An Analysis of Body Armor Sizing and the Development of an Existing Sizing System for the Indonesian National Army

Hari Purnomo, Fikrihadi Kurnia

Abstract— **A country's national army is a state instrument that provides protection against threats from foreign armed forces. For this reason, army personnel must be equipped with body armor that serves as an effective safeguard as they face such dangers. Facilitating the determination of appropriate user sizes necessitates size classification, which is aimed at ascertaining the standard size of a product on the basis of diversity in users' body dimensions. These steps constitute a sizing system. In this research, the anthropometric measurements of 150 personnel of the Indonesian National Army are taken. A total of 15 anthropometric variables were measured: height, weight, waist circumference, stomach circumference, chest circumference, front torso length, rear torso length, width between arms, front waist to rear waist span, upper arm circumference, upper arm length, hip height, hip circumference, thigh height and thigh circumference. These data were examined using factor and correlation analyses. The final validation yielded 19 sizes: S (XS, S, M, L), N (XS, S, M, L, XL), T (VS, S, M, L, XL) and VT (XS, S, M, L, XL).**

Index Terms— **Sizing system, Body armor, Anthropometry, Indonesian National Army**

I. Introduction

THE national army of a country is a state instrument that serves as protection against threats from foreign armed forces. A responsibility that highlights the need to equip army with body armor that can help them deal with the dangers. Body armor refers to clothing that provides protection, especially for the torso area, from firearms or sharp weapons that can penetrate the front, back and sides of the body [1]. Such clothing is designed to maximize security while minimizing risk [2, 3]. Other considerations in body armor design are comfort and fit, which also influence the effectiveness with which army personnel perform their duties. Fit pertains to suitability and flexibility in relation to a user's body dimensions, which are used as a basis for deriving correct sizing. Sizing accuracy, in turn, can increase comfort, as this ensures sufficient space for the body to move and breathe [1].

Product design is strongly influenced by compatibility between a product and a user's body dimensions [4–6]; this principle also applies to body armor design, which must be adapted to the bodily proportions of military service men and women. Achieving congruence between body armor and user dimensions necessitates anthropometric data, which are fundamental contributing factors for the development of products and systems [7–9]. Updates to anthropometric data are also needed because the dimensions of the human body increase over time [8]. Studies related to design have shown that anthropometric data are widely used in the creation of clothes, furniture, electronics, medical equipment and security devices [3, 6, 8, 10–12].

Facilitating the determination of appropriate sizing requires size classification, which is intended to define the standard size of a product on the basis of diversity in the body dimensions of users. Such classification begins with identifying key dimensions. The examination of key dimensions involves a statistical analysis of anthropometric data aimed at pinpointing a certain level of significance (dimensions) that can be referred to in dividing population samples into clusters characterized by similar body dimensions [13–15]. The commonly used key dimensions are height, chest girth, bust girth, waist girth and hip girth [16]. After these proportions are obtained, the appropriate sizes of a population sample are then analyzed [13, 16]. Size is said to be appropriate if it has been subjected to data validation [13]. All the aforementioned procedures generally constitute a sizing system.

Some studies on sizing systems for body armor have focused on sizing systems for the US military [12], anthropometry for sizing systems of protective equipment used by military personnel [7] and the customization of lightweight bulletproof vests for females [17]. The difference between research findings and actual designs lies in the incorporation of measured dimensions. The body dimension measurements conducted in previous studies were based on the 2017 standards of the Centre for Applied Science and Technology (CAST) [1], whose recommendations are determined by waist circumference, stomach circumference, chest circumference, front torso height and the height of the rear torso between chest widths. To this list, the current work adds several other anthropometric dimensions that are useful in determining sizes for additional vest components, such as arm protectors, cummerbunds, thigh protectors and groin locks. Some of

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these additional dimensions are upper arm length and circumference, hip circumference, waist height and thigh length and circumference. These variables are measured on the basis of variations in the sizes of bulletproof vests. Another important element is body armor size, which remains a single general measurement rather than categorized into very short, short, normal, tall and very tall proportions. The use of standard-size body armor has been met with complaints regarding discomfort and pain in the shoulder, hotness when used and looseness of certain parts, especially those anchored to the waist.

With consideration for the above-mentioned problems, this study was conducted to determine body armor sizes in accordance with user clusters and anthropometric data. It expanded an existing sizing system, which is expected to serve as input in the design of body armor dimensions for Indonesian army personnel, given that it is based on actual cluster- and function-related data on service men and women. The novelty of this research lies in the fact that it is the first study in Indonesia to carry out clustering and dimensional measurements. The study also clears the way for understanding military anthropometric data in the Indonesian context and thereby advances future research on the design, development and repair of body armor.

II. METHODS

A. Subjects

This study was aimed at designing body armor that is available in several sizes. To this end, 150 personnel of the Indonesian National Army (TNI) were recruited for participation in anthropometric measurements. The participants were selected via simple random sampling based on the following inclusion criteria: (1) active TNI personnel, having provided 2 years of service or more; (2) male; (3) aged 20 to 30 years old; and (4) a normal body mass index (BMI).

B. Anthropometry

As stipulated by the International Organization for Standardization (ISO) [18], protective clothing should adhere to three main standards, namely, innocuousness, good design and effective and comfortable bodily protection. Designing body armor requires the classification of body parts into homogeneous variables called key dimensions [15, 16, 19]. In this work, the measurement of body proportions that served as the key dimensions for the proposed expansion of the existing sizing system was grounded in the concept put forward by Zakaria and Gupta [16]. The specific measurements used were height, chest girth, bust girth, waist girth and hip girth.

The measurements incorporated into the sizing system for bulletproof vests are the body dimensions illustrated in Figure 1. The measured body dimensions and other details are listed in Table 1

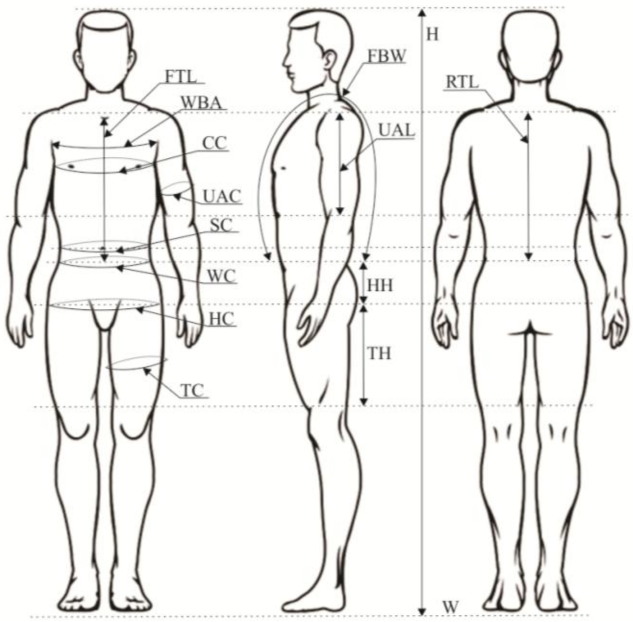


Figure. 1. Anthropometry of a Male Soldier

TABLE 1
BODY DIMENSIONS USED IN BODY ARMOR DESIGN

No.	Measurement	Code	Description
1	Height	H	Measured from head to floor
2	Weight	W	Weight measurement for military personnel
3	Waist circumference	WC	Measured at top of waist
4	Stomach circumference	SC	Measured at most prominent region of stomach
5	Chest circumference	CC	Measured at most prominent region of chest
6	Front torso length	FTL	Measured from jugular notch to top of waist
7	Rear torso length	RTL	Measured from 7th vertebra to top of waist
8	Width between arms	WBA	Span across chest, measured from deepest point of armpits
9	Front waist to rear waist	FBW	Measured distance from front waist over highest part of shoulder to rear waist
10	Upper arm circumference	UAC	Measured at middle of upper arm
11	Upper arm length	UAL	Measured from joint (between upper arm with shoulder) arm to joint (between upper arm to elbow)
12	Hip height	HH	Measured from waist tip to thigh joint
13	Hip circumference	HC	Measured in middle of hip
14	Thigh height	TH	Measured from joint (between hip and thigh) to joint (between thigh to knee)
15	Thigh circumference	TC	Measured in middle of thigh

C. Procedures

The research procedures were conducted in several stages as follows:

- In the first stage, anthropometric data were collected for use in the design of body armor. The data collection was guided by the information presented in Table 1, after which a normality test was conducted [20].

TABLE 2
MEAN, DEVIATION STANDARD AND PERCENTILE

Sample (N = 150)		Descriptive Data			Percentile					
No	Dimension	Mean	SD	CV	2.5th	5th	10th	90th	95th	97.5th
1	H	173.5	3.8	2.2	166.0	167.2	168.6	178.3	179.7	180.9
2	W	62.7	4.3	6.9	54.2	55.6	57.2	68.3	69.8	71.2
3	WC	93.6	8.8	9.4	76.4	79.2	82.4	104.9	108.1	110.9
4	SC	93.8	10.3	11.0	73.7	76.9	80.7	107.0	110.8	114.0
5	CC	100.7	10.3	10.2	80.5	83.8	87.5	113.8	117.6	120.8
6	FTL	38.6	2.8	7.2	33.2	34.1	35.1	42.2	43.2	44.1
7	RTL	44.1	3.1	7.1	38.0	39.0	40.1	48.1	49.3	50.2
8	WBA	49.7	5.9	12.0	38.0	39.9	42.0	57.3	59.4	61.3
9	FBW	96.5	1.9	2.0	92.8	93.4	94.1	98.9	99.6	100.2
10	UAC	32.2	3.2	9.9	26.0	27.0	28.1	36.2	37.4	38.4
11	UAL	21.9	1.6	7.5	18.7	19.2	19.8	24.0	24.6	25.1
12	HH	15.2	0.4	2.6	14.4	14.5	14.7	15.7	15.8	15.9
13	HC	102.1	7.5	7.3	87.5	89.8	92.6	111.7	114.4	116.8
14	TH	41.6	1.0	2.5	39.6	39.9	40.3	42.9	43.3	43.6
15	TC	46.5	4.5	9.7	37.7	39.1	40.7	52.3	54.0	55.4

Note: SD = standard deviation, CV = coefficient of variation

- The second stage involved the classification of anthropometric data and the determination of key dimensions. Calculations were carried out through univariate analysis, correlation analysis and principal component analysis [21].
- The third stage entailed the design and development of sizes on the basis of the standard sizing system for body armor. The results were then validated using Euclidean distance to determine the suitability of the expanded sizing system for the target population.
- In the fourth stage, measurements were crafted and compared with standard sizes on the basis of ISO and CAST standards.

III. RESULTS AND DISCUSSION

A. Subject Characteristics and Anthropometric Measurements

The subjects had an average age of 25.8 ± 2.64 years, an average body height of 173.46 ± 3.81 cm, an average body weight of 62.71 ± 4.33 kg and an average BMI of 20.8 ± 1.2 kg/m2. On the basis of the results, the BMI of the 150 subjects was included in the normal basic criterion for BMI, which falls between 18 and 23. The average values, standard deviations and percentile distribution of the data are shown in Table 2.

The normality test of anthropometric data was conducted using the Kolmogorov–Smirnov method, which indicated that all the data were normally distributed, with a probability value greater than 0.05 ($p > 0.05$).

B. Principal Component Analysis (PCA)

In various studies, PCA was implemented in the development of sizing systems [16, 19, 21, 22]. In the current work, PCA was carried out to classify variables into several homogeneous components and reduce the number of variables altogether. The analysis was also performed to determine the consistency of eight body dimension variables that were calculated previously. The results of the PCA calculations are presented in Table 3.

TABLE 3
PCA RESULTS

No.	Group Body	Group Size	
		Girth	Length
1	H	-	0.820
2	W	-	0.774
3	FTL	-	0.493
4	RTL	-	0.517
5	FBW	-	0.817
6	UAL	-	0.569
7	HH	-	0.917
8	TH	-	0.886

Continue TABLE 3

No	Group Body	Group Size	
		Girth	Length
9	WC	0.924	-
10	SC	0.755	-
11	CC	0.902	-
12	WBA	0.764	-
13	UAC	0.904	-
14	HC	0.912	-
15	TC	0.916	-

In the PCA analysis, the components relevant to this work were divided into length group, which consisted of units of length, width and height, and girth group, which comprised units of circumference. The vertical and horizontal groups encompassed eight and seven dimensions, respectively. The selected key dimensions were used as representatives of the groups [16, 20, 23].

C. Correlation Analysis

Multiple correlation analysis was conducted to determine the level of correlation between body dimensions [21]. Correlation level can be treated as a factor in determining the sizes of manufactured bulletproof vests. The findings of the correlation analysis are shown in Table 4.

Table 4 provides details on the correlations among the body dimensions used in vest measurements. This research identified three levels of correlation, namely, low, moderate and strong. The study also determined the correlations among height, chest circumference and waist circumference to ascertain the extent to which these key dimensions and other variables are related. The correlations are explained as follows:

TABLE 4
CORRELATION TEST RESULTS

Correlation matrix															
	H	W	WC	SC	CC	FTL	RTL	WBA	FBW	UAC	UAL	HH	HC	TH	TC
H	1.00														
W	0.51	1.00													
WC	0.67	0.33	1.00												
SC	0.59	0.33	0.76	1.00											
CC	0.68	0.33	0.90	0.73	1.00										
FTL	0.46	0.30	0.37	0.41	0.36	1.00									
RTL	0.65	0.30	0.54	0.49	0.56	0.27	1.00								
WBA	0.68	0.33	0.75	0.72	0.82	0.41	0.53	1.00							
FBW	0.97	0.50	0.65	0.59	0.67	0.45	0.64	0.65	1.00						
UAC	0.68	0.32	0.90	0.73	0.99	0.35	0.56	0.82	0.67	1.00					
UAL	0.68	0.33	0.59	0.60	0.58	0.47	0.63	0.60	0.69	0.58	1.00				
HH	0.90	0.80	0.59	0.56	0.61	0.44	0.56	0.62	0.89	0.60	0.63	1.00			
HC	0.68	0.34	0.99	0.77	0.89	0.38	0.54	0.75	0.66	0.89	0.61	0.60	1.00		
TH	0.96	0.66	0.64	0.60	0.66	0.49	0.61	0.67	0.96	0.65	0.65	0.96	0.65	1.00	
TC	0.69	0.34	0.99	0.77	0.91	0.38	0.56	0.76	0.67	0.90	0.60	0.61	0.99	0.66	1.00

Note: Correlation Level: < 0.5 = Low, 0.5–0.75 = Moderate, > 0.75 = Strong [21]

- Height is a dimension used as a basis for groupings in sizing systems. The results of the analysis showed that height was correlated with all 14 dimensions considered in this research. It was strongly correlated with FBW, HH and TH. It was minimally correlated with FTL, but this issue is negligible because the association is still close to the minimum value that reflects a moderate level. Height was correlated with the remaining 10 dimensions to a moderate degree.
- Waist circumference was strongly correlated with six dimensions: SC, CC, WBA, UAC, HC and TC. The rest of the dimensions exhibited a moderate relationship with waist circumference.
- Chest circumference was also strongly correlated with the following dimensions: SC, WC, WBA, UAC, HC and TC. The other dimensions exhibited a moderate correlation with chest circumference.

D. Initial Classification

The sample was classified into groups with similar attributes by assigning the participants to six height-related categories using the equations below [23]. The results are shown in Table 5.

Very short (VS), [VS < Mean – 2SD] (1)
Short (S), [Mean – 2SD < S < Mean – SD] (2)
Normal (N), [Mean – SD < N < Mean] (3)
Tall (T), [Mean < T > Mean + SD] (4)
Very tall (VT), [Mean + SD < VT < Mean + 2SD] (5)
Excessively tall (VVT), [VVT > Mean + 2SD] (6)

TABLE 5
CLASSIFICATION OF HEIGHT DATA

Size	Range		CP (%)*
	>	<	
VS	0	166	0 (0)
S	166	170	34 (22.67)
N	170	174	36 (24.00)
T	174	178	52 (34.67)
VT	178	182	28 (16.67)
VVT	182	0	0 (0)
Total			150 (100)

* = Cumulative Population

Table 5 indicates the formation of four initial sizing groups: the S group, which comprised 22.67% of the sample; the N group, which consisted of 24% of the sample; the T group, to which 34.67% of the sample belonged; and the VT group, under which 18.67% of the sample were classified. VS and VVT were not formulated. The minimum and maximum height levels covered by the S, N, T and VT groups were 166 and 170 cm, 170 and 174 cm, 174 and 178 cm and 178 and 182 cm, respectively. The data patterns reflected that the difference between the minimum and maximum height levels in the S group spanned 4 cm; those in the N and T groups amounted to 3 cm; and that of the VT group was 4 cm.

E. Drop Value (DV)

The DV method is an advanced classification process for grouping based on body shape; the classification is obtained by determining the relationship between key dimensions [23]. The DV derivation in this work was intended as a comparison with the previously performed classification. For the classification of body shapes in a vertical fashion (length), height was used as a basis, whereas for the classification of body shapes in a horizontal manner (girth), circumference (chest and waist) was used as a foundation. The key dimensions used were chest and waist circumference, and the formula, DV=[CC–WC] was applied [20, 21, 23].

TABLE 6
CLASSIFICATION RESULTS BASED ON DV

Body Type	DV (cm)	S (%)	N (%)	T (%)	VT (%)	CP (%)
XS	XS ≤ 1	8 (5.33)	3 (2.00)	5 (3.33)	2 (1.33)	18 (12.00)
S	1 ≥ S < 5	6 (4.00)	7 (4.67)	9 (6.00)	6 (4.00)	28 (18.67)
M	5 ≥ M < 9	13 (8.67)	19 (12.67)	12 (8.00)	8 (5.33)	52 (34.67)
L	9 ≥ L < 13	6 (4.67)	7 (4.67)	17 (11.33)	8 (5.33)	38 (25.67)
XL	XL ≥ 13	0 (0.00)	1 (0.67)	9 (6.00)	4 (2.67)	14 (9.33)
Total		33 (22.00)	37 (24.67)	52 (34.67)	28 (18.67)	150 (100)

Table 6 shows a classification that features five sizing groups. These are the XS group (DV ≤ 1 cm), comprising 12% of the sample; the S group (1 cm ≥ DV < 5 cm), consisting of 18.67% of the sample; the M group (5 cm ≥ DV < 9 cm), made up of 34.67% of the sample; the L group (9 cm ≥ DV < 13 cm), constituted by 25.67% of the sample; and the XL group (DV ≥ 13 cm), to which 9.33% of the sample belonged.

F. Validation

Validation was conducted on the basis of Euclidian distance to ensure the suitability of the developed size designs. Euclidean distance-based measurement involves determining the level of proximity between two or more data points. In this work, the validation was meant to uncover the accuracy of the designed data sizes. The calculations featured height, chest circumference and waist circumference [16, 21] and were performed using a solution size comparison and simulation anchored in the minimum and maximum sizes of the 2.5th to 97.5th percentile, 5th to 95th percentile and 10th to 90th percentile distributions of the data. After the smallest Euclidean size was obtained, another simulation was performed using a range of sizes. A final calculation was carried out to pinpoint the accuracy of the measurements, in which the percentage difference between the smallest Euclidean size obtained in a proposal and the total value derived was calculated. The results served as the final conclusions with respect to the proposed sizing system.

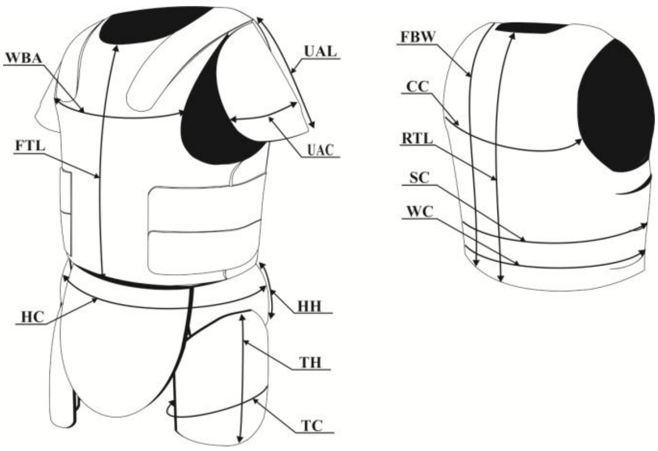
TABLE 7
VALIDATION RESULTS

Size	Sub-size	Percentile		
		2.5th–97.5th	5th–95th	10th–90th
S	XS	10.90	9.12	8.27
	S	5.52	5.16	4.16
	M	10.30	9.70	9.85
	L	15.03	11.25	10.99
N	XS	6.42	5.51	6.69
	S	12.22	11.87	12.07
	M	7.91	7.52	7.04
	L	7.26	7.31	7.45
	XL	20.28	13.07	11.27
T	XS	9.23	7.77	8.64
	S	9.05	9.38	9.38
	M	9.15	11.49	8.39
	L	12.12	12.71	9.93
	XL	9.46	8.63	8.49
VT	XS	7.18	7.00	5.39
	S	6.53	8.74	7.12
	M	11.02	10.34	10.62
	L	7.12	6.51	4.19
	XL	13.85	13.39	10.47
Average		10.03	9.29	8.44
% Accuracy		10.53	36.84	63.16

Table 7 illustrates the patterns that emerged from the comparison of Euclidean distances in each simulation. The final size classifications were characterized by 19 size variations. The minimum and maximum sizes were determined using the percentile values aimed at identifying the sizes that correspond with the requirements of the sample. After the simulations, the percentile value used as a measure was the 10th percentile for the minimum size and the 90th percentile for the maximum size. Selection can be seen from the Euclidean distance, at least in the percentiles with an accuracy of more than 60%. To increase the accuracy of the selected percentiles, another round of simulation was performed on a range of sizes. The comparison of the 2.5th and 97.5th percentile showed an accuracy of 10.53%, and that of the 5th and 95th percentile indicated an accuracy of 36.84%. The 10th to 90th percentile range was adjusted, resulting in an accuracy of 63.16%. On the basis of these findings, the final stage of the research was commenced by incorporating all the identified dimensions into size variations.

G. Proposed Sizes

The final validation informed the decision making on the proposed sizing. The validation reduced the initial 20 formulated sizes into 19, namely: S (XS, S, M, L), N (XS, S, M, L, XL), T (VS, S, M, L, XL) and VT (XS, S, M, L, XL). The sizes falling under each category are described in Table 8 and Figure 2.



(Front) (Rear)

Figure 2. Illustration Corresponding to Table 8

H. Discussion

Sizing system is a method for determining the size classification of a product based on body anthropometry [4, 7, 14]. Validation from the results of this analysis will have an impact on users' comfort and safety when using the product [2, 11]. In this study, the sizing system was carried out on the body armor of the Indonesian National Army (TNI). TNI anthropometry follows Asian body size standards, which tend to be lower compared to US and European bodies [1, 2, 9, 15, 24]. Meanwhile, the current body armor standards on the market follow the UK's CAST (Center for Applied Science and Technology) measures and US's NIJ (National Institute of Justice) [1, 2]. Based on this, the sizing system for the TNI body armor is urgently needed.

In this study, a sizing system carried out on 150 TNI personnel. The calculation method follows the results of previous studies [4, 13, 14]. The analysis begins with the calculation of the distribution of anthropometric data, followed by statistical analysis of PCA, Correlation analysis, to size classification using a DV analysis. Final validation is done by using Euclidean Distance analysis [4, 13]. Based on the validation analysis, there are 19 proposed sizes.

TABLE 8
RESULTS OF SIZE DESIGN

Size		Sub-Size			Supplement Size									
	H		CC	WC	SC	FTL	RTL	WBA	FBW	UAC	UAL	HH	HC	TH	TC
S	166-170	XS	86-87.9	82-83.9	81.95	35	40	42.45	94	28.45	20	15	93.95	40	41.45
		S	88-89.9	84-85.9	83.95	36	41	43.45	94	29.45	20	15	95.95	40	42.45
		M	90-91.9	86-87.9	85.95	37	42	44.45	94	30.45	20	15	97.95	40	43.45
		L	92-93.9	88-89.9	87.95	38	43	45.45	95	31.45	20	15	99.95	40	44.45
N	170-174	XS	90-91.9	86-87.9	85.95	36	42	44.45	95	29.45	21	15	97.95	41	43.45
		S	92-93.9	88-89.9	87.95	37	43	45.45	96	30.45	21	15	99.95	41	44.45
		M	94-95.9	90-91.9	89.95	38	44	46.45	96	31.45	21	15	101.95	41	45.45
		L	96-97.9	92-93.9	91.95	39	45	47.45	96	32.45	21	15	103.95	41	46.45
		XL	98-99.9	94-95.9	93.95	40	46	48.45	97	33.45	21	15	105.95	41	47.45
T	174-178	XS	96-97.9	92-93.9	91.95	37	43	47.45	97	30.45	22	15	99.95	42	46.45
		S	98-99.9	94-95.9	93.95	38	44	48.45	97	31.45	22	15	101.95	42	47.45
		M	100-101.9	96-97.9	95.95	39	45	49.45	98	32.45	22	16	103.95	42	48.45
		L	102-103.9	98-99.9	97.95	40	46	50.45	98	33.45	22	16	105.95	42	49.45
		XL	104-105.9	100-101.9	99.95	41	47	51.45	98	34.45	22	16	107.95	42	50.45
VT	178-182	XS	104-105.9	100-101.9	99.95	38	44	51.45	99	31.45	23	16	101.95	43	47.45
		S	106-107.9	102-103.9	101.95	39	45	52.45	99	32.45	23	16	103.95	43	48.45
		M	108-109.9	104-105.9	103.95	40	46	53.45	99	33.45	24	16	105.95	43	49.45
		L	110-111.9	104-105.9	105.95	41	47	54.45	99	34.45	24	16	107.95	43	50.45
		XL	112-113.9	104-105.9	107.95	42	48	55.45	99	35.45	24	16	109.95	43	51.45

The size comparison was intended to compare the sizes formulated in this research with those presented in journals or used as existing standards. This process is an additional procedure in ascertaining variations in size and correlation. CAST is the United Kingdom's international standardization body, which focuses on body armor design and development. It is one of the agencies recognized worldwide as an authority in standard body armor design. CAST groups body armor into three size categories, namely, small, moderate and large. An initial design is based on moderate dimensions, after which small and large sizes can be adjusted in accordance with user needs. The correlations between the sizes designed in this work and the sizing recommendations of CAST [1] are shown in Table 9.

TABLE 9
COMPARISON WITH CAST

Body dimensions	CAST*	Current
WC	94	T-S
SC	95.5	T-M
CC	104	T-XL
FTL	39	T-M
RTL	45	T-M
WBA	51	T-XL
FBW	98	T-(M-XL)

Note: All sizes are in cm.

As can be seen in the table, the moderate size for CAST is equivalent to size T in this study. As previously stated, CAST uses a moderate size as the benchmark, but the body dimensions of Europeans are larger than those of the Indonesians who took part in this work. According to Disable World [24], the average height of males in England is between 175 and 177 cm. The results of the correlation comparison indicated that the characteristics of a sample should be a consideration in design.

The ISO discusses general methods for establishing garment sizing systems in ISO 8559-3:2017 [20]. The procedures in this study were adjusted in accordance with ISO 8559-3:2017 [20] and the combined results of previous studies. ISO 13688:2013 [18] is suitable for use in research that examines the general conditions underlying the manufacture of protective clothing. Thus, this standard was used in the current work as guidance in examining the manufacture of protective torso components [18]. The correlation analyses were also grounded in the use of WC, CC and FBW as key dimensions.

IV. CONCLUSION

The basic requirements for suitable body armor are fit and comfort. The human body can take various forms and is characterized by variations in dimensions. Body armor design should therefore be based on an accurate measurement method. In particular, the body armor used by military personnel must be well designed in accordance with individual body dimensions for such products to accommodate various body types and shapes and for them to be sustainable under different levels of environmental difficulties.

This study carried out univariate and correlation analyses and PCA and performed data classification on the basis of height, DV calculation and validation. The validation, which was conducted to ensure the suitability of the sizes designed in this work, involved measuring Euclidean distance and continued on to the final decision making on the formulated sizes. The results reduced the initial 20 sizes to 19: S (XS, S, M, L), N (XS, S, M, L, XL), T (XS, S, M, L, XL) and VT (XS, S, M, L, XL). The proposed sizes can be taken into consideration in further research or used as reference by vest developers and manufacturers in enhancing their products. The adoption of the proposed sizing can help manufacturers save money and time in the production process.

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