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A Study on the Physiological Properties of Skating Players : Skin Temperature and Clothing Temperature in Body Parts

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Abstracts : This study was conducted to find out the relationship between skin temperature and clothing temperature in body parts. Four different kinds of fabrics were used in this experiment. These fabrics were a (Ny/Spun, 81.8/18.2%), b (Wool/Poly/span, 50/45/5%), c (Wool/Ny/Span70/25/5) and d (Wool/Poly/Span 45/45/10%). The subjects skated at indoor ice rink where the length was 111.12 m, the temperature was 11± 1°C and the humidity was 70± 10%. The four an male professional skaters' speed was 17± 1 sec/m/lap. Physiological parameters were skin temperature at 4 body points (chest, upper arm, thigh, leg) and clothing temperature at chest was measured every 15 second. Experiment protocol was as follows: resting before skating (5 min.), skating (5 min.), and resting after skating (10 min.). The results were as follows; The mean skin temperature by fabrics shows b > a > d > c. The mean skin temperature began to decline little by little as soon as the subjects entered the indoor ice rink. After they rested for five minutes, they started skating and the mean skin temperature declined widely. After skating, the mean skin temperature increased step by step. It maintained the similar temperature. The value of skin temperature at body points shows Leg > Chest > Upper arm > Thigh. Because of the characteristics of skating uniforms, the skin temperature of the leg is the highest. The skating uniform was designed to have a protective portion in the leg. The chest produces the highest temperature in the body. The comparison of difference values in skin temperature show Thigh > Upper arm > Chest > Leg. While skating in a cold atmosphere, the largest difference value is clothing temperature. The clothing temperature is lower than the skin temperature during skating. The difference value of clothing temperature is larger than the skin temperature of the chest.

Key words : skin temperature, clothing temperature, skating uniform

INTRODUCTION

Clothing is an important element because it influences the control of human beings' temperature. It helps people live in a comfortable atmosphere since clothing exchanges heat between body and environment. Exchanging heat makes human beings comfortable and enables them to act freely.

Especially, body temperature is affected by clothing. Human beings' skin is influenced by temperature and humidity. It is important to maintain a comfortable climate in clothing.

Besides that, a person's emotional aspect plays an important role in creating a comfortable micro climate.

A person's emotion integrates internal and external stimulus. It varies according to the person. That is the reason why it has very personal and dynamic characteristics. If the person has internal and external feelings, s/he experiences physiological change.

People feel comfort able in extreme environments because of the development of special clothing. It makes it possible for people to work effectively in different environments.

These days, people are interested in sports and other leisure activities. It is necessary to develop suitable and comfortable sportswear, accessaries and gears. For these reasons, researchers are interested in studying these areas. They are exchanging ideas with athletes and people who like sports. The creative design of sports uniforms encourages athletes to work better. For example, a skater skates faster, a marathoner reduces running time and soccer players play better.

Nowadays, uniforms made with the new comfortable and functional fabrics have been developed and worn by athletes and people who like sports. It improves the quality of sports wear. Choosing new fabrics and design is important in the aspect of visual and functional effects. Athletes and people who like sports may feel comfortable when they wear new uniforms.

Sports needs a kind of scientific approach because fabrics and designs play an important role in playing better for athletes and people who like sports. That is why we need to develop comfortable fabrics, new clothing and new functional patterns for wearables

Customers need higher quality and sensitive design of clothing. Athletes and people who like sports want to

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wear sportswear which help them play and accomplish their goals to the best of their ability.

Sportswear needs the following functions: technical movement, physiological comfort, psychological comfort, safety and endurance.

Therefore, the role of clothing is important for maintaining comfortable situational environment because of the thermal balance in all kinds of sports. The functional aspect of clothing is important to improve body operation because it emphasizes activity

The heat production during exercise is equal to the quantity and the time of exercise. The temperature caused by body heat is exchanged with the atmosphere. The loss of heat depends on exercise time, at mospheric humidity and temperature and clothing (Fox & Mathews, 1981).

Especially, when people exercise in a cold environment, they have to consider sportswear in two opposite aspects. These are the increase and decrease of body temperature while they exercise.

On the other hand, in the wearable aspect of sportswear, it needs to be built with a clothing pattern construction which does not interfere with stretching the surface of the body to maximize activity without any inconvenience.

Comfort and discomfort as a result of exercise in the cold or hot weather are related to the skin temperature, core temperature and sweating. Especially, the change of the skin temperature is closely related to the cold sensation. On the other hand, cold temperature is closely related to the warm sensation.

Therefore, we have to find out that how the difference in fabrics characteristics influences physiological change and assessment of the wearable.

To develop comfortable sportswear which suits the purpose of exercise, we are concerned with two points : the kind of exercise and exercising temperature. The longer they exercise, the more they increase their body temperature and the more they sweat. It causes physiological problems so that we need to develop new products to solve these problems.

According to research, the most comfortable clothing temperature is about 32± 1°C, humidity 50± 10%RH, air current 25± 15 cm/sec (Harata, 1982). However, according to other research, if people repeat edly exercise and rest, they feel uncomfortable in the above atmosphere because of heat production as a result of exercise (Martz 1983).

It is not known how comfortable clothing affects temperature during different kinds of exercise and we need to study about this area to create comfortable sportswear.

The purpose of this study is to develop comfortable skating uniforms for cold environments. I developed skating uniforms with four different fabrics and conducted a field test with four male professional skaters in the ice rink. I want to find out thermal comfort properties of skaters. I also wanted to find out the change of skin temperature in cold weather while they are exercising and resting. The result of this study will provide opportunities for further studies.

EXPERIMENT

The subjects

The subjects are four male professional skaters with four or five years of skating experience. They have been in the same team during the experiment so that they have similar physiological characteristics. Table 1 shows the physical characteristics of the subjects.

Uniforms for the experiment

The uniforms for the experiment are made with four different fabrics. One of them is the fabric which the skaters have chosen when they have skating competitions. The other three uniforms were developed by the researcher. The skaters complained about some problems because the former uniforms had uncomfortable elements. The researcher supplemented the weak points and developed new fabrics.

The skaters are supposed to wear helmets, gloves, skating shoes without wearing socks, and skating uniforms designed as one piece. All the experiments were conducted under the same conditions.

Table 2 shows the characteristics of fabrics for experiment.

Table 1. Physical characteristics of subjects

Sex	Subject	Age (yr)	Height (m)	Weight (kg)	B.M.I* (kg/m^2)	B.S.A** (m^2)	Exercise career (yr)
M	T.Y	15	154.7	40	16.71	1.34	4
M	K.D	16	161.4	53.5	20.54	1.57	5
M	Y.M	16	152	40	17.31	1.33	5
M	H.I	17	170	55	19.03	1.65	5

*Body Mass Index : Weight/$Height^2$× 10,000

**Body Surface Area : Weight $^{0.425}$× $Height^{0.725}$× 72.46 10,000

Table 2. Characteristics of experimental fabrics

Mark	Sample	Blend ratio (%)
a	Nylon single span	Ny/Span 81.8/18.2
b	Wool Single Span Zurry	Wool/Poly/Span 50/45/5
c	Wool Single Span	Wool/Ny/Span 70/25/5
d	Wool Cushion Span	Wool/Poly/Span 45/45/10

Table 3. Experimental protocol

Preparation		Experimental room : Ice rink				
		Time (min.)	5	5	5	5
Time (min.)	20	Accumulated time (min.)	5	10	15	20
Resting after preparation		Posture	Rest sitting	Exer-cise	Rest 1 sitting	Rest 2 sitting
Condition: 28± 1°C 70± 10%		Condition : 11± 1°C, 70± 5% Speed : 17± 1 sec/ lap Track length : 111.12 m/lap				
Take on sensor and one's sample skating uniform		Measure skin temperature Clothing temperature (every 15 sec)				

Methodology

Table 3 shows the experimental protocol.

The subjects wore skating uniforms. gloves, helmet and skating shoes, with skin temperature sensors in the preparation room at temperature 28± 1°C, humidity 70± 5%.

After the subjects rested 20 minutes, they entered the ice rink at 11± 1°C, 70± 5%. They skated at the speed 1 ± 71 sec/lap and the length of track was 111.12 m/lap.

The experimental method was that the subjects rested for five minutes, skated for five minutes and rested again for ten minutes.

To avoid prejudice, the subjects wore the uniforms randomly (Randomized Block Design).

Experimental items

Skin temperature: The four points (chest, left upper arm, thigh, left leg) were measured by Thermistor every 15 seconds.

Clothing temperature: Micro temperature between body and clothing at chest was measured every 15 seconds.

Mean skin temperature: The researcher calculated as follows :

0.3 Ttrunk + 0.3 Tarm + 0.2 Tthigh + 0.2 Tleg (Tamura, 1989)

Method of Analysis about the Results of Experiment

The statistical tool used in this experiment was SPSS.

RESULTS AND DISCUSSION

Skin temperature

Mean skin temperature : Fig. 1 shows mean skin temperature every 15 second depending upon the kinds of fabrics used during the experiment. The mean skin temperature shows the same tendency in all fabrics throughout the experiment. Expecially, fabric 'b' had a higher

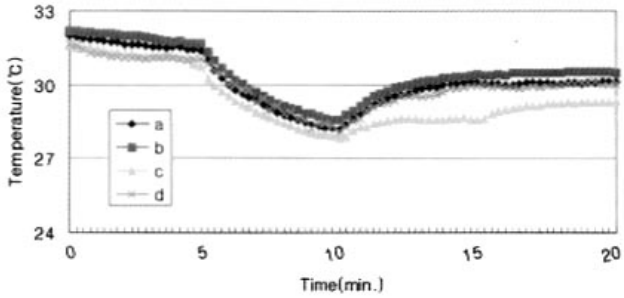


Fig. 1. Mean skin temperature by fabrics.

mean skin temperature than the other fabrics. The order of mean skin temperature was fabric 'b' 'a' 'd' 'c'.

The mean skin temperature of fabric 'b' was 30.4± 61.15°C, fabric 'a' 30.11± 1.08°C fabric 'd' 29.94± 0.91°C fabric 'c' 29.40± 1.16°C.

The mean skin temperature began to decline little by little as soon as the subjects entered the ice rink. After they rested for five minutes, they started skating and the mean skin temperature declined widely. After skating, the mean skin temperature increased step by step and it maintained the similar temperature.

When the subjects entered the cold environment, their skin temperature declined because of the heat balance. However, while the subjects were skating, their body produced heat because they were exercising. The heat did not appear during the exercise because they skated in the cold environment. That was the reason why the mean skin temperature decreased widely. After they skated, the result of heat production appeared so that their mean skin temperature increased about two minutes. When the subjects were exposed to the cold environment, their body heat did not increase any more.

Fig. 2 shows the mean skin temperature with integrated fabrics. The mean skin temperature was 31.84°C when they entered the ice rink for the first time. The temperature declined to 31.21°C. After they skated for five minutes, the temperature declined to 28.17°C. After they rested for 10 minutes, the mean skin temperature was

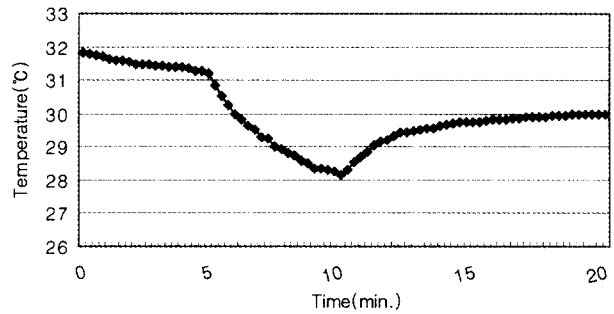


Fig 2. Mean skin temperature by whole fabrics.

restored to 29.99°C.

In other words, the body adjusts automatically in the cold environment so that the body skin temperature begins to go down slowly by 0.63°C. After they skated for five minutes with a speed of 17± 1 sec/lap, the skin temperature was reduced by 3.04°C widely. After they took a rest for 10 minutes, the skin temperature increased by 1.8°C 2little by little due to the quantity of exercise.

The researcher found out that the mean skin temperature did not return to the original temperature. If the subjects are exposed to a cold environment continuously, the loss of body temperature will be continued. Because of the result, the heat balance of the body has not been controlled. The people might end up in critical condition with hypothermia. Comfortable and functional clothing is very important to overcome this situation; it can be a life and death situation.

The change of skin temperature at the body points : In this study, the researcher tried to find out physiological properties of skating players without dividing the fabrics. When skating, it is important to find out the changes of skin temperature in body parts, because the researcher needs the data to develop comfortable skating uniforms.

Fig. 3 shows the skin temperature on the chest. Fig. 4 shows the skin temperature at the upper arm. Fig. 5 shows the skin temperature at the thigh. Fig. 6 shows the skin temperature at the leg. The results of skin temperature were the mean 30.18± 1.47°C at chest, 29.4± 71.26°C at upper arm, 28.42± 1.32°C at thigh, 32.56± 0.29°C at leg, the mean skin temperature is 29.98± 1.04°C.

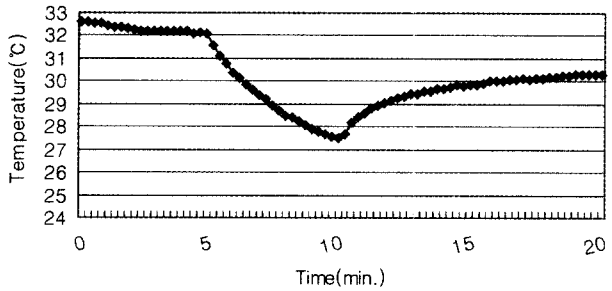


Fig 3. Chest temperature by whole fabrics.

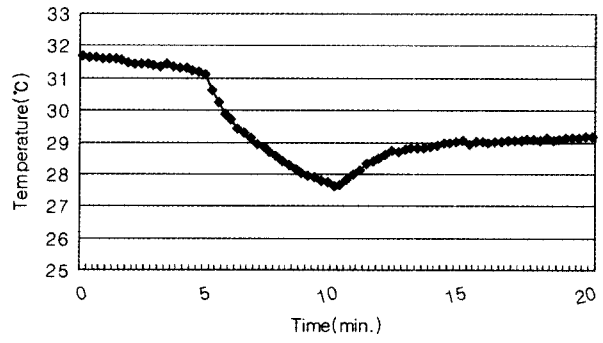


Fig 4. Upper arm temperature by whole fabrics.

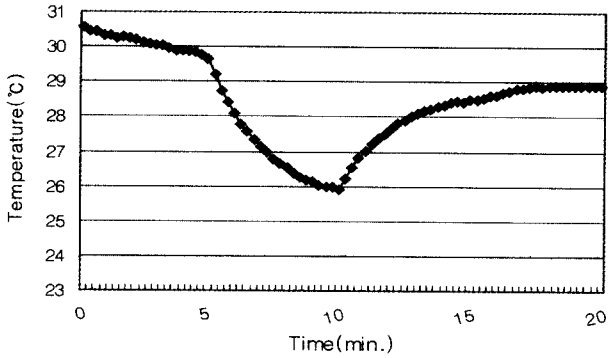


Fig. 5. Thigh skin temperature by whole fabrics.

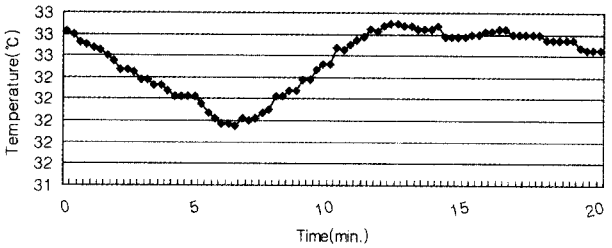


Fig. 6. Leg skin temperature by whole fabrics.

As the result, the skin temperature of the leg is higher than any other body points followed by chest, upper arm and thigh.

Because of the characteristics of the skating uniform, the skin temperature of the leg is the highest. The skating uniform was designed to have a protective portion in the leg.

The chest produces the highest temperature in the body.

It is recommended that when we design skating uniforms, we have to consider the above result. It means that the part of chest is influenced easily by the environmental temperature. The researcher suggests that it will be a good idea to use a different fabric in the chest for the better functional heat exchange.

Fig. 7 shows comparison of the effects of skin temperature by body points. The thigh part was the lowest during the experiment. It had the same tendency in the beginning of the experiment.

The comparison of skin temperature before exercising, while exercising, after exercising

Fig. 8 shows the comparison of skin temperature before exercising, while exercising and after exercising. In Fig. 8, we can see that the leg had the highest temperature followed by upper arm, chest, and thigh. This is the same tendency which we have seen in the beginning.

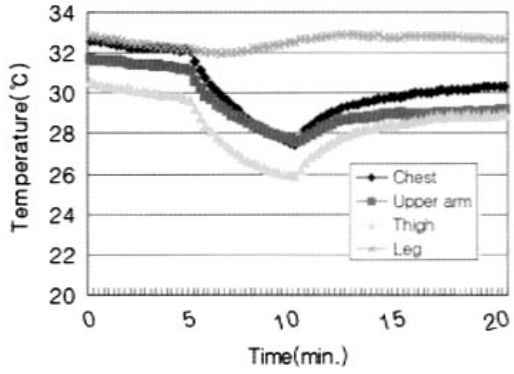
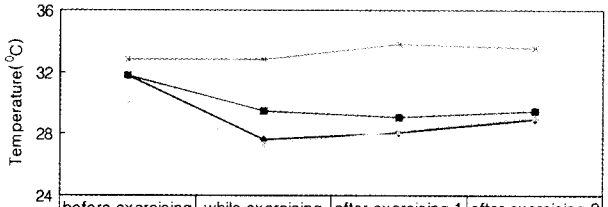


Fig. 7. Comparison of the effects of skin temperature by body parts.



	before exercising	while exercising	after exercising 1	after exercising 2
C	31.76	27.60	28.09	28.96
U	31.77	29.50	29.09	29.49
T	30.19	27.33	28.18	29.05
L	32.81	32.81	33.80	33.57

Fig. 8. Comparison of mean skin temperature before exercise, while exercise and after exercise.

Only the leg temperature was higher than the beginning. When they entered the ice rink, they rested for five minutes: the chest was 31.76°C, the upper arm was 31.77°C, the thigh was 30.19°C, the leg was 32.81°C. When they were skating: the chest was 27.60°C the upper arm was 29.50°C, the thigh was 27.33°C, the leg was 32.81°C. After skating, they rested for five minutes: the chest was 28.09°C, the upper arm was 29.09°C, the thigh was 28.18°C, the leg was 33.80°C. And then they rested for five minutes again.: the chest was 28.96°C, the upper arm was 29.49°C, the thigh was 29.05°C, the leg was 33.57°C.

Fig, 9 and 10 show the change of mean skin temperature before exercising, while exercising and after exercising. We can see the skin temperature went down drastically while exercising. It means that the temperature varies depending upon fabric property, for example, thermal property, thermal insulation, etc.

It is important to wear good sportswear for players to have good records. If the players feel comfortable in their uniform before exercising and while exercising, they can do their best. It is necessary to make good uniforms which prevent the drastic or sudden loss of body heat.

Fig. 11 shows the decrease in temperature during the experiment on skin temperature and clothing temperature. In this figure, the longer the skaters are exposed to cold temperatures. the less difference in the leg, followed by chest, upper arm and thigh. The clothing temperature showed the biggest difference.

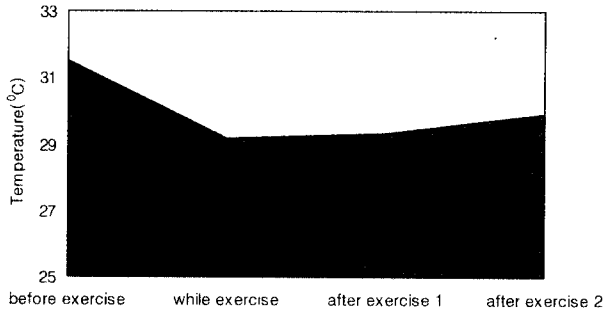


Fig. 9. Comparison of the effect of mean skin temperature through exercise before and after.

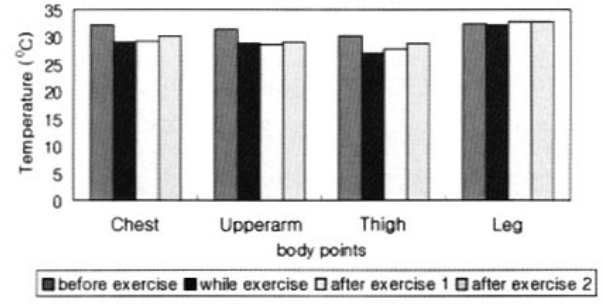


Fig. 10. Skin temperature during before exercise, while exercise and after exercise on body points.

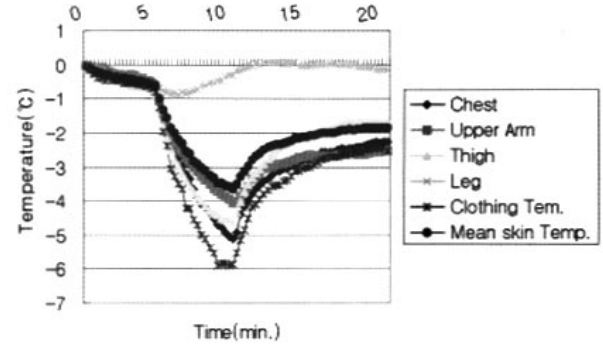


Fig. 11. Decrease temperature during experimental time on skin temperature and clothing temperature.

As we discussed before, the skin and clothing temperature at chest show the big difference. As the same result, it is considered that if we design and choose special fabric for the chest, we might create more comfortable uniforms for players.

We might also create comfortable uniforms if we decrease the difference of the skin and clothing temperature at the

Table. 4. One sample T-test of difference value in skin temperature and clothing temperature

	before exercising		while exercising		after exercising 1		after exercising 2	
	M	SD	M	SD	M	SD	M	SD
Chest	-0.32*	0.15*	-3.54*	1.25*	-3.4*	0.61*	-2.45*	0.14*
Upper Arm	-1.17*	0.16*	-3.83*	0.88*	-4.01*	0.42*	-3.52*	0.15*
Thigh	-2.51*	0.23*	-5.60*	1.00*	-4.86*	0.68*	-3.81*	0.13*
Leg	-0.15*	0.19*	-0.42*	0.19*	0.21*	0.01*	0.17*	0.01*
Clothing Temp.	-1.87*	0.18*	-5.77*	1.42*	-5.2*	0.74*	-4.02*	0.15*
Mean Skin Temp.	-1.12*	0.16*	-3.44*	0.81*	-3.28*	0.42*	-2.69*	0.02*

*p<.05

chest. We should consider the above facts seriously. The researcher suggests some ideas. For example, while skating, the skaters bend forward and their collars loosen so that the wind hits their chests. We should make the collar tighter and the back part longer with a shape like an arch. On the other hand, the front part should be shorter. We should choose fabrics which have more elastic properties. We have to consider the stretch of the body when we plan clothing construction. Another suggestion is that we have to use same fabrics for upper arm, thigh and leg. We have to use different fabrics for trunk. because the former and the latter have the different tendencies. They will supplement each element.

Table 4 is about one sample T-test of difference value in skin temperature and clothing temperature. The difference value is that the subtraction of change value of skin temperature by time from the skin temperature at the moment of the experiment.

It is accepted the difference at p<.05. Table 4 has the same result with Fig. 11. Especially, the skin temperature on the thigh decreased by 2.51°C before exercising. During exercising, the skin temperature decreased by 5.60°C. Thigh temperature may not be related to the assessment of comfortable uniforms. In further research, it is recommended to study how the difference value of thigh temperature is related to the comfortable feelings of the skaters. The chest part is different from the thigh and did not decrease widely and suddenly because of the internal organs.

Even though the thigh temperature decreased widely, it might not matter for skating at some extent as long as it decreases extremely. There should be some studies about the limit of the temperature which the tensing of thigh muscles will not hinder skating

Clothing climate

Fig. 12 shows about clothing temperature at the chest. Before skating, the clothing temperature is 30.76°C, while skating, 26.84°C, 5 minutes after skating, 27.41°C, 10 minutes after skating, 28.58°C.

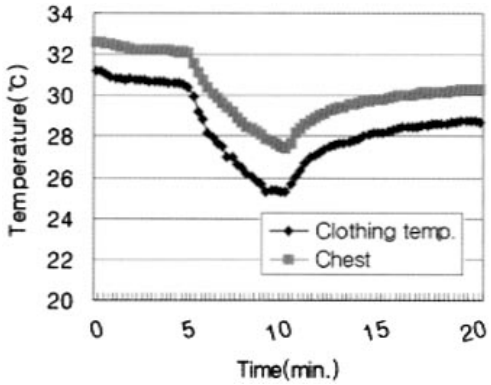


Fig. 12. Comparison of the effect of skin and clothing temperature at chest.

The decrease value is 3.92°C while skating and after 5 minute resting, 3.35°C, and after 10 minutes resting, 2.18°C.

Fig. 12 is about the comparison of the effect of skin and clothing temperature at the chest They have similar tendencies. 5 minutes before skating, the skin and clothing temperature at chest decreased by 3.92°C. Once they began skating, the clothing temperature decreased by 0.25°C more than the chest skin temperature. During 5 minutes rest after skating, the clothing temperature decreased by 0.3°C than the skin temperature.

After skating, the subjects rested for 10 minutes. At that time, the skin temperature went up at 0.01°C for the first 5 minutes but the clothing temperature went up at 0.55°C for the last 5 minutes.

The clothing temperature is lower than the skin temperature during skating.

CONCLUSIONS

This study was conducted to find out the relationship between skin temperature and clothing temperature in body parts. Four different kinds of fabrics were used in this experiment. The results of study can be used to develop comfortable skating uniforms for cold environ-

ments. I developed skating uniforms with four different fabrics and conducted a field test with four male professional skaters in the indoor ice rink. I want to find out the change of skin temperature and clothing temperature in cold weather while they are exercising and resting. The result of this study will provide the opportunity for further studies.

Clothing is an important element because it influences the control of human beings' temperature. It helps people live in a comfortable atmosphere since clothing exchanges heat between body and environment. Exchanging heat makes human beings comfortable and able to act freely.

Sports need a scientific approach because fabrics and designs play an important role in the performance of athletes and sports people. That is why we need to develop comfortable fabrics, new clothing and new functional patterns for wearables

Comfort and discomfort as a result of exercise in cold or hot weather is related to skin temperature, core temperature, and sweating. Especially, the change of the skin temperature is closely related to the cold sensation.

1. The mean skin temperature by fabrics shows b > a > d > c. The mean skin temperature began to decline little by little as soon as the subjects entered the ice rink. After they took a rest for five minutes, they started skating and the mean skin temperature declined widely. After skating, the mean skin temperature increased step by step and maintained similar levels.

When the subjects entered the cold environment, their skin temperature declined because of the heat balance. However, while the subjects were skating, their body produced heat because they were exercising. The heat did not appear during the exercise because they skated in cold temperatures. That is the reason why the mean skin temperature decreased widely. After they skated, the result of heat production appeared so that their mean skin temperature increased for about two minutes. When the subjects were exposed to the cold environment, their body heat did not increase any more.

2. The value of skin temperature on body points shows Leg > Chest > Upper arm > Thigh. Because of the characteristics of skating uniform, the skin temperature of the leg is highest. The skating uniform was designed to have a protective portion in the leg. The chest produces the highest temperature in the body. It is considered that if we design and chose a special fabric for the chest, we might create more comfortable uniforms for skater.

3. The comparison of difference values in skin temperature shows Thigh > Upper arm > Chest > Leg. While skating in a cold environment, the largest difference value is clothing temperature. The skin temperature of the leg shows a slight difference value. In case of the skin temperature of the leg, it was higher when skaters finished skating than when they began skating. The other parts of body skin temperature didn't recover from the skin temperature in the beginning.

4. The clothing temperature is lower than the skin temperature during skating. The difference value of clothing temperature is larger than the skin temperature of chest.

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