JESK J Ergon Soc Korea 2016; 35(5): 343-359
http://dx.doi.org/10.5143/JESK.2016.35.5.343
http://jesk.or.kr eISSN:2093-8462

Development and Ergonomic Evaluation of Spring and Autumn Working Clothes for Livestock Farming Workers

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Received : June 01, 2016
Accepted : October 03, 2016

Objective: In this study, we designed working clothes for livestock farmers to wear in spring and autumn to improve their work efficiency, conducted a physiological test on their performance, and evaluated their comfort.

Background: In recent years, livestock farming in Korea has expanded, yet farmers' safety and sanitation levels remain low in hazardous environments that include organic dust, toxic gas, and heat stress, as well as the risk of accidents. Furthermore, most livestock farmers wear ordinary or dust-resistant clothes that are unsuitable for rearing livestock and compromise their safety and health. Thus, it is important to design specialized working clothes for livestock farmers that are comfortable and that minimize their health and safety risks.

Method: To this end, we examined the literature on livestock (poultry, swine, and cattle) farmers' safety and sanitation issues, designed appropriate working clothes, and tested them in terms of sensory feel, physiological response, and subjective comfort.

Results: The respondents expressed satisfaction with the new working clothes. The results of a physiological test showed a decline in temperature and humidity inside the clothes, a lower pulse rate, and a lower oxygen intake compared to the measurements taken when famers wore their previous working clothes. This indicates a fall in heat stress and fatigue, which was mostly consistent with the results of the assessment of subjective comfort.

Conclusion: The results of the analysis show an improvement in the comfort of the new working clothes compared to the dust-resistant clothes that are widely worn. Based on this study, the new working clothes need to be further tested and evaluated to improve the design.

Application: This study is expected to contribute to designing better working clothes for livestock farmers.

Keywords: Livestock working clothes, Protective clothing, Thermal comfort, Ergonomic evaluation, Farming worker

1. Introduction

The livestock industry's ratio rose 9.8% in 10 years from 24.8% in 2002 to 34.6% in 2012, compared to agricultural and forestry output and GDP (MAFRA, 2013). As such, the livestock industry and associated industries take very important place in the national economy, and have steadily grown so far. However, constant work is carried out according to livestock's breeding cycle, and such characteristics as infectious disease occurrence, unexpected situation due to livestock breeding features, and various harmful materials emissions can be found in the livestock farming work. The number of people engaged in the livestock industry is estimated 560,000 (ME, 2013). The poor working environment including organic dust, harmful gas, and high temperature and humidity generated in the livestock breeding sites may decline work efficiency, owing to high probability of safety accidents and health disorders (Hwang et al., 2009). Therefore an effort for working environment improvement and personal protective equipment development, as well as for personal sanitation of livestock farmers, is a very important factor.

According to a recent safety and health situation and personal protective equipment wearing situation survey on swine, poultry, and beef cattle, which are the representative characterization of animals in the Korea's livestock industry and on dairy farmers, they are exposed to harmful and hazardous environment in and outside of livestock barns. However, the protective equipment wearing situation for personal safety and health is very poor. As for livestock working clothes, livestock farmers mostly wear comfortable clothes for work purchased in a market or everyday clothes, instead of working clothes (Kim et al., 2014a; Kim et al., 2014b; Kim et al., 2016). In view of livestock work characteristics, cautions on farmer's syndrome-related safety and health such as high temperature and humidity stress are required, as much work is done within cattle shed, pigpen, etc. Wearing working clothes unsuitable for the working environment is not only exposed to harmful materials easily, but causes heat-associated diseases, and thus reduces work efficiency and negatively affects worker's safety and health. All these can increase the occurrence rate of safety accidents (Havenith, 1999). Wearing adequate working clothes for farmers that can protect them from the farming work environment and enhance work efficiency is a task, which has to be conducted for farmers' health retention.

Studies associated with pesticide protective clothing to prevent pesticide poisoning fatal to humans were preceded as to most studies related with working clothes for farming workers (You, 2004; Hwang et al., 2006; Hwang et al., 2007). Recently, interest in safety and health increases from the aspect of safety and protection of livestock farmers. In relation with such a trend, a study on livestock farmers' safety and health status survey (Kim et al., 2014a; Kim et al., 2014b), livestock farmers' safety and health management (Korea Dairy and Beef Farmers Association, 2009; RDA, 2013; RDA, 2015), studies on personal protective equipment for livestock farmers and working clothes development for livestock farming (Hwang et al., 2008; Hwang et al., 2009; Lee et al., 2011; RDA, 2014) were conducted. Pesticide protective clothing was developed to prevent damages due to pesticide absorption and high temperature and humidity stress. In addition, clothes for high temperature and humidity to minimize high temperature and humidity stress within greenhouse facilities were developed. The closes enhanced the comfort of the farmers working in the high temperature and humidity environment using cooling fabrics (Askin fabric) with cooling effect and cool comfort fabrics drying moisture fast. Upon looking at the studies associated with the development of livestock working clothes, Hwang et al. (2009) developed farming working clothes for winter considering warmth retention, soil resistance, washing efficiency, and elasticity. Although working clothes for winter has meaning to offer warmth retention, and functionality in the case of outdoor work, they are not suitable for the high temperature and humidity environment. Also, a study on livestock working clothes materials development were carried out. The study was about the development of disposable working clothes to which 100% bio-degradable polylactic acid (PLA) was applied, and was proved to be effective to high temperature and humidity stress reduction (Lee et al., 2011; Hwang and Lee, 2012). However, there were limitations in commercialization, since study focus was on material development. There were also previous studies on comfort assessment of human body concerned with disposable non-woven fabric worn in other workplaces, in addition to livestock farming sites (Choi et al., 2004) and on the situation of wearing protective clothes for foot-and-mouth disease and clothes for prevention of epidemics (Moon and Jean, 2012). Besides, a study on the survey on consumers' awareness of working clothes and protective equipment for livestock farming through a survey on the preference and acceptability of working clothes for livestock farmers and commercialization possibility was conducted (Hwang et al., 2013).

According to the results of the previous studies, various types of R&D are carried out for the development of working clothes for farming workers depending on the agricultural environment of crop types. Although studies on the development of working clothes for farming workers for winter and materials to reduce high temperature and humidity stress were conducted in the livestock industry, there was a limitation of not applying them to real life. The reason seems that differences are revealed between the working environment and work details, and focus was on mainly research, rather than on development to actually apply to livestock farming sites. Also, there were few studies on R&D for commercialization of working clothes for livestock farmers and those to prevent safety accidents. This study aims to develop livestock working clothes with which safe and comfortable farming work activities can be carried out from collision/contact accidents with obstacles and animals and to solve such problems by reducing high temperature and humidity stress in spring and autumn.

To this end, this study developed livestock working clothes for spring and autumn by identifying the necessary performance of working clothes design, based on the survey results on the farming working environment and safety and health of livestock farmers. For objective and subjective assessment of the developed livestock working clothes, this study carried out a comparative wearing experiment with the dustproof clothes mainly worn by livestock farmers and evaluated onsite farmers' responses by assessing responses on the developed livestock working clothes through visit to livestock farms.

2. Development of Working Clothes

2.1 Pre-research

This study examined the literature on the agricultural work environment, safety and health situation, and personal protective equipment wearing situation concerned with Korea's representation characterization of animals, namely swine (RDA, 2013; Kim et al., 2014a), poultry (Kim et al., 2014b; RDA, 2015), beef cattle and dairy farming (Korea Dairy and Beef Farmers Association, 2009; Kim et al., 2006). Upon looking at by characterization of animal, collision with obstacles on the moving path, damages on the shin and foot by contact with swine, exposure to high temperature within pigpen, fall accidents on the slippery ground, contact with pollutants upon cleaning pigpen, and electric shock were surveyed to be major hazard factors (Kim et al., 2014b) in the case of swine. Concerning poultry, many portions of work including disinfection, livestock manure treatment, feeding, and chicken coop control were conducted manually. Also, high temperature and organic dust with high biological activity due to breeding chickens jamming up in the chicken coop (Shin et al., 2004) and contact of harmful substances upon chicken coop cleaning with the skin

Table 1. Hazard factors and required clothing performance in the livestock working environment

Hazard factor		Main task	Performance required for clothing
Physical	Organic dust, fine dust, noise, vibration, etc.	Barn cleaning, feeding, carrying dead animals	• Main body portion protection (protective materials such as knees, elbows) • Moisture permeable, breathable considering • Minimize contact with the bacterial virus (wrist, ankle function provides fasteners) • Minimize physical absorption of the contaminants • High temperature and humidity stress reducing material • Excellence in laundry drying • Apply reflective material part at night
Chemical	Harmful gas, odor, endotoxin, disinfectant, etc.	Manure treatment, preventative measure, carrying dead animals	
Biological	Manure, pathogenic bacteria, virus, etc.	Barn cleaning, manure treatment	
Human error	Contact with animal, obstacle collision, slide, fall, MMH, needlestick injuries, electric shock, etc.	Shipping work, barn management, feeding, vaccination, etc.	
Environmental	Low-light, high temperature, cold, etc.	All work in barn	

and respiration system were reported (RDA, 2003). Regarding the cattle breeding environment, collision and contact accidents with obstacles and animals, physical damages by handling of weights (Kim et al., 2006), and serious skin allergic responses by dust and microbes upon feeding feeds and grass were reported to be caused. Based on the literature study results, the protection of major parts of human body from the safety accident aspect, vapor resistance on harmful substances and absorption from the harmful environment aspect, and comfort of body activities in the high temperature and humidity environment are taken into account, if necessary performance for the development of livestock working clothes for the livestock working environment is summarized. Table 1 shows harmful and hazardous factors in the livestock working sites and necessary performance applied to the development of livestock working clothes (Kim et al., 2016; RDA, 2015; RDA, 2013; RDA, 2012).

2.2 Designing of working clothes

The working clothes developed in this study were two types: one is two piece type (top and bottom are separated) and the other one is an overall type. Figure 1 shows the design drawing and developed working clothes. Main fabric and protective fabric material were used commonly for the two types of working clothes. The protective fabric material was applied to the knee, shin, elbow and hip parts for the prevention of accidents caused by collision or contact with obstacles and animals. Especially, the working clothes with protective pad inside were made possible to minimize shock by contact with livestock and collision with obstacles. Self-reflective material was partially applied to the back of the working clothes to prevent traffic accidents at night. To minimize the absorption of pollutants and foul odor on human body, a tightening function at the end of the clothes on the wrist and ankle was added.

a) Two-piece b) Overall

Figure 1. Sample of working clothes

The main fabric applied to the working clothes in this study took into account the following: tensile strength and internal tearing strength for durability, internal tearing strength, moisture permeability resistance to reduce harmful substances and high temperature and humidity stress, water repellency and resistance, absorption and fast drying, and fastness according to frequent washing. The fabric was 100% polyester, it included thermoplastic poly urethane (TPU) film for water resistance and moisture permeability, and added three-quarter to it, thus the fabric consisted of 3-layers. The fabric is light, tough, and the Goretex function was added. Therefore water resistance, moisture permeability, and durability were improved. The protective fabric material that can protect major parts of human body was the fabric developed by Super Fabric, and the material with high wear property, prevention of needlestick injuries, flexibility, detergence, and water resistance was used. Table 2 shows the results of fabric's material property test conducted by a request to KATRI (Korea Apparel Testing & Research Institute) concerning the selected material.

Table 2. Fabric characteristics of the developed working clothes

Item		Testing result		Indication standard
		Main fabric	Protective fabric material	
Fastness to washing KS K ISO-C06 2012 A2S (40±2℃, ECE)	Change in color	4~5	4~5	Level 4 or above
	Contamination (polyester)	4~5	–	Level 3 or above
	Contamination (polyamide)	4~5	4~5	
	Contamination (wool)	–	4~5	
Fastness to perspiration KS K ISO 105-E04 2010 (37±2℃, 4 hours)	Acidic	4~5	4~5	Level 4 or above
	Alkalic	4~5	4~5	
Light fastness KS K ISO 105-B02 : 2010 Xenon arc	Water cooling, light fastness standard	Level 4 or above	Level 4 or above	Level 3~4 or above
Mixed (perspiration + light) KS K 0701 : 2008 Xenon arc	Acidic	4~5	4~5	Level 3~4 or above
	Alkalic	4-5	4-5	
Dimensional change percentage (%) KS K ISO 5077 : 2014	Warp (Wp)	-2.0	-0.5	±Less than 3%
	Weft (Wt)	-0.5	-0.5	
Snag resistance (level): KS K 0561 : 2011 D-2	Wale (long)	4	4	Level 3 or above
	Course (width)	4	4	
Abrasion resistance (n) KS K ISO 12947-2 : 2014 (Martintail method)		Over 20000	Over 20000	Over 20000
Tensile strength (N) KS K 0520 : 2015 (Grab method)	Warp (Wp)	940	2800	More than 180N
	Weft (Wt)	600	2300	
Internal tearing strength (N) KS K ISO 1337-2 : 2009 (Tongue method)	Warp (Wp)	19	250	More than 13N
	Weft (Wt)	13	220	
Disruptive strength (kPa): KS K 0351 : 2006 (Oil pressure method)		1512	More than 4000	More than 216N
Water penetration (cmH_2O) KS K ISO 811 : 2009 Hydraulic method		More than 1000	20.2	–
Water repellency KS K 0590 : 2008 Spray method		3, 3, 3	2, 3, 2	Level 2 or above
Deodorization rate (%): Colorimetric gas detector tubes (HN3)	30 min.	56	60	–
	60 min.	58	64	
	90 min.	60	68	
	120 min.	60	70	

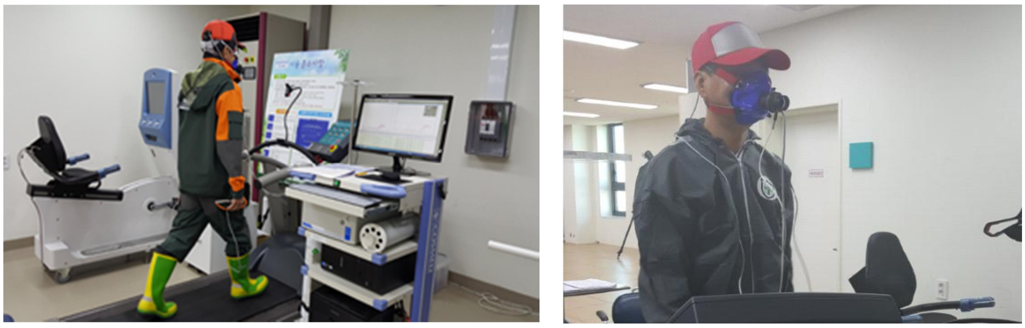
3. Evaluation of Working Clothes

3.1 Subjects

The subjects were five healthy adult males selected randomly, and their mean age was 32±1.8, mean height was 173.8±3.1cm, and mean weight was 69.4±6.2kg. Those who suffered from a specific disease, took medicine for the long-term, and exercised for the long-term were excluded from the subject selection.

3.2 Experimental environment and clothing

Concerning the laboratory environment, the experiment was carried out in a steady temperature and humidity room, where temperature and humidity are maintained constantly. 20℃ and 50%RH were maintained in consideration of the workplace environment in spring and autumn. Walking on the treadmill and resting were repeated, and exposure time was 80 minutes in total, and the temperature and humidity inside the clothes, oxygen intake, and heart rate were measured. The experiment was conducted between mid September and early October, when difference in temperature from the outside was small, in order to reduce confusion by physiological response variation according to season. As for the experimental clothes used in the experiment, one type of the developed working clothes (two-piece) and one type of dustproof clothes (two-piece) generally worn by livestock farmers, namely the two types were selected as the experimental clothes. The dustproof clothes (existing working clothes) has such characteristics as fine dust defense, water repellent function, and air permeability with main material as suponbond non-woven fabric. During the experiment, the subjects were instructed to wear the same running shirt, boxer shorts and socks inside the clothes for evaluation. Also they wore general rubber boots and a cap type work cap mainly worn during the livestock work. Figure 2 shows the scenes of the experiment.



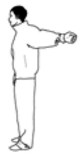
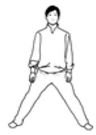
a) New b) Old (dustproof clothes)

Figure 2. Experiment of work tasks

3.3 Experimental design

The independent variables were the newly developed livestock working clothes (new) and the existing dustproof dress (old). The dependent variables were sensory test measurements as movement functionality, physiological response variables, and subjective sensation level. For the sensory test, each posture was measured by referring to a study of Kim et al. (2002), and discomfort level on each posture was evaluated with 5 point-Likert Scale from one point (very uncomfortable) to five points (very comfortable) (Table 3). Regarding physiological response evaluation, the temperature and humidity change, oxygen intake, and heart rate were measured during the whole experiment. For the measurement of temperature and humidity inside the clothes, a temperature and humidity gauge, namely Thermo Recorder RS-10, Tabai Espec Corp., Japan, was used, and the two parts (chest and thigh) were measured. The heart rate change was measured using a heart rate gauge (Polar Sports Tester, Polar Electro INC, Finland). Oxygen intake was measured using a Metabolic Gas Analyzer Test Set: Quark CPET. COSMO Co., Germany.

Table 3. The posture of sensory test

Movement	Posture				Movement	Posture			
Arm's vertical movement	AV-1 	AV-2 	AV-3 	AV-4 	Arm's horizontal movement	AH-1 	AH-2 	AH-3 	AH-4 
Waist movement	W-1 	W-2 	W-3 	W-4 	Leg movement	L-1 	L-2 	L-3 	L-4 

Evaluation on thermal, humidity (ASHRAE, 2001), pressure, and comfort sensations (Kim et al., 2006) was carried out to evaluate subjective sensation during the experiment. Table 4 shows the scale of subjective sensation. The mean values and standard deviation values on all physiological measurements for 80 minutes were presented. Concerning the difference between measurement items according to working clothes type, the validation was conducted with a paired *t*-test using the SPSS 14.0 statistical program.

Table 4. Scales of subjective sensations

Item	Thermal	Humidity	Pressure	Comfort
Sensation rate	1. Indifferent 2. Warm 3. Hot 4. Very hot	1. Very moist 2. Moist 3. Slightly moist 4. Indifferent 5. Slightly dry 6. Dry 7. Very dry	1. Very loose 2. Loose 3. Slightly loose 4. Indifferent 5. Slightly tight 6. Tight 7. Very tight	1. Very comfortable 2. Comfortable 3. Slightly comfortable 4. Uncomfortable

3.4 Experimental procedure

Prior to the experiment, the subjects participated in the experiment voluntarily by being precisely notified of the method, purpose and cautions of the experiment. The subjects wore the clothes for experiment, and their body specifications (i.e. age, height, and weight) were measured. In addition, a body activity sensory test was conducted by movement and clothes part on the developed working clothes. The subjects participated in the experiment, after sensors were attached, and they took enough rest. The experiment was conducted for 80 minutes including rest (stabilization) step for 15 minutes and 65 minutes for three sets of exercise and recovery. The subjects conducted walking on the treadmill with 4km/h during the exercise, and they took a comfortable sitting posture during the rest. During 80 minutes of the experiment, temperature, humidity, oxygen intake, and heart rate (HR) inside the clothes were measured subsequently. All physiological measurement items were automatically recorded with 0.5 minute interval, and the subjects answered the questionnaire at six points in time in terms of subjective sensation at rest starting point, rest ending point, exercise 1, 2, and 3 ending point, and recovery 3 ending point. Table 5 shows the overall protocol of the experiment.

Table 5. Experimental procedure and protocol

Total: 80min	-	15	10	10	10	10	10	15
Item \ Step	Preparation	Rest	Exercise	Recovery	Exercise	Recovery	Exercise	Recovery
Wearability test	○							
Microclimates inside clothing		○	○	○	○	○	○	○
Heart rate (HR)		○	○	○	○	○	○	○
Oxygen uptake		○	○	○	○	○	○	○
Subjective sensations		○	○	○	○	○	○	○

To evaluate workers' responses to the developed livestock working clothes, farms were visited in this study. For onsite evaluation, the subjects were instructed to wear the developed working clothes, and carried out the sensory test movements of Kim (2002), and then subjective sensation and satisfaction with wearing were evaluated. This study evaluated five subjective sensations (material performance, functionality, safety, aesthetics, and sense of belonging) (Oh et al., 2014; Hwang et al., 2013) and five items for satisfaction with wearing (wearing sensation, ease of movement, comfortability, ease of dressing, and ease of undressing) (Kim et al., 2006). The opinions and needs of the developed working clothes were collected after the evaluation.

4. Results and Discussion

4.1 Laboratory environment evaluation

4.1.1 Wearability test

As a result of wearability evaluation on major movements after wearing the working clothes, the satisfaction with each body part of the two types of working clothes was higher than 4.0 (Figure 3). Upon looking at by body part, 4.19±0.13 and 4.63±0.32 were shown in the developed working clothes and dustproof clothes, respectively, in the arm's vertical movement. 4.19±0.24 and 4.56±0.13 were shown in the developed working clothes and dustproof clothes, respectively, in the arm's horizontal movement. 4.69±0.38 and 4.88±0.25 were shown in the developed working clothes and dustproof clothes, respectively, in the waist movement. 4.25±0.61 and 4.69±0.38 in the developed working clothes and dustproof clothes, respectively, in the leg movement. Although existing dustproof clothes showed higher scores overall than the newly developed clothes, no statistically significant differences were shown. Such a result showed almost no differences from the existing dustproof clothes made in consideration of physical activity range, and thus the newly developed working clothes can be judged at satisfactory level. However, the newly developed working clothes showed less than 4.0 in L-3 posture in the leg movement, and therefore correction considering the squatting posture seems to be needed.

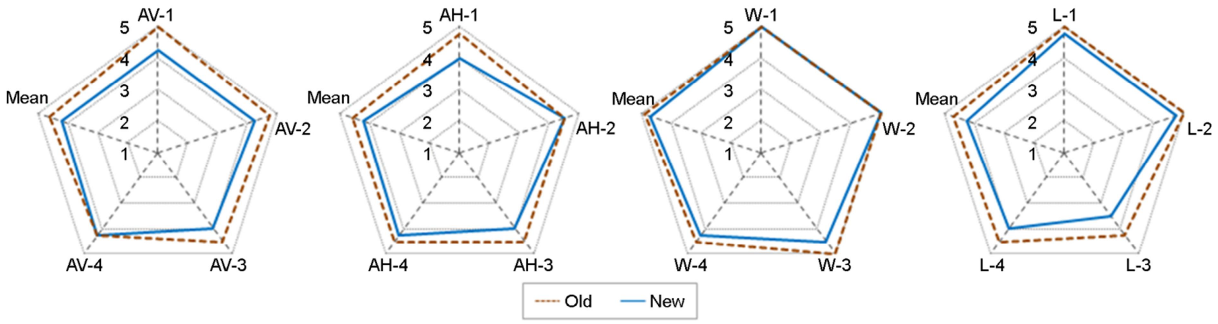


Figure 3. Sensory test about movement of body

4.1.2 Physiological responses

Microclimates inside clothing

As a result of measuring temperature and humidity inside the clothes around the chest and thigh, the temperature and humidity were 30.76±0.48℃, 60.85±13.92%RH and 30.52±0.52℃, 55.53±10.16%RH on average around the chest inside the dustproof clothes and the developed working clothes, respectively. The temperature and humidity were 30.73±0.80℃, 59.86±13.06%RH, and 29.68±0.66℃, 54.34±10.05%RH on average around the thigh inside the existing dustproof clothes and the developed working clothes, respectively (Figure 4). Although there was no statistically significant difference was shown between the working clothes in terms of temperature change amount comparison around the chest, humidity showed statistically significant difference ($p<$ .0001). According to the temperature and humidity change amount comparison result around the thigh, both temperature and humidity showed statistically significant differences ($p<$ .0001). Additionally, during the task performance for 80 minutes, as a result of humidity change analysis inside the working clothes, statistically significant differences were shown between the new working clothes and existing dustproof clothes from the Recovery 1 section to the ending point around the chest and thigh ($p<$ .05). However, temperature change did not show statistically significant differences by section. The reason why such a result was shown is that the newly developed working clothes appear to discharge heat and perspiration generated from the body quickly, since the air permeability of the material of the newly developed working clothes is higher than the existing dustproof clothes. Namely, the developed livestock working clothes is conjected to be more effective to the reduction of high temperature and humidity stress. The experiment randomly reenacted the same environment, and therefore the temperature and humidity are expected to be higher inside the clothes in the poor livestock working environment.

Heart rate

Figure 5 shows heart rate change amount. As a result of heart rate measurement, the mean heart rate of the existing dustproof clothes showed 96.14±6.49bmp, and that of the developed working clothes was 92.96±6.39bmp, and statistically significant difference between the working clothes were shown overall ($p<$ .001). Regarding the differences during the recovery and exercise periods, the heart rate and stroke volume are judged to increase to raise thermal radiation inside body in terms of high temperature and humidity stress during the task performance. Heart rate shows a positive relation with energy consumption (ISO 8996, 1986), and it can be measured the most easily. Heart rate is used to estimate energy consumption (Song et al., 2005). When the result above is calculated into energy consumption using heart rate, it was 3.71kcal/min for the existing dustproof clothes, and it was 3.32kcal/min for the developed working clothes, which reveals that the newly developed working clothes' energy consumption is smaller. Even though heart rate does not sensitively respond in the state that high temperature and humidity stress is not relatively high, it is a main factor to identify human body's physiological stress level (Newburgh, 1968). Through the experiment, the developed working clothes in this study was confirmed to be effective to the reduction of physical stress upon wearing the clothes. As a result

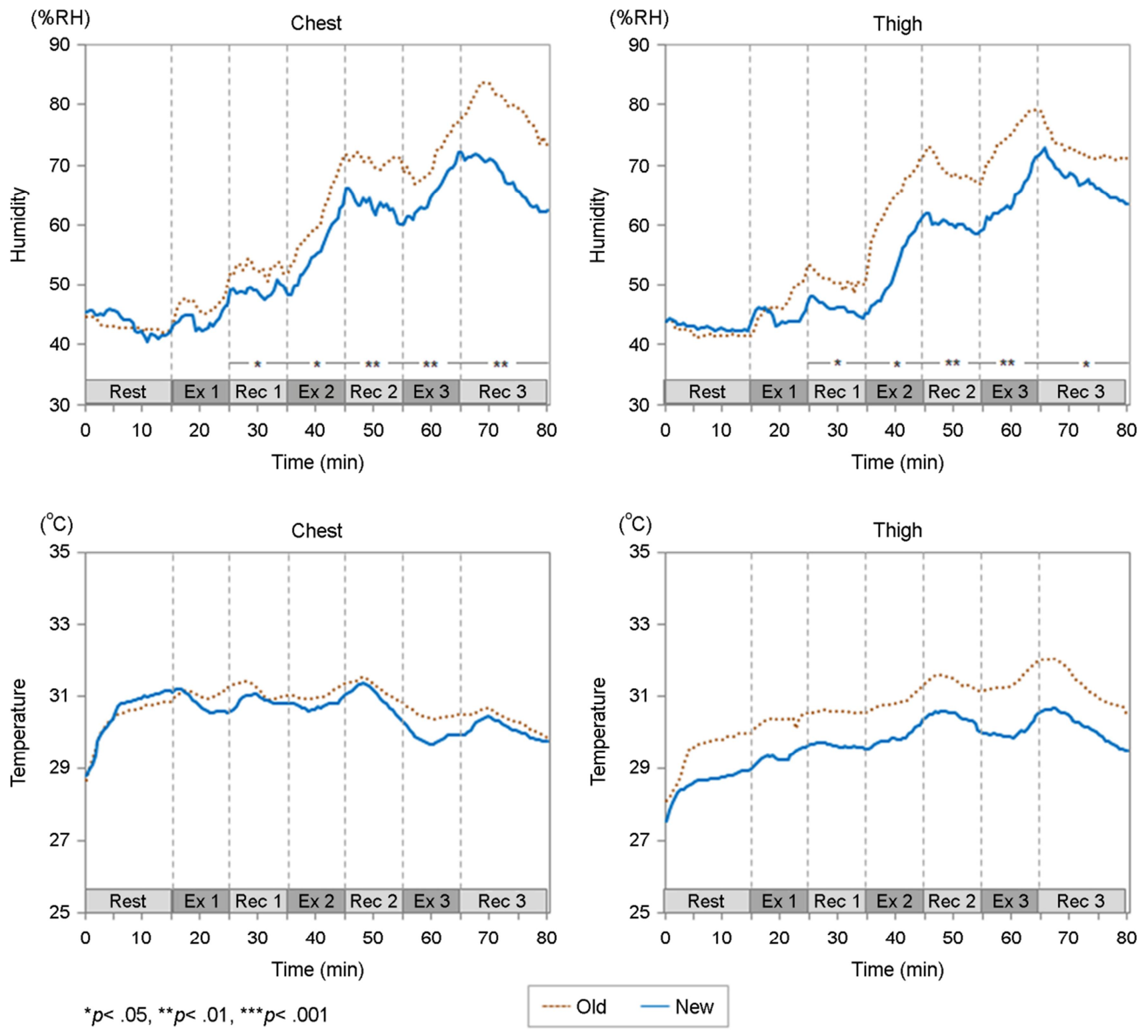


Figure 4. Clothing microclimate temperature and humidity during 80min

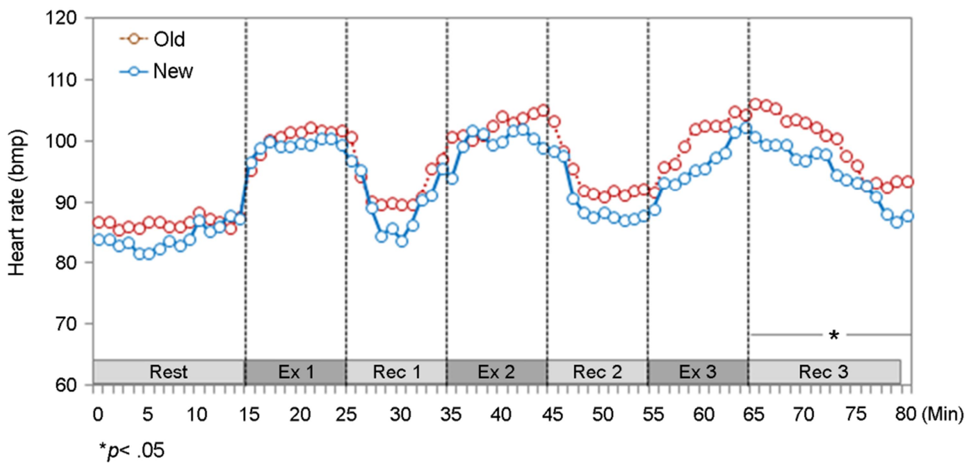


Figure 5. Heart rate during wearability test

of analyzing differences between the working clothes by task section, significant differences were shown in Recovery 3, and thus recovery time was reduced with wearing the new working clothes ($p< .05$). However, in the case of heart rate, the influence of workload and work intensity is big (Choi and Park, 2007), and the result cannot be assured to be the influence of clothes. Also, more time was measured in Recovery 3 than in Recovery 1 and Recovery 2, and therefore an additional study is judged to be needed taking into account sufficient recovery time in Recovery 1 and Recovery 2.

Oxygen intake

Figure 6 shows the result of mean oxygen intake according to exercise, after wearing the subjects wore the existing dustproof clothes and newly developed working clothes. The mean oxygen intake of the dustproof clothes and the newly developed working clothes were 562.70±256.02ml/min and 529.48±239.37ml/min, respectively, which showed statistically significant result ($p< .001$). As a result of analysis by task section, significant differences were shown in Exercise 1, Exercise 2, and Recovery 3 ($p< .05$). The mean intake of the existing dustproof clothes was 8.11ml/kg/min, and it was 12.47ml/kg/min during exercise. The mean intake of the newly developed working clothes was 7.63ml/kg/min, and it was 11.69ml/kg/min during exercise. If 3.5ml/kg/min of energy metabolic load in stability is 1METs (Metabolic Equivalents), the mean value of the dustproof clothes was 2.32METs, and it was 3.56METs during exercise. The mean energy metabolic load in stability of the newly developed working clothes was 2.18METs, and it was 3.36METs during exercise. If physical activity energy (calorie) is calculated on the basis of calorie consumption per liter of oxygen using the indirect calorimetry (Bahr and Sejersted, 1991), the mean value of the existing dustproof clothes was 2.81kal/min, and the mean value during exercise was 4.32Kal/min. The mean value of the newly developed working clothes was 2.65kal/min, and it was 4.057Kal/min during exercise. Aerobic energy production can be precisely estimated relatively by measuring oxygen intake (Wilmore and Costill, 2004). Namely, all the results above show that more energy is consumed, if a person conducts the same work wearing the existing working clothes. This means that working clothes can be a cause of reduced work efficiency or fatigue (Kim and Kim, 2008). Although, there was some difference in oxygen intake during the exercise, the oxygen intake in Recovery 1 and Recovery 2 was similar in the two types of working clothes. However, difference was shown in Recovery 3 between the two types of working clothes.

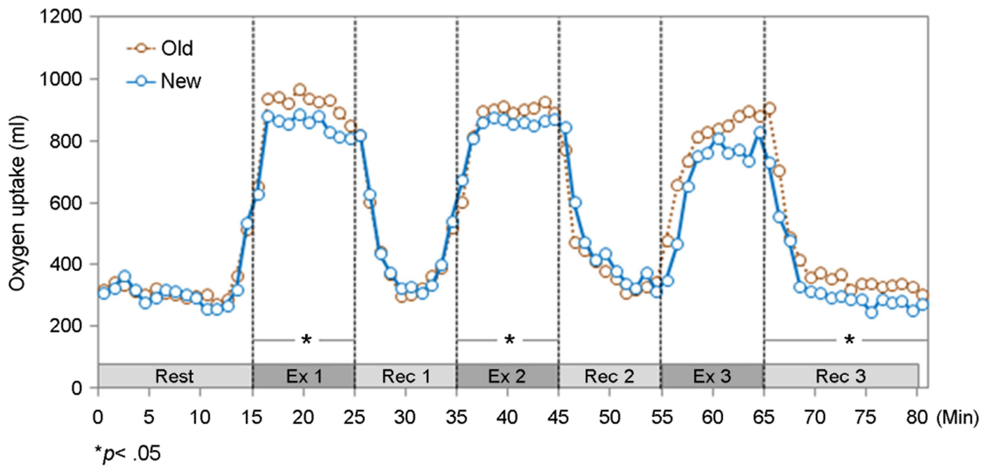


Figure 6. Oxygen intake of two types of experiment clothes

4.1.3 Subjective sensations

In the experiment, four subjective sensations in wearing were measured during the experiment. Figure 7 shows responses according to time passage. Although significant differences were shown in thermal, humidity, and comfort sensations, no significant difference was shown in pressure sensation. The thermal sensation was 2.00±1.15 and 1.37±0.93 in the cases of wearing the existing dustproof clothes and the newly developed working clothes, respectively (p< .05). The sensation of humidity was 3.17±0.74 and 3.70±0.72 in the cases of wearing the existing dustproof clothes and the newly developed working clothes (p< .05). The sensation of comfort was 1.53±0.52 and 1.23±0.46 in the cases of wearing the existing dustproof clothes and the newly developed working clothes, respectively. Therefore, the livestock farmers felt cooler and more comfortable, when they wore the newly developed working clothes (p< .001). Concerning the thermal and humidity sensations, that more differences were shown, as wearing time was longer, can be consistent with the measurement results of temperature and humidity inside the clothes. Regarding the sensation of pressure, there was no difference between the working clothes, which means there was no discomfort on movement by body part upon wearing the working clothes. Such a result is consistent with the sensory test result of wearing. From the results above, the newly developed working clothes is more effective from the aspect of heat discharge inside the clothes, which implies that high temperature and humidity stress caused upon working in the inside of high temperature and highly humid pigpen or cattle shed environment can be reduced.

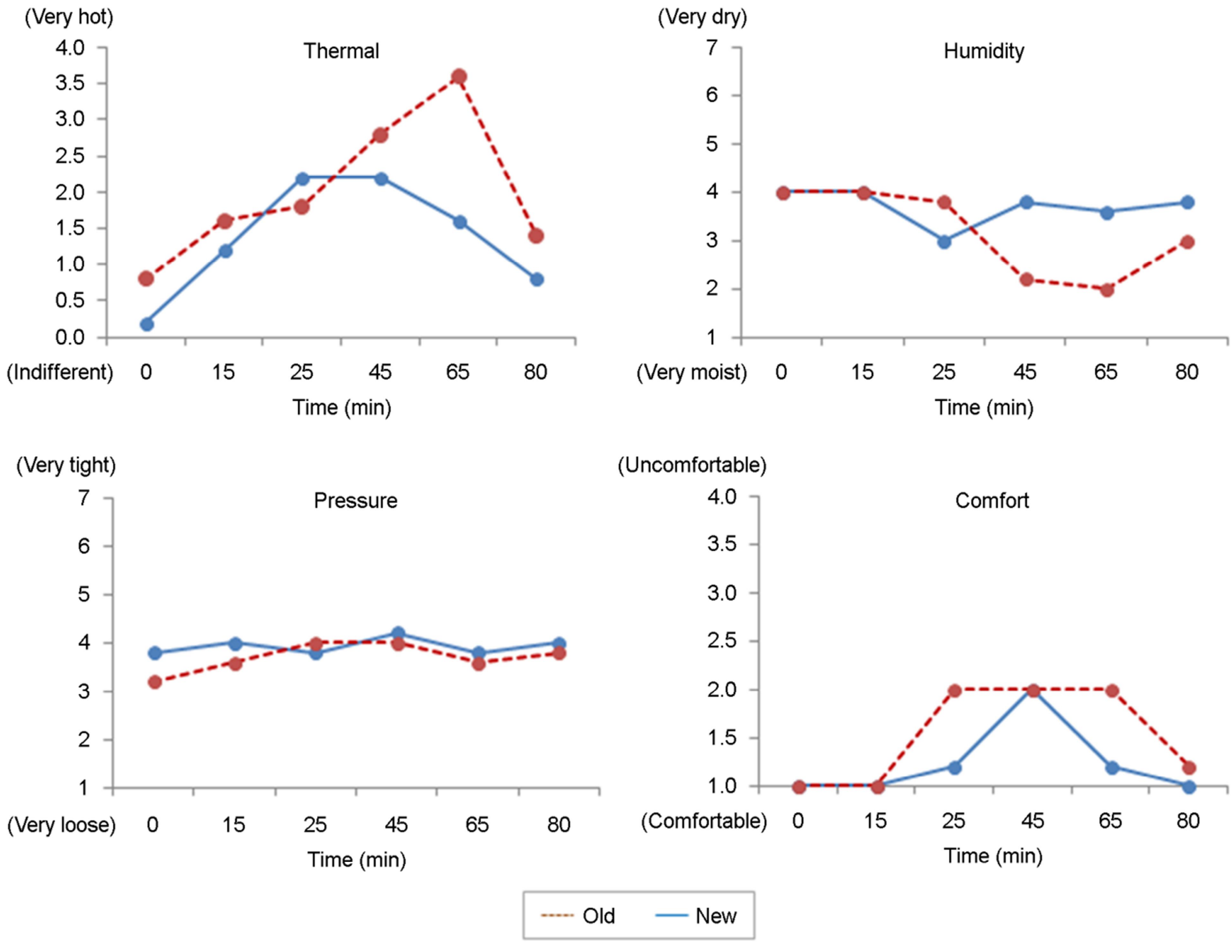


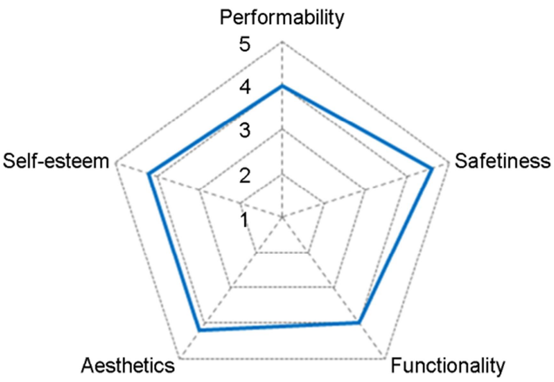
Figure 7. Subjective sensations (thermal, humidity, pressure, and comfort) during 80min

4.2 Evaluation of field wearability

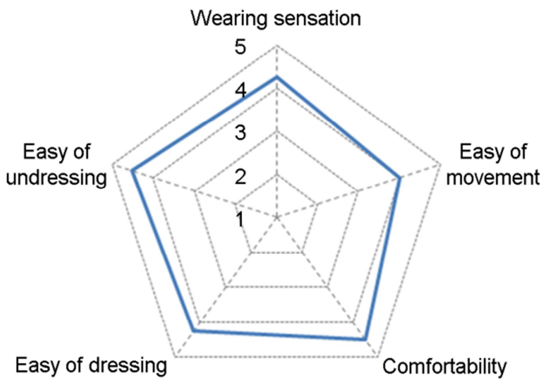
To identify the comfort and satisfaction of wearability felt by field farmers on the developed working clothes, this study carried out evaluation targeting field livestock farmers. Six livestock farmers (age: 54±5, height: 170±0.5, and weight: 68±2.4kg) were instructed to wear the developed working clothes, and wearability and satisfaction evaluation was conducted. Their mean service years in the livestock industry was 18±3.4 years. Figure 8 shows the scenes evaluating the working clothes by visiting a farm.

Figure 8. Field wearability test

According to the subjective wearability evaluation result, higher than 4.0 was shown in all items, and safety (protection) aspect showed 4.5 points, and thus quite satisfactory result was shown. The reason seems that knee protective material was used to prevent collision/contact accidents with obstacles upon moving within the cattle shed or pigpen. In the evaluation of satisfaction with wearing, all five items showed higher than 4.0 points, which was satisfactory level. The east of movement was relatively lower, compared to other items, and the reason is that the subjects were not familiar with the protective fabric material attached to major parts (knee, elbow, and hip) to protect body. Such a result is judged to affect the squatting posture (L-3) in the sensory evaluation of wearing. More comfortable movement needs to be offered through correction on the protective fabric material and its size in the future. Figure 9 shows subjective sensory evaluation result.



a) Subjective satisfaction



b) Wearability

Figure 9. Subjective satisfaction and qearability

5. Conclusion

This study was conducted to develop working clothes used in spring and autumn suitable for the livestock farming environment. To this end, this study reviewed the harmful and hazardous factors, safety and health situation, and literature related with working clothes of the existing livestock workplaces and defined the required performance for working clothes design. Based on the performance required for the development of livestock working clothes, this study made working clothes for spring and autumn. To analyze the suitability of wearing the developed working clothes, this study conducted a sensory test, a physiological response experiment, and an evaluation on satisfaction targeting field livestock farmers.

Upon looking at the study results, the developed working clothes made in consideration of physical activity scope sufficiently was evaluated to have no difference from the existing dustproof clothes from the sensory aspect of wearing in comparison with the existing dustproof clothes, which can be at satisfactory level. The microclimate (temperature and humidity) of the developed working clothes was lower than that of the existing dustproof clothes in the physiological response experiment, and the former was confirmed to be more effective to the reduction of high temperature and humidity stress. In the heart rate and oxygen intake measurements, the developed working clothes' energy consumption was remarkably lower than the existing dustproof clothe, and thus the work efficiency of the developed working clothes was higher. In the subjective sensation, the thermal, humidity, and comfort sensations showed satisfactory levels. Also, positive results on the wearability and satisfaction of field livestock farmers on the developed working clothes were acquired. Especially, very positive responses were shown on the protective material attached to major body parts to protect human body for agricultural work safety, which is expected to effectively function for safety accident prevention.

From the results above, the livestock working clothes for spring and autumn developed in this study showed excellence in the physiological and subjective evaluation, compared to the existing dustproof clothes. In this regard, the developed working clothes can be utilized for comfortable livestock farming activities. The protective fabric material applied for accident prevention by collision/contact with obstacles and animals and its function seem to contribute to safe livestock farming work for livestock farmers. However, the improvement in the ease of movement according to protective material and function application appears to be needed in the sensory evaluation of wearing and livestock farmers' satisfaction survey. This study was carried out, centered on the evaluation on the farming workers' wearability and high temperature and humidity stress. Therefore a safety evaluation aspect was slightly ignored, and there can be a limitation in that actual livestock farming environment was not adequately considered, because the experiment was performed in a steady temperature and humidity room. For the livestock working clothes for spring and autumn to be applied to real life, more realistic effect validation should be carried out in the livestock sites. Lastly, this study is expected to be the basic data to prevent livestock farmers' high temperature and humidity stress and safety accidents.

Acknowledgements

This work was carried out with the support of "Cooperative Research Program for Agricultural Science & Technology Development (Project No. PJ00867807)" Rural Development Administration, Republic of Korea.

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