UTILIZATION OF AN ICE VEST AND ITS EFFECTS ON CORE BODY TEMPERATURE IN WHEELCHAIR RUGBY PLAYERS DURING A SIMULATED GAME SITUATION

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ABSTRACT

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Purpose: This study was conducted in order to examine the effects of an ice vest on core body temperature and performance among wheelchair rugby players during a simulated game in a moderate ambient temperature. **Methods:** Eight wheelchair rugby players (7 of them are among the level of C_5/C_6 to C_6/C_7, one has no spinal cord problem, because he has not lower arms and legs, he played in the wheelchair rugby team) exercised twice during a simulated game situation. One bout of exercise was performed with the ice vest to pre-cool down the subject's body, another bout of exercise was performed without an ice vest, in a moderate environment (22ºC). Core body temperature, blood lactate (BLa), the rating of perceived exertion (RPE), heart rate and 20m self-powered wheelchair rolling time were monitored. **Results:** No significant differences between the two exercise modes on core body temperature, BLa, RPE, heart rate and 20m rolling time were observed. **Conclusion:** The benefit of using an ice vest is limited because no decreased core body temperature or improved performance in wheelchair rugby players were observed during a simulated game situation.

Keywords: core body temperature, ice vest, moderate environment.

CONTENTS

1. INTRODUCTION

1.1 Body thermoregulation systems

Thermoregulation is defined as the ability of an organism to keep its body temperature within certain boundaries, even when the temperature in the surrounding environment is very different from the body. Thermoregulation is one of the important aspects of human homeostasis; it is a dynamic state of stability between internal environment and external environment. The spinal cord (figure 1), the main pathway for information connecting the brain and peripheral nervous system in human being, is divided into 31 different segments, 12 of which are thoracic segments (T_1--T_{12}). These thoracic segments are responsible for temperature regulation in body. Humans have been able to adapt to a great diversity of climates, including hot humid and hot arid. (Wong 2005)

Thermoregulation works like this: warm and cold sensors in the skin, as well as the core body areas, send information (input) to the central nervous system. This information is integrated in the hypothalamus of the brain. From there, the effector mechanisms (output) are set in motion either for heat production or for heat loss. How this central command system works is still under active investigation. Temperature regulation is often compared to the working of a thermostat – at a set temperature, the system clicks and heating or cooling starts. In homoeothermic animals and humans, temperature regulation is much more complex – regulation can occur at different temperature levels and at a range of temperatures. Also, during physical activity, body temperature can reach a plateau and then be regulated to maintain at that higher level. (Donhoffer 2008) The same is true in heat and cold adaptation, in fever, and during hibernation.

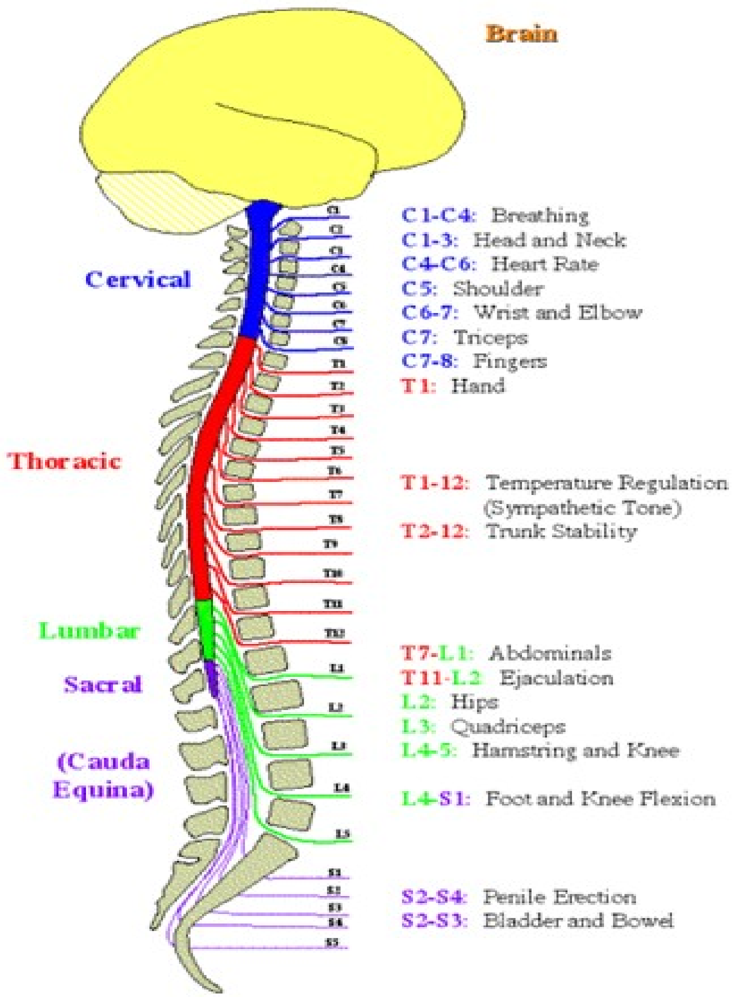


FIGURE 1. The schematic view of a spinal cord.

(http://www.reeve.uci.edu/anatomy/images/scns_1b.gif)

Thermoregulation does not work alone. It is also affected by nonthermal influences such as sleep, dehydration, blood glucose level, stress and emotions, endocrine factors, genetics, and certain medications. (Donhoffer 2008)

The temperatures measured in the axilla (arm pit), the mouth, inside the ear canal, or the rectum do not change as much as the temperatures taken on our fingers and toes. They represent the temperature of our core body (which includes the brain and the organs in the chest and belly), also known as core temperature. Core temperature is not constant, it changes within narrow limits. (Donhoffer 2008)

The normal core body temperature of a healthy, resting adult human being is reported to be at 37.0 degrees Celsius. The normal range of human body temperature varies due to an individual’s metabolic rate; the higher (faster) it is the higher the normal body temperature or the slower the metabolic rate the lower the normal body temperature. Other factors that might affect the body temperature of an individual may be the time of day or the part of the body in which the temperature is measured at. Body temperature is typically lower in the morning, due to the rest the body has received during the night, and higher at night after a day of muscular activity and food intake. Though the body temperature measured from an individual may vary, a healthy human body can maintain a fairly consistent body temperature that is around 37.0 degrees Celsius. (Glenn 2005)

To maintain core body temperature within a wide range of environmental temperatures requires a regulation mechanism. In the cold, heat loss is minimized and/or heat production is increased. In a hot environment or when excessive heat is produced by physical activity (work or exercise), heat loss mechanisms must be activated. Heat production and heat loss must also be in balance. The mechanism by which this balance is achieved is called thermoregulation. (Donhoffer 2008) Take hot environment for example, the body takes up heat from a hot environment. Heat production cannot be decreased below the basal metabolic rate, thus heat-loss mechanisms must be activated to prevent the increase of body temperature beyond its limit. When the blood vessels in the skin dilate, they allow large increase in skin blood flow and sweating ensues. Blood flow to the skin can reach up to between 6 and 8 L/min in comparison with 0.25 L/min at rest in a thermoneutral environment. This rise in body temperature is accompanied by an increase in the metabolic rate. For each 1°C increase in body temperature, metabolic rate increases by 14%. Sweating is an effective way to cool down body temperature: each gram of water evaporated from the skin requires approximately 0.6 kcal of energy, the amount of heat lost by the body. In an extremely hot environment, these regulatory mechanisms may fail. Large water and electrolyte loss by sweating and the strain on the cardiovascular system then might lead to heat stroke. (Donhoffer 2008)

During exercise and physical work, the muscles produce a large amount of heat. At the beginning of activity, heat production increases, and after a short lag of time, heat loss also increases. The balance between heat production and heat loss is restored, but the core temperature remains higher. After muscle activity stops, heat loss continues during the cool down period until the original body temperature is reached.

Working in a hot environment is challenging. At high temperatures, we feel that “it is too hot to move”. The large amount of heat produced by muscle activity is mainly dissipated by evaporation. The human body has a total of two to four million sweat glands that produce a large amount of sweat. A water loss of 4 L/h has been documented during exercising in hot conditions. It is not unusual to sweat 1.5 L/h, which amounts to 900 kcal of heat loss per hour, a figure that is calculated considering that the evaporation of 1L of sweat removes 600 kcal of heat from the body.

In dry weather, the sweat evaporates to achieve maximal cooling. As the relative humidity of air increases, less and less sweat evaporates. When the humidity reaches 100%, evaporation stops. In humid weather, sweat runs wn on our skin because it is not removed by evaporation at the same rate as it is produced on time. It is important to replace the water and salt lost in sweating because failing to do so may lead to heat stroke. (Donhoffer 2008)

1.2 Thermoregulation among people with spinal cord injuries

The spinal cord is the main information pathway between brain and peripheral extremes so, when the spinal cord is injured, information, including those related to motor, sense, and nerve, can not be transported.
For example, when there is an injury to the spinal cord, information on temperature from the limbs can not travel to the brain through the spinal cord. As a result, the brain can not instruct the temperature regulation system to adjust according to the change of temperature of extremes.

The level and completeness of spinal cord damage determine an individual's capacity to use their thermoregulation system, and also determines an individual's capacity to gain and lose heat. The capacity to produce heat is dictated by the amount of active innervated muscle mass. Because of a reduced centrally innervated muscle mass in spinal cord patients (people with SCI), their heat generating capacity is reduced. Furthermore, because the available area for sweating is related to the level and completeness of spinal cord injury, spinal cord patients' centrally driven sweating response will also be compromised. Basically there is no sweat response in the paralyzed area, so heat loss from a paraplegic individual is disturbed according to the level of the SCI. Generally, the higher the level of spinal cord injury, the more the core temperature increases during exercise and heat exposure (Masahiro et al. 2003). For example, in Price and Campbell's study (2003), TP (tetraplegic) individuals demonstrated higher aural temperature than HP (high-level paraplegic) and LP (low-level paraplegic) (figure 2).

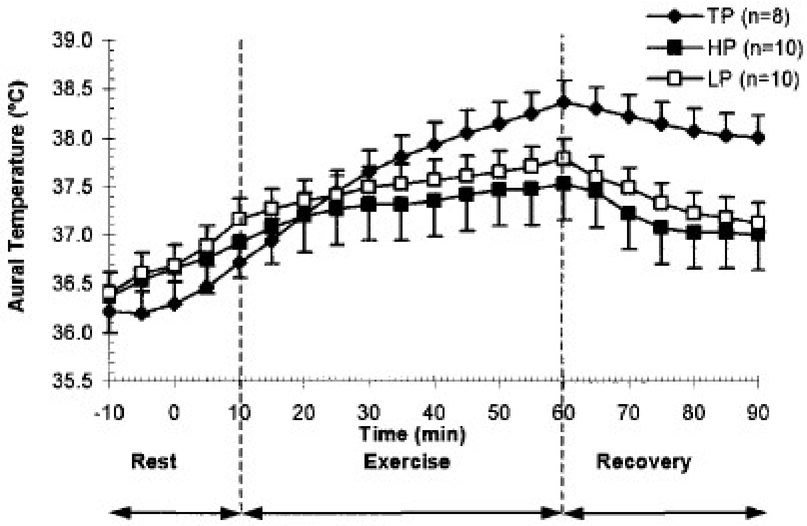


FIGURE 2. Aural temperature for the TP, HP, and LP athletes at rest, during exercise, and recovery in warm conditions. (Price and Campbell 2003)

Because of a diminished and uncoordinated sweating response, the capacity to eliminate stored heat may place an athlete with SCI at risk of heat-related disorders. Furthermore, the reduced capacity of the central drive to affect sweating may also be associated with a reduced capacity to control skin and other organ blood flow (Greg. 1996).

A spinal cord injury impairs one's ability to thermoregulate, because of: (a) loss of autonomic nervous system control for vasomotor and sudomotor responses in the areas of the insensate skin; (b) a reduced thermoregulatory effector response for a given core temperature; and (c) a loss of skeletal muscle pump activity from the paralyzed limbs. As a result, a spinal cord injured person has a reduced ability to tolerate thermal extremes and to perform aerobic exercise. (Sawka. et al. 1989)

Since paraplegic and tetraplegic athletes may not exhibit centrally driven sweating below their spinal cord lesion, they can still use the physics of evaporation to help them to reduce heat storage, such as, fine spraying of water on the insentient skin (Greg. 1996).

Thermoregulatory responses are proportional to the level of lesion, reflecting the amount of sympathetic nervous system available for sweating and blood redistribution. In general, although paraplegics have been shown to regulate body temperature effectively at rest, they show greater increases in core temperature when compared with able-bodied subjects. Furthermore, paraplegics with lesions at T6 and below demonstrate smaller increases in core temperature than those with lesions above T6, who in turn demonstrate smaller increases than subjects with a cervical lesion (tetraplegics). The latter subject group exhibits the least effective thermoregulation due to complete absence of sweating capacity (Price and Campbell 1998). Petrofsky (1992) conducted a study involving 12 people with spinal cord injuries and 4 healthy men; he found that individuals with quadriplegia had the poorest tolerance for heat.

Subjects with SCI will sweat under central control above their spinal cord lesion, and may do so at a higher rate for a given core temperature (Greg 1996). On the other hand, an increase in the metabolic activity of skeletal muscle during exercise produces an increase in body temperature. (Vidal et al. 2003)

1.3. Pre-cooling methods

In order to prevent hyperthermia and improve exercise performance during training as well as competition in hot conditions, several strategies, such as heat-acclimatization, pre-cooling methods and fluid ingestion before exercise or/and during exercise, have been proposed (Marino 2002).

The concept of reducing skin or core temperature prior to endurance competition, which is known as pre-cooling, has been investigated since 1980. Lower skin temperatures enable a greater temperature gradient for dissipating heat from deeper regions of the body. Cooler skin temperatures mean that less of the total cardiac output is directed toward the skin, possibly allowing more blood to be directed to active skeletal muscle. Lower skin and core temperatures can also delay the onset of sweating and decrease sweat rate, resulting in a conservation of body water during a prolonged competitive event. (Martin 1998)

The aim of pre-cooling strategy is to reduce skin and core body temperature before training and competition, so as to increase the margin for the increase in metabolic heat production. Pre-cooling is also expected to increase the time to reach the critical limiting temperature at which a given exercise intensity can no longer be maintained (Marino 2002). It is believed that pre-cooling would be more effective before prolonged exercise in hot environments rather than warm conditions. Webborn et al. (2005) conducted a study and found that by pre-cooling, the core temperature of athletes were lower than the other two groups, and it continued to be lower until the end of exercise (figure 3).

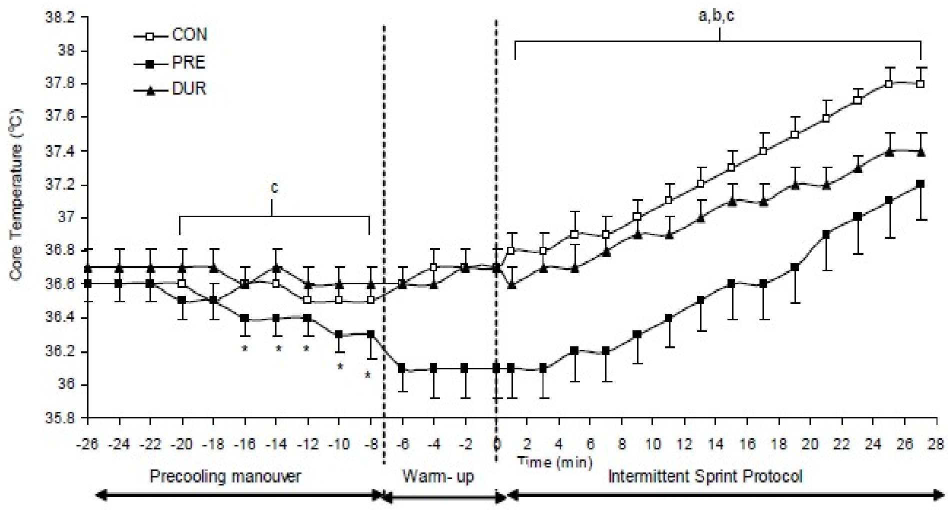


FIGURE 3. Core temperature during the pre-cooling manouver, warm up and intermittent Sprint Protocol for the CON, PRE and DUR conditions in a hot, humid environment. (Webborn et al. 2005)

During the past decades, a lot of research has been conducted to study the effect of different kinds of pre-cooling methods, such as cold air, cold water, and the ice vest for improving exercise performance.

Cold Air Lee and Haymes (1995) pre-cooled 14 physically fit male runners for 30 min with cold air. They found that pre-cooling caused a 0.37°C drop in core temperature as well as an improvement in running time from 22.4 to 26.2 min, or 17% longer (equivalent to about 1% in an event). Booth et al. (1997) cooled their subjects by about 0.5ºC using a 20-min cold-water bath. During a subsequent 30-min maximal running test in hot humid conditions (32ºC, 62% humidity), maximal 30-min- run distance increased by about 2%. Hessermer et al. (1984) found that eight well-trained rowers improved their average power output by 6.8% when the 60-min time trial was preceded by a cold air pre-cooling maneuver that decreased mean skin temperature by 4.5ºC.

Cold Water Wilson, et al (2002) studied the effects of pre-exercise cooling with controlled water immersions on exercise-induced thermal loads derived from steady-state submaximal exercise. The authors observed positive results finding that pre-cooling resulted in significant negative body heat storage during immersion which allowed greater heat storage during exercise. This technique also significantly lowered rectal, mean skin, and mean body temperatures. Therefore, the authors concluded that lower-body pre-cooling is effective in decreasing body heat storage prior to exercise and in decreasing reliance on heat dissipation mechanisms during exercise.

Ice Vest Myler and Tumilty (1989) investigated the effects of pre-cooling on the ability of rowers to perform at 30ºC and 30% humidity. The authors found that performance of a 6-min maximal rowing effort improved significantly after 5 min of icing the skin. The increase in power output averaged ~3%.

Even though the results of most research on pre-cooling methods have been positive, there are still some negative results. For example, Drust, et al (2000) evaluated the effect of pre-cooling on intermittent activity. Even though the pre-cooling manoeuvre reduced the starting rectal temperature (T_{re}) by approximately 0.3°C, it still had limited effect, if any, on the physiological responses measured. The authors concluded that pre-cooling is of no significant benefit for intermittent exercise of similar duration.

1.4 CNS, cardiovascular, and metabolic responses to exercise after pre-cooling

Few studies have been conducted on cardiovascular and metabolic responses after pre-cooling, even though the cardiovascular and metabolic responses to exercise under various conditions and interventions are well documented. Clearly, the fact that exercise performance in most reported studies is improved after pre-cooling suggests that offsetting or decreasing the rate of rise in core temperature is a major determining factor. However, whether this in turn impacts substrate availability, cardiovascular function, skeletal muscle function, or the CNS, or if exercise capacity maybe limited after that still remains unclear.

There is one study showed that in the presence of high internal body temperature, the skeletal muscles which were not used during the preceding exercise bout were unable to reproduce baseline force values. This finding implicated that CNS has effect in the reduction of skeletal muscle force output. In other word, when core body temperature is higher than that during warm environment, the CNS instructs the body to use less skeletal muscles during exercise. In general, the responses of these systems have not been studied during exercise after pre-cooling; which makes it difficult to ascertain how pre-cooling maneuvers may affect them. (Febbraio 2000)

There is an emerging consensus that fatigue during exercise in the heat may be due to a reduced CNS motor drive. This hypothesis has not been directly evaluated; however, there is some evidence for neuromuscular fatigue during high intensity cycling in the heat (Kay et al. 2001). During the study (Marino 2000), subjects self-selected running speeds during a

30-minute treadmill run in the heat, it was clear that subjects changed their pace speed compared with a similar trial in cooler conditions in order to ensure that they were able to finish the run. These findings suggested that a subconscious control may have been operating in order to reduce the likelihood of cellular injury in the heat.

In contrast with the responses of the CNS, the cardiovascular system during exercise after pre-cooling has been reasonably well studied. The assumption here is that by reducing the rate of rise in body temperature, the need for skin blood flow is reduced, thereby increasing the volume of blood available for the central circulation. (Marino 2002) This would naturally lead to an increased stroke volume and hence a reduced heart rate response for a given level of exercise intensity. Indeed, many studies (Schmidt and Brück 1981; Hessemer et al. 1984; Lee and Haymes 1995) indicate that, under steady state conditions, heart rate during exercise after pre-cooling is attenuated.

An analysis of the literature indicates that heart rate is lower during the initial 15 minutes of exercise after pre-cooling, with this difference disappearing for the remaining portion of the exercise. In fact, heart rate at the end of exercise has been shown to be similar in control and pre-cooling conditions irrespective of ambient temperatures. (Booth et al 1997; Lee and Haymes 1995)

However, González-Alonso et al. (1999) examined the effect of pre-heating and pre-cooling on exercise time to exhaustion. It seemed clear that if esophagus temperature (T_{es}), skin temperature, and skin blood flow were increased before exercise by preheating, cardiac output reduced secondary to a diminished stroke volume. Interestingly, Marino (2001) found that the differences in cardiovascular responses disappeared after about 10 minutes of exercise, with subjects terminating exercise at similar T_{es}, heart rate, cardiac output, and stroke volume. In addition to this data, it has also been shown that neither blood volume nor plasma volume are sufficiently attenuated to account for reduced cardiovascular strain during exercise under pre-cooled conditions.

So far, the metabolic responses to exercise after pre-cooling have not been extensively documented. Most studies showed that oxygen consumption remains unchanged with pre-cooling after 10 minutes of exercise, and that no relationship exists between exercise performance and oxygen consumption after pre-cooling (Kay et al. 1999; Lee and Haymes 1995; Booth et al. 1997). It has been proposed that pre-cooling may enhance exercise performance by reducing the metabolic perturbation usually observed with increased body and muscle temperatures. Indeed, if the rise in core temperature is blunted during exercise, the result is attenuation in net muscle glycogen use (Febbraio et al. 1996).

A study showed that pre-cooling had a very limited effect on substrate provision during exercise heat stress. That is, despite lower T_{es} and muscle temperature (T_{muscle}) after pre-cooling, muscle glycogen utilization was not different at the end of exercise compared with a control trial. The authors suggested that T_{muscle} may need to exceed a critical level before muscle energy metabolism is altered sufficiently to impact on exercise. However, in this study, the muscle glycogen levels before exercise were not similar in the two trials, making these findings difficult to interpret. Furthermore, energy metabolism can not by itself explain a reduction in exercise performance, since the substrates are never fully depleted. (Booth et al. 2001)

Marino (2002) suggested that the obtainment of higher body temperature is unavoidable in hot and moderate environment, which is considered to be a main factor limiting endurance performance in those conditions as well. In order to improve exercise performance and prevent hyperthermia in hot conditions, several strategies have been recommended, such as heat acclimatization, pre-cooling, and fluid ingestion.

Studies conducted to study the effect of pre-cooling methods on athletes with spinal cord injury usually take place in a laboratory. For example, Webborn et al. (2005) studied the effects of two cooling strategies on thermoregulatory responses of tetraplegic athletes in the laboratory undertaking intermittent sprint protocols for 28 minutes on an arm crank ergometer, with three conditions, on cooling control, 20 minutes of pre-cooling, and cooling during exercise.

On the other hand, no studies were conducted specifically on wheelchair rugby players. Price and Campbell (1998) recruited subjects for their study from wheelchair rugby, wheelchair basketball and wheelchair track. In the present study, all subjects were recruited from wheelchair rugby, and the study was designed to be as similar as possible to a real competition and was undertaken in ambient temperature. We did not modify or set any conditions factitiously, thus only difference was using the ice vest or not.

In recent decades, a lot of research has been conducted to study the effects of cooling methods in offsetting an increase in body temperature, both core body temperature and skin temperature, in hot environments. These methods include pre-cooling methods, cooling during the competition, and cooling after exercise. As for pre-cooling methods, such as cold air, cold water, and ice vest have been used to study their effects on preventing heat-induced problems and improving exercise performance.

In this present study, an ice vest was used as the method to pre-cool the athletes in stimulated competition exercise. The ice vest is a new innovation designed to offset the increase in body temperature, both skin and core body temperature, and improve the perceived comfort level. There have already some studies been conducted on using ice vest in hot environment before (David 1998; Cotter et al. 2001).

However, no studies have been conducted that use the ice vest in a moderate environment (20-25ºC). The reason for not using the ice vest in a moderate environment is that, for healthy athletes, it is unnecessary to use the ice vest in a moderate environment. Athletes with spinal cord injuries, however, have an incomplete capacity in thermoregulation. Thus, their heat dissipation by a centrally driven sweating response is compromised even when doing exercise in moderate environment, with the available area for sweating being related to the level and completeness of the spinal cord injury.

Wheelchair rugby players have problems in heat dissipation under the injury lesion during training and competition, even in mild temperature environments. Thus, their body temperatures, both core body temperature and skin temperature, increased more than able-athletes do during physical activity. Therefore, it is meaningful to design a study to see if using an ice vest as a pre-cooling method can help them.

2. PURPOSE OF THE STUDY

The purpose of this study was to investigate the effect of using an ice vest on core body temperature in wheelchair rugby players.

2.1 Research objectives

1. To examine the effect of using an ice vest on deceasing core body temperature in wheelchair rugby players.
2. To examine whether using an ice vest can improve the performance during simulated game situation.

2.2. Hypothesis

1. Pre-cooling by using an ice vest will decrease the core body temperature of wheelchair rugby players during exercise;
2. Pre-cooling by using an ice vest will improve the performance of wheelchair rugby players during a simulated game situation.

3. METHODS

3.1. Subjects

Eight male wheelchair rugby players (age from 21 to 49ys; body mass from 46 to 111kg) volunteered to participate in the study after being informed of the experimental procedures and signing a written informed content. Participants were tetraplegic athletes (C_5/C_6-C_6/C_7, while one subject has no problem with his spinal cord, though he does not have lower arms and legs, and played on the wheelchair rugby team). All subjects were able to use their arms for wheelchair propulsion but had impaired use of their hands. All subjects trained and competed regularly in wheelchair rugby at a national level.

3. 2. Measurements and analysis

During the present study, several parameters, such as core body temperature, blood lactate, rating of perceived exertion (RPE), mean heart rate and 20m self-powered wheelchair self-powered rolling time were measured.

3.2.1 Core body temperature

Cord body temperature was measured by telemetry pill (figure 4), a wireless transmitter in the shape of a pill, which is ingested orally. The telemetry pill detects surrounding temperature and transmits a temperature variable signal via short electromagnetic waves to a hand held recorder continuously (Webborn et al. 2005). The telemetry pill used in the present study is produced by HQ CorTempTM, HQ Inc, Florida, USA. The pill must be ingested 3 to 4 hours before the experiment.

FIGURE 4. The comparison of the size between a telemetry pill and a classical thermometer.

3.2.2 Blood lactate

Blood lactate was analyzed by Lactate Pro analyzer (figure 5) which is produced by Lactate Pro, Arkray Inc, Japan. Lactate Pro analyzer does not require costly control solutions. Meter function is controlled by the use of unique calibration and check strips. Blood Lactate can be measured by taking a drop of blood from the finger tip or earlobe.

FIGURE 5. Lactate analyzer.

Blood lactate is a common parameter which is measured often in experiments when an aspect human physiology is studied. Blood lactate can be used to see the exercise state, whether it is aerobic or anaerobic or both, and how much anaerobical exercise is involved. Usually, it is taken before and after exercise, and the difference between them is examined.

3.2.3 Rating of perceived exertion (RPE)

RPE is an ordinal scale with values from 6 to 20, which is developed based on Borg’s psychophysical and physiological experiments. As for the numbers, the greater the exertion felt the greater the number reported by the individual being tested. (Roberts 1997, Chapter 12)

The scale used in the present study was not exactly the same scale created by Borg; as it did not have a scale from 6 to 20, but from 1 to 10. However, the measured effect was the same. RPE was used to examine the degree of subjectively-judged load during exercise.

3.2.4 Mean heart rate

Heart rate is a useful indicator of physiological adaptation and intensity of effort. A heart rate monitor is a device that allows a user to measure heart rate in real time. A heart rate monitor usually consists of two elements: a chest strap transmitter and a wrist receiver (which usually doubles as a watch). Heart rate was monitored continuously during the whole exercise test. The analysis of heart rate data included mean heart rate during each half period and is compared between the two exercise bouts.

During the present study, Suunto T6 heart rate monitor (Suunto Inc, Vantaa, Finland) was used. Since subjects’ have to work in order to roll their own wheelchair, heart rate monitor was attached to the wheel of the wheelchair for each subject.

3.2.5 Twenty meters self-powered rolling time

Twenty meter rolling time was measured by marking two lines in the field with a distance of 20 meters. There was a sensor in the starting line; and a receptor at the finish line. When the subject passed the starting line, the sensor sends information to the receptor, and the receptor started to time. After the subject passed the end line, the receptor stopped timing immediately, and the time showed on the screen of the receptor was the 20m rolling time.

3.2.6 Ice vest

Ice vests are designed for healthy athletes to use in hot environment, the effective area is around the trunk, which is the white area in figure 6.

FIGURE 6. Ice vest.

3.3 The design of the present study

The experiment took place at an indoor basketball court in Helsinki. The temperature inside was 22ºC. Small blocks were placed in lines at both sides, and a 20m track was in the middle with electric sensors. All participants were asked to move along the block in “Z” shape as to simulate the real situation during competition. They were also asked to move through the track, and their moving propulsion times were recorded by the electric sensors.

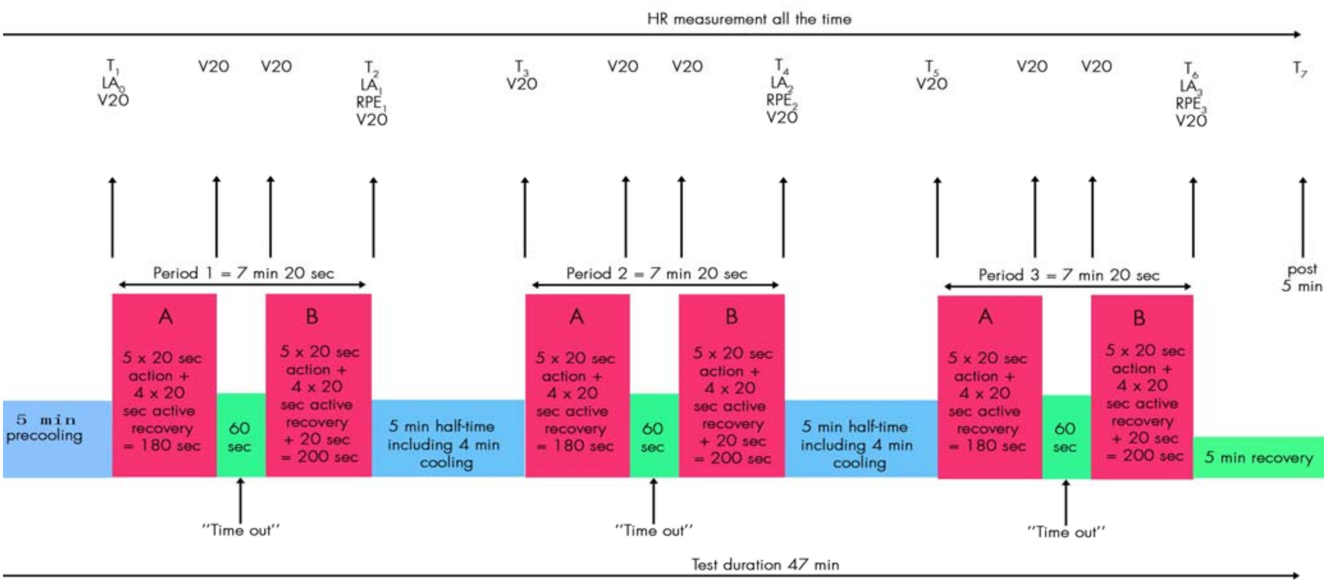


FIGURE 7. Design of the experiment and measurements.

Each participant did this experiment twice on sequential days, once with the ice vest, and once without it, the other procedures were similar (figure 7). The participant who had experiment with the ice vest ingested a telemetry bill (HQ CorTempTM, HQInc, Florida, USA) 3-4 hours before the experiment. The transmitter pill transmitted the data of the core body temperature to a receiver instantaneously.

Before putting on the ice vest, core body temperature was measured and marked as T_0. After that, the subject used the ice vest for 5 minutes. At the end of 5 minutes, T_1 was measured as along with blood lactate, which was marked as LA_0. Blood samples were taken from the earlobe with lactate equipment (Lactate Pro, Arkray Inc, Japan). Then, three periods of exercise were performed to simulate a real competition. Each period lasted 7 minutes and 20 seconds with a pause of 5 minutes between the two periods.

During the 5-minute break, the participant put on the ice vest for 4 minutes. Both before and after each period, core body temperature was checked.

These temperatures were labelled as T_1, T_2, T_3, T_4, T_5, and T_6. At the end of each period, lactate and RPE were checked and labelled as LA_1, RPE_1, LA_2, PRE_2, LA_3, and RPE_3. Each period was additionally separated into two parts, A and B, with a break of 60 seconds between them. A period included 5 times of actions, each one lasted 20 seconds, and 4 times of active recovery, each one also lasted 20s.

During the action, the participant moved in his wheelchair in a “Z” shape around the blocks as fast as he could. During active recovery, the participant just moved the wheelchair slowly, also in “Z” shape. After finishing the 3rd period, the participant rested for another 5 minutes, and the last core body temperature was measured and marked as T_7. Heart rate was recorded continuously throughout the experiment with Suunto T6. (Suunto Inc, Vantaa, Finland)

3.4 Statistical analysis

Nonparametric tests and repeated ANOVA measures were used to examine the difference in core body temperature, lactate, RPE, mean heart rate and 20m rolling time. Excel was used to examine the association between the individual changes.

4. RESULTS

4.1 Core body temperature

During the experiment, only 5 subject's data of core body temperature was gotten. For the exercise bout using the ice vest, the core body temperature increased from 37.5±0.3ºC to 38.2±0.6ºC; while without using the ice vest, the core body temperature increased from 37.1±0.5ºC to 37.9±0.5ºC. Figure 8 shows the changed temperature values subtracted by the temperature 5 minute in both exercise bouts before measurement. There is no significant difference between the two exercise bouts at each time point, except T_3. At T_3 point ($p<0.05$), it showed there was a bit difference at that time point.

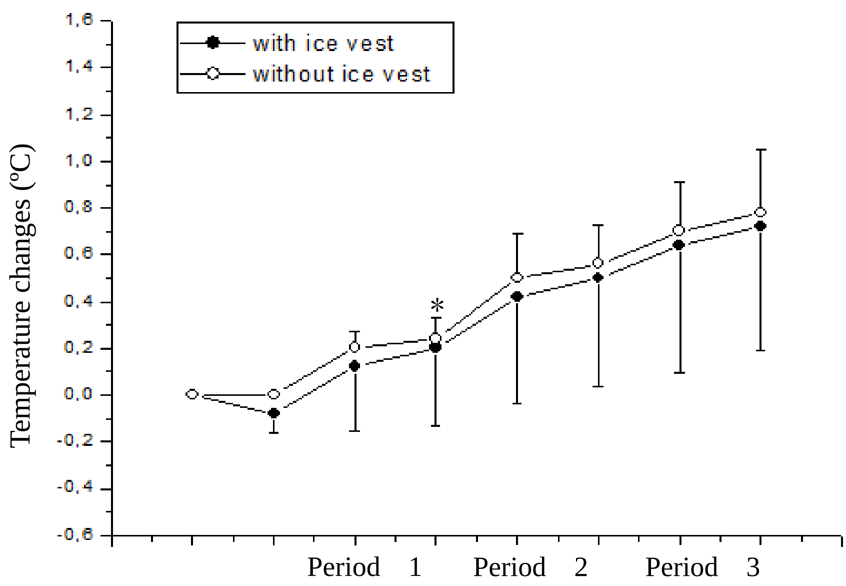


FIGURE 8. The increasing values of core body temperature from both of

experiment bouts. *p=0,043.

For the exercise bout using the ice vest (table 1), there were slightly differences between T_3 and T_4 (p=0,042), T_6 and T_7 (p=0,046). For the exercise bout performed without ice vest, there were slight differences between T_1 and T_2 (p=0,039), T_5 and T_6 (p=0,038). The trend of the two exercise bouts were not the same.

TABLE 1. The statistical differences between two adjacent core temperature values (two adjacent measured points in each exercise bout). $^*p< 0.05$.

	Exercise bouts	
	Pre-cool	No pre-cool
$T_0 – T_1$	0,102	1,000
$T_1 – T_2$	0,109	0,039*
$T_2 – T_3$	0.102	0,157
$T_3 – T_4$	0,042*	0,066
$T_4 – T_5$	0,102	0,183
$T_5 – T_6$	0,059	0,038*
$T_6 – T_7$	0,046*	0,357

4.2 Blood lactate

There were eight subjects' data of blood lactate data collected during the experiment. LA0 is the mean blood lactate measured before exercise. LA1 is the mean blood lactate checked after the period 1, LA2 is after period 2, and LA3 is right after period 3. Blood lactate increased sharply in both groups during the first period and then followed the same pattern for decreasing during subsequent periods.

As it shown in figure 9, BLa changed from 1.4±0.4 to 5.6±2.8 mmol/L without using the ice vest and from 1.4±0.4 to 4.9±1.9 mmol/L with using the ice vest. Even though there is small difference between LA2 and LA3, and the difference was not statistically significant.

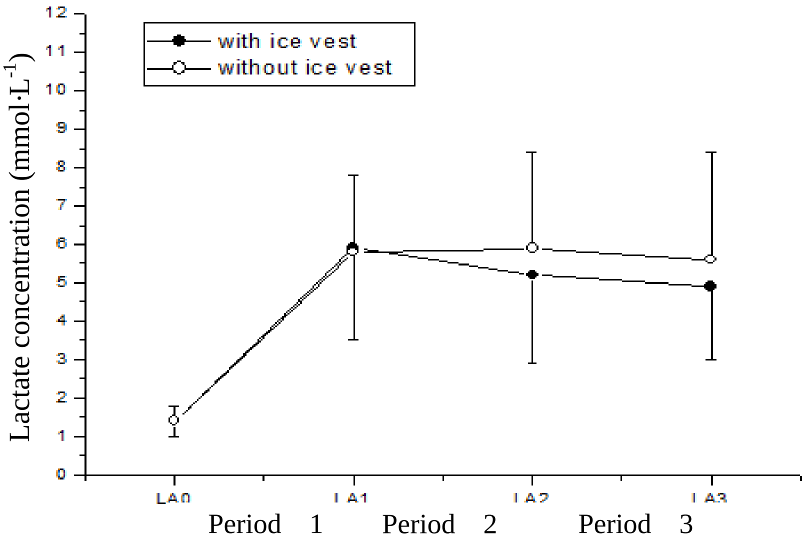


FIGURE 9. Blood lactates (BLa), measured before exercise, and after every period of exercise for both of exercise bouts.

TABLE 2. The statistical differences between two adjacent blood lactate values (two adjacent measured points in each exercise bout). $^{*}p < 0.05$

Exercise bouts	LA0 –LA1	LA1 –LA2	LA2 –LA3
Pre-cool	0,012*	0,080	0,528
No pre-cool	0,012*	0,674	0,484

As it is showed in table 2, the trends for both exercise bouts in terms of blood lactate are similar.

4.3 The rating of perceived exertion (RPE)

The RPE value was asked immediately after each period of exercise, which were marked as RPE1、RPE2 and RPE3. From figure 10, it can be seen that, RPE increased from 5.7±2.0 to 7.1±1.8 when ice vest was not used. RPE rose from 5.4±2.1 to 7.2±2.0 when ice vest was used. Here is no significant difference between groups at any time point.

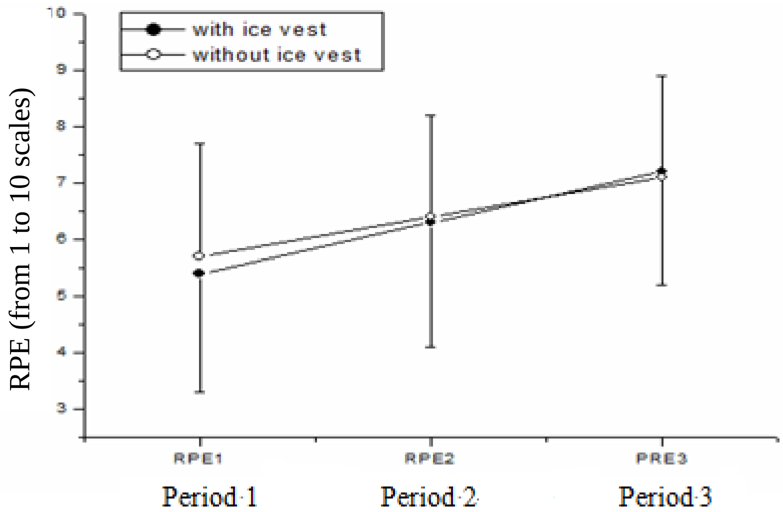


FIGURE 10. The changes in RPE values for each period for both exercise bouts.

TABLE 3. The statistical differences between two adjacent RPE values (two adjacent measured points in each exercise bout). $^{*}p<0.05$.

Exercise bouts	RPE2 –RPE1	RPE3 –RPE2
Pre-cool	0,020*	0,026*
No pre-cool	0,201	0,066

The trends for both exercise bouts about RPE are not the same, for the exercise bout using ice vest, there were significant differences between adjacent two points. However, for the exercise bout without using ice vest, there were no significant differences between adjacent two points.

4.4 Mean heart rates

Figure 11 shows that all the mean heart rates were within the range of 120—135 bpm. Mean heart rate changed from 128 ±22 bpm to 134±27 bpm when using the ice vest, from 122±19 bpm to 129±24 bpm without using the ice vest. It can be seen from the figure that, mean heart rate (during each half period) while using the ice vest was higher than that without using the ice vest. However, no significant differences between the conditions were observed.

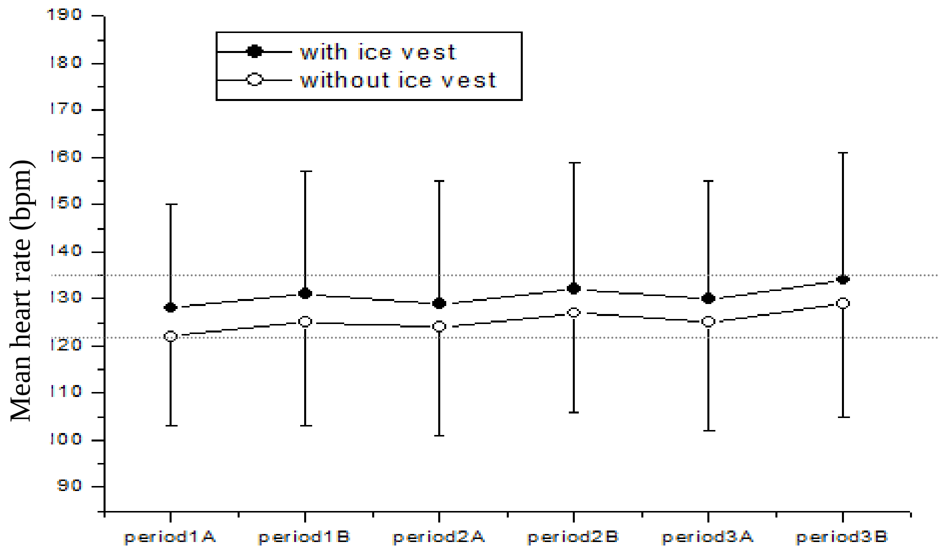


FIGURE 11. The changes in mean heart rate during the whole experiment for both bouts.

TABLE 4. The statistical differences between two adjacent mean heart rate values (two adjacent measured points in each exercise bout). *$p<0.05$.

	Exercise bouts	
	Pre-cool	No pre-cool
period1A –1B	0,102	1,000
period1B –2A	0,109	0,039*
period2A –2B	0.102	0,157
period2B –3A	0,042*	0,066
period3A –3B	0,102	0,183

The trends for both exercise bouts about heart rate are not the same. For the exercise bout when using the ice vest, there was a slightly difference between period 2B and period 3A. There was a slightly difference between period1B and period 2A, when the ice vest was not used.

4.5 Twenty meters self-powered rolling time

The twenty meters rolling time was measured four times during each period, one before the former half period and one is after it, the third one is before the latter half period and the forth one is after it. After analyzing by nonparametric tests, there was no significant difference between the two lines at any time point, which is clearly showed in figure 12.

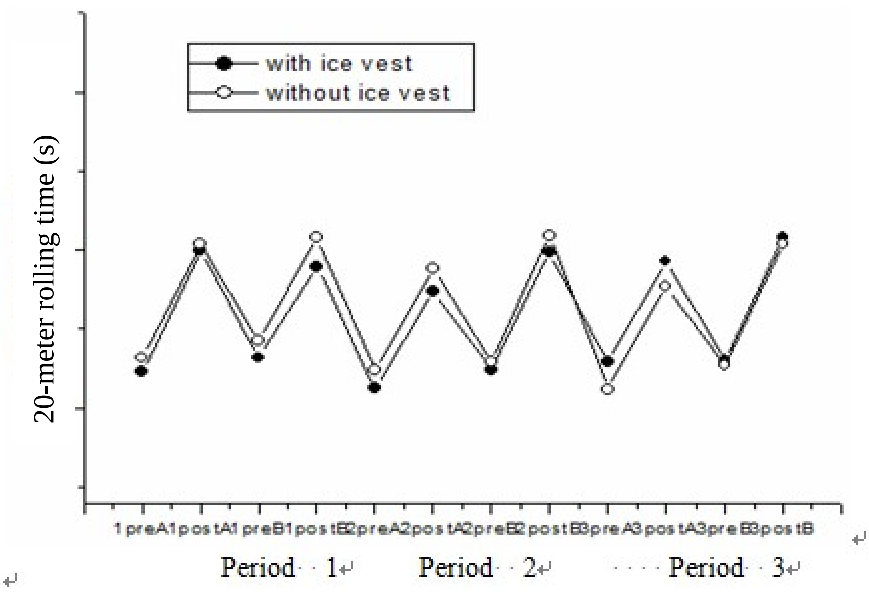


FIGURE 12. The values for the 20 meters rolling time for the two exercise bouts.

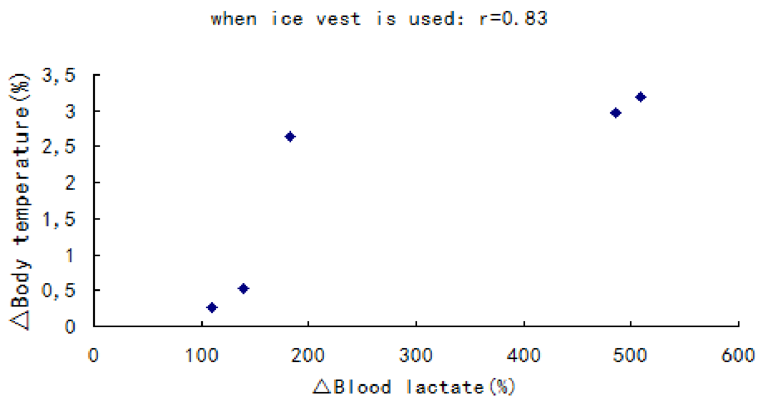
TABLE 5. The statistical differences between two adjacent 20-meter self-powered rolling time values (two adjacent measured points in each exercise bout). $^{*}p<0.05$.

	Exercise bouts	
	Pre-cool	No pre-cool
1postA - 1preA	0,017*	0,012*
1postB - 1preB	0,012*	0,012*
2postA - 2preA	0,012*	0,012*
2postB - 1preB	0,012*	0,012*
3postA - 3preA	0,012*	0,012*
3postB - 3preB	0,012*	0,012*

It can be seen from table 5 that the trends for both exercise bouts are similar.

4.6 Association between some parameters

The association values between △core body temperature and △blood lactate for both bouts are quite high (figure 13). The association value with using the ice vest is 0.83. The association value between △core body temperature and △blood lactate is 0.88 without using the ice vest. These high association values mean that the change of core body temperature is highly associated with the changes of blood lactate. The higher level of blood lactate, which indicated the degree of anaerobic metabolism, the more the core body temperature increased during exercise.



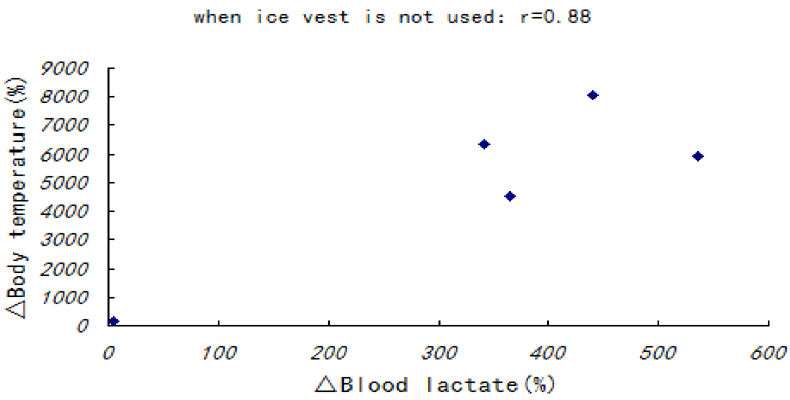


FIGURE 13: The association between △individual core body temperature (the difference value between T7 and T0) and △individual blood lactate (the difference value between LA3 and LA0). The one above is with ice vest, and the one below is without ice vest.

5. DISCUSSION

The main findings of the present study show that, there is no significant difference between two exercise bouts, one with the ice vest as a pre-cooling method, and the other without pre-cooling. For all the parameters measured, such as core body temperature, blood lactate, RPE, heart rate and twenty meters self-powered rolling time, there are no significant difference existed.

5.1 Core body temperature

Figure 8 shows the changes in core body temperatures. Every point, except the first one, represents the changed value in core body temperature between it and the core temperature 5 minutes right before exercise, no matter whether ice vest was used or not. The first point which represented the core body temperature 5 minutes before exercise did not exist; it was created by hypothesis. The hypothesis is based on the fact that without using ice vest, the participants just sit for the first five minutes before experiment, no core body temperature changes would happen. Therefore, it showed the changed value of core body temperature since the experiment started.

For example, the first filled round which mean ice vest was being used is gotten by subtracting the mean core body temperature taken 5 minutes before the start of the experiment from the mean core body temperature taken right before the start of experiment when ice vest was used. It showed that by using ice vest for 5 minutes during the rest period before exercise, the mean core body temperature decreased 0.08ºC. By using the nonparametric tests, there was no significant difference between the conditions for every pair of points between two exercise bouts.

Based on the assumption for the core body temperature measured 5 minutes before exercise, after 5 minutes of pre-cooling with ice vest, the mean core body temperature of the participants dropped first 0.08ºC compared to exercise bout without using ice vest. Then, the core body temperature increased steadily. 0.08ºC showed the change for core body temperature after using ice vest, even though there was no significant difference between the two exercise bouts. The difference value between two exercise bouts 5 minutes after exercise is 0.06ºC. So, we could say that, the effect of ice vest as a pre-cooling tool does exist somehow. It decreased the core body temperature a bit, even though there is no significant difference existed. However, it can be said that the ice vest increased the margin for the increase of core body temperature, which made a difference for the last stage, even though there were not significantly different.

Looking more carefully at the period 1 and period 2 in figure 8, it could be seen that for both of the exercise bouts, with using the ice vest and without using the ice vest, the increase rate of mean core body temperature during the former half period, both of period 1 and period 2, is higher than the latter half period. It could be concluded that, during the exercise, the core body temperature increased more during the first part, and then it slowed down a bit, probably because of the enhancement of body heat-dissipation system when the body started to adapt to the exercise (Donhoffer 2008).

Most studies conducted by other researchers before indicated that there should be some differences between the two exercise bouts when the exercise conditions were not the same. In other words, subjects' core body temperature should be lower when the ice vest was used than that when ice vest was not used as a pre-cooling method, at least for the first period and second period.

There were 8 subjects that voluntarily joined in the experiment; however, core body temperature data were collected from 5 subjects. Two subjects' data was excluded because of technical difficulty and the third subject could not ingest the telemetry pill.

5.2 Blood lactate

The amount of lactate released by muscle into the blood is dependent on both the production of lactate by anaerobic glucose metabolism in the muscle, and the use of lactate as fuel within the muscle. As exercise workloads increase, there is an increase in anaerobic metabolism, resulting in increased lactate production. However, the use of lactate as a fuel within the muscle can reduce the amount of lactate that is released into the blood. (Dario 2004)

During this study, during the first period, the lactate increased rapidly to 5.9±2.4 mmol/L with the ice vest or 5.8±2.0 mmol/L without ice vest (figure 9). Both exercise bouts surpassed the 4.0 mmol/L. The 4.0 mmol/L lactate threshold means that during the first period, the participants in both exercise bouts started to use an-aerobic metabolism. During period 2 and period 3, the blood lactate in both exercise bouts decreased a bit, which means they have used the lactate as a fuel during the rest of the experiment. However, there is no significant difference between the two exercise bouts.

The level of blood lactate can be used to show the degree of anaerobic metabolism of the participants. The decline of blood lactate is most likely caused by an increase in lactate utilization by other tissues during exercise after period 1.

5.3 Rating of perceived exertion (RPE)

It can be seen from the figure 10 that the standard deviation is quite high, which indicated that the individual differences were very high. This suggests that different subjects experienced different feelings of heaviness and strain during the experiment.

RPE is defined as the degree of heaviness and strain experienced in physical work as estimated according to a specific rating method. In our study, there is no significant difference between using the ice vest and not using the ice vest.

The interesting thing is about the subjective estimation of benefits of cooling. All the subjects were asked to give their own subjective estimation of benefits of cooling after the measurements. 1 means no benefit at all, 5 means very beneficial. 1 of them marked as 3.5; 3 of them marked as 3; 2 of them marked as 2; and 2 of them marked as 1. Generally, this means that 75% of the subjects felt subjectively that the ice vest benefited them mentally.

5.4 Mean heart rate

As for interment exercise in the present experiment, the mean heart rate for both exercise bouts was not high. It is believed that the heart of athletes should beat less per minute when the ice vest was used in comparison to the exercise bout when ice vest was not used, at least on the first stage. When the ice vest is used, the skin temperature is cooled down, so less blood is needed to circulate to the skin area to dissipate the heat from the core body part. Thus for the same exercise intensity, fewer heart beats occur. For example, in Hiroshi et al. study (2004), the authors found that the heart rate in control group was higher than the others when cooling methods were adopted. However, in our study, the athletes' heart rate was higher when the ice vest is present in comparison to the exercise bout without the ice vest, even though no significant difference existed. This is quite a surprising result.

5.5 Twenty meters self-powered rolling time

Twenty meters rolling time is the most important parameter among those parameters measured in this study. During real competition, the speed of short bursts of wheelchair self-powered rolling determines who is the one who gets to a certain point faster, or who will score points or who can stop an opponent from scoring or who will not be stopped by an opponent. In our study, no matter whether or not the ice vest was used, the 20m rolling is almost the same; there is no significant difference between the two bouts.

It is easy to find that there are similar trends for both lines (figure 12). By looking deeper, there are similar trends for each period for both bouts of exercise. The rolling speed is fastest at the start of each period, after half period, their speed slowed down. After 1-minute of rest, subjects mostly recovered, but perhaps not fully as the following rolling speed was still slower than the first one. At the end of the whole period, rolling speeds were the lowest among the four times of rolling in each period.

5.6. Association between some parameters

The association between the individual changes was also analyzed between △core body temperature and △Blood lactate. It was found that, regardless of whether or not the ice vest was utilized, the changes of core body temperature were highly associated with the changes in blood lactate. This suggests that the higher level of blood lactate, which indicates the degree of anaerobic metabolism, the more the core body temperature increased.

5.7 The reliability of the equipments used

The reliability and validity of telemetry pill is high. It has been concluded from a study (Byrne and Chin 2007) that the ingestible telemetric temperature sensors represents a valid index of core body temperature (T_c) and shows excellent utility for ambulatory field-based applications. The advantage of using the telemetry pill is its reliability while the disadvantage is its cost. The pill’s design is quite complicated, so the price is high, and since it can only be used once, the cost is further increased.

As for the Lactate Pro blood lactate analyzer, there is a publication which states, "A total of 166 intravenous and 39 capillary samples from 13 subjects were tested concomitantly on three different lactate meters (3 different Lactate Pro meters). The meter readings were compared with the lactate concentration determined by the laboratory gold-standard enzymatic colorimetric assay. Almost no inter-meter variability was found. The lactate meter values had outstanding correlation with the laboratory lactate determination. The portable lactate meter is a highly accurate tool for monitoring lactate concentrations" (US and UK Association for Glycogen Storage Disease).

As for reliability and validity, RPE scale can provide valuable supplementary information for interpretation and understanding of subjects' level of physical effort. However, not all people can be expected to give reliable or valid ratings according to any scaling method. A small percentage of adults, about 5 -10%, may have difficulties in understanding the instruction and the requests to respond according to the Borg RPE scale. This would be more common if individuals with lower mean intelligence and poor verbal and mathematical abilities were used.

5.8 previous similar studies

During the past decades, a lot of research has been conducted to study the effect of different kinds of pre-cooling methods, such as cold air, cold water, and the ice vest in the area of improving exercise performance. Most of those studies have positive findings. Hessermer et al. (1984) found eight well-trained rowers improved their average power output by 6.8% when a 60-min time trial was preceded by a cold air pre-cooling maneuver that decreased mean skin temperature by 4.5ºC.

In Lee and Haymes (1995) study, they used cold air too. The subjects’ core temperature dropped 0.37°C and their running time increased 17% after using cold air as a pre-cooling method. Two years later, Booth et al. cooled their subjects by 20-min cold-water bath. They found about 0.5ºC drop in body temperature and a 2% improvement in running distance in hot humid conditions (32ºC, 62% humidity).

5.9 Limitations of present study

5.9.1 Ice vest

As for those athletes with SCI in the present study, they have to use quite a wide belt accompanied with the wheelchair to tie their trunks very firmly to the wheelchair, so their bodies could be stabilized with the wheelchair and so that the athlete would not be thrown about when falling down.

Since the tie has to be used at all times during the experiment and the ice vest is only to be used as a pre-cooling method which has to be taken away right before the exercise, the ice vest must be put on over wide belt instead of under it. Therefore, half of the effective area within the ice vest is not in contact with the trunk of the subject and thus it is ineffective. Perhaps, this is a reason for why the effect of the ice vest in the present study is insignificant.

It might be necessary to adapt the ice vest in order for it to be used by wheelchair rugby players. For example, a more effective area should be fixed around the upper part of the ice vest and even the shoulder of the ice vest could be filled with ice.

5.9.2 The number of participants

The amount of subjects involved in this study is quite small; only 8 wheelchair rugby players at the national level were present. Furthermore, because of some problems mentioned before, only 5 subjects' data regarding core body temperature was obtained. The conclusion that the ice vest has an effect on wheelchair rugby players in moderate ambient temperatures can not be made. Further studies are needed.

5.10 Conclusion

The present study was conducted to examine the effect and how much effect, if any, an ice vest would have on core body temperature as well as on improving exercise performance during a simulated game among wheelchair rugby players in a moderate ambient temperature environment. The results of the present study showed that the benefit of ice vest on wheelchair rugby players in terms of decreasing core body temperature and improving performance is almost none.

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