FASHION STUDIES

ANTHROPOMETRIC STUDY OF LOWER EXTREMITY OF MEN OF DELHI NCR FOR FOOTWEAR LAST MODELLING

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ABSTRACT

In the Indian context, footwear size generally denotes the length. However there is a variation in the girths of feet of Indian men. As part of the research, anthropometric dimensions of lower extremity of 57 healthy men of NCR were collected. Results of analysis on the sample lead to the conclusion that more than one girth option should be made available for the same lengths. The proposal for size and fitting range was prepared. The data which relates to the central sizes and fittings of the sample were selected and central values of dimensions required for last modelling were computed.

Keywords: Anthropometric dimensions, Footwear, girth, lower extremity, men, modelling, size.

INTRODUCTION

Footwear retailing has a considerable share in the Indian consumer market. The Indian footwear sector has a sizeable contribution to the overall economy, GDP and is well positioned globally. It also generates employment opportunities which are quite diverse, inclusive and equitable embracing weaker and minority communities. Considering segmentation on the usage pattern, men's footwear occupies the maximum market share. However India lacks robust statistical data on anthropometric dimensions of lower extremity which are essential for manufacturing shoes and boots which would fit the Indian lower extremity type. Shoes and boots manufacturers primarily rely heavily on size charts of European countries. This dependence is harmful to both the lower extremity as well as the shoe and boot. The shoe and boot not only protect the feet but also affects the human physiology and also pathology. The design and manufacture of shoes and boots according to the anthropometric dimensions of the lower extremity is made possible through a three dimensional solid form of the lower extremity referred to as the 'last'.

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Owing to the improved standard of living and other stimulating factors, the present day children and young persons mature early, both physically and mentally. One concept used is that of secular acceleration evidenced by the faster growth of the lower extremity. This also affects the final length of the lower extremity and the proportional growth of all zones of the lower extremity. (Stastna, 1991). In order to propose a strategy for providing well fitting shoes and boots to Indian office going men, anthropometric dimensions of the lower extremity were collected and the results of the survey are discussed in this paper.

METHODS

The lower extremity referred to in this paper includes the leg and the feet.

Anthropometric dimensions

Feet

Identified anthropometric dimensions of feet of Indian men, have been collected following Shoe and Allied Trades Research Association (SATRA) foot measurement system for both the right and left feet.

Leg

Since styles of men's workplace casual footwear includes boots, certain anthropometric dimensions of both the legs were also collected using the procedure outlined in ISO 8559:1989(en) standards.

Population Group

The geographic area of the survey was restricted to the Delhi - National Capital Region (NCR). Migrants from other states constitute a sizeable portion of Delhi's population. Employment factor and the capital's strong labour market is the major reason for migration of the population, especially men, from other states to Delhi (Dupont, 2000). The migrants are mainly from the northern, eastern, central and other regions. (Department of Urban Development, 2009).

Inclusion Criteria

All participants whose anthropometric dimensions were taken up for further statistical analysis met the following inclusion criteria: participants were to be without any lower extremity and lumbosacral (lower back) anomaly (Tomassoni, Traini & Amenta, 2014). The survey was also restricted to people whose both feet appeared similar (Gopalkrishna, 2014).

Male volunteer subjects from among offices located in the National Capital Region of Delhi participated in the survey. All subjects were physically active. A total of 74 adult male subjects participated. 57 of them fulfilled the inclusion criteria and the anthropometric dimensions data from the rest 17 subjects were eliminated from the analysis. The age range of the subjects varied between 20 to 59 years.

These data were entered in an Excel spreadsheet for further analysis using SPSS software. The mean data for the anthropometric dimensions of the right and left lower extremity was calculated and entered in additional spreadsheets in the same excel file. Data fields were

regrouped state – wise (domicile/ ethnic origin) and size wise and additional spreadsheets were created in the same master file.

Table 1: Domicile State – wise break up of subjects

S.No.	Data record from state	Subjects	x 94
1	Uttar Pradesh	16	1504
2	Uttarakhand	10	940
3	Haryana	8	752
4	Native Delhites	6	564
5	Bihar	6	564
6	Tamil Nadu	6	564
7	Rajasthan	2	188
8	Punjab	1	94
9	Orissa	1	94
10	Andhra Pradesh	1	94
	Total	**57**	**5358**

Data of each state was compared with that of rest of sample, i.e. it was tested whether foot sizes of subjects with ethnic origin of a particular state for e.g. Uttar Pradesh differs significantly from the foot sizes representing rest of the sample. The computation results were summarized for the main parameters such as stature, body mass, stick length, plan length, size measured through combination Brannock device, joint width and four girths measured.

In the Indian context footwear size generally denotes the length. Only a few retail brands offer a range of width fittings for each size in India. In the absence of fitting options for given length of shoes in retail outlets, there would be a feet Vs shoe mismatch, since there is a variation in the widths of feet of Indian men.

By using the joint girth for determining fitting groups there are two alternatives

Table 2: Alternatives for levels of coverage

Alternative		Explanation %	Fitting coverage
1	4s/6	$= \pm 2s$	90
2	2s/6	$= \pm 1s$	75

Real coverage is the product of the coverage in length and girth. Thus the first proposed option offers 81% (0.9 * 0.9 = 0.81), the other 67.5% (0.9 * 0.75 = 0.675) coverage. The number of fitting groups to be retailed varies between 4 and 8. This may be reduced if the same computation is made for sub-domiciles where deviations in girth are smaller. The basic input data consisted of computed central tendencies of sizes by applying a conversion formula to stick length, SD (σ), half size Δ and batch size.

When considering the length of the foot and footwear it is obvious that footwear ought to be longer than the foot for so – called toe allowance. According to last designing principles it

could be of two kinds: allowance calculated by taking into account medical recommendations – minimum allowance – and fashion trends – decorative allowance. Functional allowance provides available free room not limiting functional movements of the foot, of changing the foot length caused by both external and internal reasons. Additional allowance is applied to the toe shape of footwear (its width, height) and changes from 0 up to 25 mm, in some cases even longer.

Detailed researches have shown that functional allowance should not be identical for the lasts of different size groups, and also for the lasts of various lengths in identical size groups. In the footwear for adults growth of whose foot in length is completed, functional allowance should be 2.5 to 3% of the foot length (Chentsova, 1974). Such allowance provides in exact measure free room in footwear, necessary room for lengthening the foot during movement (apparent increase of the foot length), and also for the foot lengthening under load, daily changes etc.

The analysis steps were performed primarily for English foot sizing system. This task required recommendation of girth increments for sizes and fittings in order to cater to maximum percentage of the population.

The English size system

1 English size = 1/3 inch = 8.46 mm, the English size is the number of English units rounded off to the nearest whole number, beginning with 4 inches, i.e.,

English half size = {[3 x (Stick length in millimetres + 12.7)]/ 25.4} - 25 rounded off to the next higher half size.

The batch size assumed is 60. Central tendencies, SD (σ) of dimensions of each size were used to create girth groups. The number of fittings required was computed as shown in equation

$$w_g \quad \frac{\lambda s}{\Delta x}$$

w_g – no. of fitting groups

s - SD (σ) of girth

Δ_x – joint girth increment

Most commonly used increment in girth is 6 mm.

Joint Girth Increments.

When grading shoe lasts (and subsequent basic shells, upper and other component patterns) two increments are usually in use.

1. Girth increment of two subsequent sizes of same fitting group

2. Girth increment of two subsequent fittings of same size.

The analysis was done on one sizing system which can be easily extrapolated to other systems. Weighted averages as in following equation were used to compute the girth increments.

$$\Delta \bar{g}_1 = \frac{\sum\limits_{i=Z_{min}+\Delta z}^{Z_{max}} n_i (x_i - x_{i-1})}{N}$$

Z_{min} – smallest size

Z_{max} – largest size

Δz – size increment

n_i – no. of measured feet i th size

x_i - mean joint girth of i th size.

Computations were carried out in a spreadsheet. A faster alternative way to calculate increments in other size systems, is as shown in following equation.

$$\Delta g_1 = \Delta g_0 \frac{\Delta z_1}{\Delta z_0}$$

where Δg_1 is the required increment in the target size system with Δz_1 increment of the length scale, Δg_0 and Δz_0 are the known values (all expressed in mm).

Based on the experience accumulated by shoe last designers and shoe fitters (retailers) over the past decades the following simple basic rules for transforming girth and width dimensions of feet into the same of shoe lasts are adopted:

1. The last girths are five to ten millimeters < feet girths.
2. The last joint width is usually 90% of feet joint width.
3. The last heel width is usually 95% of feet heel width.

JOINT GIRTH SPREAD AND COVERAGE

The ultimate aim of any lower extremity anthropometric survey is to create and recommend appropriate tables consisting basic dimensions to model lasts of size range which will cater to maximum percentage of the population. In order to achieve this

1. English half size system was followed for the research reported in this thesis.
2. Establish the starting point of fitting groups, which is the central size and fitting and the related girths deduced from lower extremity anthropometric measurement;
3. Girth increments for sizes and fittings

The actual joint girth was calculated as shown in the following equation:

$$g_{z,w} = g_0 + \frac{z - z_0}{\Delta z} \Delta l_z + \frac{w - w_0}{\Delta w} \Delta l_w$$

- $g_{z,w}$ - joint girth, z – size w - fitting,

- g_0 – joint girth of central size
- z_0 - size, w_0 - fitting of central size
- Δz – half size increment Δw – fitting increment, $\Delta z = 0.5$ or $\Delta w = 1$ for English half sizes),
- Δl_z – joint girth increment by size, Δl_w – joint girth increment by fitting

Another option of arriving at the central fitting is through the following equation:

$$c_g = g_0 - \frac{z_0}{\Delta z} \Delta l_z - \frac{w_0}{\Delta w} \Delta l_w$$

The joint girth was now computed by using the respective simple linear equation which is as follows:

$g_{w,z} = z \, \Delta l_z + w \, \Delta w + c$

- where $c = c_g$ for computation of joint girth.

Sample shoe lasts are built on the bottom insole pattern when normal cemented technology is applied in shoe assembly. The procedure of constructing the shoe last bottom, longitudinal section and a couple of cross section patterns, is as per the methods outlined in Last designing & making manual based on the geometric method by George Koleff, 1997.

DISCUSSION

Based on the statistical analysis the following were the findings:

1. Significant differences were observed in stick length, plan length, Size – heel to toe measured using combination Brannock device, joint width, joint girth, long heel girth and short heel girth of men of Bihar as domicile to the men from rest of the sample.

2. Feet of men with Bihar as domicile are about 12 mm or three English half sizes shorter than feet of men from rest of the sample. The required size range is also narrower in case of men with Bihar as domicile.

When significant differences in foot dimensions are detected between men of different domicile then the size group can be divided into sub groups.

The two types of foot length – stick length and plan length are interchangeable, but stick length is a key dimension. Results of the regression analysis over sample yielded the following results:

1. Impact of body mass and stature is decreasing by age. The volume of men's feet does not depend on the body structure.

2. Most of the linear measurements of the same direction i.e. length dimensions exhibit stronger relationships.

3. Height direction has no strong relationship with length and width directions.

4. Stick length did not have relationship with most of the girth dimensions. Therefore for healthy shoes and boots more than one girth option should be made available for the

same lengths.

5. Girths do not correlate with the respective heights therefore joint girth should be used as one of the volumetric property of feet and shoes.

6. Since stick length correlates with more other measurements than joint width or girth it should be the main foot dimension for size indications.

7. Multiple linear regression does not show much stronger relations than paired.

Creation of Size Range

After having entered the inputs the computations were made in SPSS software as per normal distribution and size range was recommended together with the number of pairs to be supplied in each size. As the actual computation was made on a discrete variable and the algorithm included rounding off functions, the results i.e. the total number of pairs and actual coverage will always differ slightly from the targeted values indicated by inputs. Thus the proposal for size range was prepared. Recommended size range for English half size is reported in the Ph D Thesis.

When 90% size coverage is mentioned this is with reference to stick length only. The low correlation between length and girth measurements suggests that for a given length multiple joint girth options need to be provided.

The number of joint girth options to be provided for each English half size for both 90% and 75% population coverage was found out. Joint girth increments were computed and based on international conventions one fitting range was recommended for India. The theoretical increment of ball girth by English half sizes was found. Based on the lower extremity survey results and taking into consideration the international practice a table of increments was recommended to be adopted in Delhi NCR. Joint girth increments in mm by length and by width group were recommended. Using the basic data derived from the lower extremity anthropometric survey the central size for last of sample was deduced. Using the results of the anthropometric survey of lower extremity starting (central) values of joint girth of central sizes were set for fitting tables of the sample. The central fitting group rounded off was found in English half size. Substituting the recommended values in the equation, intersection with vertical axis/ constant for computing joint girth was proposed.

The central dimensions derived from the anthropometric survey mentioned are dimensions of the lower extremity of men. There is no scientific algorithm to convert these dimensions to last dimensions. But these dimensions are to be graded to get the required size and fitting ranges.

The data which fell into the central sizes and fittings of the sample were selected and central values of dimensions required for last modeling were computed. Using the data from the lower extremity survey the shoe last patterns was constructed for the mean size of the sample. This is then used for constructing patterns for components such as insoles, heels, shanks, outsoles and or for the cavity of corresponding moulds. The pattern is also used for quality control and shoe size grading. Joint girth table for men's shoe lasts for English half size was recommended.

The logistic regression models obtained clearly point out that not only lower extremity dimensions are important for footwear comfort but also fit preferences. However, future research may look into wider fitting trials to rate user's expectations and measure plantar pressure distribution, weight and shock absorption which perhaps can be considered for a foolproof comfort. Modern 3D surface scanning systems can also be employed for effective production.

ACKNOWLEDGEMENTS

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