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Size India Defence Personnel and Development of Sizing Software

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Abstract: The Indian Army Combat uniform, then, was being procured from Ordnance Factory Boards in four/five sizes from small to extra large wherein the shirt and trouser were given as separate unit. This created mismatch to the final users in terms of size and colour. To address this problem, the main requirement of this sizing survey was to provide them the combat uniform in a set with shirt and trouser as one unit. DIPAS acquired a state of art facility, 3D Human Body Scanner to carry out 3D anthropometric survey in different phases in different units to study the size rolls of troops of the Indian army by using 3d human body scanner with primary objective of improvement of army combat uniform.

Methods: SYMCAD human whole body scanner was utilized to garner the anthropometric scans of 7956 Indian male personnel's as the anthropometric dimensions of other countries populace cannot be transferred to Indian population for the design and sizing of an any personal protective gear or combat uniform because the population is made up of diffeent ethnic composition.

Result: For Indian army combat uniform, thirteen (13) sizes were recommended and implemented by the Indian army. For developing the desired combinations chest girth and navel waist girth were taken up as critical variables. Data analysis was performed by a statistical package, SPSS (20.0v). Bi-variate analysis was done by taking up the critical variables and frequency tables were obtained in the form of cross tabs. It helped in making size classes based on the two critical parameters i.e. chest girth and navel waist girth.

The present paper also shows the development of a new sizing software (Defence Size India or DSI), which was based on 7,956 Indian soldiers' anthropometric data. DSI is designed to maintain the combat uniform details of all the army units at central place. This will reduce human error in making reports and generating demands for uniform. DSI will save many man hours and reports can be generated in a few seconds. Using this DSI, by entering only two major parameters i.e., chest girth and navel girth, all the other seven parameters are calculated and stored in the database automatically, thus efficiently reducing and saving time.

Keywords: *combat, uniform, sizing, defence, software.*

INTRODUCTION:

SIZE INDIA DEFENCE

It was highlighted that the Army Combat uniform, then, was being procured from Ordnance Factory Boards (OFB) in four/five sizes from small to extra large wherein the shirt and trouser were given as separate unit. This created mismatch to the final users in terms of size and colour. To address this problem, the main requirement of this sizing survey was to provide them the combat uniform in a set with shirt and trouser as one unit.

DIPAS acquired a state of art facility, 3D Human Body Scanner to carry out 3D anthropometric survey in different phases in different units and all logistics like ethnic wise unit identification and allocation, period of survey, area at station,

manpower, and transportation of 3D scanner were undertaken with the help of MGO, Sena Bhawan. Thus, "Survey of Size Rolls of troops of the Indian army by using 3D human body scanner" is the user requirement project of DIPAS in partnership with Master General of Ordnance, Dir, EM (GS&C), Sena Bhawan, with the primary objective of 'Improvement of Army Combat Uniform.'

The basic concept

The distinctive feature that separates a civilian from a non-civilian is his/her uniform. A well- fitting garment or uniform that is comfortable to wear, well fitted and provided with enough room for easy movement, without unnecessary wrinkles and bunching of the fabric or too loose in fit, aesthetically acceptable. Stamper et al., (1991). A garment of the correct size, in combination with the correct body measurements, ought to result in a notable fit.

Fitting is adjusting design to human figure. This depends on several body measurements like waist, hips, length of shoulder and sizes of other parts of the body, depending on the design requirements. These are generally summed up as garment size. Clothing that fit too tightly and cling to the skin reduce the effective movement of air surrounding the body. Each individual differs as to what they describe as a good fit and how they like their clothing to fit their bodies, so fit is subjective.

Generally, the most notable differences in body size and shape are related to nutritional aspects, ethnic diversity, age and gender. Secular trend and age wise differences needs for regular monitoring of human measurement especially for the achievement and provision of adequate clothing.

Variation in the Indian population

India is a vast country and has a vast range of geographical regions including plains, hills, mountains, plateaus and deserts. This geographical diversity endows India with a variety of climates which account for different cultures and lifestyle. There is a distinct signature of ethnicity, geographical conditions, culture and language in peoples from North to South and East to West of India. Ethnic group variations are much more complex in India than in any other country of the world. India is a melting pot of ethnicities. Thus, a comprehensive study of ethical diverse Indian populations is a great challenge for any anthropologist. A knowledge of human body dimensions or anthropometric data provide us important quantitative information to distinguish individuals and populations, and their varying needs at work or rest. Changes in body dimensions reflect the overall health and welfare of individuals and populations. Anthropometry is used to assess and predict performance, health and survival of individuals and reflect the economic and social well-being of populations.

Anthropometry

Anthropometry is the foundation of human factors engineering and ergonomic designing because it provides necessary inputs regarding reaches, clearances and other constraints that users may face during work. It is used extensively in product design, particularly when usability and safety requires a close fit between people and their environment, e.g. detailed anthropometric studies should be carried out during automobile design to make sure that people with a range of stature can have an adequate field of view, reach the pedals and hand controls, fit comfortably in the seats and not be exposed to avoidable safety risk in collisions. Anthropometric measurements are also useful in the assessment of body composition providing knowledge of total body water, bone mineral content etc. Anthropometric methods are non-invasive, economic and practical and hence very successful in conducting large scale population surveys and for assessing health status and growth pattern of a population.

Nowadays, many countries have undertaken innumerable anthropometric surveys to develop their own sizing systems. As it has been acknowledged that the extent to which one sizing system may be applied to different populations is limited due to the variation of body shapes and sizes. So, various countries have developed their own sizing systems in order to reduce problems associated with clothing sizes and fit.

International Scenario

The last decade of the twentieth century has seen considerable developments in the science of anthropometry. The technology of three dimensional (3D) bodies scanning has been used most extensively by the military to rapidly and accurately scan, extract measurements and automatically select sizes for issuing garme US army nts to military recruits. Plans are for the scanning process to be integrated into recruit issue line so that it will take less than a minute to scan and size each recruit (Su-Jeong Hwang 2001). In a span of about 40 years (1945-1988), the US Army undertook over 40 anthropometric surveys of its military personnel and the well known ANSUR data of its troops containing 240 measurements was taken. (Claire C. Gordon, *et al.* 1986). Pioneering work on human body scan was the joint U.S., Italian, and Dutch CAESAR (Civilian American and European Surface Anthropometry Resource) Project in 2000, which gathered digital data on nearly 8000 subjects from these three countries to generate a database of human physical dimensions. The project collected data on 24,000 US and Canadian and 2,000 European civilians and a database was developed (SAE International, 2005). It was the first international survey of its kind to utilize body scanning technology.

UK conducted the largest sizing survey using 3D laser scanners, where 11,000 men and women from various parts of Britain were measured (Size UK Since then, there have been

several national surveys which have followed in the UK's pioneering steps, notably these build Size USA (TC^2).

An anthropometric study of US army personnel was conducted by Gordon et al. (1986) in which 1,774 men and 2,208 women were measured for the design and sizing of clothing and equipment. Anthropometric study on 841 Sudan army officers was also collected by Elawad et al 2015 to devise new sizing system for Sudan army.

The objective of garment sizing is to fit the maximum number of people with the minimum number of sizes by dividing standardized dimensions for the body and garments into different categories. In any sizing system, the main purpose of setting up size classes is to group together individuals with common body measurements. It should be remembered, however, that a sizing system refers to people, not to garments and is intended to identify the size of an individual so that garments can be selected which will fit the wearer. The control of the variability of measurements within each size group can be accomplished either directly or indirectly; body measurement charts indicate sample coverage of body measurements for the designated population.

3D Body Scanner: A new tool in anthropometry

In our study we have used Telmat's 3D System for Measuring and Creating Anthropometric Database (SYMCAD) which utilizes structured light. To capture the 3D data, an individual standing inside the booth is projected with a set of white light stripes. To avoid errors due to natural body movement or sway and prevent reflectance due to different colours of the underwear, the scanner has a new special tracking (ST) version that applies 3D digitizing to the captured data. (Telmat Industries, 2009).

The SYMCAD system is controlled using PC Pentium with latest windows version like windows 8.1 or 10. Data file format is done with a proprietary format and IV, DXF, VRML and the output type is s 3D XYZ data cloud. The system is integrated with size charts and the garment sizes data can be imported from Microsoft excel files. The SYMCAD software is customized with the customers' data and it is available in various languages.

METHODOLOGY

The purpose of this paper is to present a detailed anthropometric body measurements of the Indian male population using 3D Whole body scanner. A total of 7,956 volunteers aged between 18 and 50 years were scanned/measured using the SYMCAD Scanner developed by TELMAT Industrie. (System for Measuring and Creating Anthropometric Database,). Telmat's turbo flash/3D scanning system uses projected structured light and consists of a small enclosed cabin with illuminated walls, four cameras and a workstation with computer. The participant enters the booth, removes their clothing and stands in their undergarments in front of the illuminated wall. A set of white light stripes is projected onto the participant for data capture. Three different poses of the participant are photographed: facing the camera with arms slightly apart from the body, from the side straight on, and facing the wall. The 3D scanner has a computer with software attached to it that allows the 3D images and measurement data extracted to be visualized and manipulated. Within 8-10 seconds, around 140 measurements can be taken and stored in the computer. The body measurements were taken in conformity with the ISO 8559 (1989) to ensure reliability and validity of the results. Although the scan is not intrusive and scans a person in his undergarments inside a covered booth, ethical issues were considered due to the nature of the survey. Information and consent forms highlighting privacy of the volunteer, the right of the volunteer to withdraw from the survey and health and safety issues were discussed with volunteers prior to the survey. Volunteers were reassured of confidentiality and anonymity and changing cabins were provided to address the privacy issue.

Data analysis

The 3D anthropometric data obtained from the whole body scanner served as the basis of information for the analysis. The Statistical Package for the Social Sciences (SPSS) Version 20.0 for windows was employed for data analysis using PCA.

Sampling Strategy

In the initial design and development stage, for the collection of anthropometric data, the number of volunteers needed for a study is normally calculated based on a number of factors. These are: the variability of the dimensions being surveyed; and the level of accuracy and precision required for the final data. Guidance on making the calculations is provided in the ISO "General requirements for establishing anthropometric databases", which is described as follows:

Statistical analysis

Statistical Package for the Social Sciences (SPSS) Version 21.0 for Windows was used for data analysis. Descriptive statistics including mean, standard deviation, minimum, maximum and percentile values were calculated and used for analysis and determining correlations. Values calculated in centimetres were used in the determination of parameters according to BS 7231 (BSI, 1990).

BS 7231 states that there is no relationship if the correlation coefficient is less than 0.5; there is a mild relationship if correlation co-efficient is between 0.60 – 0.75 and a strong or high relationship if correlation co-efficient is more than 0.76.

Sizing Software Development process:

Information and database system projects are initiated to improve the accuracy of the processing data and ensure the procedure prescribing how to do a specific task. To reduce manual error and enable more study at a lower cost and lesser effort, a computer program can undertake automatic calculations, automatic data insertion and faster retrieval of

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data while at the same time managing the data accuracy and a consistent database, thereby improving performance (Pavitra, 2010).

Defense Size India (DSI) is the software, based on 7,956 Indian soldiers' anthropometric data. DSI is designed to maintain the combat uniform details of all the army units at central place. This will reduce the human error in making reports and generating the demands for the uniforms. This will save many human hours and do generate report in few seconds. We have developed for the versions of the software one will work as stand-alone application for the units where no network connectivity and second version is web application for intranet.

Using DSI by entering only two major parameters i.e., chest girth and navel girth all other seven parameters are calculated and stored in database automatically. By this, many hours job is reduced to few minutes work.

This study or software is developed using Java Server Pages (JSP), TOMCAT, JAVA, JAVA SCRIPT,HTML and SQL Server. In the present study, we have selected the JSP (Java Server Pages) for its ease in portability, efficiency, robustness, dependency of layers and easy integration with other sources like Java Database Connectivity (JDBC).

DSI has four major modules

1. Main Home Page
2. Unit Module
3. Combat Uniform Module
4. Report Module

Main Home Page

This will be the very first page that appears when software run. This page is having many information including about the portal, user guide, contact details, and menu bars. There are three main menu bars for other three modules of the software.

Unit Module

This is the very first section/module that should be completed before using the other modules. Under this module Admin of the unit has to add all unit personnel details into the database. Admin can also delete the already filled unit information from the database if it requires. There are two sub menus (Add Unit and Delete Unit) with respect to add unit details and delete unit details as per requirement under this main Unit Module as shown in Figure 1.

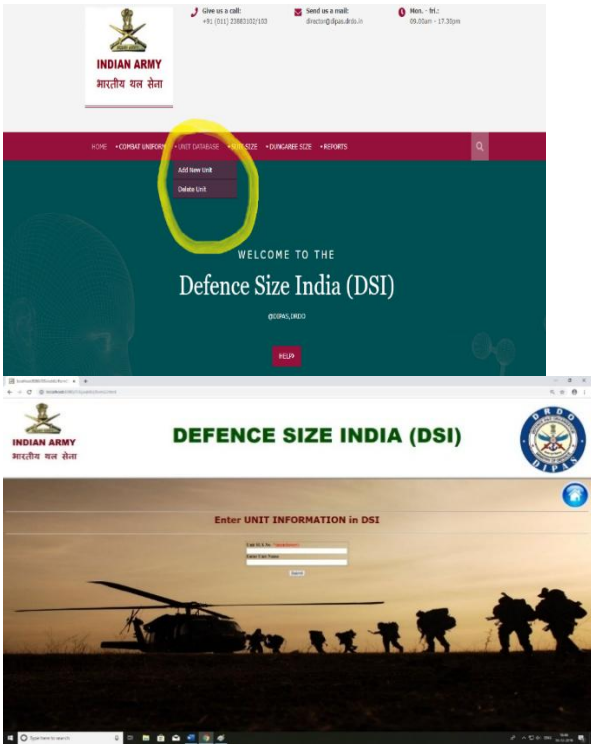

Figure 1:Unit Module Screenshots

Combat Uniform Module

This is the module where all the uniform details are to filled. By using this module unit admin can add and delete the combat uniform details of the unit personnel's of that particular unit. This module is having two sub menus as shown in Figure 2.

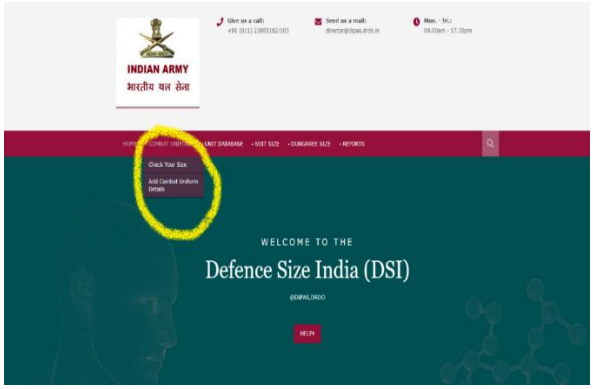

Figure-2: Combat Uniform

1. Check your size

This will help the user in finding his set size for the combat uniform. User has to enter some basic details as Name, Company, Chest Girth, Navel waist Girth in the form. After filling all the details click on check my size button, this will show the respective user set size with other additional details.

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2. COMBAT UNIFORM DETAILS

Under this Module Unit Admin can **add, delete and update** the unit personnel combat uniform details of the unit. Mandatory fields are indicated with red color*, so that these fields can't be left blank. Chest Girth and Navel waist Girth are the main parameters admin need to enter/fill rest all other parameters are calculate and added to the database automatically. Fig 3 shows the "Add Combat Uniform" form.

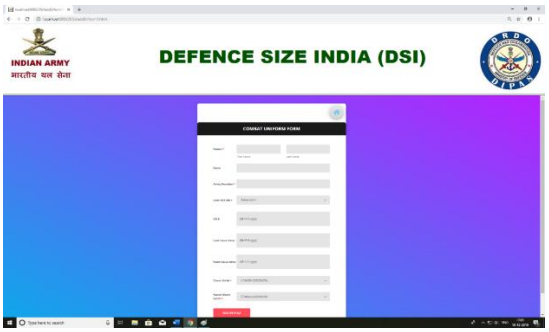

Figure-3: Add Combat Uniform form

Report Module

Report module is designed to generate the three types of report that are required by the Units. Some time there is requirement to get the details how many combats uniform is required for a particular size in a particular time for a particular unit. These all queries will be solved by this module this will help in generating the reports base on Unit, Set Size and Month and year wise as per the requirement. The one important facility this software provides is that these reports can be saved in excel forms for future use by the units. Fig 4 and Fig 5 shows report module screen shots.

Figure-4: Unit wise Report
Figure-5: Unit wise Report

Principle of white-light-scanner

3D scanner is an advanced technology for anthropometry as compared to the traditional manual measurement of anthropometric data when measuring a large number of locations on the human body. Optical triangulation is the principle of 3D body scanning systems used in the present study, by non-contact methods using light projection systems. The body scanner scans the surface of the volunteer, projecting light, and using four cameras to capture the shape of the volunteer. Anthropometric data from the scan is extracted by the inbuilt software program. Light patterns are projected onto the human body form, and cameras measure the distortions caused by the surface details of the human body.

Result, Discussion and study limitations:

A total of 7956 soldiers (males, age group 18-55) were scanned with the help of 3-D scanners. Secular trends, unsatisfactory uniform fitting and colour mismatch made it necessary to revise the sizing for combat uniform. It should be emphasized, that a size system refers to people, not to garments and is intended to identify the size of an individual so that garments can be selected which fit him/her.

Anthropometric measurements were recorded as the first step for the sizing process. Data cleaning and removal of outlier values for all the parameters was done. In sizing system it is the first job to categorize the persons with almost same values

for all the variables. In order to build such categories we developed size classes. Thus the main purpose of setting up size classes is to group together individuals whose body measurements are nearly alike and can have same garment sizing. This helps to cover the population with the smallest possible number of sizes to the largest ones with selected range of tolerances. The critical variables (variables crucial for sizing of the garment) were selected by observing the correlation values among various variables using ISI standards and taking consensus from various tailors.

Sizing for Shirt and Trousers as set

As per directives of MGO, new size rolls for combat uniform comprising of shirt & trouser as a set were proposed.

For developing the desired combinations chest girth and navel waist girth were taken up as critical variables. Data analysis was done by using statistical package SPSS (20.0 v). Bivariate analysis was done by taking up the critical variables and frequency tables were obtained in the form of cross tabs. It helped in making size classes based on the two critical parameters i.e. chest girth and navel waist girth. (Table-1)

In the table-1, size classes for the chest girth and the navel waist girth were obtained by keeping the interval difference of 10. For chest girth 75 to 84.99cm became the first and 115 to 124.99cm the last range of data. Similarly for navel waist girth, the observed range was 65 to 124.99cm. 65 to 74.99 cm interval became the smallest and 115 to 124.99 cm for the largest size group. 5 interval classes for chest girth and 6 interval classes for navel waist girth were thus obtained. The values shown as highlighted boxes in count represent the set of chest girth v/s navel waist girth with maximum frequency of population falling under that category. Frequency is observed in terms of percentage to get a better picture of population falling under the same category. From the table-1 it can be seen that first interval i.e. 75 to 84.99 cm of chest girth v/s navel waist girths did not show any significant number of persons falling in the category. Thus first interval can be eliminated from the process to make the sizes. The sizes were obtained and named as for eg 1A. Number 1, 2, 3 and 4 represents the interval classes of chest girth and alphabet A, B, C, D and E represents the intervals of navel waist girth. Thus 12 sizes are made 1A, 1B, 2A, 2B, 2C, 2D, 3B, 3C, 3D, 3E, 4D and 4E.

Though it is not possible to provide well fitted uniforms to entire service men, but with these 12 sizes we assume statistically to cover 97.7% of the army population. Based on these results sizing for the pair of shirt and trouser is obtained (Table-2).

The mean and SD were calculated for each variable for all the sizes. 4 sizes were obtained based on chest girths (1st - 1A, 1B; 2nd - 2A, 2B, 2C and 2D; 3rd -3B, 3C, 3D and 3E; 4th – 4D and 4E) which were set in parallel to the navel waist girth. Thus size 1A represents sizing for both shirt and for the trouser. For 1A size the shirt will be of chest girth ranging from 85-94.99 with inter-acromion of 43.00 cm, Arm length of 55.80 Neck girth of 37.00 cm. Similarly Size 1A for trouser will be of navel waist girth ranging in 65-74.99 with outside leg length 103.50 cm, body rise (one side) 31.00cm . Tolerance was applied to each control dimension, thereby covering a large proportion of the population in each size group.

For the finished garment, the navel waist girth and chest girth may be kept at the upper value, i.e. 65-74.99cm as 75.00cm, 75.00- 84.99 as 85.00cm and so on. People with smaller navel waist girth may require some tightening device on either side like buckles, belts, Velcro etc. Loose allowance to the tune of 10cm over anthropometric chest girth can be provided to shirt for undergarment. The loose allowance may vary depending on the number of layers and the thickness of the clothing. Since the side seam length, back and front rise and seat girth have been specified for the lower garment, hence, the inside leg length need not be calculated. This dimension or parameter can be worked out by the tailor in stitching the garment.

Thus for Indian army 12 sizes are thus proposed based on two critical measurements and after human trial one more size (1C) was also included and these 13 sizes were implemented by Indian army.

Note: Common fitting adjustments like length of trousers and width of thigh area, adding and subtracting shirt’s upper arm width can be done based upon tailor expertise.

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Table 1: Bivariate frequency distribution of army personnel with respect to chest girth & navel waist girth

				NAVEL WAIST GIRTH					
				A	B	C	D	E	F
				65 -74.99	75 - 84.99	85 - 94.99	95 - 104.99	105 - 114.99	115 - 124.99
CHEST GIRTH	1	75 - 84.99	Count	1	7	0	0	0	0
			%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%
	2	85 - 94.99	Count	218(1A)	282(1B)	68 (1C)	5	1	0
			%	2.70%	3.50%	0.90%	0.10%	0.00%	0.00%
	3	95 - 104.99	Count	290(2A)	1683(2B)	1645(2C)	189(2D)	6	0
			%	3.60%	21.20%	20.70%	2.40%	0.10%	0.00%
	4	105 - 114.99	Count	18	298(3B)	1647(3C)	1100(3D)	86(3E)	2
			%	0.20%	3.70%	20.70%	13.80%	1.10%	0.00%
	5	115 -124.99	Count	0	4	65	244(4D)	92(4E)	5
			%	0.00%	0.10%	0.80%	3.10%	1.20%	0.10%

Table 2: 13 Sizes for trouser and shirt as a set

		SHIRT MEASUREMENTS				TROUSER MEASUREMENTS		
S.No.	SIZE*	CHEST GIRTH	NECK GIRTH	INTER ACROMION LENGTH	ARM LENGTH ACR TO WRIST	NAVEL WAIST GIRTH	OUTSIDE LEG LENGTH	BODY RISE
1	1A	85-94.99	37.00	43.00	55.80	65-74.99	103.50	31.00
2	1B	85-94.99	37.00	43.00	55.80	75-84.99	109.30	32.10
3	1C	85-94.99	37.00	43.00	55.80	85-94.99	113.00	33.70
4	2A	95-104.99	40.60	46.30	58.20	65-74.99	103.50	31.00
5	2B	95-104.99	40.60	46.30	58.20	75-84.99	109.30	32.10
6	2C	95-104.99	40.60	46.30	58.20	85-94.99	113.00	33.70
7	2D	95-104.99	40.60	46.30	58.20	95-104.99	117.10	34.10
8	3B	105-114.99	44.30	48.30	60.60	75-84.99	109.30	32.10
9	3C	105-114.99	44.30	48.30	60.60	85-94.99	113.00	33.70
10	3D	105-114.99	44.30	48.30	60.60	95-104.99	117.10	34.10
11	3E	105-114.99	1044.30	48.30	60.60	105-114.99	119.17	34.70
12	4D	115-124.99	46.50	50.40	64.30	95-104.99	117.10	34.10
13	4E	115-124.99	46.50	50.40	64.30	105-114.99	119.17	34.70

Note: *Numerals in size column of table 1&2 indicate Chest Girth and alphabet indicate Navel waist girth.

CONCLUSION AND RECOMMENDATIONS

This is the first anthropometric data base using 3D whole scanner for Indian army with detailed anthropometric measurements on human body. A total of 7,956 Indian Army personnel anthropometric data was collected from various ethnic groups of different units situated all over the country. The main objective of the project was to give the sizes of combat uniform as a combined set of shirt and trousers. Based on correlation among the anthropometric variables, literature review and consensus of the tailors, two critical parameters were obtained. For shirt: chest girth and arm length. For trouser: Navel waist girth and navel height. For set of trouser and shirt: chest girth and navel waist girth. After further statistical analysis, four sizes for shirt and five sizes of trousers were considered. Finally, 13 sizes as a set of combat uniform sizes was recommended using various permutations and combinations and all 13 sizes were implemented by Indian army after human trials. This has been accepted by MGO for implementation w.e.f 2019-20. This innovation opens a new arena for wide explorations in the field of Male specific gears and ensembles as per Indian anthropometry.

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