Defence Life Science Journal, Vol. 6, No. 4, October 2021, pp. 275-283, DOI : 10.14429/dlsj.6.16602

Data Mining Anthropometric Parameters for the Design and Sizing of Female Full Body Protector

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ABSTRACT

Since the entry of female troops in different paramilitary forces, there is a dearth of well-fitted personal protective gear for them to maximise operational safety and protection. A mismatch of anthropometry in design adversely affected the user's performance during critical operation, compromising the safety and well-being of an individual. A detailed anthropometry-based sizing study was conducted by the research team, on the Indian female paramilitary troops for proper sizing of their protective gears and ensembles. An anthropometric survey of 325 female para-military troops, posted in two locations with age ranged from 21 to 54 years (mean ± SD) value: 37.14 ± 8.49 years was done. Each subject's 28 different body dimensions were taken. The data was then investigated using the factor analysis method. Principal component analysis technique was used to reduce the variables to similar factor components where, two components with an Eigenvalue of more than 1 were selected. viz. Principal component 1 (girth dimensions) and Principal component 2 (abdomen or waist dimension). These two key variables were used to divide the population into three separate clusters using the K-means cluster method. These cluster groups were validated using a regression tree. Descriptive statistical analysis of data was conducted followed by Cluster analysis (of key components shortlisted) using Statistical Product and Service Solution (SPSS) version 21. The current study was the first complete anthropometric survey of Indian female paramilitary personnel for the development of a female-specific sizing system for a full-body protector (FBP) design resulting is an improved fit of full-body protector.

Keywords: Female; Protector; Anthropometry; Sizing; Ensemble

1. INTRODUCTION

Full Body Protector is the basic requirement for the police and security troops deployed especially in riot conditions.

A body armor that does not fit properly poses a problem when shooting, moving and communicating. Military Medicine report in 2015, stated that among females who had served in Afghanistan, 20 per cent of musculoskeletal injuries in females were associated with body armor, compared to only 4 per cent for men. A body armour that is used in the shooting range can adversely affect female service members if it is ill fitted.

In a study of female soldiers providing their own anthropometric dimensions for the redesign of a protective wear, the U.S. Army Natick Soldier Research, Development, and Engineering Center (NSRDEC) came up with a newly designed vest known as small-statured and female soldier body armor and was awarded the TIME best invention in 2012. The re designed protective wear had smaller side plates, fits the soldiers at the shoulder part better and didn't obstruct soldier's hair or headgear while wearing it[1].

When female soldiers wore body armor designed for men in the U.S. military, several problems were encountered like impeding the wearer's range of movement, affecting their aim with a firearm and ability to swiftly get in and out of a vehicle. Moreover, during hand-to-hand combat the ill fit creates gaps that an opponent can grab onto.

When it comes to designing a female-specific body protector, there are some design challenges like fitting the curved armor plates to fit the female form, while for men, covering the somewhat barrel-like shape of an average male torso is a comparatively uncomplicated design procedure[2].

In Australia, a survey on female troops for understanding the efficacy of body protector in terms of its fitment and functionality was carried out. Results indicated that the body protector was ill-fitting as 68 per cent of the participants reported musculoskeletal pain and discomfort in the neck, upper and lower back, thigh in addition to pain at shoulders, abdomen and hips. It was recommended to modify these body armours, in terms of target operators, viz. female soldiers[3].

In India, especially among female troops, there is a need for female-specific equipment. Very frequently, extra-large sizes of male body protector were given to female troops for accommodating their bust size. However, this being too large for target user population, caused several issues during operational maneuvers, like, the front plates pushed against the chin while

Received : 04 January 2021, Revised : 19 August 2021
Accepted : 02 September 2021, Online published : 06 October 2021

sitting, difficulty in bending at the waist while getting in or out of military vehicles (armoured or without armour). Currently available ensembles do not incorporate gender-specific design inputs and the usage of materials approved according to recent security specification norms.

These problems were directly affecting the operational ability of these female troops in riot control situations, researchers in DIPAS began looking for a solution. Existing literature showed that there was a lacuna for specific female full body protectors both in India and abroad. With this in mind, the researchers took the anthropometric measurements of Indian female users to be used in the design of a new full-body protector.

With the request from RAF, the survey was carried out by DIPAS towards the end of 2016 to create this new anti-riot female-specific body armor as it was reported that female troops were having issues with the fit of the existing full body protector.

As of today, the new full-body protector is a brand new anti-riot vest tailored to the female body. The new female full body protector is designed to follow the shape of the female anatomy, and the different parts of the protector are of different sizes and are adjustable to fit each woman, distinct from the unwieldly full body protector of the males they had been wearing till now.

2. BACKGROUND

In the development of a sizing system, anthropometric survey is one of the first and most important component that plays a key role in the final fitment of any clothing ensemble. Yet, to date, there has never been any anthropometric body dimensions survey of Indian female paramilitary troops for the design of protective gears. Hence, there is a need to establish a standard sizing system according to the anthropometric study which will help improve the sizing chart and also resulting in a well-fitted ensemble to the user population for optimal performance in their duties.

Initially, the Indian female troops had to wear the male FBP (full body protector), which was ill-fitting and a glaring problem faced by the troops. Instead of safeguarding them and letting them give their best in such pressing conditions, the ensemble was a hindrance to their mobility and protection itself.

3. AIM OF THE STUDY

In this study, we proposed to give three different sizes of female full body protectors for the upper and lower gears separately.

4. SCOPE AND DELIVERABLES

This study size recommendation can be used by other organisations that may need both upper and lower sizes differently like Indian apparel design houses for sizing tariffs of active Indian women.

5. MATERIAL AND METHODS

5.1 Sampling Strategy

To understand human body measurements of a specific population is the role of an anthropometric survey[4-5]. The purpose of an anthropometric measurement is to ensure that the sizing method is based on body measurement like height, weight, and other body dimensions.

In the present study, a sizing system was developed using both statistical methods and data mining techniques. At the start, principal component analysis (PCA) was used to classify body dimensions to be used for the next process- i.e. data mining which is a prevalent statistical method used in many studies as a reduction procedure[6-10].

6. METHODOLOGY

Though a full body protector for the safety of troops existed before, however, it was exclusively designed and sized as per the Indian male body dimensions and used by both genders, resulting in immense discomfort and difficulty in mobility and safety of female troops. There was a necessity for female specific design in Indian context as the ensembles in use are totally male specific, with anthropometric dimensions apt for males only. Hence, they are a huge threat to the safety of the women wearing them, in action roles, with great unease, poor fit and restricted maneuverability.

Using the methodology and power equation analysis recommended by ISO 15535:2006(E)[12], the sample size was calculated using the following equation.

Sample size calculation $N = \left(\frac{1.96CV}{a}\right)^2 1.5342$

$$CV = \frac{SD*100}{x}$$

where,

a=per centage of relative error

x = mean

SD = Standard Deviation

Critical value (z scores) from a standard normal distribution for 95 per cent confidence interval

1.534 is derived from an algebraic determination of the standard error of the per centile with the z-value of 1.645 to signify the 5th to 95th per centile of the standard normal curve. The sample population required is around 348 as calculated from a previous study of Indian population[13].

To achieve this target, authors had requested before the study being conducted, permission for the study and providing the study team the required sample size.

The research team carried out an anthropometric survey of 325 female para-military troops, posted in two locations with age ranged from 21 to 54 years (mean ± SD) value: 37.14 ± 8.49 years. Participants for this study were recruited by the unit branches headquarters after ensuring that volunteers were a mix of different ethnic composition and that the population was a heterogeneous one. Most of the female troops were belonging to North India since the units were based in and around Delhi, viz. CRPF Mahila Batallion Dwarka and Karawal Nagar Wazirabad. A list of body landmarks, postures, dimensions, and definitions was obtained from international standards such as ISO 7250, ISO 8559. The body measurements were taken according the ISO 8559/1989 body measurement standard[14]. In addition, to develop a good sizing system it should be based on anthropometric data[15-17].

The requirements of an ideal sizing system are:

- It must be based upon the body measurements of the population to be fitted.
- It must provide a size group for practically every individual in the population which will specify an acceptable fit for any given kind of garment.
- It must provide a direct and simple means based on a few measurements for assigning each individual to his proper size group without trial and error fitting.

7. DATA ANALYSIS

Statistical Package for the Social Sciences (SPSS) Version 21.0 for Windows was used for data analysis. Frequency tables, per centiles, standard deviations, mean, minimum, maximum, kurtosis, skewness were performed for the anthropometric data of the paramilitary record of 325 females. All values of the standard deviation are rounded to two decimal places. There were six girth measurements and four vertical measurements. The correlation coefficient was used for determining the relationships between the body dimensions.

According to BS 7231[18], the values used in the determination of parameters specifies that if the correlation coefficient is <0.5 it means there is no correlation; if it is between 0.60 - 0.75 then there is a minor correlation, and if it is >0.76 it shows a strong correlation.

To reduce the twelve anthropometric measurements into the first two principal components, appropriate to setting up a size and shape specification for a realistic sizing system, Principal Component analysis was used. Cluster analysis, and classification tree analysis were performed for the total group and body variables were extracted using Varimax rotation. There are three conditions to be considered viz. latent root criterion, per centage of variance criterion, and scree test criterion to identify the number of components to be retained. We used the Eigenvalue >1 criterion, and for the selection of key dimensions, we chose those variables with the highest loading.

The primary anthropometric variable in establishing sizing systems in the field of garment making is the chest parameter[19], even though the waist measurement is an important variable too, in sizing garments.

After initial process of selecting key variables, to identify typical clusters within the female volunteers, we used data mining due to the nature of human body variability and the cluster technique to group analogous body contours according to key body variables. The clusters formed with this procedure must be vastly identical internally (where members are similar to one another) and highly diverse externally (where members are not like members of other clusters)[20]. This is important to have distinct groups between each other while at the same time, within their clusters, members nearly have the same body types.

Next, we used a decision tree or regression tree for the continuous data in order to validate the cluster groups[11]. Decision tree serves the double purpose of profiling the data visually and furthermore, to determine other significant variables that co-occur beside the main dimensions selected from PCA. From the tree diagram, the target variable and predicted variables can then be easily profiled[20].

7.1 Cluster Analysis

We have used the non-hierarchical K-means clustering because it is a modest clustering method and displays optimum results. However, all variables must be independent and normally distributed population is grouped according to identical group.

7.2 Classification Tree

The regression tree or classification tree was used to classify the variables, to certify the cluster sets, to profile the

Table 1. Descriptive data analysis of female paramilitary personnel anthropometry

Variables (In cm)	N	Range	Min	Max	Mean		Std. Deviation	Skewness		Kurtosis	
Chest Girth	325	44.60	72.40	117.00	90.37	0.42	7.58	0.35	0.14	0.20	0.27
Abdomen Girth	325	60.20	61.80	122.00	87.66	0.51	9.21	0.31	0.14	0.91	0.27
Thigh Girth	325	32.80	40.20	73.00	55.98	0.30	5.48	-0.18	0.14	0.01	0.27
Hip Girth	325	41.00	84.00	125.00	100.00	0.37	6.73	0.38	0.14	0.43	0.27
Calf Girth	325	18.50	26.50	45.00	36.24	0.15	2.73	-0.08	0.14	0.43	0.27
Arm Scye	325	26.00	29.00	55.00	39.03	0.23	4.20	0.16	0.14	0.13	0.27
Arm Length	325	15.30	43.40	58.70	49.98	0.13	2.38	0.14	0.14	1.15	0.27
Upper Arm Length	325	14.00	25.80	39.80	31.54	0.11	1.97	0.29	0.14	0.95	0.27
Outside Leg Length	325	36.00	78.50	114.50	94.76	0.38	6.84	1.22	0.14	1.55	0.27
Inside Leg Length	325	31.70	50.70	82.40	71.05	0.29	5.22	-0.97	0.14	1.43	0.27

data better, and moreover to validate the additional significant variables of the cluster groups. The dependent variable was the cluster group and the variables from the whole body formed the independent variables.

Clustering of Anthropometric Measurements

To identify easily natural sizing, cluster analysis is an unsupervised learning data mining technique used for the anthropometric data to distribute a set of variables into subsets or clusters based on data similarity[21-22]. In general, the optimal size interval for girth dimensions is 4 cm to 6 cm[23,10].

Data mining was used to develop the sizing system of the female full body protector by means of cluster analysis and classification tree method. This study has productively created three main sizing systems for the upper and lower protective gears of paramilitary forces. The sizing system coverage for them is found to be about 98.5 per cent for the upper frame of the body and 99 per cent for the lower frame of the female body.

This is an original complete anthropometric survey conducted to develop a sizing system in Indian Central Armed Police force (CAPF) for their Full Body Protector (FBP) design. The result is an enhanced fit of FBP and a guideline for a proper sizing system and sizing designation.

Table 2. KMO Bartlett's test

KMO & Bartlett's test		For upper full body protector	For lower full body protector
Sampling adequacy using kaiser-meyer-olkin measure		0.79	0.700
Bartlett's test of sphericity	Approximate chi-square	1705.64	822.157
	df	66	15
	Sig.	0.000	0.000

8. SALIENT FEATURES OF FEMALE FULL BODY PROTECTOR (FFBP)

The FFBP is a new lightweight protective ensemble that provides close combat protection against projectiles and other possible threats to the most vulnerable parts of the human body in riot situations. It has been ergonomically designed using Indian anthropometric data of female troops and given in three sizes namely Small, Medium and Large to provide for female troops of all ethnicities.

Full Body Protector **(**FBP) consist of different parts, as follows:

- Front shield: Designed based on the female anatomy/ contours to accommodate users without hindrance in mobility.
- Back shield: Ergonomic design with embossing and grooves to decrease the impact of a projectile.
- Shoulder pads and side shield: Designed to safeguard shoulder region of the user, with a system to integrate and disintegrate quickly with torso guard.
- Armguards (lower and upper): Designed in two segments: Upper arm guard for upper arm region and lower arm guard (with full coverage and adjustability) integrated with elbow protecting shield for both sides of the arm.
- Leg protector (upper and lower): Designed in two segments: Thigh guard associated with a belt safeguarding pelvic region and Lower Leg Guard (ample coverage using shin guard and calves guard) associated with a knee protection shield. There is an option of wearing upper, lower, and peripheral protection separately as per riot situation demand. The unique design allows adjustability of all parts as per the physique of the user, with comfort and maneuverability.

Table 3. Latent root criterion or the eigenvalue-one criterion

Total variance explained (for upper gear components)

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1	4.137	34.475	34.475	4.137	34.475	34.475	3.190	26.584	26.584
2	2.954	24.616	59.091	2.954	24.616	59.091	2.992	24.934	51.518
3	1.131	9.429	68.520	1.131	9.429	68.520	2.040	17.002	68.520

Extraction method: Principal component analysis.

Total variance explained (for lower gear components)

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.867	47.777	47.777	2.867	47.777	47.777	2.842	47.362	47.362
2	1.569	26.152	73.929	1.569	26.152	73.929	1.594	26.567	73.929

Extraction method: Principal component analysis.

9. RESULTS

Descriptive summary for the measured female troops anthropometric dimensions are presented in Table 1. For further analysis, principal component analysis was conducted for 325 females. To measure the correlation between the individual two anthropometric measurements were considered—circumferences and lengths. All parameters were correlated with each other as shown by the correlation matrix. KMO and Bartlett's measures the overall measure of sampling adequacy for the set of variables and this value was 0.799, which was highly significant at 0.001 level.

Table 2 shows the Anti-image matrix in the PCA revealing that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) for all of the variables included in the analysis >0.5, hence they are retained in the analysis. Two principal components appear with Eigenvalues >1.0 when we analysed the total variance, explaining 73.92 per cent cumulative variance of the total parameters.

The latent root criterion or the Eigen value-one criterion is shown in Table 3. In this table, principal component 1 (girth indicator) accounted for the largest proportion of variance in the data explaining 26.58 per cent alone, followed by 24.93 per cent by component 2 (body length indicator), and 17.00 per cent by component 3 (body breadth indicator). The total variance explained by the three components was 68.52 per cent. The latent root criterion indicates that there were three components to be extracted for these variables. Each detected variable adds one unit of variance to the entire variance in the data set (the 1.0 on the diagonal of the correlation matrix). Any element that shows an Eigenvalue > 1.0 accounts for a larger sum of variance than was contributed by one variable. Such an element, thus, accounts for a significant sum of variance and is taken. On the other hand, an element with an Eigenvalue <1.0 accounts for less variance than had been contributed by one variable.

In Table 3 too, the latent root criterion or the Eigen value-one criterion is shown for lower body components. Here, the principal component 1 (girths indicator) accounted for the largest proportion of variance in the data explaining 47.78 per cent alone, followed by 26.15 per cent by component 2 (body length indicator). The total variance explained by the three components was 73.93 per cent. The latent root criterion for numerous factors to develop would show that there were two components to be mined for these variables. When the extraction of factors has been finished adequately, the resultant factor matrix, which displays the association of the original variables to the factors, is rotated to make it easier to interpret.

9.1 The Scree Test

Eigen values associated with each element are plotted against their ordinal numbers (i.e. first Eigenvalue, second Eigenvalue, etc). The level of succeeding Eigenvalues expresses a sharp descent and then inclines to level off and usually the commendation is to keep all the Eigenvalues (and corresponding components) before the first one on the line where they start to level off. The Scree test is precise in identifying the correct number of factors with a sample size greater than 250 and communalities greater than 0.60. In Fig. 1, we saw that the third component is the area where it starts to level off.

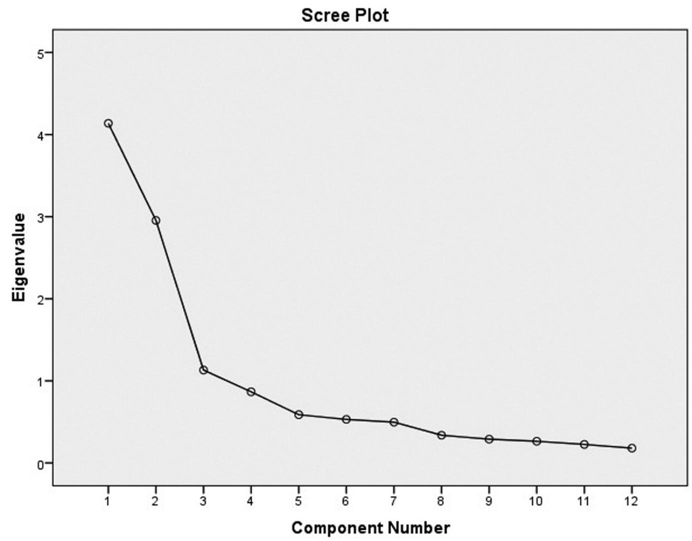

Figure 1. Scree plot for the upper gear size component.

Table 4. Shows the final cluster of anthropometric parameters

Upper Gear Components (In cm)	Cluster		
	1	2	3
Chest Girth	101.15	82.22	91.06
Arm Scye	42.46	35.39	39.96
Arm Length	49.16	50.23	50.16
Lower Gear Components	**Cluster**		
	1	**2**	**3**
Abdomen	78.57	89.29	96.95
Hip Girth	93.78	101.00	106.52
Inside Leg Length	71.76	73.31	66.77
Outside Leg Length	93.52	98.54	90.73

Figure 2 showed the regression tree that can profile the body types correctly and effortlessly, where the dependent variable is the chest girth in cm and the independent variables are the arm length and Scye. From the tree, we can see that the small chest small size category 1 denotes ≤89 cm, the middle size category is 90-96 cm, and the large size category ≥97 cm is category 3. From the tree, we can see six nodes and five terminal nodes. For the armscye≤36.7 cm, the highest number (82.3 %) was the small chest size category. This was followed by the medium chest size category that showed a per centage of 13.5 per cent, while the large size chest category had a per centage of only 4.2 per cent for this armscye range.

The armscye of >39 cm showed had a maximum number (46.8 %) of total three chest size categories, where medium size chest category had the maximum per centage with 40.1 per cent followed closely by the large size chest category with 36.2 per cent in this armscye node.

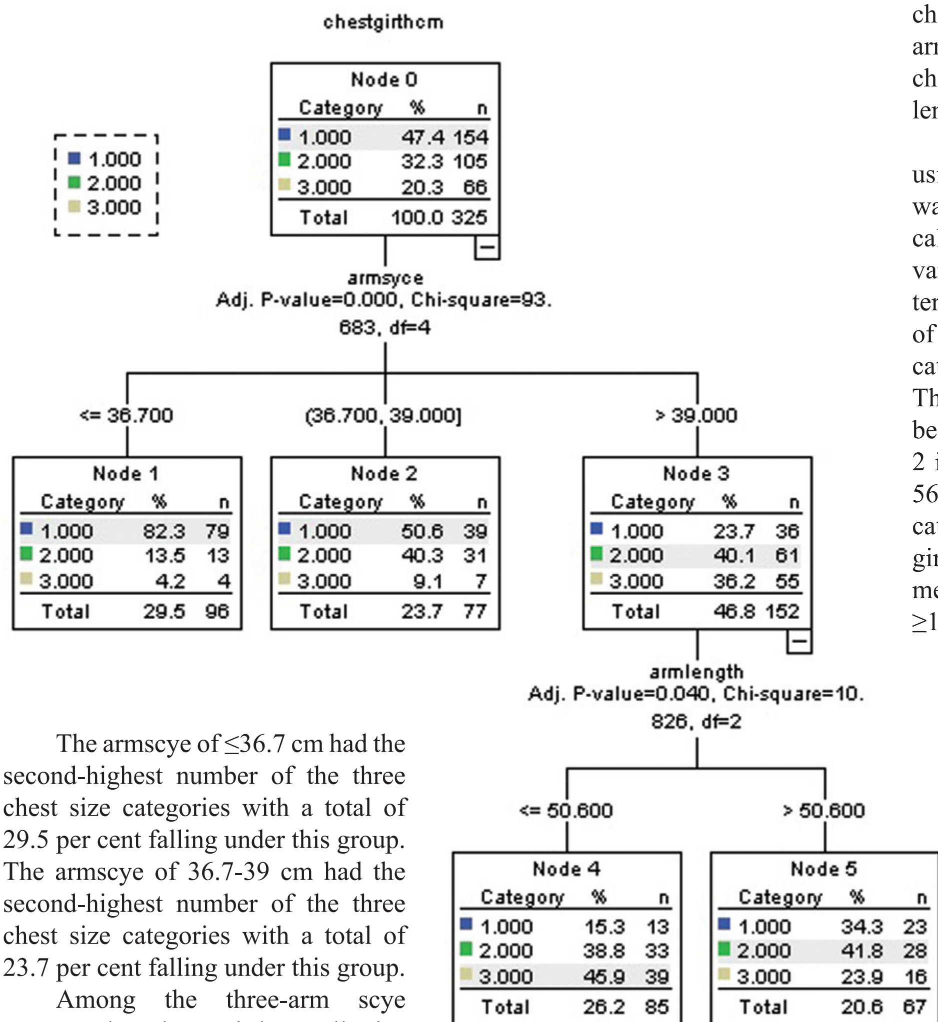

Figure 2. Regression tree for the upper gear sizes using CHAID method.

The armscye of ≤36.7 cm had the second-highest number of the three chest size categories with a total of 29.5 per cent falling under this group. The armscye of 36.7-39 cm had the second-highest number of the three chest size categories with a total of 23.7 per cent falling under this group.

Among the three-arm scye groups, the chest girth small size category had the highest per centage of 82.3 per cent in the first node, followed by the chest size small group with 50.6 per cent in the second node and the medium chest size category with 40.1 per cent in the third node. For the third arm scye node, there were two categories of arm length. 45.9 per cent of the large chest size category falls under the ≤ 50.6 cm arm length, while 4.8 per cent of the medium chest size group fell under the ≥50.6 cm arm length group.

Figure 4 shows the regression tree model using the CHAID method where the abdomen waist girth is the dependent variable and the calf girth and hip girth are the independent variables. There were five nodes and four terminal nodes, where the highest per centage of 84.6 per cent of the small waist girth category 1 were in the ≤94.8 cm hip girth node. There was a good per centage of 71.3 per cent belonging to the medium waist girth category 2 in the 94.8-99.66 cm hip girth node. About 56.7 per cent of the medium waist size waist categories were under the 94.8-99.6 cm hip girth node group and 53.2 per cent of the same medium size waist category were found in the ≥105 cm hip girth node group.

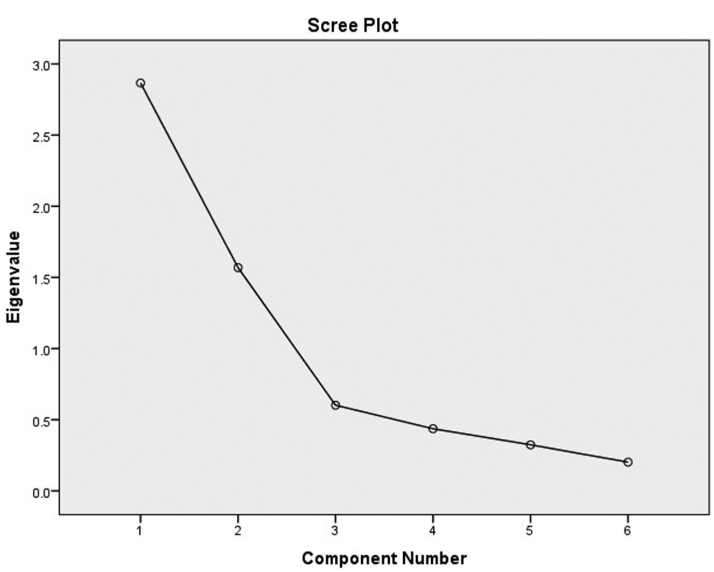

Figure 3. Scree plot for the lower gear size component.

10. DISCUSSION

In absence of gender-specific protective gears, the challenging duties of female troops proved to be more and more daunting when dealing with armed mobs. Surprisingly, until now, such women-specific protective gears were conspicuous by their unavailability in the market.

The urgent need for this kind of study can be evaluated from a similar study report undertaken in the U.S. Army Natick Soldier Research, Development and Engineering Centre where they reported that about 85 per cent of female troops were wearing a vest one size too large and about 52 per cent were wearing a vest about two sizes too large[24].

The project commenced with anthropometric data collection of female RAF troops of different ethnicities. The problems in existing FBP (i.e., male-specific ones) were identified and listed, along with feedback from its female users. With statistical tools & the application of an anthropometric database, a design was developed after immense research. Thereafter, a 3D Model of female full body protector (FFBP) was created over an average female virtual manikin whose dimensions were arrived upon after statistical implications of the database generated from RAF female troops.

With the aim to provide a well-suited FBP to the female troops, a study was undertaken for an anthropometric survey of female Indian troops working for riot control. Consequently, the data collected was analysed and with the aid of different designing tools and came up with an ergonomically designed Female Full Body Protector (FFBP), tested and approved in various security specifications norms, and undergone successful user trials. The Female Full Body Protector was developed with an ergonomic design principle based on anthropometric dimensions collected from volunteers employed in action roles.

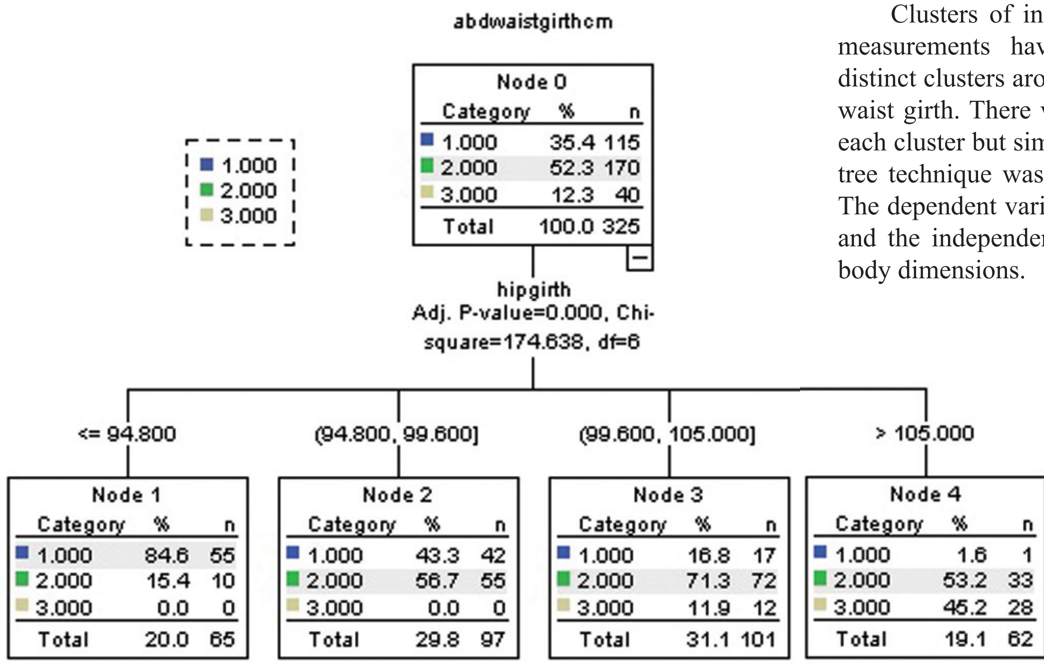

Figure 4. Regression tree for the lower gear sizes using CHAID method.

Table 5. Final size distribution for both upper and lower gear size

Upper gear parameters (In cm)	Small		Medium	Large	
	S1	S2	M1	L1	L2
Chest Girth	76-82	83-89	90-96	97-103	104-110
Arm Scye	33-36	37-40	41-44	45-48	49-52
Arm Length	44-48	44-48	49-53	54-58	54-58
Lower gear parameters					
Abdomen Waist Girth	64-74	75-85	86-96	97-107	108-118
Hip Girth	84-90	91-97	98-104	105-111	112-118
Inside Leg Length	50-55	56-61	62-67	68-73	74-79
Outside Leg Length	78-84	85-91	92-98	99-105	106-112

This protector delivered features to its users like better fit and protection, with an easy to wear mechanism accommodated in a user friendly-design with negligible hindrance to her maneuverability.

325 female paramilitary forces with 28 anthropometric variables show two factors: girth (Principal Component (PC1)) and length (Principal Component (PC2)) factors, using principal component analysis. The girth (PC1) was highly related with quite a few upper or whole body dimensions. Those variables that have high loadings in girth PC are chest girth, abdomen waist girth, thigh girth, calf girth, hip girth and arm scye girth. As for length, PC2, the body dimensions that have high loadings are upper arm length, arm length, inside leg length and outside leg length.

Clusters of individuals that have similar body measurements have also been identified. Three distinct clusters arose using chest girth and abdomen waist girth. There were distinct differences between each cluster but similar within each cluster. Decision tree technique was also used to verify the clusters. The dependent variable comprise of the luster group and the independent group comprises of the upper body dimensions.

In one study among male personnel, which focused on the effect of body armor fit, to see the overall protection coverage versus exposure area, it was reported that at exposed areas like the neck and underarms, there were better covered if the wearer was given one size smaller body armor system[25]. Such similar studies on female troops have not been undertaken yet. Hence the importance of gender-specific study for Indian female body protector is required.

The design was proposed in 3 sizes to provide coverage to the 5th to 95th per centile of the user population. Three design registrations and three patents were filed and lined for a grant by IP India. Thereafter, a prototype was developed for testing & user trials purposes. The FFBP with its unique properties (anti- stab, anti-puncture, flame retardant, and acid resistant) is developed, trial evaluated, tested & verified by the Rapid Action Force formations.

11. CONCLUSIONS

- This is the first comprehensive anthropometric survey conducted to develop a sizing system in Indian paramilitary personnel for their full body protector design. The outcome is an enhanced fit of Full Body Protector (FBP) and a guideline for a proper sizing system and sizing designation.
- The study have identified in female personnel, a principal component closely estimates the significant girth body dimensions and the body length dimensions that can be used towards the development of sizing system for upper and lower body.
- Design of a well-fitting functional protective gear is crucial to ensure the safety of personnel who works in daring and potentially hazardous environments. The current study contributes towards the development of a new female specific sizing system for protective gear design and sizing industry which is lacking in India.
- For the upper protective gear, the chest circumference small size (S) is <89 cm, size medium (M) is 90– 96 cm and size large (L) is above 97 cm with corresponding abdomen or waist girth value of small size (S) <85 cm, size medium (M) 86-96 cm and size large (L) above 97 cm respectively for the lower protective gear sizes.

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