A study on the optimal dimension design of a Military Backpack considering body size characteristics

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Abstract

Military backpack used by army soldiers is a necessary item designed to carry military supplies. Considering that soldiers have to carry the backpacks over an average of 50km per day, it is very important that they fit the size of the soldiers' body comfortably. However, only one size of the military backpack is supplied in the army. Previous studies have attempted to improve the fit of the military backpack by changing frame structure of the backpack to distribute the load concentrated at a specific body part, or applying adjustable straps for shoulder or chest. However, there is a lack of studies for the military backpack design to reflect the characteristics of users with various body sizes. Therefore, this study proposed a methodology to derive design variables of the military backpack to reflect users' body size characteristics. The back panel size that 58 % of army soldiers were unsatisfied in a preliminary survey was studied to derive the optimal design dimension using the following steps. First, the Size Korea data was used to choose the human body size variables which can be reflected in the design variables. Next, a correlation analysis was applied among the variables to select the human body size variables that best fit the dimension of the military backpack. Finally, clustering analysis was used and five types of back panel size were developed to be applicable to soldiers with different body size characteristics. This methodology can also be applied to derive optimal dimensions of other design parameters such as shoulder strap length, waist pad width, etc. Then, the military backpack can be better improved to be fitted to the wearer and the load can be distributed with wider contact area of the wearer.

Keywords: Military backpack, Body size characteristics, Optimal design dimension

Introduction

Military backpacks used by ROK Army soldiers are very useful supplies designed to carry a variety of military items at once, while deploying from a garrison to a specific target area. If the entire unit needs to travel long distances, it may be possible to use buses, trucks, vessels, etc., but there are many operational zones where large transportation means can't be accessed such as narrow roads or mountainous areas. Also, if a road is lost due to a battle, or when a port is closed, soldiers must move on their feet while carrying their own items, so the military backpack is an indispensable item for soldiers. Considering the mission characteristics of carrying the backpack more than 50 km per day, using a backpack that does not guarantee the user's comfort is a very serious problem that can result in failure of the operation.[1]

However, the current military backpack has been changed by only two improvement projects since its foundation. Although the body size of the soldiers has changed significantly compared to the past, only single-size backpack is supplied to the soldiers. In addition, various military equipment have been developed, so that the number of items to be carried by one soldier has increased. Further, the total weight of the backpack has also increased sharply, but the same backpack has been

used for more than 10 years.

Of course, the ROK Army continues to pursue projects to reduce the weight of various military equipment components and to eliminate unnecessary components. However, efforts to capture and improve the problems of the military backpack are still lacking.

Previous studies have attempted to improve the fit of the military backpack by changing frame structure of the backpack to distribute the load concentrated at a specific body part[2], or applying adjustable straps for shoulder or chest [3]. However, there is a lack of studies for the military backpack design to reflect the characteristics of users with various body sizes.

Therefore, this study proposes a methodology to derive the design dimension of the military backpack by reflecting the size characteristics of the user. Back plate (BP) length of the backpack, which 58% of users are unsatisfied in the preliminary survey, was investigated as a case study.

Method

Although the retirement age of Korean soldiers is varied depending on their rank, there are soldiers of various ages from 18 to 56. In recent years, the number of female soldiers has steadily increased, and now there are more than 10,000 female soldiers fulfilling the duty

of national defense. Therefore, this study utilized anthropometric data of 6,413 Korean males and females aged between 18 and 56 years old provided by 'Size Korea'.

SPSS with version 25 was used in statistical analysis. Correlation analysis was applied to identify the relationship between the various human body characteristic variables that can be used to select design variable. K-means clustering analysis was used to classify various user groups according to the body size characteristics.

In this study, the process of deriving the design dimension of the army backpack was proposed as shown in Figure 1 to reflect the body size characteristics in the design dimension of the military backpack.

The first step was deciding that which dimension of the backpack should be derived. The 'BP length of the backpack', which had been considered to be the most uncomfortable from the result of the preliminary questionnaire, was selected as the target design variable.

The second step was listing the human body characteristics that can be used as a reference index to determine the dimension of the target design variable 'BP length of the backpack'. In this process, among the 131 human body characteristic variables in the 7th human body size data (2015) provided by the Size Korea, the length variables of the human body which can be referred to in BP length determination were listed.

Figure 1. Process of deriving the design dimensions for BP

The next step was to examine the feasibility of a number of human body size characteristic data and to select the appropriate human body size characteristic variables that could be used to determine the dimensions of design variable. At this stage, we

considered the ease of measurement, the contact area between the backpack and body, and the correlation with other human body characteristics.

Since the shape of back and waist of human is not a straight line but a curved one, it is difficult to design a fitted backpack just based on the calculation of vertical distance from the contact area between the back and backpack. Accordingly, it was necessary to consider the variables that can take into account the vertical length of the BP and the shape of the human body, and the combinations of the size measurements in Size Korea were used to derive the required variables.

Next, a clustering analysis was performed on the variables. Of course, as the size specification of the backpack is varied, the user satisfaction will increase. However, in this study, the number of military backpack types was limited to five in maximum by gender with consideration of economic feasibility. The optimal number of clusters was determined according to decision-making table which is based on the analysis results with different number of clusters from three to five.

In addition, we could confirm the body shape characteristics of each cluster and suggested the specification of BP length for the each shape.

Results

The length of the BP, which is the target design variable selected in this study, refers to the total length of the curved BP from the point where the shoulder strap is sewn to the midpoint of the back pad.

Among the 133 measurement items in Size Korea, the items considered to be in relation with the length and the contact area of BP were extracted (Figure 2).

Figure 2 List of body characteristic variables for the BP

First, 'stature' is the most accurate and general human characteristic variable that users easily perceive, but it can be approximated to the length of BP by subtracting head height and waist height that are not in contact with the backpack. However, the stature is a human characteristic variable that is the easiest to measure. If there is a high correlation with the dimensions of the contact area with the BP, it is easy and convenient for

the users to select appropriate size of the backpack.

The upper part where the backpack is in contact with the human body can be represented by using the cervical height or the shoulder height, and the lower part where the backpack is in contact can be expressed by using the Waist height (Omphalion) or Iliac spine height.

However, as shown in Figure 3, when walking while wearing the military backpack, the upper contact area is related to cervical height rather than shoulder height, and the lower part of the BP in contact with back of the wearer is related to the waist height (Omphalion). As a result of interviews with 100 army soldiers, the majority of respondents said that they pull the shoulder straps as much as possible to make the backpack close to their upper body. Otherwise, the backpack was pulled downward and they felt difficulties to walk due to the interference with the movement of the lower body part.

Figure 3. Wearing a Military Backpack

Therefore, the variable (1) and (2) were derived by combination of body dimensions in contact with the military backpack.

H = Cervical Height – Waist Height(Ophalion) (1)

L = Waist Back Length(Ophalion)..... (2)

Table 1. Correlation between body size variables

Gender	Variables	Height	H	L
Men (n=2441)	Stature	1		
	H	.542***	1	
	L	.502***	.830***	1
Women (n=2398)	Stature	1		
	H	.433***	1	
	L	.529***	.822***	1

As a result, there was a significant correlation between the stature and the variables H and L but the correlation was not high overall. Therefore, we decided to perform the cluster analysis on the variable H and L to derive the length of BP by different body size.

The number of clusters was divided into 3, 4, and 5 by gender considering economic limitations and the results were compared. As shown in Table 2, scores were given from 1 to 3 points, taking into account the case distribution for each cluster, the maximum distance in each cluster (radius of the cluster), the distance between the final cluster centers, and the dimensional gap by each cluster.

Table 2. Decision making table for determining number of clusters

Gender	Number of Clusters	Case Distribution	DGC ¹	MDC ²	DBFC ³	Final score
Men	3	3	3	1	3	10
	4	3	3	3	3	12
	5	1	2	3	1	7
Women	3	3	2	1	2	8
	4	1	3	3	3	10
	5	1	1	3	1	6

DGC¹ : Dimensional Gap by Clusters

DBFC³: Distances Between Final Cluster centers

MDC²: Maximum Distance in each Clusters

Higher scores were given with following criteria: 1) the number of case distribution was close to equal by each cluster, 2) the dimensional gap was close to equal by each cluster, 3) the maximum distance in each cluster was small, and 4) the distance between final cluster centers was farther. As a result of the decision

The body dimensions of each cluster by gender was shown in Table 3. The H represents the vertical height of the body part where the backpack is located, so that it can be reflected in determining the straight length of BP.

Table 3. Body dimension by cluster

Gender	Variable	1	2	3	4
Men	(1)	502	473	430	452
	(2)	519	490	440	467
Women	(1)	446	471	425	402
	(2)	463	495	439	414

The L represents the curved length of the body part where the backpack is in contact, so that it can be reflected in determining the curved length of the BP. On the other hand, some of the body dimensions in man and woman clusters are similar following: 2nd cluster and 2nd cluster; 3rd cluster and 3rd cluster; 4th cluster and 1st cluster. Therefore, it is possible to accommodate both men and women of different body sizes with five sizes of BP length by integrating overlapping dimensions.

Table 4. Optimal BP dimension proposal

Dimension	XS	S	M	L	XL
BP Straight Height	402	427	449	472	502
BP Curve Length	414	440	465	493	519

Table 4 summarizes the design specifications of the five sizes of military backpacks from XS to XL by integrating overlapping human body dimension clusters of men and women.

For example, the M size backpack should designed with 449mm of the vertical distance of BP and 465 mm of the length of BP according to the shape of body.

Discussion

In this study, it was recognized that the military backpack currently used by Army soldiers was manufactured in a single size without consideration of the different body sizes and variations of them. According to the preliminary questionnaire survey, the length of BP was selected as a case study to develop the

making process, it was found to be appropriate selecting four clusters for each men and women. When divided into four clusters by gender, the center of each cluster was chosen as standard for the design dimension of the length of BP.

methodology and process of deriving the optimal design dimension.

This study considered the important body dimensions to design the BP of military backpack. In order to fit the backpack to the body, the straight length of the BP and the curved length of the BP according to the body shape were found to be necessary and should be reflected in the design.

In addition, based on the anthropometric data of 4839 adult men and women, the dimensions of the human body in contact with the backpack were analyzed with suggesting of the design specifications for five specification sizes of military backpacks.

The methodology proposed in this study can be applied not only to the BP size of the backpack but also to the ranges of the dimensions of various design parameters such as shoulder strap length and waist pad width. Finally it is expected to improve the wearing comfort of the military backpacks for soldiers of various body sizes.

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