A Novel Approach Towards Design and Development of Indian Men's Workplace Casual Footwear with Specific Reference to Sizing

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1 Introduction

India's annual footwear consumption stands at 2.1 billion pairs and it is the third largest footwear consumer, globally after China and the USA and has recorded a healthy growth over the last decade, driven by the rise in income levels, growing fashion consciousness and increasing discretionary spending [1]. The domestic footwear industry in India is valued at approximately ₹. 22,697 crores (US $ 319.27 crores), projected growth at 11–12% per annum. Footwear retailing constitute about 9% in the total consumer market [2]. The Indian footwear market can be bifurcated into men, women and kids' segments. Men's footwear occupies the maximum share in the Indian footwear market. The share of men's footwear was around 54% in 2016, followed by women's footwear which was around 37%. Further, kids' footwear was around 0.9% in the market [1]. The footwear industry in India is further bifurcated into casual footwear, mass footwear, premium and sports footwear. Mass footwear usually refers to low price footwear and majorly consists of slippers. On the other hand, casual footwear involves those preferred by people for daily wear in schools, colleges or workplace, etc. Casual footwear dominates the market followed by mass footwear. The share of casual footwear was estimated to be 61% in 2012. However, casual footwear is expected to continue to dominate the market, the share of sports and premium footwear is expected to increase [3]. The common styles of men's workplace casual footwear are moccasin, boot, derby, brogue and sneaker [4].

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The study by Anand and Alekya [3] analyses the consumption pattern of footwear consumers restricted to the twin cities of Hyderabad and Secunderabad. People consider comfort as the primary important factor while purchasing footwear. While men consider quality as the second important factor. Young people prefer to have multiple footwear of different variety. Other age groups prefer to have one pair but which is comfortable and long lasting. The case study by Sarkar [5] discusses the challenges faced by the domestic footwear sector. The study by Aout et al. [6] advocates barefoot walking, which helps to preserve natural foot function. When the substrate does not allow for barefoot locomotion, footwear should be worn that protects the foot from injury, but that is unrestrictive enabling the foot to function as much as possible as in the unshod condition. The review by Rossi and Tenant [7] discusses the shoe fitting procedure comprehensively along with outlining fifteen test points for footwear fit. Delhi Economic Survey [8] lists the workplaces with reference to the National Capital Territory (NCT) of Delhi. The research by Chien-Chung [9] discusses in detail three existing foot measurement systems in the UK footwear industry and also the differences among these three measurement systems. The Shoe and Allied Trade Research Association (SATRA), Kettering, UK the biggest footwear technology research centre in the world, offers a foot measuring system for use in footwear research and development. Tomassoni et al. [10] outlined the inclusion criteria for their study which analysed the main morphological parameters of foot of a large population of individuals of different ages, to provide basic information for the development of appropriate footwear for the elderly. The research report by Clapham, SATRA [11] offers a surer means of measuring dimensions of the feet for arriving at correct last dimensions. ISO 8559:1989(en) [12] includes the procedure for taking girth measurements of the leg which are essential for the manufacture of boots, which is one of the styles of Indian men's workplace casual footwear. IS:1638–1969, [13], Bureau of Indian Standards—this standard prescribes the sizes and fittings for footwear last which are required for manufacture of footwear along with the specifications with respect to foot and last dimensions and;

1. The approximate equivalent shoe sizes in Paris Point size scale, English size scale and American size scale.
2. Formulae for interconversion of Paris Point size and English size.

4.0 Industry Standards promotes the use of smart technology and product design based on user centred parameters, etc. AK A64—WMS, Germany provides shoe last design guidelines. The developed shoe last has three available widths viz.

- W (Weit = Wide).
- M (Mittel = Medium).
- S (Schmal = Narrow).

The shoe system is quite elaborate on the foot dimensions. The dimensions are measured in millimetres. It also outlines the guidelines to be followed by last designers to develop the flattened last bottom profile/plan. A set of prescribed points on the feather edge/line could be moved by the minimum amount, so that the resulting last bottom surface would flatten to best fit [14].

Footwear sizes are one of the most complicated and erratic areas of the whole footwear fitting process. And no matter the experience of the fitter, footwear sizes are one of the least understood, or the most misunderstood, elements in footwear fitting. While size is obviously important, we tend to overmagnify its importance by the assumption that if the footwear is the right size it will automatically deliver the proper fit. This of course is quite untrue. From the stand point of the fitter, footwear size consists primarily of two measurements: overall length and ball width. These measurements however do not indicate the true size of the foot or the footwear. Heel width, waist girth, instep, heel to ball, arch length also come in "sizes". The footwear is presumably "sized" in its various sections to match the corresponding sections of the foot. At least that's the way it is supposed to be. But often it doesn't happen that way [15].

Due to the lack of Indian sizing surveys, footwear manufacturers are forced to use the size charts of other countries where the anthropometric make of the population is very different from that of India. This results in manufacturing of a product which might not fit the Indian feet types.

Few systems abroad, also take the width/girth of the feet into account. Some regions use different footwear size systems for different types of footwear—men, women, children, sports or safety footwear. Each size of footwear is considered suitable for a small interval of foot lengths. In order to accommodate variations in foot sizes, alternative width fittings are available. By the use of fittings it is possible to fit greater number of feet more efficiently. The number of fittings used will be governed by the class of trade being catered for [16].

Only a few retail brands like Bata, Action, Liberty, Relaxo, J. D. Williams offer a range of fittings for each size in India. NIKE seems to offer customized trainers and sneakers in India, in the price range of ₹ 8000–27,000 (US $ 120–406). When footwear of different width options is not available for the same length then people with wider feet are forced to purchase shoes of larger sizes while those having narrower feet will have to wear too wide shoes. In both cases feet may suffer, but certainly shoes will go out of their shape much faster than in case of normal fit and their durability will also be reduced.

The comfort of shoes seems to affect the fatigue, the injury outcome and the performance of each person [17]. One of the major causes of foot debilitation is the wearing of ill fitting and improper footwear which causes blisters, corns and other foot injuries which if left untreated could lead to limb impairment and damage. To avoid such an occurrence, it becomes imperative to design and develop proper and correctly fitting footwear and the major ingredient in the success and provision of correctly fitting footwear is the "last", which is a three dimensional form of the foot and on which the footwear would be made [18]. The shoe last is a model representation of the feet—a kind of average of the given person's or population's feet. This lends the correct shape, fitting and dimensions to the footwear. Information on the shape and dimensions of the foot is of key importance in ensuring that footwear is designed to fit correctly. As with all physical objects, the human foot can be characterized by its dimensions. The appropriate set of measurements, processed according to established techniques is used in the development of sizing systems

[19]. In the footwear industry it is essential to have statistical data of the proportions of the foot of the local population. This is essential for last development as lasts designed and manufactured in other countries cannot serve their purpose in India, owing to differences in population, climate, wearing conditions, urbanization, etc. Last manufacturers use at least 30 dimensions to build a foot last [15]. The dimensions of the lasts in present use were valid for a population representative of the United Kingdom or France decades ago. Fit and comfort, i.e. consumers' satisfaction as well as design and pattern engineering, tooling of the production, component supply (coordination) all depend on the successful design of the shoe last. For this purpose, accurate data are required on the geometry of foot. At the present time, characterized by a transition to a free market economy, this requires even more urgency because the products have to stand up to strong competition from all over the world.

Thus, the main aim of the present study is to come up with a strategy for providing well-fitting footwear to Indian office going men. In order to achieve this identified anthropometric dimensions of feet of Indian men, were collected. It is expected that the survey would.

- Reveal differences among various ethnic groups—if they exist or prove that no differentiation is needed when footwear is produced and supplied.
- Set basic measurements to be used for marking sizes of footwear, establish size ranges providing the required coverage of the population with footwear to be produced using industrial technology for retail.
- Produce rules and numerical databases for designing well-fitting shoe lasts which will avoid development of static and other foot diseases caused by wearing shoes which are not comfortable.

The results of anthropometric measuring provide an insight into the occurrence and regional distribution of certain sizes in the investigated population. The information and results of the foot measurement system can also be used in research, made to measure services, retail studies, demography, ergonomy, etc. [19].

2   Experimental

Due to the lack of up to date published material related to the subject of research it has been necessary to visit the shoe and last manufacturers in order to gain a better understanding of the production processes and standard model last design and making techniques. Consultations and interviews were conducted with specialists and experts from the factories and experienced faculty members in footwear development. Some related research centres and manufacturers were also visited. A series of informal visits to experienced engineers and technicians, and discussions with supervisors were first carried out. These resulted in the modification of the area of enquiry and the identification of additional informants or sources of information.

Experts in the field were consulted through a semi-structured interview schedule to.

1. Validate the existence of the problem of footwear sizing for Indian men's workplace casual footwear in the NCT/NCR region.
2. Understand the methodology of fit and field trials.
3. Ascertain availability of infrastructure, facilities and other resources with respect to anthropometric survey of feet in NCT/NCR, last assessment and design in NCT/NCR regions, development of customized shoes in NCT/NCR regions and footwear comfort testing, insole pressure measurement, etc.

Further primary and secondary data has been collected for a pilot study to ascertain problems related to men's footwear, in Indian retail market. The total sample size of 71 respondents was drawn from a variety of consumer groups who have diverse demographic backgrounds and societal lifestyles. The area of the study was primarily National Capital Region (NCR).

Further identified anthropometric dimensions of feet of Indian men, have been collected following SATRA foot measurement system for both the right and left feet. Since styles of 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. Morphological characteristics included thirty-one anthropometric dimensions of feet and leg of Indian men, which in turn included four angle measurements, ten length measurements, ten girth measurements, four height measurements and three width measurements [9, 12].

After thorough review of existing literature in the area, the list of anthropometric measurements to be collected was identified and the required list of instruments/tools, stationery, consumables were also identified and mobilized. A foot anthropometric measurements/dimensions chart was designed and drafted along with a voluntary consent form which each subject would sign.

Subjects. New Delhi, the capital of India, sprawled over the west bank of the river Yamuna is one of the fastest growing cities in India. It is surrounded on three sides by Haryana and to the east, across the river Yamuna by Uttar Pradesh. As per 2011 census the population of National Capital Territory (NCT) is 1,67,53,235 out of which the male population is 89,78,154 and female population is 77,75,081.

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 [20]. The migrants are mainly from the states of Uttar Pradesh (UP), Haryana, Bihar, Rajasthan, Punjab, West Bengal (WB), Madhya Pradesh (MP) and other states [21]. The user is either of middle or top management level for whom there is usually no specified uniform, even though a dress code might exist.

Inclusion criteria. All participants were to meet the following inclusion criteria:

(1) No history of congenital deformity in the lower extremity or foot;
(2) No previous history of lower extremity or foot fractures;
(3) No surgical operation on foot and lower extremity;
(4) No systemic diseases that could affect lower extremity or foot posture;

(5) No history of trauma or pain to either foot, lower extremity or lumbosacral (lower back) region at least 12 months prior to start of the investigation [10].

The survey was also restricted to people whose differences between the left and right feet were not visible in the first sight, the person can walk and run without any difficulties [19].

2.1 Measurement Methodology

Anthropometric foot measurement instrumentation. The following is the list of tools, instruments, stationery etc., used for measuring and recording the foot data (Figs. 1, 2, 3 and 4).

Fig. 1 Stature measurement scale

Fig. 2 Weighing scale, in-house developed scriber block, shoe makers square, small bone anthropometer, footwear measuring tape, combination measuring device, pen, eye liner pencil, marker, HB pencil, eraser, sharpener, stapler and steel scale

Fig. 3 Graph sheet

Fig. 4 Cutting mat, protractor, set square, scale, pattern master, double punch and paper cutter

1	Properly designed chart
2	Thermocare height measurement scale for baby and adult 2 m
3	Body weight weighing scale
4	Scriber block
5	Shoemakers square © 1995
6	Footwear measuring tape
7	Small bone anthropometer,
8	Combination measuring device
9	Ball point pen, marker and eye liner pencil
10	Cutting mat

(continued)

(continued)

11	Graph sheets A3 size,
12	HB Pencil, eraser, sharpener, stapler
13	Steel scale, set squares, protractor

The instruments and tools. Thermocare height measurement scale for baby and adult 2 m was mounted on the wall, which was covered with white garment pattern making sheets. The other instruments and tools like body weight weighing scale, in house developed wooden scriber block, shoemakers square © 1995, footwear measuring tape, small bone anthropometer, combination measuring device etc. are portable, so data collection relating to determining shoe size ranges, feet variation by geographic regions, etc. were carried out on the spot with minimum efforts wasted in setting up the system.

The measurement methodology consisted of a precision manual measuring procedure where the subjects' feet and leg are measured as per the procedure outlined in SATRA foot measuring system and ISO 8559:1989(en) standards.

Descriptive statistics/demographic and personal characteristics such as:

1	Date of birth and age
2	Stature/height
3	Body mass
4	Occupation/employment details
5	Ethnic group

were recorded through questionnaire and by using wall mounted height measuring scale and body weight weighing scale.

Morphological characteristics/foot anthropometric measurements/dimensions. The feet and leg of the subjects were felt for some bony and anatomical points. Six anatomical points on the foot and four anatomical points on the leg were marked with an eye liner pencil. The foot plan of both the feet, were drawn on suitable size graph sheet using the in house made wooden scriber block and HB pencil. The corresponding positions of the six anatomical points on the foot were marked on the foot plan using steel scale and shoe makers square. Morphological characteristics which include thirty-one anthropometric dimensions of feet of Indian men, which in turn included four angle measurements, ten length measurements, ten girth measurements, four height measurements and three width measurements were measured using protractor, scale, measuring tape and small bone anthropometer. The size heel to toe and heel to ball and fitting of the foot was measured using combination measuring Brannock device.

Measuring conditions. The most important condition is the body position of the subject while the measurements were taken as well as when the girths were measured. The person stood on both feet, whereby the two feet were placed parallel approximately in a distant equivalent to the shoulder span (width), while the body weight was

equally distributed between the two feet. Both the feet of the subjects were measured in this survey.

The measuring procedure. After recording the descriptive statistics/demographic and personal characteristics in the properly designed foot anthropometric measurements/dimensions chart, the information on confirmation for the inclusion criteria were recorded. The height and weight were measured using the appropriate instruments. The anatomical points on both the feet and leg which define the foot measures were marked using the eye liner pencil. The foot plan of the feet were drawn using the in-house developed wooden scriber block and pencil on appropriate size graph sheet and the positions of the anatomical points were also marked on the foot plan. The girths were measured using a footwear measuring tape. Angle measurements were measured from the foot plan using protractor. Length and width measurements were measured using scale. Certain height measurements were measured using a small bone anthropometer. The size and fittings were noted using combination measuring device. The longest toe, i.e. the big toe or the second toe, etc. was noted on the foot anthropometric measurements/dimensions chart. After ensuring that all the required measurements were recorded, the foot anthropometric measurements/dimensions chart of individual subjects, the graph sheets on which the foot plan is drawn and the consent forms were filed in the dedicated box files. Measurements of different morphometric parameters for each subject were recorded in millimetres and the values obtained from the right and left foot were summed up and divided by two. Hence values on which statistical analysis are to be conducted refer to the mean value of right and left foot parameters under evaluation.

3 Results and Discussion

3.1 Semi-Structured Interviews of Experts in the Field Were Conducted and the Following Are the Outcome of the Research Conducted so Far

According to Debasish Das Gupta (Interview, August 28, 2017) faced with problems of non-standard size grading etc., India is not able to compete with China in non-leather shoes. Due to lack of awareness the Indian consumer emphasises more on looks rather than technical aspects and sizing of footwear. In house product development of lasts is lacking in India. According to Ms. Satyam Srivasatava, Senior Consultant (Footwear Technology), Footwear Design & Development Institute (FDDI), Noida (Interview, August 30, 2017) testing facilities for SATRA Footwear Comfort Index etc., is not available in India.

According to Mr. Shravan Kumar Singh, General Manager—Product Development, Mmojah, Sonipat, Haryana (Interview, October 10, 2017), in the current scenario, emphasis is more on look rather than on sizing. Russia uses Mondopoint sizing system. Bata did a foot survey around 50–70 years back. But due to feasibility

issues did not use the data and continued with the European sizing system. There is a lot of difference between the feet of the urban population in comparison to the rural one. Width increment is 1/3rd each ball girth increment. Indicative fitting is used by the manufacturer and wholesaler and real fitting is for the consumer. G-Wide and H-Very Wide fittings are mostly used in India. There are three stages for ensuring the correct fit before the bulk production starts, by the manufacturer.

1. Last.
2. Fit test—done in a lab.
3. Fit wear test—an employee of the matching size is made to wear the footwear and Quality Control inspection is done after 15, 30 and 45 days. A set of questions are asked to the employee as per a prescribed format.

There is an average of 15 mm gap at the toe portion between the feet and the shoe. Only 1% complaints received from footwear consumers during after sales service are genuine in India.

Mr. Kripal Singh, Top Lasts, Noida (Interview, December 07, 2017) explained the principles of last making.

Each last manufacturing company follows its own single colour for last, because changing colour is difficult. Top lasts uses RECAD—a Poland based software.

3.2 The Primary Data for the Study Was also Collected from a Random Sample Using a Questionnaire. The Respondents of Various Age Groups, Income Levels, Occupations Were Asked for Their Consumption Pattern

(See Table 1).

- 42% respondents reported to have a foot injury/illness. The occurrence of foot injuries in descending order is heel pain followed by heel spur, Achilles tendonitis, arch pain, bunion, callus, claw toe and Morton's neuroma.
- The respondents' preference of style of men's workplace casual footwear in descending order is Derby followed by boot, sneakers, brogue and moccasin. On an average each respondent possessed 5 pairs of footwear at any given point of time. Maximum number of respondents used leather footwear. The respondents' preference of brands for men's workplace casual footwear in descending order is Woodlands followed by Bata, Lacoste, Liberty, Action, Lee Cooper and HRX.
- The preferred mode of purchase of footwear in descending order is through retail outlets followed by online, through factory outlets. 39% respondents availed of after sales service for their workplace casual footwear. The maximum complaints in workplace casual footwear in the descending order was on account of sole cracking/breaking followed by sizing, manufacturing defects, workmanship and colour fading of trims.

Table 1 Demographic profile

Category	Respondents	Percentage
Age (years)		
21–30	19	27
31–40	08	11
41–50	21	30
51–60	20	28
61–70	02	03
71–80	00	00
81–90	01	01
Monthly Income (₹)	Respondents	
15,000–50,000	26	
50,000–1,00,000	15	
1,00,000–1,50,000	05	
1,50,000–2,00,000	07	
2,00,000–2,50,000	04	
≥2,50,000	14	
Workplace	Respondents	Percentage
Bank	05	07
Corporate office	09	13
Educational institution	10	14
Factory	05	07
Government office	16	23
Hotel	01	01
Hospital	05	07
Media	03	04
Restaurant	01	01
Others	16	23
Ethnic group	Respondents	Percentage
Purvanchali	10	14
UP	12	17
Uttaranchal	01	01
Haryana	11	16
Bihar	08	11
Jharkhand	03	04
Rajasthan	02	03
Punjab	16	23
West Bengal	02	03
Madhya Pradesh	01	01
Other states	05	07

- The usage of sizing system in descending order is British followed by American, Europoint and French. Only 9% of respondents used width fittings. 25% of respondents faced problems with available sizes/sizing in workplace casual footwear.

3.3 Anthropometric Survey

Statistical analysis. The task is to select those measurements which can determine all others, whereas the number of basic measurements should be kept to the minimum. If there is a strong relationship between one of the measured leg or foot dimensions and all others then the given property can be treated as the major size of the foot or shoe. The history of shoemaking had selected the foot length, the ball girth and/or width as such basic data out of which all other parameters required for designing shoe lasts, shoe upper and bottom patterns can be derived either by using (simple) equations or appropriately constructed tables. A large number of anthropometric surveys made in several countries also proved that measurements oriented in the same direction of the space (axes of the Cartesian system of coordinates) correlate very well (e.g., instep or waist or heel measure have strong correlation with the ball girth). The foot and leg survey should either verify the existing practice or find better, stronger, simpler and/or more reliable rules. The ideal correlation and regression analysis would investigate all possible combinations of the data fields (measurements and personal data) and various types of relationships (e.g.,) linear, quadratic or higher degree of paired, multivariable linear equations). There are three major directions in foot: length, width, while relationship of the measurements in the third direction (height) with other needs to be ascertained. Correlation coefficients for the same are to be calculated and correlation tables created. Histograms belonging to frequency variable in the new tables to be generated. Using the statistical Means of these tables we could select the so-called middle size values and calculate the typical geometric data for last modelling.

Size table to be created with frequencies, mean and deviations for English sizing system. The average foot length, the standard deviation, the size increment and the batch volume are to be computed. A batch may be a complete order or its fraction, the number of pairs in the production lot, the amount of footwear kept together in handling, packaging, shipping, transporting, storing, ordering, etc. The footwear industry uses the typical batch sizes which are 6, 10, 12, 60, 100, 120, 144, 500, 600, 1000 pairs. The method to be used for testing differences between samples from different geographic and/or ethnic regions is based on Student's t distribution. To increase the reliability of retail sale, i.e., maximize the likelihood of serving every consumer with well-fitting footwear with minimum size inventory, then the distribution of characteristic anthropometric measurements in regional sub groups should also be compared. This would be done using the F test. Data are first grouped by foot length expressed in a given size system (in our case in English half sizes), then average ball girths and widths are computed for each size. Mean and deviation

of stature, weight, stick length, plan length, ball width, seat width etc. for the given size number are to be computed. Now the increments in girth/width can be computed for each adjacent pair of length sizes: the weighted average of these Figs will give the computed (theoretical) increment by (English half) sizes.

Discussion

The key challenge to the referred study was to define and identify statistically relevant sample size and further ensure that the data collection is from the relevant sample. It would, moreover, not be feasible as the majority of the paired comparisons are meaningless in footwear technology. Complicated rules—even with appropriate computer programmes—would hardly be used by shoe designers and marketing department. Domestic vendors especially small players, order footwear in small batches and at less regular frequency. In this scenario, the size of market, type and quality of product to be manufactured broadly determines the choice of production technology in different market segments. Due to the cost involved in investing in a specific sizing system for the market under reference, industry may not see it as a commercially viable option. Redesigned footwear to fall within the financial affordability of the consumer. Availability of resource with regard to state of art laboratory facilities within the vicinity of geographical region where research was conducted to assess long-term comfort of the shoes constructed on the redesigned lasts was also an issue.

4   Conclusion

Capacity building in product development of footwear lasts would in a great way lead to use of more comfortable footwear by Indian office going men. India's dependence on foreign players for quality footwear would also be reduced. Though there are lot of factors and costs involved in following a better and foolproof footwear sizing system, a beginning has to be made which would lead to lot of technological advancements in the area.

Competing Interests The authors declare that they have no competing interests.

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