived. Illayperuma and Nanayakkara [13] have developed a regression equation for Sri Lankan male; $Y = 79.042 + 3.590X$ (Where Y = Total height and X = Foot length). These results indicate that foot length provides an accurate and reliable means in estimating the height of an individual.

Anthropometric data in manufacturing socks

Normally, the sizes of the socks are based on the foot measurement [3]. Since the height is positively related to the foot length, the leg length of the sock is considered to be equal to the foot length in this study, although some international size charts have used slightly more or less leg lengths of the sock than the foot length of the sock. Sometimes this value has been used based on the age; the leg length of an adult sock is shorter than foot length, while for school socks, leg length is longer than the foot length. Most of the socks manufacturers in Sri Lanka have been using the anthropometric data of non Sri Lankans due to non availability of data specifically measure to manufacture socks. Although a buyer can do a wear trail before buying some garments, wear trials are not allowed for most intimate garment. The wearers after buying may not be satisfied with the comfort parameters of the sock.

3-D Body scanning

Customized garments, medical devices etc. are being manufactured by obtaining anthropometric data through 3D body scanning. The body scanning devices capture the photographs of the relevant areas of the body using various techniques. These photographs are compiled to produce the body measurements. These measurements may be translated into patterns to cut garment panels [14] using flattering algorithms to transform three dimensional garment models to two dimensional garment panels [15]. These devices offer rapid response and have promising advantages for the apparel industry. They can provide accurate, speedy and consistent data to redefine available sizing standards; therefore useful in mass customization [16]. In addition to the linear data more commonly used by the apparel industry, the 3D body scanners can provide body shapes and angles [17]. However, mass customization is an expensive solution for a product like sock.

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MATERIALS AND METHODS

The population of this research was the school boys in Sri Lanka. In order to represent the total Sri Lankan school boys, the population was divided provincially using the stratified sampling method. So there were nine strata from nine provinces. Because provinces are mutually exclusive and collectively exhaustive the requirements of strata was fulfilled by them.

Selection of the sample

The average total school population in Sri Lanka is considered as 4,000,000.00. According to the figures shown in the report, 'Students and New admissions in government Schools'[18], it can be considered that nearly half of the student population is boys. Assuming that the boys: girls ratio as 1:1, the total sample size of school boys in Sri Lanka is 2,000,000.00. Since the sample size is considerably high, desired margin of error has taken as 2.5% and the confidence interval as 99% and the sample size becomes 2670. The sample was collected from 10 schools in six provinces. 25 students were randomly selected from each grade (grade 1 to grade 11).

Table 1 indicates the distribution of students among different provinces and the no. of schools selected from each province.

The measurements obtained were based on the standard anthropometric measurements [19]. The measurements are, foot length, foot breadth and arc (girth measurement), elastic top circumference, foot arch circumference (foot arc), minimal distal calf circumference, height from base to ankle, Girth measurement taken at a height equal to foot length from base, minimum calf (girth measurement). Height of the sock was taken as the foot length.

1. *Foot length*: - This is measured as the linear distance between the back of the heel and the tip of the most prominent toe.
2. *Foot breadth*: - This is measured as the linear distance between widest points of the foot in width wise.
3. *Elastic top circumference*: Using the flexible measurement tape, measure circularly at the leg height point.
4. Minimum Distal Calf Circumference: - Using the flexible measurement tape, measure just superiorly to the ankle.
5. Foot Arch Circumference: - Measure the circumference of the foot halfway between the ankle joint and the ball of the foot using the flexible measuring tape.
6. Right Malleolus Height: - Have the subject stand erect with their heels together and the weight distributed equally on both feet. Measure the distance between the floor and the lateral malleolus (ankle bone).

Although Lohman et al. [20] has indicated that there are no significant measurement differences between the right and left side of the human, the Asian countries usually measure the left side and also it is the recommendation of The International Biological programme. Therefore, the measurements of the left foot was taken.

RESULTS AND DISCUSSION

Analysis of data

A descriptive analysis presented in Table 2 for each variable (measurement) is to identify the basic features of the measurements. The summary of the descriptive analysis is given below in table 2.

Cluster analysis required the data to be normally distributed. Figure 1illustrate that all five measurements are normally distributed (analyzed using MINITAB software) and therefore cluster analysis can be carried out.

The data in cluster analysis is presented in Table 3 and the cells contain the p-values of Pearson Correlation. The correlations analysis is not done for the sock height as it is similar to the foot length and further it is not a body measurement (garment measurement).

Identifying a single measurement in a size chart is important and that should be correlated to the other measurements. The data in Table 3 shows that the foot length and foot width are highly correlated. Thus the foot length (length of folded sock) can be identified as the main parameter of the size chart. Further, this is a convenient measurement for customers and shoppers and linked to the shoe sizes.

According to the BS 7231 standard [21], if the correlation co-efficient is 0.76 or more, it indicates a strong positive relationship.

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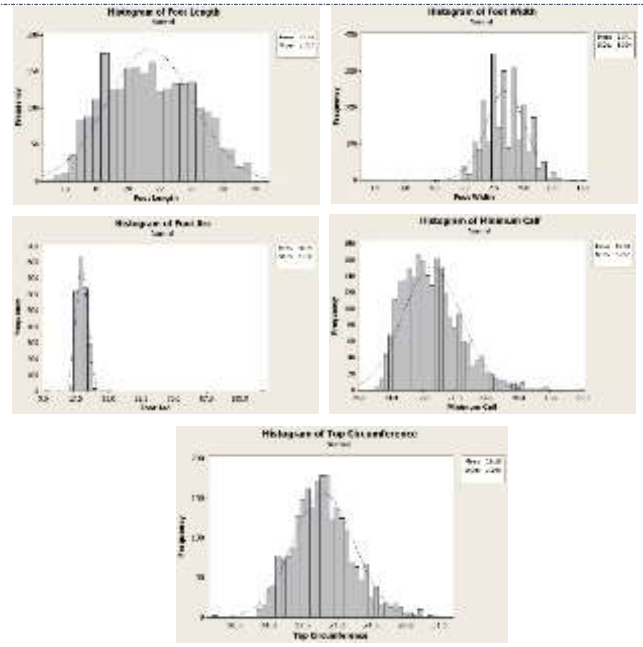

Figure 1– Histograms for key foot measurements

Cluster analysis (K-mean clustering)

Hierarchical clustering requires a distance or similarity matrix between all pairs of cases. If the data are in thousands, it might take a large amount of time; even today's computers will take pause. *k*-mean clustering does not require computation of all possible distances. According to Moore [22], in order to cluster a large number of data, the most suitable method is the *k*-means clustering. The number of clusters should be known in advance. The algorithm repeatedly reassigns cases to clusters, so the same observation can move from cluster to cluster during the analysis. Each observation is assigned to the group, whose mean is closest, and then based on that categorization, new group means are determined. These steps continue until no observations change groups.

The number of socks sizes required was decided as five. In agglomerative hierarchical clustering, cases are added only to existing clusters. They are forever captive in the initially formed cluster, with a widening circle of neighbors. A case is assigned to the cluster for which its distance to the cluster mean is the smallest. The purpose of the algorithm is to find out the *k* number of means. The final output after subjecting the data to *k*-means cluster analysis on MINIAB is shown in Table 4.

Size Chart for Socks

Sock is a stretchable garment and it is reasonable to round off the sock sizes denoted by foot length to nearest/suitable whole number and round off other dimensions the middle of the first decimal place. Table 5 shows the classification of actual foot measurements into the sizes identified. The values are rounded off to the nearest whole number.

Tables:

Table 1- Percentage student distribution of students in different provinces and no. of schools selected from each province

Province	Student %	No. of schools
Western	24	4
Central	14	1
Southern	13	2
North Central	6	1
Uva	7	1
Sabaragamuwa	9	1
Total	100	10

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Table 2- Summary of the descriptive analysis of the foot measurements

	Foot Length	Foot width	Foot arc	Min. calf	Circ. at the elastic top
Mean (cm)	21.36	8.071	20.59	18.50	19.59
Range (cm)	14.8-28.8	5.4-10.9	13.8-31.3	11.8-31.3	11.8-32.8
Standard Deviation	2.727	1.004	3.268	3.242	3.140

Table 3 – Correlations analysis of the four foot measurements

Correlations	Foot length	Foot width	Top circ	Min. calf
Foot width	0.833	-	-	-
Top circ.	0.717	0.646	-	-
Min.calf	0.697	0.668	0.403	-
Foot arc	0.712	0.656	0.567	0.600

Table 4- K-mean clustering analysis of the foot measurements

	Cluster Centroids					Grand Centroid
Variable	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	
Foot length	19.5747	17.6607	21.2574	23.1116	25.3353	21.4059
Foot width	7.5562	6.9741	7.9980	8.5992	9.2992	8.0907
Top circ	19.2855	17.8530	20.3482	22.1068	24.4554	20.8246
min. calf	15.9237	14.6312	17.1327	18.8629	20.5544	17.4348
foot arc	18.9594	17.4789	20.3558	22.1948	24.0397	20.6211

Table 5 - Size chart with actual foot measurements

Measurement	Size range (cm)				
	S	M	L	XL	XXL
Foot Length	17	19	21	23	25
Foot Width	7.0	7.5	8.0	8.5	9.0
Top Circumference	17.0	19.0	20.0	22.0	24.0
Minimum Calf	14.5	16.0	17.0	19.0	20.5
Foot Arc	17.5	19.0	20.0	22.0	24.0

CONCLUSION

All five foot measurements; Foot length, Foot width, Top circ., minimum calf and foot arc taken to develop the size chart for socks for school children are normally distributed. The p-value of the Pearson correlation resulted that the foot length is correlated to the other four measurements. Therefore, the sock sizes are denoted by the length of the sock. Further length of a sock/ shoe is the most convenient measurements for the consumers. Five socks sizes are identified as small, medium, larger, extra large and double extra large using the *k*-means clustering technique. The dimensions to which the socks should be knitted in order to achieve these relaxed dimensions depend on knitting and yarn parameters. Thus the manufactures need to establish the knitting dimensions as per the yarn and the knitted structure intended to use in manufacturing the sock.

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