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Mixed Methodology based Experimental Research for Designing NCC Uniforms for Female Cadets

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ABSTRACT

Uniforms designed without considering the anthropometric differences of the female body types not only fit women badly, and prove uncomfortable but also impede physical movement and performance, particularly in actions involving motion. This study aimed at understanding the problem and its contributing factors to find a practicable solution with reference to the uniforms worn by the female NCC cadets. This study used qualitative methods such as focus group discussion and web based image analysis to understand the problem. It used the quantitative method of factor score based cluster analysis to create body type segmentation and an experiment to try out the uniforms stitched based on the statistical outputs. It is a pioneering study inasmuch as it used body composition variables along with apparel design measurements to segment the sample population of adult girls by body type and then prepare size charts for each body type group. The uniforms stitched based on size charts developed for each body type were tested on the female cadets belonging to the respective group. The cadets found the uniforms to be very good or good, except for the smallest group which required more fine grained size charts. This study finds merit in first identifying the body types and then defining the size charts for each type for designing female or unisex uniforms.

Key Words : Anthropometric body-types, Body-type based size-charts, Women Uniforms

INTRODUCTION

Women are increasingly participating in a variety of vocations along with men as equal partners. As a result, new categories of women clothing have been evolving from time to time. For example, with more and more women taking up jobs and occupying leadership positions in business, a comprehensive range of women business attire has emerged. So has been the case with sportswear and active-wear. However, the design of uniforms for women in security forces has not received adequate attention. Although women have been working in Indian armed forces since 1992, they constitute only 0.56% of the 1.4 million army personnel. The new policy of the Indian Government, which enables women to join military colleges and become eligible for permanent commissions will certainly pave the way for more women joining the armed forces (BBC, 2022). Although women in police force constitute only 7.28% of the total, as of 2017, the fact that their share has increased from a meager 3.89% in 2007 (CSDS, 2019) augurs well for the future. Therefore, it is time address the problems associated with the design of uniforms worn by women in security forces.

Recent media reports show that there have been several initiatives aimed at redesigning the uniforms of security forces. On the Army Day in 2022, the Indian Army unveiled a new combat uniform designed by the National Institute of Fashion Design (NIFT) (Indian Express, 2022). In 2017, the National Institute of Design (NID) showcased nine prototypes of police uniforms developed in collaboration with the Bureau of Police Research and Development (BPRD) (Times of India, 2017). While the new army uniform aims at enhancing comfort and camouflage, the new police uniform design

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focuses on creating a national identity, besides improved comfort, for the police forces across the country. The Delhi Police is also reported to have approached NIFT to redesign its uniform for greater comfort (Indian Express (2), 2022). However, the challenge of designing and sizing women oriented uniforms remains unaddressed.

Research Objectives:

The objective of the experimental research presented in this paper is to develop an alternative methodology for designing uniforms that would suit the female NCC cadets as well as women working in security forces better.

Overall Research Phases:

This research was carried out in a period 12 months and was conducted in the following three phases:

1. Qualitative Preliminary research to understand the problem and design challenges
2. Quantitative research to collect and analyze the data required for designing new uniforms
3. Experimental research involving the actual construction and evaluation of the uniforms.

METHODOLOGY

Qualitative Preliminary Research:

The preliminary research began with a survey of latest developments relating to the redesign of security force uniforms as well as the research studies that dealt with the design and sizing of uniforms, particularly military uniforms. It was accompanied by a web-based image search covering female NCC cadets in uniforms participating in activities like marching, saluting, etc. It was followed by a structured focus group discussion of 24 female NCC cadets drawn from 4 Delhi University colleges. They were also asked to rate the existing uniforms on different parameters. Finally, the uniforms worn by 25 female NCC cadets of Bhagini Nivedita College were physically checked for fit, style and workmanship.

Quantitative Research :

The quantitative research started with the collection of the anthropometric data required for body type segmentation and size charting. 50 female NCC cadets from 4 different Delhi University colleges were selected for this study using height as the classifier for stratified random sampling. TANITA Body Composition Monitor (BCM) was used for gathering body composition related data. Other equipment used for collecting the necessary anthropometric data included a digital stadiometer, anthropometric rods, standard measuring tapes and a weighing machine. In all, data was collected for 26 parameters for shirts and 15 parameters for trousers - covering body composition parameters and garment design measurements. Of these 7 body composition parameters remained common. Since BCM could not generate the required data in the case of two cadets, the sample size was reduced to 48.

SPSS Version 13 was used for performing the statistical analyses. The data was tested for sampling adequacy using Kaiser-Meyer-Olkin (KMO) and for sphericity based on Bartlett's Test to confirm that the data set met the data quality requirements of factor analysis which was needed to reduce the larger number of variables into a smaller number of factors and generate the case-wise factor scores to be used in the cluster analysis for segmenting the population into body type groups. Factor scores provide the only logical way to use the FA outputs in further analysis (Mary, 2010). These also serve as the ideal input for the cluster analysis as these are already standardised and normalized (Christine, Min and Diana, 2009). Factor Analysis was performed using the Principal Component Analysis Procedure with Varimax rotation and Kaiser normalization. The sample population was then segmented into distinct body type groups with the help of the Two Step Cluster Analysis procedure (TSCA). Log-likelihood was used as the distance measure. Plots were generated to depict the 1) within cluster variation of factors and 2) the variable-wise importance within each cluster. These helped in intuitively understanding the key body type features of the different clusters.

Experimental Research:

The experimental research was done by importing the case-wise cluster membership generated by TSCA into the original spreadsheet containing the actual body measurements. The spreadsheet was sorted based on the imported cluster membership data. After creating the body type segmentation of the sample, the respective cluster means was used as the basis for designing medium size uniforms of the respective clusters and preparing their patterns. The knowledge gained through both the qualitative and quantitative phases of the research were kept in mind while preparing the patterns. The patterns were graded for one size larger or smaller as was

necessary in the identified clusters. The cadets were then asked to wear the uniforms stitched using the patterns relevant for the concerned cluster. They were asked to rate the new uniforms on a scale of 5 where 5 stood for very good and 1 for bad with 3 representing the midpoint average.

RESULTS AND DISCUSSION

Results of the Qualitative Preliminary Research:

Literature Survey:

Historically, armed forces uniforms have been male oriented. One of the often cited feedback on the unisex combat uniforms worn by women soldiers is of the 2008 US Army Focus Group Report which pointed out that the men-oriented unisex combat uniforms designed for men fitted many women badly in the shoulders, bust, hips and crotch and forced them to wear larger uniforms. These women soldiers were about 20 per cent more likely than males to report musculoskeletal disorders. According to this report women who wore these were more vulnerable and less effective. They also spent more time in attending to the calls of nature. Ill-fitting uniforms make women in forces 'more vulnerable and less effective (Joyner, 2013 and Ferri, 2020). Following this report, the US Army introduced redesigned combat uniform in 2013 with features such as narrower shoulders, fitted waist and repositioned pockets, rank and name tapes in jackets and elastic waistband in trousers that addressed the needs of women soldiers (Medical Daily, 2013). Since then there has been continuous improvements and in 2021, the US Army 'created specific design features and additional sizes (US Army, 2021). As of 2021, the Australian Army is also trialing combat equipment and uniforms designed for women following the opening of combat roles for women in 2016 (Australian Army, 2021).

Security forces have tried to overcome the fit problem by offering larger number of sizes. The original US Army combat uniform came in 36 sizes with 4 length variations each. And yet these could not fit many women soldiers well as these were designed by men for men (Joyner, 2013). The root cause of the problem is the traditional sizing system which relies on only linear anthropometric measurements. In recent times, however, 3D scanning has become popular for taking accurate measurements for achieving better fit (Spahiu, Shehi, and Piperi, 2015). There is also new research focused on including body motions as the fourth dimension to improve the ease of mobility (Anke *et al.*, 2020). Linear programming methods (Gupta *et al.*, 2006) and clustering algorithms have also been developed to incorporate body type variations in the size charts (Ting-Chen *et al.*, 2019). Another research focused on developing unisex garments based on body types, however, relies on the generic body types such as the triangle, inverted triangle, diamond rectangular, etc. than identifying the body types using anthropometric data to segment the target population by body types (Sunitha, Pujar and Gopalakrishnan, 2019).

Web-based Image Collection and Analysis:

Detailed analysis of the images collected from Internet revealed the following:

– Rolled up sleeves: Most women cadets marched with rolled up sleeves although the general dress code

Table 1 : Descriptive Statistics and FA Communalities of variables included in the analysis

Sr. No.	Measurement	Mean	Standard Deviation (SD)	Communalities
1.	Leg Length(Cm)	90.6604	5.67659	.775
2.	Hip Circumference(Cm)	89.4688	5.74031	.843
3.	Waist Circumference(Cm)	69.3167	8.76299	.593
4.	Calf Circumference(Cm)	31.3021	8.37533	.653
5.	Knee Circumference(Cm)	32.9563	2.49731	.750
6.	Thigh circumference(Cm)	45.5625	5.01341	.826
7.	Weight(kg)	47.7042	7.70081	.985
8.	Degree of Obesity(%)	-9.9125	12.27883	.960
9.	Sitting Height(Cm)	81.8375	3.63737	.655
10.	Body Height (Cm)	155.5833	6.43066	.941
11.	Fat(%)	25.1229	5.78591	.754
12.	Fat Mass(kg)	12.4708	4.42613	.970
13.	Fat Free Mass - FFM(kg)	35.2396	3.91711	.961
14.	Bone Mass (kg)	1.9354	.33738	.950
15.	Deviation from Ideal Weight	5.3667	6.70190	.965

required full sleeve shirts. Rolled up sleeves seems to have become an accepted practice for coping with sleeve length related problems

- Oversized shirts: Many women cadets were found wearing oversized shirts with drooping shoulders possibly for getting the necessary chest width
- Oversized shirts created a very ungainly look with the excess fabric of the shirt resulting in folds and bulges.
- Lack of ease in armholes and sleeve circumference: Cadets wearing shirts that fitted them well often put up with constrictions of the armhole as well as restricted elbow movements while marching and saluting
- Baggy trousers: Women cadets were also seen wearing oversized trousers that looked more like skirts
- Oversized accessories: Women cadets were also seen wearing larger accessories that did not go with their body frame.
- Need for assistance from others: It also appeared that women cadets often required the assistance of their colleagues to cope with the ill-fitting uniforms or those which did not suit their body type.

Evaluation based on actual wearing and physical checking:

In order to understand the design and fit problems faced by women cadets, a close examination of the uniforms actually worn by the cadets was also done. It was observed that the uniforms were either too loose or too tight. Some of the design elements like pockets and cuff openings were disproportionately large. Some uniforms did not at all suit the body frame of the cadets and the workmanship was generally poor.

Focus Group Discussion:

The cadets felt a great sense of pride and patriotism wearing the uniform. However, they also felt that the uniform supplied to them left a lot to be desired. On a scale of 5 they rated it at 1 in terms of overall fit and comfort and 2 with respect to its look and feel. While problems relating to fit as well as look and feel were commonly felt by all, it was felt more acutely by the cadets who were either tall, short, fat or thin. Shoulders, waists, armholes and sleeve length were identified as common problem areas

Results of the Quantitative Research:

Although this research project collected and analyzed data relating to shirts and trousers, this paper deals with the data and analysis pertaining to trousers only.

Sampling Adequacy Testing:

Kaiser-Meyer-Olkin (KMO) measure of Sampling Adequacy returned a value of .776, which is well above the minimum required value of .5 and very close to .8, which is considered good. Similarly Bartlett's test was significant with a value of .000 well below the norm of .05. Both the tests confirmed the suitability of the data for using the Principal Components Analysis (PCA) of Factor Analysis (FA) and generating the factor scores to be used in the Cluster Analysis.

Descriptive Statistics and Communalities:

The descriptive statistics and communalities with respect each research variable are given in Table 1. The descriptive statistics shows wide dispersal of data - with some parameters like the degree of obesity, waist and calf circumferences, weight, height, fat%, hip circumference, etc. having relatively higher standard deviation. At the same time, all the parameters have significant communality values of over .5 confirming their suitability for inclusion in FA.

Principal Component Analysis:

The PCA process generated three orthogonal components as shown in Table 2. Factors were allowed to be extracted automatically based on the principle Eigenvalue> 1. The PCA output tallied with Scree Plot also.

What is noteworthy is that the PCA had

Table 2 : Principal Components Extracted by Factor Analysis

Component	Extracted Solution		Rotated Solution	
	% Variation	Cumulative %	% Variation	Cumulative %
1	54.752	54.752	47.769	47.769
2	22.375	77.127	27.409	75.178
3	6.747	83.874	8.696	83.874

automatically extracted 3 factors, which explained a total variance of 83.847%, which is well above the acceptable level of 65%. The rotation converged in 5 iterations as against 25 iterations set as the maximum permissible limit in the FA procedure. These certainly reflect the quality of the data used in FA.

The rotated component matrix was examined to identify the variables loading strongly or weakly onto each factor. As per standard practice a minimum cut-off loading of .4 was set for considering the influence of any variable on to a factor. Table 3 presents the factor wise loading of the variables.

The first factor accounted for about 48% of the variance in the data. All the 10 constituent variables have a loading of over .5 and relate to relatively heavier body with a degree of obesity. In view of this, it was named as one representing 'heavy build/obesity'.

The second factor accounted for about 27% of the variance in the data. In all 5 variables had a loading of over .5. These relate to the tallness, heavier bone weight and muscularity. Keeping these in view, it was named as one representing 'tall, bony and muscular' nature of the body type.

The third factor, which explained about 9% of the variation has only three variables having a loading of over .4. Based on these, this factor is named to represent 'heavy thigh and calf'.

Cluster Analysis:

Automatic clustering resulted in a single cluster. Since the objective of this project is to group the cases based on the factors extracted in the previous process, it became necessary to specify the number of clusters to be created. First, clustering was done for 3 to 5 clusters on an experimental basis keeping in mind the three factors extracted by FA. Variable wise importance plots were also checked to see whether the variables of importance were meeting the critical value criteria or not. After analyzing the output of the experimental runs, results were finally obtained for a 4 cluster solution. The cluster distribution produced by the TSCA procedure is shown in Table 4.

Interpretation of the cluster characteristics was done with the help of the within cluster variation of factors (Fig. 1) and the variable-wise importance within each cluster (Fig. 2).

As can be seen in the 'heavy build/obesity' factor plot in Fig. 2, this factor has a distinct positive association with cluster 4 and a negative association with cluster 3. In clusters 1 and 2 this factor plays a limited role since its mean is very close to the overall mean.

The plot the 'tall, bony, muscular' factor shows that this factor has a distinct positive role in Cluster 1 as well as a distinct negative association with cluster 2. Its impact is somewhat neutral in the other three clusters since its

Table 3 : Principal Component Factors and their Constituent Variables

Variable	Loading	Variable	Loading
Factor 1: Heavy body build/obese		*Factor 2:* Tall, bony/muscular	
Degree of Obesity(%)	0.980	Body Height (Cm)	0.956
Fat Mass(kg)	0.971	Leg Length(Cm)	0.880
Weight(kg)	0.870	Sitting Height(Cm)	0.774
Hip Circumference (Cm)	0.860	Bone Mass (kg)	0.741
Fat(%)	0.851	FFM(kg)	0.738
Thigh circumference(Cm)	0.808	Waist Circumference(Cm)	0.496
Knee Circumference(Cm)	0.653	Weight(kg)	0.469
FFM(kg)	0.611	*Factor 3:* Heavy thigh and Calf	
Bone Mass (kg)	0.599	Calf Circumference(Cm)	0.731
Waist Circumference(Cm)	0.520	Knee Circumference(Cm)	0.540
Deviation from Ideal Weight	-0.979	Thigh circumference(Cm)	0.409

Table 4 : Cluster sizes and membership (Log-likelihood was used as the distance measure)

Cluster	Members	% of total	Cluster	Members	% of total
1	10	20.8%	3	15	31.3%
2	14	29.2%	4	9	18.8%

mean value in these clusters are close to the overall mean and cluster members are spread on both sides of the overall mean.

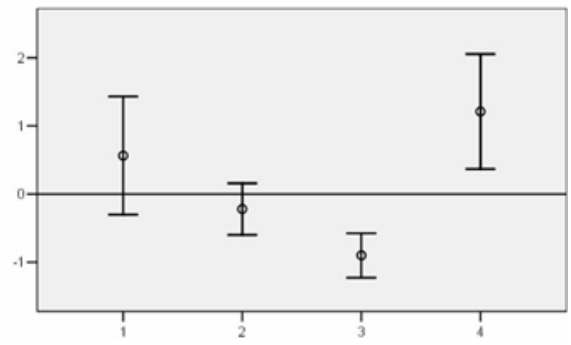
In the plot of the 'heavy thigh and calf' factor, it is seen that this factor has a nearly distinct negative association with cluster 3 and a distinct positive association with cluster 4. Its impact is somewhat neutral in clusters 1 and 2 since its mean value in this clusters are spread on both sides of the overall mean. The importance or otherwise of the variables (component factors) in the 4 clusters is shown in Fig. 2.

The variable-wise importance plot of Cluster 1 clearly shows a positive association with the 'tall, bony and muscular' factor as it meets the critical value criteria. It also displays the existence of somewhat positive association with the 'heavy build and obesity' factor. Based on the results and looking at the variables that load on to these respective factors, this cluster is named as 'Tall and Muscular' Cluster. This is the third largest of the cluster and accounts for 20.83% of the sample population. In the Cluster 2 plot, there is a significant negative associations with the tall, bony, muscular factor which also meets the critical value requirement. It also has a negative association with the heavy build and obesity though not to a statistically significant extent. Based on the evaluation of the results, this cluster is named as short and slender. This is the second largest among the four clusters and accounts for 29.17% of the sample population. The plot of Cluster 3 shows a significant negative association with heavy build / obesity factor and a near significant negative association with heavy thigh and calf factor. It has a noticeable positive association with the tall, bony muscular factor. This cluster is the largest among the four clusters and accounts for 31.25% of the sample population. It is named as the 'Medium Build' cluster. Cluster 4 is the smallest of all the four. But it has two very significant positive associations with 1) heavy thigh and calf factor and 2) heavy build and obesity factor. It has also a very noticeable negative association with the tall, bony and muscular factor. Based on these results, this cluster is categorized as short and stout.

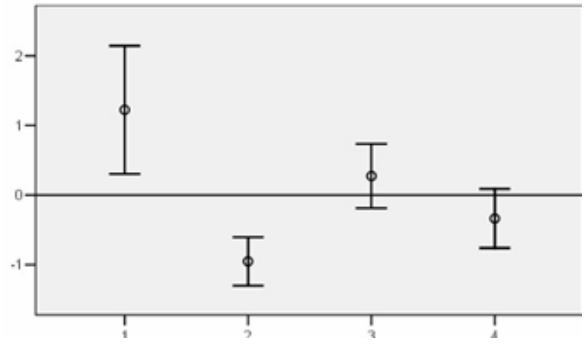
The most important result of the statistical analysis carried out on the anthropometric and apparel design measurements with the help of factor analysis and factor score based cluster analysis is the case wise cluster membership data generated for the entire sample. This

Fig. 1 : Within Cluster Variation of the 5 extracted factors

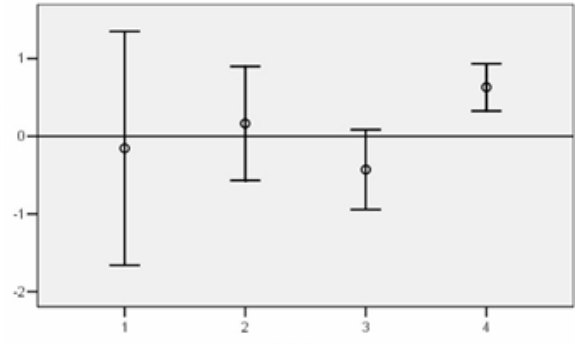
Factor 1: Heavy body build/obese



Factor 2: Tall, bony/muscular



Factor 3: Heavy thigh and calf



Factor 5: Longforearm

Legend

X axis indicates clusters by their number Y axis represents regression factor scores in -3 to +3 Z Score format with 0 in the middle indicating the mean score.

The horizontal line from the factor score mean 0.0 helps understand how far or close the clusters are to the mean of the concerned factor score

data formed the basis for the experimental research.

Results of the Experimental Research:

Preparation of Size Charts and Construction of Uniforms:

In the experimental phase the cluster membership data generated by the TSCA was imported into the spreadsheet containing the apparel design measurements of the sample population. Size charts for trousers to be stitched for each cluster were generated by calculating the mean apparel design measurements of the respective cluster members. These size charts were then extrapolated into small, large and extra large sizes where necessary depending on the maximum and minimum measurements in different clusters.

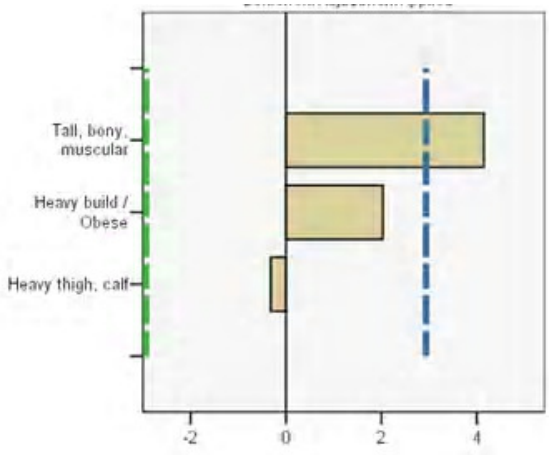
Trial and Evaluation of the stitched Uniforms:

The trousers stitched based on the cluster data was tested on the female NCC cadets belonging to the respective clusters. In view of the limited number of cadets included in the sample population and the very small number of cadets in some clusters, test fitting of the trousers was limited to only two sizes per cluster. The average feedback rating given after the actual trial of the unoforms is given in Table 5.

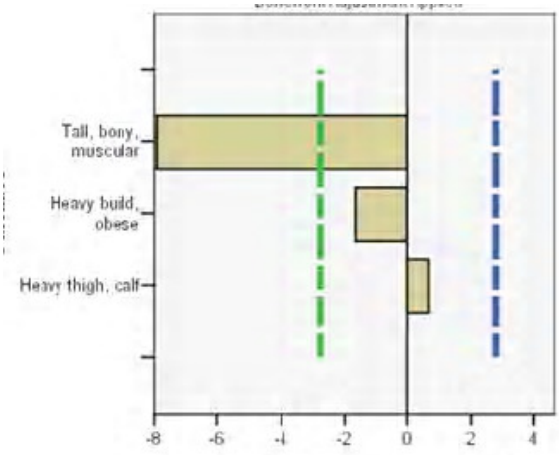
The approval rating obtained by the NCC uniforms are far above the 20% approval rating for readymade garments made using the standard size charts (Gupta and Gangadhar, 2004). The parameter wise rating received from the trials are also far above the ratings of the existing uniforms received in the focus group at the

Fig. 2 : Variable-wise Importance in the 4 Clusters*

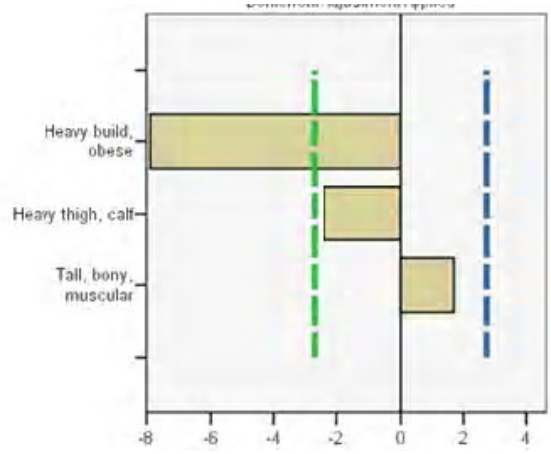
Cluster 1: Tall and Muscular



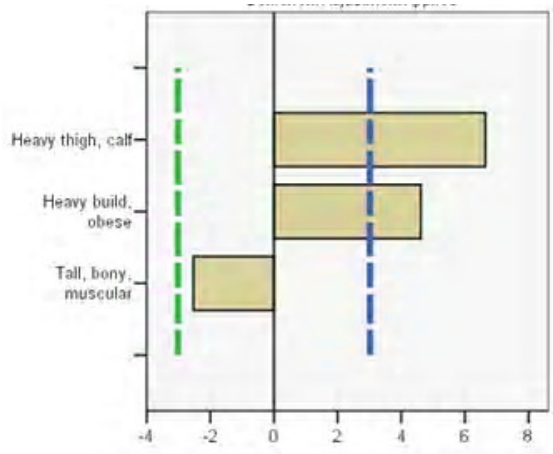
Cluster 2: Short and Slender



Cluster 3: Medium Buikd



Cluster 4: Short and Stout



*Benferroni Adjustment applied: Dashed vertical line on the left indicate negative critical values; Dashed vertical line on the right indicate positive critical values; Horizontal bars on the left and the right represent t test values; X axis represents Student's t values (- and + values on either side of mid point '0')

Table 5 : Average Feedback Score on Trouser Trial

Parameter	Average Score (Excluding Cluster 4)	Average Score (All Clusters)
Look	4.83	4.71
Comfort	4.33	3.86
Overall Feel	4.66	4.57
Fit	4.00	3.71
Ease of Movement	3.83	3.42
Better than current uniform	5.00	4.71

Rating Scale: 5 = Very Good; 4 = Good; 3 = Average; 2 = Bad; 1= Very Bad.

beginning of this research project.

Conclusion:

As a pioneering study, this research provides a proof of the concept of designing and sizing women's uniforms by segmenting the target population into body type groups and preparing size charts separately for each body type group using the cluster means as the reference point. This study also calls for including body composition parameters for more accurate identification of body types. The methodology used in this could also be gainfully used in designing and sizing plus size garments. It could also help develop a minus size category to cater to the short and stout as well as the short and slender.

This study also acknowledges the challenges of sizing in the case of clusters having outliers or widely dispersed characteristics. Although this study found that the residual cluster constituted less than 20% of the target population, it may be possible to reduce the outliers by including more vatiables, by accepting larger number of clusters and by doing more fine grained sizing for each cluster. The sample size of the present research was also small. There is certainly a need for conducting a similar research with a larger sample size.

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