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The ergonomics design of the military backpack for Indonesian national soldiers using virtual environment model

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Abstract. This research studies the ergonomic aspect of military backpack design using virtual environment model. The purpose of this study is to evaluate the actual design of military backpack and determine the most ergonomic configuration which concerns on width of the backpack, height of the backpack, and maximum load that can be lifted by a soldier who was based on anthropometry Indonesian national army soldiers. Actual postures of military personnel are being observed and reconstructed on virtual environment using Jack software task analysis toolkits which are Low Back Analysis, Ovako Working Posture Analysis, and Rapid Upper Limb Assessment. The results of the research are the length and width of an ergonomic military backpack with the maximum weight that can be carried by a soldier-based anthropometry Indonesian national army soldiers.

1. Introduction

Indonesian National Army (TNI) is a state agency that has a fundamental duty to uphold state sovereignty, territorial integrity, and defend the unitary state of Indonesia. To support the task, required tools and equipment are needed. Most of the major military equipment and supplies are foreign-made products that are designed based on the human's body (soldiers) of the State makers. Military backpacks are one of the main equipment that should be carried by every TNI soldier as tool for carrying the equipment for military training or war. Until this time, the Indonesian national army is still using Korean-made military backpack which is designed for Korean soldier's postures.

Based on the data obtained from the questionnaire pre-study conducted by the number of 45 respondents from soldiers, ages 20-35 years, it is known that 51% of soldiers feel uncomfortable and as much as 20% is not very convenient when using a backpack. Then, it is known that 40% of respondents raise military backpack with a load of more than 21% from their body weight and as much as 64.44% of respondents use a backpack during exercise with duration of more than 75 minutes, while carrying a backpack with a load of 10% body weight for 30 minutes can cause injury to the spine [4]. This research aims to address the design of an ergonomic military backpack for Indonesian National Soldiers.

2. Method and Materials

2.1. Sample preparation

The data required for this research can be divided into two types of data; those are soldiers complaint data while using military backpack used to amplify the problem, and the soldier's anthropometry data used for designing ergonomic military backpack.

The data about the complaints experienced by soldiers, complaint data experienced by soldiers are obtained by spreading questionnaire to Indonesia national army with 100 respondents, the numbers are obtained by using Yamane sample calculation method:

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{328517}{1 + 328517(0.1)^2}$$

$$n = 99.96 \approx 100 \text{ sample}$$

In this study, the anthropometry data used are the soldiers' antopometry data (men) with a non-commissioned rank to officer rank around the age of 20-35 years, as many as 100 people. The data are collected directly in the army Dislitbang Jakarta by using the antropometer. The measures taken in the process of collecting anthropometry data are:

a) Height & Weight (1)
b) *Sitting Shoulder Height* (10)
c) *Shoulder Elbow Length* (15)
d) *Cheast depth* (22)
e) *Abdominal Depth* (23)
f) *Shoulder Breadth (Biacromial)* (26)
g) *Shoulder Breadth (Bideltroid)* (27)
h) *Hip Breadth* (28)

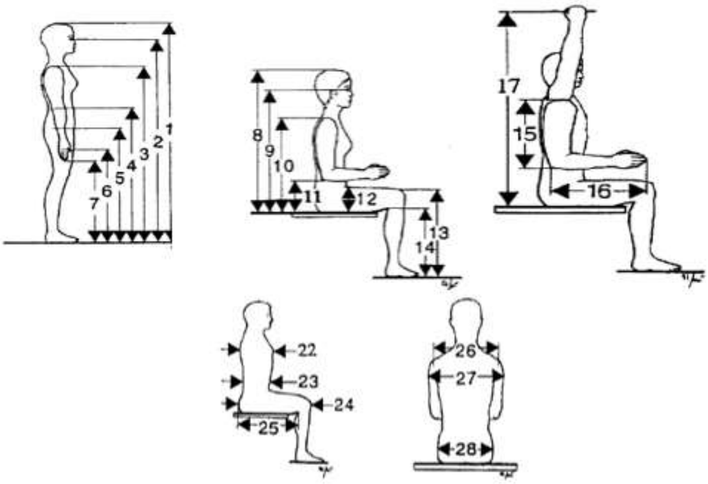

Fig 2.1 Body Part Measured in Process Data Collection

2.2. Method

2.2.1. Normality Test. After the soldier's anthropometry data are obtained, the next step is testing the normality of data. The data test is intended to determine whether the data obtained normally distributed or not, this is important because to make the percentile of the anthropometry data, the main requirement is that data should be normally distributed. After getting the necessary data, the next step is processing the data.

2.2.2. Jack Human Simulation Software. Data processing is done by using software Jack 6.1. The steps being taken in the modeling study include: creating the first virtual environment (virtual environment), creating a virtual human model (virtual human model), positioning virtual human on virtual environment models in accordance with the state planned, and verification and validation of the model which has been created and the last is analyzing the performance of virtual human models by using task analysis toolkit in Jack software 6.1.

In this research, there will be research scenario or configuration, the configuration of this research is based on the length and width of a military backpack. By Chris Adams (2006), the size of the bag should be adjusted to the size of the soldiers' back waist width and height of the back. Maximum size for the length of a backpack is a high back plus 5 cm, while the maximum size for a backpack width is the width of the waist plus 5 cm.

Dimensions designs of backpack is based on the ergonomics reference length ideal backpack which is a measure of the shoulder to the waist or if taken from anthropometry data will be equal to the height of the back (sitting shoulder height), while the width dimension backpack design is based on ergonomics that reference backpack ideal width is the size of the waist that is equal to the width of the waist (hip breadth, sitting). Based on backpack ergonomic references by Chris Adams (2006), the concluded configuration research as follows:

Table 2.1 Proposed Configuration Dimensions and Weight of Military Backpack

No	Configuration	Percentile	Length (cm)	Width (cm)	Backpack Weight (% Body Weight)
1	1A	5%	58 (Aktual)	44 (Aktual)	≤ 10%
					10% - 15%
					≥ 15%
	1B	95%	58 (Aktual)	44 (Aktual)	≤ 10%
					10% - 15%
					≥ 15%
2	2A	5%	46 (+ 0)	25 (+ 0)	≤ 10%
					10% - 15%
					≥ 15%
	2B	95%	57 (+ 0)	34 (+ 0)	≤ 10%
					10% - 15%
					≥ 15%
3	3A	5%	46 (+ 0)	30 (+ 5)	≤ 10%
					10% - 15%
					≥ 15%
	3B	95%	57 (+ 0)	39 (+ 5)	≤ 10%
					10% - 15%
					≥ 15%
4	4A	5%	51 (+ 5)	25 (+ 0)	≤ 10%
					10% - 15%
					≥ 15%
	4B	95%	62 (+ 5)	34 (+ 0)	≤ 10%
					10% - 15%
					≥ 15%
5	5A	5%	51 (+ 5)	30 (+ 5)	≤ 10%
					10% - 15%
					≥ 15%
	5B	95%	62 (+ 5)	39 (+ 5)	≤ 10%
					10% - 15%
					≥ 15%

3. Results and Discussion

3.1. Comparison of PEI 5th percentile

The value of PEI for soldier's bags will be compared in actual and recommendations conditions with each load carried by the soldier (≤ 10% of body weight, between 10% - 15% of body weight, and > 15% of body weight). The configuration that gives the best PEI value for all loads is 5A configuration, by changing the length of the bag into as long as the length of the soldier's back with an additional 5 cm and the width of the bag into as wide as the width of the soldier's waist with an additional 5cm.

PEI value on military backpacks for soldiers 5 percentile decreased quite large, especially when the soldier was carrying the load ≤ 10% of body weight, from 1.225 to 1.177. The decline of PEI value is considerable due to changes in each ergonomics grade, such as LBA, OWAS, and RULA that between the actual condition and recommended condition on decreased as can be seen in Table 3.1.

Fig 3.1 Comparison of Actual Results and Recommendations PEI Value 5th percentile

From Table 3.1, when the soldiers are carrying a backpack with weights ≤ 10% of their body weight, LBA value decreased from 556 Newton to 394 Newton. When carry the load between 10% -15% of their body weight, LBA value is decreased from 606 Newton to 527 Newton, and when the load is > 15% of body weight, LBA value also decreased from 848 Newton to 790 Newton.

Table 3.1 Comparison Values Military Backpacks Ergonomics for TNI Soldiers 5th Percentile

Load	Condition	LBA	OWAS	RULA	PEI
≤ 10% Body Weight	Actual	556	1	4	1.225
	Configuration 5A	394	1	4	1.177
10% - 15% Body Weight	Actual	606	1	4	1.24
	Configuration 5A	527	1	4	1.216
> 15% Body Weight	Actual	848	1	5	1.311
	Configuration 5A	790	1	4	1.294

3.2. Comparison of PEI 95th Percentile

The configuration that gives the best PEI value for all loads is 3B configuration, by changing the length of the bag into as long as the length of the soldier's back and the width of the bag into as wide as the width of the soldier's waist with an additional 5cm.

PEI value on military backpack for soldier's percentile 95 decreased quite large, especially when the soldier was carrying the burden of body weight ≤ 10% and > 15% of body weight, from 1.27 to 1.23 and 1.384 to 1.336, respectively.

Fig 3.2 Comparison of Actual Results and Recommendations PEI Value 95th Percentile

In Table 3.2, it can be seen that when the army soldiers carry a backpack with weights of ≤ 10% of their body weight, LBA value decreased from 708 Newton to 597 Newton as well as soldiers carry the load between 10% -15% of their body weight, the LBA value decreased from 850 Newton to 734 Newton, and when the load was increased to > 15% of body weight, LBA value also decreased from 1097 Newton to 932 Newton.

Table 3.2 Comparison Values Military Backpacks Ergonomics for TNI Soldiers 95th Percentile

Load	Condition	LBA	OWAS	RULA	PEI
≤ 10% Body Weight	Actual	708	1	4	1.270
	Configuration 3B	597	1	4	1.237
10% - 15% Body Weight	Actual	850	1	4	1.311
	Configuration 3B	734	1	4	1.277
> 15% Body Weight	Actual	1097	1	5	1.384
	Configuration 3B	932	1	4	1.336

4. Conclusion
Based on the analysis of the optimum value of PEI resulted on every change made of a military backpack, the best size for the 5th percentile is 51 cm for the length of the backpack and 30 cm for the width of the backpack. While for the 95th percentile is 57 cm for the length of the backpack and 39 cm for the width of the bacpack. The maximum load that can be carried by soldiers based on this research are 10% of the weight of the body so that the posture of soldiers remained normal and would not cause musculoskeletal injuries.

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6. References

[1] Aydin, Tozeren. 2000. Human Body Dynamics Classical Mechanics and Human Movement. Washinton: Springer.
[2] Bridger. R.S. 2003. Introduction to Ergonomics. New York: Taylor & Francis Group.
[3] Caputro, F., Di Gironimo G., Marzano, A. 2006. Ergonomics Optimization of a Manufacturing System Work Cell in a Virtual environment. Acta Polytechnica Vol.46 No.5/2006.
[4] Chow, Daniel Hung-Kay., et al. 2010. Carry-over effects of backpack carriage on trunk posture and repositioning ability. International Journal of Industrial Ergonomics, 41 (2011). pp. 530-535.
[5] Don B. Chaffin, G Lawton, and Louise G. Johnson, Some Biomechanical Perspectives on Musculoskeletal Disorders: Causation and Prevention, University of Michigan, 2003.
[6] Gregory, J.S and Deton, A.C. 2009. The Skeletal and Muscular Systems. New York: Chelsea Hause.
[7] Irving, P.H. 2007. Physics of The Human Body. New York: Springer.
[8] Kalawsky, R. 1993. The Science of Virtual Reality and Virtual environments. Gambridge: Addison-Wesley Publishing Company.
[9] Karwowski, Weldemar. 1991. Complexity, Fuzziness, and Ergonomics Incompability Issue in the Control of Dynamic work environment. Ergonomics 34, 671-686
[10] NIOSH. 1998. NIOSH Document, Applications Manual for the Revised NIOSH Lifting Equation, NIOSH Publication Number 94-110.
[11] Norman, I.B, Cory, B.P, and Bonnie, L.W. 1999. Simulating Humans Computer Graphics Animation and Control. Philadelphia: Oxford University Press.
[12] Pheasant, Stephen. 2003. Bodyspace: Anthropometry, Ergonomics and Design of Work. London: Taylor & Francis.
[13] Sanders, Mark and Ernest McCormick. 1993. Human Factors in Engineering and Design 7th Edition. New York: McGraw-Hill.