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# Design of Ergonomic Assault Vest for Indonesian Army with Modular Concept

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**Abstract.** Assault vest is one of crucial products for Indonesian army infantry soldiers to support their activities in the battlefield. Despite its importance, however, the design of the assault vest of Indonesian army was not considered Ergonomics aspects. Based on the deep interview and questionnaires distributed to 30 Indonesian Army infantry soldiers, the current design was not really comfortable and limit the freedom of movement in the battlefield. Because of this, this research aims to design a modular assault vest for Indonesian army infantry that considering Ergonomics aspects. The object of this study was the 411 Infantry Batalyon / Pandawa located in Salatiga City, Central Java Province, with a total sample of 30 active infantry soldiers involve in this study. The research was conducted by using Nordic Body Map method, questionnaire, deep interview, and TAFEI (Task Analysis for Error Identification) as well as Kansei Engineering. The prototype was built to test the proposed assault vest design. A physiological test using the physiological test method of Dr. Woldemar Gerschler was conducted to test the prototype and then the results of the data (VO<sub>2</sub>) are tested by applying t-test statistical analysis to see whether the proposed assault vest design will have better performance than existing assault vest. Physiological tests were carried out by 23 respondents who were members of a football club. The test indicate that the proposed design show better result in terms of oxygen consumption.

## 1. Introduction

Indonesia is a very large country, it rank to the 13th largest country in the world [1]. To maintain its sovereignty, a reliable and resilient army and infantry forces are required. In order to protect the country, the army particularly the infantry need to be equipped with good quality of equipment. One of the essential equipment for infantry is assault vest. Like assault rifles, the existence of assault vests cannot be separated from infantry soldiers. Besides functioning as a carrying equipment, an assault vest also serves as a protector for soldiers from the possibility of being hit by bullet or explosives. To support the activities of soldiers in the battlefield, assault vests must be made as light as possible and had as minimum as possible ornaments and parts that are not important so that the vest is comfortable to use, while it still has a good protection system [1]. So an assault vest must be made as simple as possible in accordance with the field and what or how long the mission is being carried out. The design needs of an assault vest are very depend on the type of terrain where the battle takes place. For example, for jungle battles, the assault vest is designed to have more open parts and the pouches are only at the waist, this is intended rather the body can breathe more freely in areas of high humidity. While for city battles an assault vest is designed to cover the chest and back (with bullet proof armor layer) so that the soldiers safety is higher, because in city warfare, bullets can come from any direction. Mean while for



surveillance and patrol missions, soldiers only need pouches to store ammunition and drinking bottles so that the burden can be minimal and the mobility of soldiers remains high. From the fact in the field, it can be seen that infantry soldiers needed many types of assault vests to support their missions and carry and store various types of vests very inefficient. From that facts, came an idea to create a modular assault vest that could be removed as a puzzle according to the battlefield and the type of mission to be carried out.

## 2. Literature Review

Several research has been carried out regarding assault vests. Coombes and Kingswell [3] in their research describe regulation of load limits that must be carried by soldiers and how to arrange the load distribution optimally in assault vest so that soldiers can move freely, feel comfortable and require less energy while they are in the battlefield. this research method is that respondents walk on a force plate carrying loads 8, 16, 24, and 32 kg, with a combination of various load distributions on their bodies. Then the kinetic data is measured and the next step is determine which distribution load layout is the best. Birrel and Haslam [4] in their study discussed the comparison between biomechanical M-83 and conventional webbing vests. The aspects that are considered in this study are energy consumption, stride frequency and stride length. This research method was carried out by comparing the results of  $VO_{2max}$  produced, how much the stride frequency, dan how far is stride length when soldiers used m83 vests and conventional webbing vests. The study conclude that the design of M-83 model vest is better than conventional webbing vests. Additionally, Tutton [3] discusses what specifications and requirements must be considered when designing an assault vest. In his research, it was mentioned the needs of soldiers, types of battles, material and trends were very important to consider in designing the assault vest. However, the research was not discuss specific design of vest types or what models are appropriate to meet the needs of soldiers in the battlefield.

Referring to previous research, this present study will focus on how to design a good assault vest and design an assault vest that meet the needs of Indonesian infantry soldiers in the battlefield. It will consider the needs and complaints of soldiers. The proposed assault vest is designed since current design of the Indonesian Army assault vest does not adequately accommodate the need of Indonesian infantry. Its lack of comfort and limit the infantry soldier performance on the battlefield.

## 3. Methodology

This research is conducted through several stages. The description of the stages are as follows:

### 3.1. Data Collecting

The first stages is data collection. The first step of data collection is to collect the pain complaints of soldiers using Nordic Body Map (NBM). The Nordic Body Map method is used to find out which body parts of a soldier feel pain when using Indonesian Army assault vest. This method is often used to assess in which body parts the pain is experienced by the workers[6]. Questionnaire of NBM were distributed and filled by 30 infantry respondent. The pain value consists of 4 points (A- no pain; B-less pain; C-painful; D-very painful) [6]. The results of the NBM questionnaire state that most of the pain that occurs when using a standard Indonesian Army assault vest is felt on the shoulders and back neck. Second steps is to generate modular assault vest concept by using questionnaire. The questionnaire method was used to determine the design requirements and shape of the assault vest structurally. The questionnaire is also used to find out what items are needed and should be included in the vest. The design of the vest should be made as simple as possible, with less unnecessary ornaments attached without scarifying its main function. In addition, data were also obtained on what combat positions were disturbed when using current assault vests, these may include position such as: running, jumping, lying down, crawling, aiming, climbing, squatting, kneeling, and sitting. After this step, the next step is to identify soldier's needs in regard to assault vest design by using in-depth interview technique. In-depth interview was conducted by directly interviewing 5 soldiers which consisted of one company commander officer, one team commander, and three private soldiers who had experience in military operations in Papua in order

to fight the rebel movement. In-depth interviews were conducted aim to gain data on the needs of infantry soldiers in the field in more detail based on their experience in the battlefield.

### 3.2. Data Processing

The next step is looking for errors commonly done by soldiers when wearing assault vest using TAFEI (Task Analysis for Error Identification) method. TAFEI is a method to predict errors in the use of a device or tool by modeling interactions between users (operators) with these devices. This tool can be used to identify what errors occur when soldiers use existing assault vests. The TAFEI method is done in three stages, namely: creating hierarchical task analysis (HTA), then creating a State / Space Diagram (SSD), then transition matrix, then TAFEI diagram on each type of Indonesian Army assault vest[8]. The results of the TAFEI analysis state that the assault vest should make it easier for the soldier when using and removing the vest, so that systems such as buckles, zippers and velcros should be made as visible as possible. After that, the process continues with the Kansei Engineering (type 1) method. The Kansei Engineering method is used to determine the feeling of the soldiers when using assault vests and feelings arising about what kind of assault vests can meet their needs in the battlefield [9]. This method begins with collecting kansei words about assault vests. Then continue with applying the differential semantic questionnaire, then the design element division was carried out using the two step clustering method with *SPSS software* [8], then determining what design items were needed to make a good assault vest with linear regression with *Microsoft Excel software* [8]. The results of Kansei Engineering's analysis state that the safety of the vest from 5.56 mm caliber bullets, the softness and simplicity of the vest silhouette, the strength of the material, and the speed and rigidness of the modular system are very important for the assault vest design. The next step is to translating the design elements/attributes to technical requirements. This process is conducted by using Quality Function Deployment (QFD) method to find the priority of the user needs which then continued with the design sketch and the making of modular assault vest prototype [9]. The next step that will be done after making the prototype is testing the modular assault vest prototype using physiological test method. Physiological test was carried out by collecting 23 male respondents who were active in futsal activities aged 18-29 years, who were then instructed to run on a treadmill while wearing Indonesia Army assault vests and modular assault vests using Dr. Woldemar Gerschler with the method of 90 seconds running light and 120 seconds running (repeated as many as 4x)[12]. After that their heart rate was measured using a smart watch with the brand Iwofit I-6 HR. Then, heart rate data (HR) is used to calculate the VO<sub>2</sub> value generated by each respondent on the use of each assault vest using the following VO<sub>2</sub> formula [12].

$$VO_2 = 0.019HR - 0.024h + 0.016w + 0.045a + 1.15 \quad (1)$$

where:

VO<sub>2</sub> : oxygen consumption (l/m)

HR : heart rate (b/m)

h : body height (cm)

w : body weight (kg)

a : age (years old)

The next step is looking for differences between Indonesian Army assault vest VO<sub>2</sub> and modular assault vest VO<sub>2</sub> data. The t-test method was conducted to determine whether there were differences or not between the results of VO<sub>2</sub> wearing the Indonesian Army assault vest and a modular assault vest. The t test is done by first determining the H<sub>0</sub> and H<sub>1</sub> hypotheses. H<sub>0</sub> states that there is no difference, while H<sub>1</sub> states that there is a difference. This method is done with the help of Microsoft Excel software. After that, the result of t count is compared with the result of t table, whether the result is appropriate. If appropriate, then the t test results are said to be valid [13].

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} - 2r\left(\frac{s_1}{\sqrt{n_1}}\right)\left(\frac{s_2}{\sqrt{n_2}}\right)}} \quad (2)$$

where:

$\bar{x}_1$  : sample average 1

$\bar{x}_2$  : sample average 2

$S_1$  : standard deviation of sample 1

$S_2$  : standard deviation of sample 2

$S_1^2$  : sample variance 1

$S_2^2$  : sample variance 2

$r$  : correlation between two samples

#### 4. Case Study

The object of this study was the 411 Infantry Battalion / Pandawa located in Salatiga City, Central Java Province with 30 active infantry soldiers involve in this study. Infantry Battalion 411 was chosen as the respondent since respondents meet the following criteria:

- One of the oldest and largest infantry battalions in Indonesia.
- Infantry battalions who are willing to be retrieved and used as objects of research in modular assault vests.
- The oldest and largest infantry battalion with the closest distance to the city of Surabaya, making it easily accessible.
- There is a rifle company and has a raider qualification, where fast reaction is ready to fight whenever and wherever is their motto.

The infantry soldiers who were used as respondents were 30 soldiers who had taken part in Indonesian military operations, who were experienced at fighting, moving and using military equipment.

#### 5. Result and Discussion

After all the data was collected from 30 respondents using the methods above, it is known that the body parts of the soldier who often feel pain are the right and left shoulder, and the back of the neck. Therefore, the design, shape and dimensions of the assault vest should be made as comfortable as possible on the shoulders and neck. In addition, it was also found that the concept of the assault vest needed was an assault vest that could be changed its basic shape according to the needs and conditions of the operating field. While the items needed by soldiers in assault vests are: 2 spare bullet magasen, drinking water bottles, maps, compass, GPS, flashlight, knife, and radio. While the combat position which was disturbed by the design of the Indonesian Army assault vest was: running, jumping, lying down, crawling, climbing, squatting, and sitting. While complaints from the infantry forces were lack of simplicity in the design of Indonesian Army assault vests, as well as too many parts and accessories of assault vests to disrupt their activities. Their main complaint also came from bulletproof steel plates that were too heavy. One piece of bulletproof steel plate weighs 2.5 kg, while in each assault vest there are 2 steel plates on the chest and back, so the total weight of the steel plate that the soldier must carry is 5 kg. So the conclusion is a modular assault vest that has a simple silhouette with a protection system using much lighter soft armor, but with a less high risk of protection power (because the soft armor with the highest specifications (level IIIA) is only able to hold bullets with a maximum caliber of 5.56 mm NATO) [15]. Meanwhile, the results of the TAFEI method state that assault vests must have operational parts that are easily found and seen by soldiers, so that errors when using assault vests can be reduced. The Kansei Engineering method shows that: soft, simple, safe, strong, fast, rigid is the right kansei word that represents an assault vest. Therefore, assault vests should be divided into two design elements (appearance and system), while each design element has a basic vest and material design form, as well as a modular system of basic shapes and a modular system of vest bags (system). After Nordic Body Map, questionnaires, deep interview, TAFEI, Kansei Engineering data collected, the next step is looking

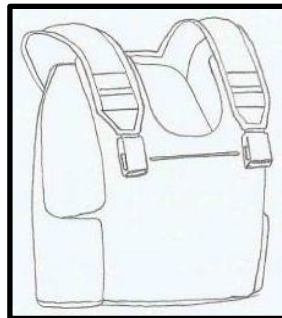
for requirement priority and user needs using Quality Function Deployment (QFD). After the QFD method is done, the results of the design requirement ranking are as follows:

1. Design
2. Shape
3. Material
4. Feature
5. Mechanism
6. Sizing

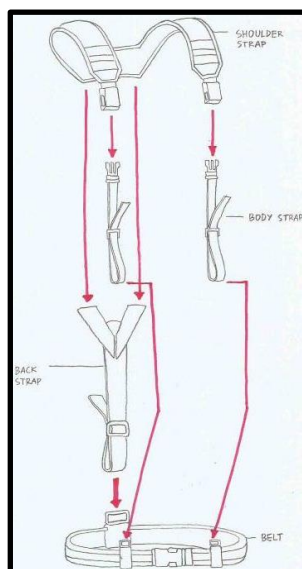
After collecting data specifications needed by infantry soldiers regarding their assault vests from previous methods, the next step is to design and make a prototype assault vest.

### 5.1. Design Sketching

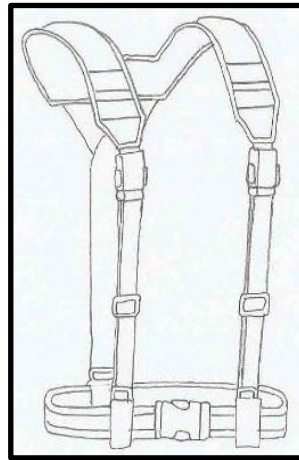
The design step is done by manually hand sketching. Hand sketches make the design steps easier and geometric shapes can be felt more. The results of the assault vest design are shown in figure 1 to figure 4 below. Prototype was created to test the proposed design. Figure 5 shows the prototype of the proposed modular design.



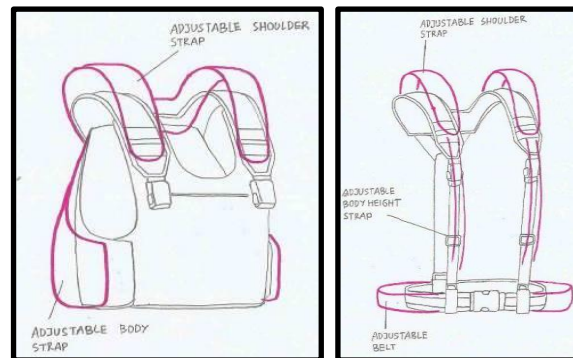
**Figure 1.** A perspective image of a modular assault vest when in the form of a basic vest



**Figure 2.** The transition image of a modular basic assault vest into a webbing model vest



**Figure 3.** The perspective image of a modular assault vest when it becomes an assault vest webbing model



**Figure 4.** Drawings of parts of a modular model basic assault vest and a modular assault webbing vest that has an adjustable feature



**Figure 5.** Modular assault vest prototype

### 5.2. Physiology Test

After the physiological test and  $VO_2$  calculation, data was generated that modular assault vests produce smaller values than Indonesian Army assault vests, but with a not so significant value comparison. Physiological tests were carried out by 23 respondents who were members of a football club. Respondents who are members of football clubs are chosen because they are physically good because

they practice physically every day. The VO2 results of the use of Indonesian Army assault vests and modular assault vests appear in the table 1 below.

**Table 1.** VO2 test result

Participant	VO2 I A assault vest (l/m)	VO2 modular assault vest (l/m)
Participant 1	13.6	13.3
Participant 2	10.8	10.4
Participant 3	13.3	13.2
Participant 4	11.2	11.1
Participant 5	11	10.6
Participant 6	12.2	11.9
Participant 7	12	11.8
Participant 8	11.5	11.1
Participant 9	12.6	12.4
Participant 10	10.9	10.9
Participant 11	11.2	11.2
Participant 12	10.7	10.5
Participant 13	10.2	10
Participant 14	10	9.7
Participant 15	9.1	8.8
Participant 16	9.1	8.9
Participant 17	8.8	8.5
Participant 18	8.9	8.8
Participant 19	10.1	9.8
Participant 20	10.7	10.4
Participant 21	1.3	10.3
Participant 22	10.8	10.7
Participant 23	9.3	8.9

### 5.3. T-test

After VO2 data gathered, to get the results of the difference in VO2 values between Indonesian Army assault vests and modular assault vests, t-tests were carried out with the help of *Microsoft Excel* software with the following results (table 2):

**Table 2.** T-test result

t-Test: Paired Two Sample for Means		
	IAA Vest	MA Vest
Mean	10.79565217	10.57391304
Variance	1.772252964	1.819288538
Observations	23	23
tStat	8.100713526	
t Critical one-tail	1.717144374	
t Critical two-tail	2.073879068	

After the t-test was carried out, it was found that there was indeed a difference between the results of VO2 using Indonesian Army assault vests and modular assault vests with H1 acceptance and rejected



H0 because the value of t-stat showed values still within the t-critical value limit (two-tail). So it can be stated that by choosing to use a modular assault vest, soldiers can save energy significantly rather than using a Indonesian Army assault vest.

## 6. Conclusion

From the data collection, design and testing of vests, it was found that modular assault vests can reduce the burden of the soldier in terms of the number of parts or types of assault vests which must be taken into the battlefield by infantry. In addition, the replacement of bulletproof steel plates with soft armor proved to be effective in reducing the weight of the assault vest, which resulted in a smaller value of VO<sub>2</sub> produced when using a modular vest rather than an Indonesia Army assault vest.

## References

- [1] Central Intelligence Agency, World Factbook 2013 (Virginia: Langley)
- [2] Grant H, et al 2012 *Armor Use, Care, and Performance in Real World Conditions: Findings from a National Survey*, 1st ed 55 (Washington DC: US Department of Justice)
- [3] Birrell S and Haslam R 2010 *Appl. Ergon* **41** 585-90
- [4] Coombes J and Kingswell C 2005 *Appl. Ergon* **36** 49-53
- [5] Tutton W 2012 *Designing Load Carriage System (LCS)*, in *Advances in Military Textiles and Personal Equipment 1st ed* (Cambridge: Woodhead Publishing)
- [6] Corlett E and Wilson J 1992 *Evaluation of human work. 1st ed* (Florida: Taylor & Francis)
- [7] Tarwaka, Bakri, and Sudiajeng 2004 *Ergonomics for Safety, Occupational Health and Productivity. 1st ed.* (Surakarta: UNIBA Press)
- [8] Mohammadian M, Choobineh A, Mostafavi Nave A, and Hashemi Nejad N 2013 *JOHE* **1** 49-53.
- [9] Nagamachi M and Lokman A 2010 *Innovations of Kansei Engineering: The Emergence of Kansei Engineering. 1st ed* (Boca Raton Florida: CRC Press)
- [10] Tan P, Steinbach M, and Kumar V 2005 *Introduction to data mining. 1st ed* (London: Dorling Kindersley & Pearson Addison W)
- [11] Akao Y 2004 *Quality function deployment. 2nd ed* (Cambridge: Productivity Press)
- [12] Science of Running 2016 available at: <https://www.scienceofrunning.com/2016/08/a-brief-history-of-interval-training-the-1800s-to-now.html?v=b718adec73e0#comments>
- [13] Widyasmara W 2007 *Determination of Oxygen Consumption Based on Physiological, Anthropometric, and Demographic Variables in Young Adult Men (A Preliminary Study)*, (Bandung: ITB)
- [14] Wibowo A. 2008 *Uji Komparasi untuk Data Berpasangan” in Biostatistika Non Parametrik, 1st ed* (Surabaya: UNAIR Press)
- [15] Level IIIA Body Armor 2018 available at <https://www.ar500armor.com/ar500-armor-body-armor/level-iiia-body-armor.html>