JESK J Ergon Soc Korea 2016; 35(5): 439-447
http://dx.doi.org/10.5143/JESK.2016.35.5.439
http://jesk.or.kr eISSN:2093-8462

Designing a Snow-removing Tool Through Ergonomic Approach

Kwang Tae Jung, Jung Min Nam

Koreatech, Industrial Design Engineering, Chungnam, 32153

Corresponding Author
Kwang Tae Jung
Koreatech, Industrial Design Engineering, Chungnam, 32153
Mobile : +82-10-8838-9306
Email : ktjung@koreatech.ac.kr

Received : August 30, 2016
Accepted : September 17, 2016

Objective: The purpose of this study is to design a snow-removing tool using an ergonomic approach.

Background: It is necessary to remove snow on the garden of a house or side street to prevent a fall hazard. When a user removes snow using a snow-removing tool, he or she experiences lots of physical discomfort. Therefore it is necessary to design a snow-removing tool to reduce a user's physical discomfort.

Method: In this study, a new design for a snow-removing tool was developed considering user needs. The design prototype was compared with an existing tool through electromyography and subjective evaluation.

Results: From the comparison evaluation, significant differences between the new design and the existing tool were identified in both muscle fatigue and subjective rating of discomfort.

Conclusion: The result showed that the new design is better from the aspect of easing physical discomfort.

Application: A new snow-removing tool can be developed using the design so that it can reduce a user's physical discomfort.

Keywords: Snow removal tool, Physical discomfort, Electromyography

1. Introduction

1.1 Background and purpose

The amount of fresh snow cover (depth of fresh snow accumulated for a specific period) in Korea has shown an increasing trend since 2000 despite a large annual deviation. The numbers of heavy snowfall watch and heavy snowfall warning have been constantly increasing since 2003. Damages due to heavy snowfall for the past 10 years in Korea reached about 30 cases, with the loss of lives being 14 and property damage standing at KRW 1.3 trillion (Oh, 2014). Snow cover limits people's activity domain and threatens their safety due to the occurrence of fall accidents (OSHA, 2015). According to the Ministry of Public Safety and Security, fall accidents frequently occur due to insufficient snow removing in front of each house. 1,843 fall accident cases were reported in Seoul alone in December 2012 due to slipping on icy roads, while

148 people suffered from fractures. Also, people aged 50 or over took up 72.4% of those fractured individuals (Newswire, 2013).

Due to recent snow-removing tool developments, a positive evaluation that snow removal on Korea's main roads had been relatively good was made. However, either snow-removing work using snow-removing tools on the alleys or backside roads is difficult or snow removing is not done well, owing to the lack of specialized work force which becomes a major cause to fall accidents on the icy roads. To prevent such an accident, residents need to voluntarily remove snow in a residential area; the government actively encourages such a campaign. In 2005, the Law of the Natural Disaster was revised, snow-removing obligation was imposed upon building managers, most local governments enacted ordinances for snow removing in front of each house and store, and active snow removing campaigns were waged by residents. However, the participation of numerous citizens was still lacking.

According to the snow-removing tool classification by the Ministry of Public Safety and Security, there are many snow-removing tools for main roads, public places, and wide districts. However, only three types of personal snow-removing tools, namely shovels, snowplows, and brooms are available. Concerning such personal snow-removing tools, people have a perception that snow-removing is difficult and hard because much muscle strength is required, negatively affecting participation in voluntary snow-removing work. Therefore, designing a snow-removing tool to carry out snow-removing work easily by employing a user's small muscular strength can be an important solution although there can be many methods to increase residents' voluntary participation ratio in snow-removing in front of each house and store.

According to such a need, this study proposed a design, which will effectively aid snow-removing work by expending only a user's small muscular strength, after identifying and solving problems from the ergonomic perspective targeting the snowplow, the most used personal snow-removing tool. This study also identified the suitability of a new design by analyzing physical discomfort upon carrying out snow-removing work.

1.2 Category for snow-removing tools

Upon looking at snow-removing tool types used for snow removing, many specialized snow-removing tools used in wide spaces including public places can be found (MAPC, 2012). However, there are only shovels, snowplows, and brooms as personal snow-removing tools that can be used at home as non-motorized tools (Table 1). Since the focus of this study was on personal snow-removing tools, this study analyzed the utilization method and merits and demerits of each personal snow-removing tool used the most, namely shovel, snowplow, and broom. Snow-removing work consists of three phases: the first phase concerns roughly cleaning lots of snow, the second phase involves meticulously cleaning snow clinging to the ground, and the third phase entails snow-carrying work or putting aside gathered snow. Also, the tools for each work are different.

Table 1. Snow-removing tools

Snow-removing tools	Product case	Usage environment	Strength	Weakness
Snowplow		Used mainly for the first phase of work	Lots of snow removing at a time	• Much strength is required. • Snow escapes to both sides. • The second phase of snow-removing work is necessary. • The snowplow easily breaks if it is stuck to the ground. • It is difficult to store due to its bulky size.

Table 1. Snow-removing tools (Continued)

Snow-removing tools	Product case	Usage environment	Strength	Weakness
Shovel		Used to break ice or scoop up snow and when calcium chloride is distributed	Can break hard ice	• The shovel's lower bottom can be easily damaged. • The grip feeling is not good.
Broom		Used when sweeping snow	Easily used regardless of age	• With this, hard snow is difficult to remove. • The grip feeling is unsatisfactory. • The broom's brush is separated easily.
Tool for vehicle		Used diversely since the uses of front and rear parts are different	Storage is simple due to small size; efficient for small areas	• A long time is required if the area where the snow is removed is big.

2. Surveying User Experience

The specialized snow-removing tool used to remove snow in front of a house or a store is snowplow. This study targeted existing snowplow users to identify problems and to identify design improvement areas in the use of existing snowplows. To this end, interviews were carried aiming at citizens residing in detached houses or stores. Also, the process of using a snowplow when removing snow was observed.

2.1 Survey on the environment where snow-removing tools are used

The places where snow-removing tools, depending mainly upon snow-removing workers' muscular strength, are used and where

Figure 1. Removing snow using a snow-removing tool

specialized snow-removing tools are not used are typically the garden or sidewalk in front of individually owned houses or stores. The tools are mainly used in the spaces where pedestrians' businesses are carried out. Specifically, a resident living in a detached house should remove snow at the spaces surrounding his/her house and the sidewalk in front of the house. In this case, lots of time and labor are needed for snow removing. Figure 1 shows snow-removing work using a snowplow. Most of this work depends upon a user's muscular strength.

2.2 User interview

To find out inconveniences or improvements of a tool used for snow removing around a house, this study carried out interviews with ten detached house residents. The interviews were carried out in December 2014, the participants' mean age was 57, and six men and four women participated in the interviews. The following items were surveyed for the interview:

Based on the interview results mentioned above, the main problem of snow-removing tools is that they cause physical fatigue, and they cause pain in the joint parts like the waist since the snow -removing process mainly depends on a user's muscular strength (Table 2). Therefore, snow-removing tools need to be designed to offer physical comfort and convenience to the user. In particular, such a problem should be improved more seriously for the elderly, whose muscular strength and physical strength are weak, in view of the trend that only elderly people live in a house.

Table 2. Interview for using a snow-removing tool

Question	Answer
Any dangerous situation due to snow?	Slipped and fell (6 people)
Who mainly removes snow around the house?	Husband (4), wife (2), not removing snow well (4)
What is your main snow-removing tool?	Snowplow, broom, shovel (in order)
If you do not remove snow, what is the eason?	Hard and troublesome
Is there anything that is difficult in snow-removing work?	Waist is very sore. Hands and arms are sore and difficulty is felt. Ache all over one's body. One's wrist is sore.
What can be the improvement direction of a snow-removing tool?	One wishes one did not feel fatigued. It would be better if the tool was stronger.

3. Design

This study tried to address the problems causing physical discomfort in the use of existing snowplows. Snow-removing work involves the process of removing and carrying snow, and there were many difficulties in carrying out the two types work using the existing snowplows. Although there are some snowplows with wheels to offer ease in pushing, they are effective only for pushing snow towards a singular direction, after which they simply leave snow around. They cannot offer ease in carrying snow to a certain place.

This study set up an all-in-one design, where snow-removing work and carrying work can be easily carried out and they constitute the design concept. Through this, elderly people, as well as young adults and middle-aged people, can easily use the snowplow. To meet the design concept of this study, the design aimed to relieve the physical burden on the wrist, elbow, knee, and waist.

The snowplow design allows it to function as a cart type that can easily handle heavy snow that is carried.

Concrete design direction is as follows: the wheeled-type design was made to minimize the physical burden on the wrist, elbow, knee, and waist in the snow-removing process. Also, when a user pushes down the handle, the container part carrying heavy snow is raised with minimal strength through the principle of lever, and the snow can be easily carried. Figure 2 shows the primary design result.

Figure 2. Design model of snow-removing tool

4. Design Evaluation

4.1 Experiment method

This study conducted electromyography and a questionnaire survey to evaluate whether the newly designed snowplow in this study causes smaller physical discomfort to users, compared to the existing snowplow. For the evaluation experiment, the newly designed snowplow's prototype was manufactured, and snow-removing work simulation using the two models was carried out.

Eight college students (four men and four women) without physical disability participated in the experiment. Their mean age was 26. The independent variable in the electromyography experiment was snowplow design (existing product vs. new design model), and the measuring variable was EMG signal measured from the muscles and used for snow-removing work. After the experiment, physical discomfort in using the experimental tools was evaluated using 5-point Likert scale. Experimental work was divided into snow-removing work within a certain range (Task 1), and carrying the snow to another place (Task 2). Since the experiment was conducted in a laboratory, earth was used instead of snow as the experimental material.

In Task 1, after earth was evenly spread with the height of 10mm in a 600 x 2000 (mm^2) area on the ground as shown in Figure 3, the participants were instructed to remove the earth using each snow-removing tool. In Task 2, the participants were asked to carry 1kg of earth to a place 2m away.

The experiment tool for each task was selected randomly. After the experiment was carried out for one tool, the experiment for the other tool was carried out after more than one hour of break. For electromyography, EMG was measured from the brachioradialis (muscle 1) and deltoid (muscle 2) in Task 1, and deltoid (muscle 1) and backbone erector (muscle 2) in Task 2 (Figure 4). After each work was repeated five times, EMG signals, which were measured for 10 seconds, were used.

Figure 3. Experiment Scenes (above: snow removing, down: snow carrying, left: existing tool, right: newly designed tool)

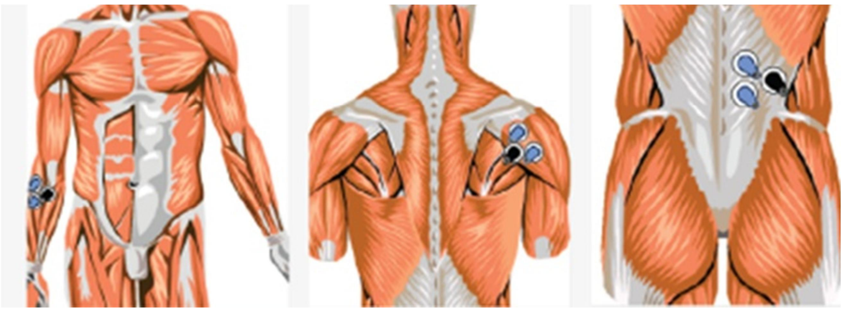

Figure 4. Muscles for EMG Measurement (brachioradialis, deltoid, backbone erector)

The participants were instructed to avoid radical exercise that may affect muscle fatigue in the preceding day of the experiment and to focus on the experiment by maintaining their usual physical state. After the experiment purpose was sufficiently delivered to the participants before the experiment, they became fully aware of the experiment method and procedure before the experiment was conducted.

4.2 Analysis of results

When a muscle becomes tired, not only does strength decrease upon contraction, mean EMG frequency moves from high frequency to low frequency. Therefore, EMG spectrum changes according to the transposition width change caused by muscle contraction. An analysis on muscle fatigue can be made if a frequency analysis is carried out based on the EMG spectrum change (Kim et al., 2012; Jung, 2012; Kim et al., 2005). According to muscle fatigue, mean power frequency (MPF) and median frequency (MF) decrease, and such can be a typical feature (Bartuzi and Roman, 2014). Therefore, this study identified the excellence of the improved snow-removing tool using MF as a parameter after the rectification of the source data acquired through the EMG system. This study used SPSS 18.0 for significance analysis and conducted a paired *t*-test.

According to the analysis results above (Table 3), significant differences were revealed at the significance level of 0.05 on the MF of EMG measured from the brachioradialis and deltoid regarding snow-removing work (brachioradialis: $p=0.000<0.05$, deltoid: $p=0.002<0.05$). Concerning snow-carrying work, a significant difference was not revealed at the significance level of 0.05 on the MF of EMG measured from the deltoid ($p=0.07>0.05$); however, a significant difference was shown on the backbone erector ($p=0.002<0.05$).

Table 3. Paired *t*-test

Task	Muscle	Paired Difference					*t*	df	Sig. (2-tailed)
		Mean	Standard diviation	Standard mean error	95% confidence interval of the difference				
					Lower	Upper			
1	Brachioradialis	-12.125	4.912	1.737	-16.231	-8.019	-6.982	7	0.000
	Deltoid	-4.125	2.357	0.833	-6.095	-2.155	-4.951	7	0.002
2	Deltoid	-29.000	38.326	13.550	-61.-41	3.041	-2.140	7	0.070
	Backbone erector	-4.500	2.673	0.945	-6.734	-2.266	-4.762	7	0.002

Upon looking at the mean value of MF difference between the newly designed tool and existing tool, it can be found that all were negative numbers. This can mean that the existing tool causes more muscle fatigue since its MF value is smaller than that of the newly designed tool.

According to the questionnaire survey results on physical discomfort upon using the two models, significant differences were shown at a significance level of 0.05 ($p=0.001<0.05$). Upon looking at the mean physical discomfort, the newly designed model showed more comfort (Figure 5).

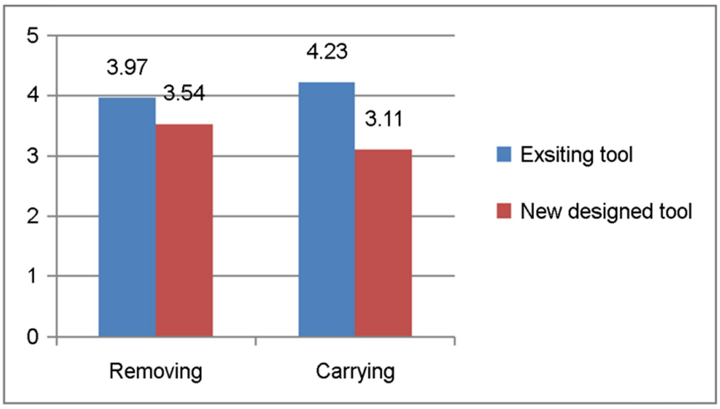

Figure 5. Subjective evaluation

Judging from an electromyography analysis and the subjective evaluation results on physical discomfort, this improved snow-removing tool causes less physical discomfort than the existing snow-removing tool.

5. Conclusion

This study centers on a snow-removing tool design for a user's physical discomfort reduction. This paper also presented a direction to reduce physical discomfort and to achieve ease upon changing the tool's shape for snow removing and carrying. In this way, men and women of all ages can more easily conduct snow-removing work. In the process of the participants' using the prototype tool through the experiment process, an opinion that the snowplow made with two bars is desirable to enhance the stability and solidity of the tool, compared to the tool made with one bar, was presented. Thus, the design result as shown in Figure 6 was produced finally.

Figure 6. Final design and use process

References

Bartuzi, P. and Roman, D., Assessment of muscle load and fatigue with the usage of frequency and time-frequency analysis of the EMG signal, Acta of Bioengineering and Biomechanics, 16(2), 31-39, 2014.

Jung, K., Ergonomic Design of Magic Saw Handle, *Journal of the Ergonomics Society of Korea*, 31(3), 469-474, 2012.

Kim, J., Kim, K., Yu, C., Oh, S., Lee, C., Kim, D., Hwang, B., Moon, Y., Jeong, G. and Kwon, T., The Fatigue Analysis of Urban Bus Driver with Electromyography (EMG) Analysis, *Journal of the Korean Society for Precision Engineering*, 29(10), 1149-1156, 2012.

Kim, M., Lee, J., Jung, D. and Jung, M., Effects of Back-belt on Electromyographic Activities and Angle of Lower Back and Extremity during Lifting, *Korean J Occup. Environ. Med.*, 17(4), 259-266, 2005.

MAPC (Metropolitan Area Planning Council), Snow Removal Policy Toolkit, 2012.

Newswire, http://www.newswire.co.kr/newsRead.php?no=678083, 2013.

Oh, B., VIP Report: Snow and Economy, Hyundai Research Institute, 2014.

OSHA, Falls and Other Hazards to Workers Removing Snow from Rooftops and Other Elevated Surfaces, 2015.

Author listings

Kwang Tae Jung: ktjung@koreatech.ac.kr
Highest degree: PhD, Department of Industrial Engineering, KAIST
Position title: Professor, Department of Industrial Design Engineering, Koreatech
Areas of interest: Applied Ergonomics and Design, Emotional Design, HCI

Jung Min Nam: njm0118@koreatech.ac.kr
Position title: Undergraduate student, Department of Industrial Design Engineering, Koreatech
Areas of interest: Applied Ergonomics and Design