

**PALM HEAT REDUCTION USING RAPID THERMAL
EXCHANGE UNIT DURING SIMULATED
TAEKWONDO COMPETITION**

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PALM HEAT REDUCTION USING RAPID THERMAL EXCHANGE UNIT DURING
SIMULATED TAEKWONDO COMPETITION

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ABSTRACT

Purpose: To investigate the effects of rapid palm cooling during 1-min rest period between 3 simulated consecutive bouts on physiological responses and anaerobic performance of Taekwondo athletes. **Methods:** Ten male Taekwondo subjects performed 3 sets (separated by a week) of 3 repeated-2 min anaerobic bouts with 1-min rest using modified Wingate Anaerobic test, loaded at $0.06/5 \times$ body weight (kg). Subjects, who had no intervention, sat quietly during the rest period (group 1, control), or received palm cooling without (group 2) or with vacuum (group 3) and were randomly intervened using a rapid thermal exchange unit (RTX) during the 1-min rest period between bouts. Cardiovascular and thermoregulatory indicators were collected during exercise bouts, 1-min during rest period in each bout, and at 5 and 30 min after the 3rd bout. **Results:** All three groups showed a significant drop in anaerobic peak power during the 2nd bout whereas the RTX with vacuum group had significantly recovered in peak power during the 3rd bout ($p < 0.05$). The control group had a significantly higher tympanic temperature (T_{tymp}) and thermal sensation scale during the 3rd round ($p < 0.05$), 5 min ($p < 0.05$) but lower T_{tymp} than in the RTX with no vacuum group at 30 min post exercise ($p < 0.05$). The RTX with vacuum group incurred lower forearm, hand and mean skin temperatures than the control group for the 30 min recovery period ($p < 0.05$). Furthermore, no changes in blood flow, heart rate and mean body temperature were detected between the 3 groups ($p > 0.05$). **Conclusion:** Rapid palm cooling method, applied during the 1-min rest period, improved the anaerobic peak power in Taekwondo athletes, particularly on the 3rd round. This technique offers better thermoregulatory changes during repeated exercise bouts.

KEY WORDS: RAPID THERMAL EXCHANGE / WINGATE ANAEROBIC TEST /
TAEKWONDO

118 pages

การลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิชนิดเร็วในระหว่างภาวะเลียนแบบการแข่งขันกีฬาเทควันโด
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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของการลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิชนิดเร็วในช่วงพัก 1 นาทีระหว่างภาวะเลียนแบบการแข่งขันเทควันโด โดยศึกษาผลการตอบสนองด้านสรีรวิทยาและสมรรถภาพการทำงานแบบแอนแอโรบิก กลุ่มตัวอย่างเป็นนักกีฬาเทควันโด 10 คน เข้าร่วมการทดลอง 3 ครั้ง แยกห่างกัน 1 สัปดาห์ โดยใช้โปรแกรม Modified Wingate Anaerobic Test ที่ความหนัก $0.06/5 \times$ น้ำหนักตัว (กิโลกรัม) เพื่อเลียนแบบการชกรวม 3 ยกๆละ 2 นาที พัก 1 นาที ผู้เข้าร่วมวิจัยซึ่งไม่ได้รับการทดสอบด้วยเครื่องมือใดๆจะนั่งพักนิ่งๆ (กลุ่ม 1, กลุ่มควบคุม), การให้ความเย็นที่ฝ่ามือแบบไม่มีสุญญากาศ (กลุ่ม 2) หรือแบบมีสุญญากาศ (กลุ่ม 3) ทำการเก็บข้อมูลของระบบหัวใจไหลเวียนเลือด ระบบควบคุมอุณหภูมิกายระหว่างการออกกำลังกาย, ช่วงพัก 1 นาทีระหว่างยก, 5 และ 30 นาทีภายหลังการออกกำลังกาย ผลการศึกษาพบว่าทั้งสามกลุ่ม สมรรถภาพการทำงานแบบแอนแอโรบิกลดลงในยกที่ 2 ในขณะที่กลุ่มที่ได้รับการทดลองด้วยเครื่องลดอุณหภูมิชนิดเร็วแบบมีสุญญากาศพบว่ามีเพิ่มขึ้นของสมรรถภาพการทำงานแบบแอนแอโรบิกในยกที่ 3 กลุ่มควบคุมมีอุณหภูมิในช่องหู, การรับรู้ความร้อน เพิ่มขึ้นภายหลังการออกกำลังกายในนาทีที่ 5 แต่ในนาทีที่ 30 กลุ่มควบคุมมีอุณหภูมิในช่องหูลดลงต่ำกว่ากลุ่มที่ 3 ในกลุ่มที่ใช้เครื่องลดอุณหภูมิชนิดเร็วแบบมีสุญญากาศ มีการลดลงอย่างมีนัยสำคัญของอุณหภูมิที่ท่อนแขนด้านล่าง, มือ และค่าเฉลี่ยอุณหภูมิผิวหนังมากกว่ากลุ่มควบคุมในช่วงพักนาทีที่ 30 นอกจากนี้ ไม่พบการเปลี่ยนแปลงของอัตราการไหลเวียนเลือด, อัตราการเต้นของชีพจร และค่าเฉลี่ยอุณหภูมิกายทั้ง 3 กลุ่ม จากผลการศึกษาแสดงให้เห็นว่าการลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิชนิดเร็วช่วยฟื้นสมรรถภาพการทำงานแบบแอนแอโรบิกในนักกีฬาเทควันโด โดยเฉพาะในยกที่ 3 อีกทั้งยังแสดงถึงการเปลี่ยนแปลงที่ดีขึ้นของระบบควบคุมอุณหภูมิกาย ในระหว่างการออกกำลังกายหลายๆยก

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CHAPTER I

INTRODUCTION

Thermoregulation in humans is necessarily maintained in a relatively constant range to offers efficient cellular metabolism at 37°C. When the body fails to maintain a normal temperature and it increases significantly above normal range, such condition is known as hyperthermia. If the body temperature decreases below normal range, this is known as hypothermia. Mean body temperature composes of 60-70% core temperature and 30-40% surface or shell temperatures (Ramanathan, 1964). Most body heat is generated in the organs, especially the liver, brain, heart, and contraction of skeletal muscles (Guyton & Hall, 2006). A condition known as heat balance is normally matched between heat gain: metabolic heat, environmental heat and heat loss: convection, conduction, radiation, and evaporation.

In human, body temperature is controlled by the pre-optic area of the anterior hypothalamus (Romanovsky, 2007). It receives input from two sets of thermoreceptors: receptors in the hypothalamus itself which monitors the temperature of the blood as it passes through the brain (the core temperature), and receptors in the skin (especially on the trunk) which monitors the external temperature. Both sets of information are needed so that the body can made appropriate adjustments (Homeostasis, 2006). In general, humans appear physiologically well adapted to hot dry conditions (Jones *et al.*, 1994). Under hot condition, heat loss centre in the hypothalamus is stimulated effectively in two categories: 1). Behavioral responses e.g. stretching out, finding shade, swimming, removing clothes and 2). Autonomic responses: sweat glands under the skin secrete sweat about 80% during exercise but under high humidity, and tight clothing made of man-made fibers reduce the ability of the sweat to evaporate and so make us uncomfortable in hot weather (Bindon, 2002).

Additionally, many other factors involve with heat transfer in human. For example: a). heat loss may be enhanced by smooth muscles in arterioles in the skin via vasodilatation mechanism. As a result, more heat is possibly carried from the core to

the surface, where it is lost by convection and radiation (conduction is generally low, except when in water) (Homeostasis, 2006) and b). architecture of hair on the skin which lies flat, preventing heat from being trapped by the layer of still air between the hair, this architectural adjustment is caused by tiny muscles under the surface of the skin call “erector pili muscles”, which normally in the relax state so that their attached hair follicles are not erect. These flat hairs increase the flow air next to the skin, which in turn, increases heat loss by convection. Another factor involves with hormonal changes, for example, adrenal and thyroid glands which manipulate amount of secreting adrenaline and thyroxin.

During exercise/physical activity, certain amount of metabolic energy production is induced by working muscles. In term of efficiency, it is estimated about 25-30% is for mechanical efficiency and about 75-80% of the total energy expenditure released as heat (Powers & Howley, 1997; Mirkin, 2008). Previous study found that in a 3-miles race in a hot summer day, lasting only 14 minutes, a runner's rectal temperature may rise up to 41.1°C., with heat stroke imminent (Robinson, 1963). Throughout exercise, the estimation of mean body temperature using core temperature together with mean skin temperature irrespective of weighting is inaccurate even with a correction factor customized for the specific conditions (Jay *et al.*, 2007; Sawka & Castellani, 2007). In 1999, Fritzsche reported that during prolonged exercise in a neutral environment the decline in stroke volume (SV) is related to the increase in heart rate (HR) but not affected by cutaneous blood flow (Rowell, 1986). This cardiovascular drifting is the consequence of a progressive increase in cutaneous blood flow (CBF) as body temperature rises. It is thought that the rise in CBF would lead to an increase in skin venous volume, reducing ventricular filling pressure, end-diastolic volume, and thus stroke volume (Rowell, 1986). Several literature reviews have accepted that a progressive increase in CBF is the main cause of the decline in SV during prolonged exercise (Johnson, 1987; Mole & Coulson, 1985; Raven, 1988; Rowell, 1974). When heat accumulation in body rises thus it affects physical performance as most of blood is being sent to active muscles but diminished certain amount of blood to skin for heat dissipation.

Investigations have been made to prevent effect of heat accumulation as previously mentioned. Among these includes the recovery models using cooling techniques such as ice packs, ice bags, cold water circulating units, cooling jackets, ice massage, cold-or ice-water immersion and cold whirlpool, vapocoolant sprays, and cryo-therapy (McCarty *et al.*, 2004; Venter, 2008). The above reports mentioned that ice is often considered to be one of the most common modality of choices to treat hyperthermia.

One among cooling methods which has been proved that efficiency use in athletic training is “Hand Cooling Methods”. It is recommended for a two-minute ice bath at 12-15°C for team-sport athletes at the end of a recovery session (Coutts & Sirotic, 2004). House and co-workers in 1997 found that hand immersion in water at 10°C within 20 minutes is an effective technique for reducing heat strain in Royal Navy. Clements and co-workers in 2002 compared the cooling rate of immersion in ice water with immersion in cold water in runners with exercise-induced hyperthermia. They found that these two treatments showed similarities in the cooling rates of rectal temperatures and recommended that these can be chosen for treating hyperthermia in athletes. Tolfrey and co-workers in 2007 studied hand cooling condition within 10 min recovery period using both hands immersion up to the wrists in container of 10°C water in a prolong exercise-induced hyperthermia and found that this method can reduce core temperature thus, can improve wheelchair distance-race performance in disabled athletes. Grahn and co-workers in 2008 studied about cooling via one hand using RTX (Rapid Thermal Exchange) which improves physical performance in heat-sensitive individuals with multiple sclerosis. As a result this convenient cooling method increases exercise duration by 35% of walking on a treadmill. Yang Zhang and co-workers in 2009 found that this cooling device resulted in significant lower rectal temperature compared with passive cooling. Reduction in heat storage enhances human safety and performance in hot environments.

Taekwondo, a 1500 years martial art derived from Korea, was originally designed for warfare and self-defense. Over the centuries, taekwondo has spread throughout the world and this well-recognized sport had been officially introduced in International Athletic Competition, Sydney Olympic Games 2000. This sport requires high level of physical fitness of either anaerobic (Ghosh *et al.*, 1999) or aerobic

(Howley *et al.*, 1995; Wisloff *et al.*, 2002). Taekwondo needs high physical performed such as cardio-respiratory function, speed, flexibility, muscle strength especially in lower-limb, an aerobic power and capacity (Hiroyuki *et al.*, 1999; Heller *et al.*, 1998; Melhim, 2001; Toskovic *et al.*, 2004). Taekwondo ranking due to athlete's body weight then athletes sometime have to avoid water to continuous training (Flemming & Costarelli, 2009). The competition consists of 3 rounds of 2 minutes each, with 1 minute recovery. With high physical effort, this makes body temperature rises. Thus it requires rapid recovery technique, which is thought to be a key factor to sustain physical fitness.

New tool to reduce body's heat, such as Rapid Thermal Exchange (RTX), has been reported recently to use as a effective cooling tool in human (Brown *et al.*, 1999; Hagobian *et al.*, 2004). This device divides into 3 main parts: a) first part is Vacuum controller which works as a pump with a maximum pressure of 47 mmHg, b) second part is an attachment hose that brings cold water to body part, and c) the last part is thermal exchange chamber made by a special materials that transfer heat very quickly (Rickart *et al.*, 2005). At the present time RTX has been used in sport research to lower core temperature that affects the recovery of anaerobic function (Whitish *et al.*, 2003) and reduces recovery time from virtually aerobic (Elliott *et al.*, 2003). This technique to accelerate recovery is a significant success factor in boxers (Khanna *et al.*, 2006). RTX will not clearly exert its efficiency in light exercise such as walking and running (Walker *et al.*, 2009). Recently, RTX has been extensively used in military training (Whitmore *et al.*, 2007).

When training time is last longer than 45 minutes in hot environment, core temperature may rise up to 39°C and pulse can reach up to 95% of the maximum pulse (Kellett *et al.*, 2001). Physiological basis of training states that the resilient on both short and long term will require returning processing from delayed biochemical and aerobic processes, and this primary recovery process results in amount of heat production (Tessitore *et al.*, 2007; Scott, 2000). Techniques that have been proven to help body cooling include half and full body water immersion and ice massage (Yeargin *et al.*, 2006). These techniques are, therefore, difficult and inconvenient to be conducted. The use of RTX with palm cooling device seems easier.

However, very few studies had been focused on Taekwondo recovery profile (Heller *et al.*, 1998; Thomson *et al.*, 1991). The difficulty is that this sport requires both aerobic and anaerobic processes (Melhim, 2001). Most of previous researches on Taekwondo paid attention on physical needs, none of them concerns on recovery strategy. New knowledge gained from this study benefits not only in Taekwondo but also in boxing, wrestling and other martial arts sports. This study believes that specific RTX cooling technique used during a short braking period between the fight might positively affect physiologic body's recovery which enable athletes to sustain high performance for the subsequent rounds.

Purposes of the study

General objectives

The main purpose of the study is to investigate the effects of rapid palm cooling (RTX Core Control method) on physiological responses and physical performance of Taekwondo athletes during recovery in between and post competition events.

Specific objectives

1. To investigate effects of rapid palm cooling method (RTX Core Control method) on subsequently changes of anaerobic power and capacity in Taekwondo athletes.
2. To compare the changes in physiologic variables including Thermoregulatory, Cardiorespiratory, and Metabolic variables and subjective evaluation (RPE) between RTX treated and control Taekwondo athletic groups.

Hypothesis of the study

Rapid palm cooling (RTX Core Control method) enhances recovery in Taekwondo athletes in between and post competition events.

Scope of the study

This study will investigate the effects of rapid palm cooling (RTX Core Control method) in male Taekwondo athletes during 1 min of recover period of simulated 3 rounds competition, at 5 and 30 min after the final round. Changes of cardiorespiratory system (HR, BP, forearm blood flow), thermoregulation (skin and core body temperatures, thermal sensation scale), blood chemistry (lactate concentration) and subjective evaluation (RPE) between treated and control groups will be compared. Comparisons of performance, including anaerobic power and capacity, of 3 rounds will be investigated for effectiveness of RTX.

Advantages of the study

1. To understand changes in physiological variables related to physical performance in Taekwondo athletes
2. To develop the appropriate physical conditioning program in Taekwondo athletes of both during training period and competition
3. To use as guidelines for excellent performance of other competitive martial art sports

CHAPTER II

LITERATURE REVIEW

2.1 Human Thermoregulation

Body temperature is necessarily maintained in a relatively constant range because most cellular functions can effectively work at 37°C. Changes in body temperature affect cellular structures, enzyme, systems, and numerous temperature dependent chemical reactions and physical processes that take place in the body (Astrand *et al.*, 2003). At temperature below 34°C cellular metabolism slows greatly, leading to unconsciousness and cardiac arrhythmia (Guyton, 2000). Physical activity results in heat production which may affect biochemical action.

In terms of medical applications, in addition to vital sign, changes of body temperature will be used to indicate the state of the body injuries. Mammalians, include human, are homeothermic or warm blood animals that can control body temperature, constantly at 37° C in human. Thermal generating in one part often makes the body responses via either central or peripheral thermoregulatory control mechanisms. It is generally known that higher center in hypothalamus responses for precise temperature regulation in warm-blooded animals.

2.2 Heat balance during physical activity

Main function of human thermoregulation is to maintain relatively constant of core- body temperature and prevent overheating or overcooling from changes of environment. When the body is unable to maintain a normal temperature and it increases significantly above normal range, a condition known as hyperthermia and if body temperature decreases below normal range, is known as hypothermia. To prevent hyperthermic and hypothermic conditions, body mechanism must match between heat gain and heat loss that called “heat balance” in the physiologic range. During high physical activity, body metabolic energy production by working muscles may rise up

to in which about 75-80% of the total energy expenditure is released as heat (Scott K. Powers and Edward T. Howley, 1997; Gabe Mirkin, 2008). Under such condition, various physiologic functions play critical role to control body heat. These include cardiac, respiratory and circulatory systems. Blood is very effective to store or release heat. At vigorous exercise, core temperature has tendency to rise from above metabolism of working muscle blood flow, this may shut certain amount of blood flow to skin. As a result, dissipation of heat to the environment becomes impair and core temperature rises up. In summary, human, which is one of the homeotherms animals, can maintain his constant core-body temperature by matching between heat gain and heat loss via regulation between two main parts: deep body (core temperature) and shell (skin) temperatures (Gilbert S.S.,2004; Wenger C.B.,2001).

2.3 Normal Body Temperature

Normal range of body temperature variations are in narrow range of about 98° to 99°F (35.5°C to 37°C) orally and 99° to 100°F (37°C to 38°C) rectally, where it is much in the wider ranges for skin. (Mosby, 2009). Body temperature (T_{body}) is the summary of core temperature (T_{core}) 70% and skin temperature (T_{shell}) 30% as shown in equation:

$$\text{Eq. 1: } T_{\text{body}} = (0.7 \times T_{\text{core}} + 0.3 \times T_{\text{shell}}),$$

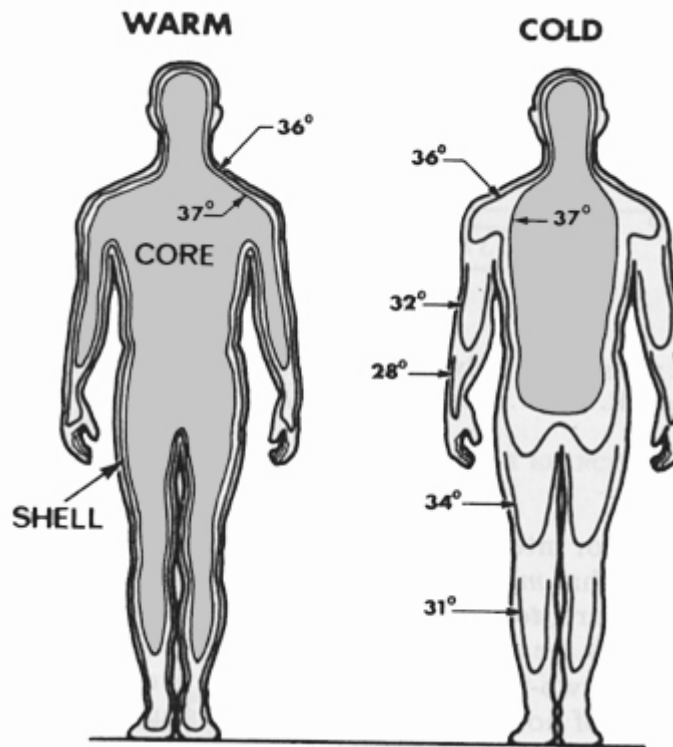


Figure 2.1 Core and skin temperatures during in surrounding warm (left) and cold (right) (Rhoades & Pflanger, 1989).

2.3.1 Core temperature

Temperature of the internal part of the body remains quite stable, unlike the temperature of the outer body surfaces which is generally affected by the environment. Core-body temperature can be measured at many sites such as in rectum, esophageal, tympanic using thermometers or any devices named as thermocouples or thermistors (Foss & Keteyian, 1998). The average normal human core temperature is around 98.2° F (36.8° C), with minor variations of +1.3 degrees Fahrenheit (0.7° C) when taken orally, and about 1.0° F (0.5° C) higher when taken rectally. The core temperature of a human actually fluctuates over the course of a day, becoming higher when a person is more active, and dropping to its lowest point halfway through the sleep cycle. Traditionally the core temperature of a person is given as 98.6° F, which is a conversion of an earlier measurement from the 19th century, which recorded average core temperature as 37° C. Core temperature is closely monitored by nerve cells throughout the body. When they detect a change in temperature from the ideal core

temperature, the nerve cells in the hypothalamus of the brain respond by either speeding up or slowing down in their impulse generation. (www.wisegeek.com)

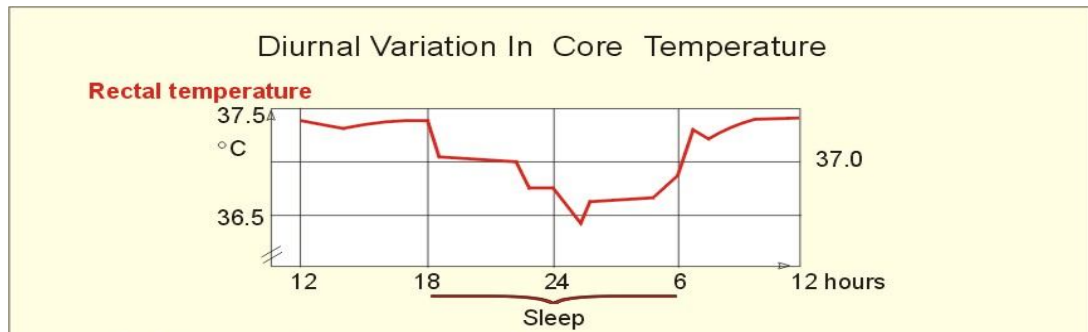


Figure 2.2 Variations of the core temperatures during 24 hours with lowest value during sleep (Paulev, 2000).

2.3.2 Skin temperature

Body shell refers to those outer parts of the body (skin and subcutaneous tissue) that is affected by changes in environmental temperature (Paulev, 2000). Two types of thermo sensitive receptor at nerves endings underneath the skin are classified as cold and warm receptors (Wenger, 2001; Somchai, 2008). Cold receptors are activated in range of -5 to 43°C, warm receptors response only above 30°C. There is some overlapping of the static discharge of warm and cold receptors populations in a range from about 30 to 43°C (Hensel, 1981). Skin temperature can be measured relatively easily with commercially available skin temperature sensors placed on various skin locations (Astrand *et al.*, 2003). Mean skin temperature can be calculated by assigning certain factors to each individual skin measurement in proportion to the fraction of the body's total surface area that each measurement represents. For example, mean skin temperature (T_s) can be estimated from skin temperatures measured on the forehead, chest, forearm, thigh, calf, abdomen, and back respectively using the following formula: (Kenney.,1988)

$$\text{Eq. 2: } T_s = (T_{\text{forehead}} + T_{\text{chest}} + T_{\text{forearm}} + T_{\text{thigh}} + T_{\text{calf}} + T_{\text{abdomen}} + T_{\text{back}}) / 7$$

Persons exposed to general anaesthesia, alcohol, and certain drugs lose the autonomic thermoregulation. Cold-blooded animals must live with varying core and shell temperatures, whereby the rate of their cellular activities varies with the surrounding temperature (Figure 2.3) (Paulev, 2000).

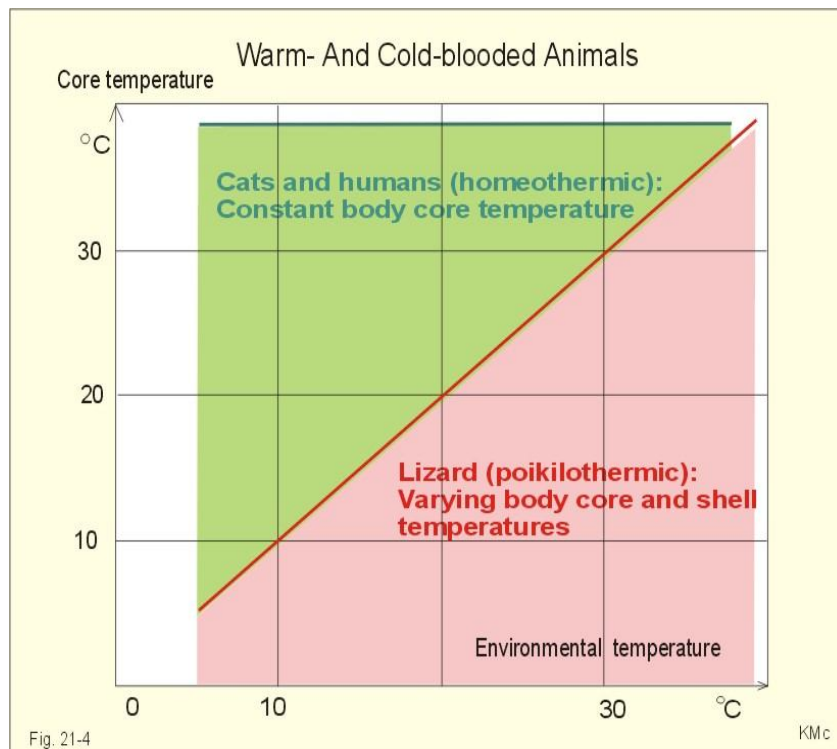


Figure 2.3 Body core temperature and environmental temperatures for a warm-blooded animal (cat) and a cold-blooded animal (lizard). (Paulev, 2000)

2.4 Heat Production and Heat loss

According to previously stated, body temperature is physical factor that important to be maintained in the relatively constant range. This regulation is achieved by balance controlling the rate of heat production and heat loss (Figure 2.4).

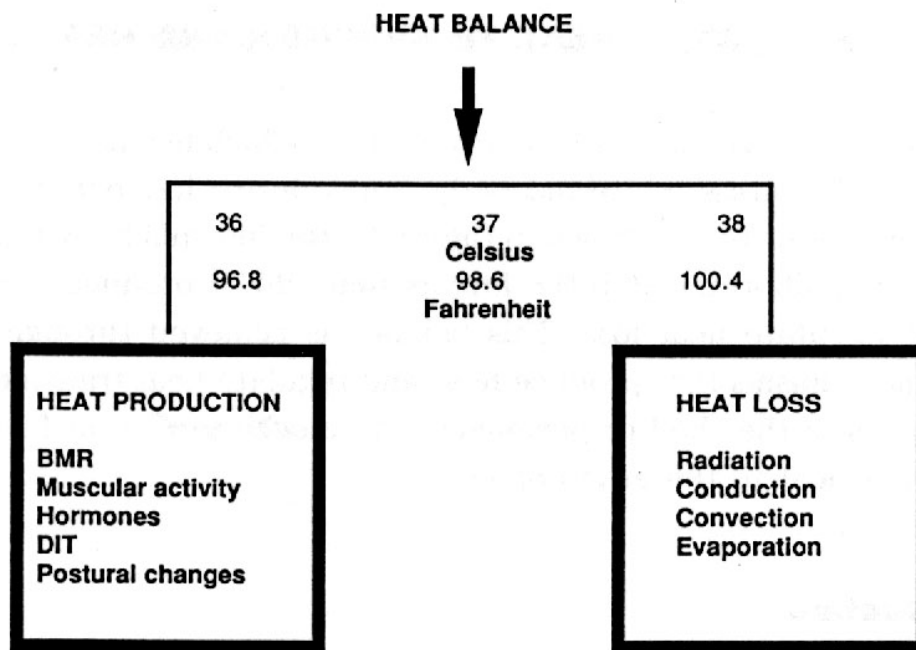


Figure 2.4 Heat balance is adjusted by heat production and heat loss (Bindon, 2002)

2.4.1 Heat Production

The unit of heat energy most commonly used is the calorie, which defined as the amount of heat required to raise the temperature of 1 gm of water up to 1°C. The kilocalorie (kcal) is the amount of heat required to raise the temperature of 1 kg of water 1°C which is called as specific heat of water. Specific heat of body's tissues is 0.83 kcal. kg-1. °C-1. For example, a person weighting 70 kg must "store" 58 kcal of heat (0.83 x 70) to increase the body temperature 1°C (Foss & Keteyian, 1998).

Body produces internal heat due to normal metabolic processes including digestion of food, contraction of skeletal muscles, and secretion of some hormones. During rest or sleep, metabolic heat, basal metabolic rate or BMR, is small but during exercise metabolic heat is large from active muscles. Body heat can be produced and classified as voluntary (exercise) or involuntary (shivering or biomechanical) heat production cause by the secretion of hormones such as thyroxine and catecholamines) (Powers & Howley, 1997; Ganong, 2003). Moreover, physical work assigned in hot/humid environment serves as a serious test of the body's ability to lose heat. When exposure to cold, heat will primary be affected by shivering. The maximal shivering can increase the body's heat production by approximately five times the resting value

(Brooks & Fahey, 1987; Fox, 2006; Powers & Howley, 1997). Thyroxine acts by increasing the metabolic rate of all cells in the body produces a slowly developing but prolong increase (Clasen *et al.*, 1991; Piyarit, 2004). In contrast, catecholamines (epinephrine and norepinephrine) increase rapid heat production but short-lived by improving the rate of cellular metabolism (Guyton, 2005; Powers & Howley, 1997)

2.4.2 Heat loss

Heat exchange between the body and environment takes place at all time (Figure 5). Key concepts of heat exchange system on the core-shell model include: a). heat flows down the temperature gradient, for example, from muscle (where the heat is produced) to the core and to the skin via convection; b).some heat is conducted directly to the surface of the skin from both muscle and the core. Transfer of heat from skin to environment depends on: a) temperature gradient between skin and air for both convection and radiation and b) rate of evaporation, which is greatly dependent on the difference in vapor pressure between the skin and the environment. (Nadel, 1979; Taylor *et al.*,1943; Foss & Keteyian, 1998).

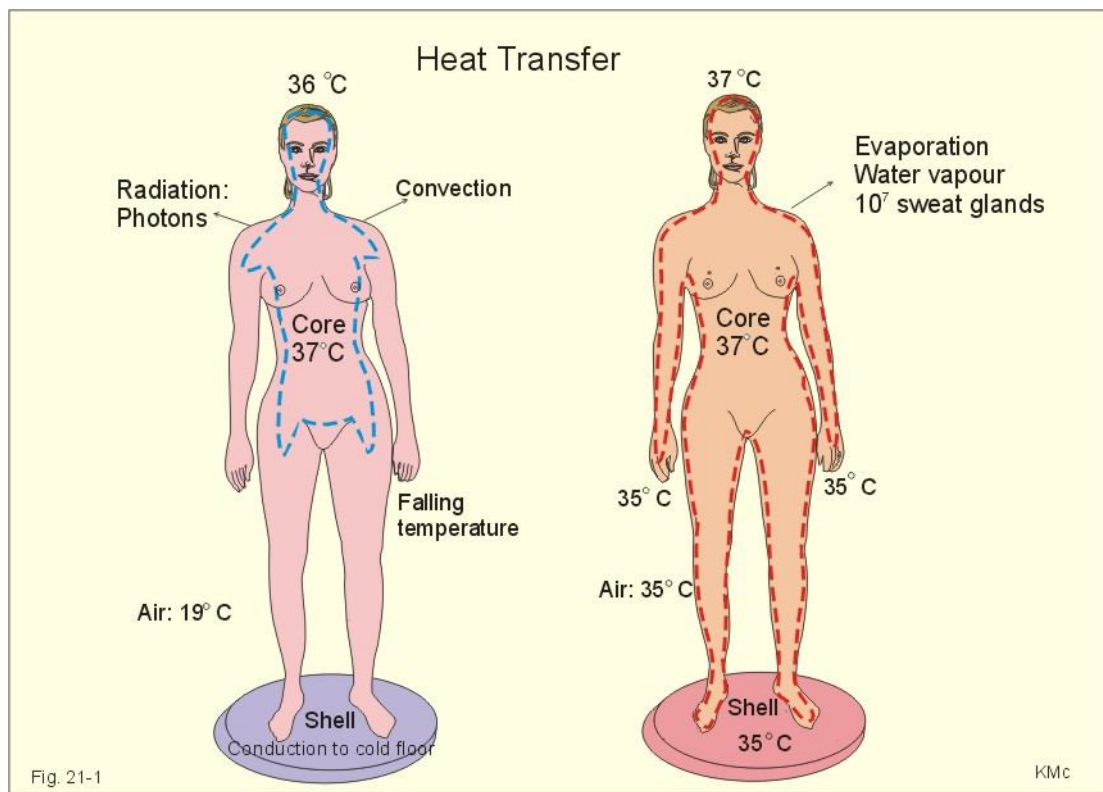


Figure 2.5 Heat transfers, body cores and shells temperatures of a naked person standing in cold and warm air, respectively. (Paulev, 2000).

Routes of heat loss

Body heat can be lost by four mechanisms: radiation, convection, conduction and evaporation. Temperature gradient between skin and environment dictates heat loss processes. (Powers & Howley, 1997; Leonard, 1998; Guyton, 2000; Ganong, 2003; Piyarit, 2004).

Radiation

Radiation is heat loss between body and environment in form of infrared rays or electromagnetic waves (photons). It relates transfer of heat from the surface of one object to the surface of another without molecular contact between subjects. Net loss of the body heat occurs due to the thermal gradient. Radiation is primary important method of heat loss about 60% at rest in a comfortable environment. On the other hand, on sunny day where environment temperature is higher than skin temperature then the body can also gain heat via radiation instead of heat loss from the skin to environment. For example, a person seated in a dry sauna with the temperature set at 120°F would obviously gain more heat from radiating light bulbs and heating elements than he or she could lose through radiation (Foss & Keteyian, 1998). During athletic field training, clothing will significantly alter the radiant heat loss or heat gain. When time of the day is between 12:00 noon and 4:00 P.M., this can considerably be heat gained from the sun through radiation. But clothing can reduce heat dissipate by evaporation (Foss & Keteyian, 1998).

Convection

Convection is defined as the transfer of heat from one place to another by the motion of a heated substance such as gas or liquid. In convection heat loss, air or water molecules are warmed and move away from the source of the heat and are replaced by cooler molecules. Thus heat loss via convection is greater on a windy day, because warmed air is quickly replaced by colder air. Amount of heat loss due to convection depends on airflow over the skin. For example of forced convection is an electric fan pushing large quantities of air past the skin; this would increase the number of air molecules coming in contact with the skin and thus promote heat loss. However, water's effectiveness in cooling is about 25 times greater than of air at the

same temperature (Powers & Howley, 1997). Immersion in cooling water also results in strong convection heat loss. Naturally, gas convection is greatly influenced by barometric environment; only respiratory convection can dissipate more heat than metabolism can produce (Hensel, 1981). The convection heat loss is calculated by Eq3.

$$\text{Eq. 3: } H_{CON} = 0.5 * (T_{\text{shell}} - T_{\text{air}}) \text{ in kJ per min.}$$

Conduction

Conduction describes as a direct transfer of heat energy by contact between two bodies of different temperatures (e.g. skin and objects). It contributes to about 3% of heat loss (Hensel, 1981). The direction of heat flow is always from the warmer to the molecules of cooler objects. In human body, heat generated can be conducted through contacting tissue until it reaches the cooler surface. For example, while a person is sitting on a metal chair, heat loss occurs as long as the chair is cooler than the body surface. Although conduction has less important role in heat balance but it can also lead to local injury when direct contact bare skin with extremely hot or cold objects, e.g. burns or frostbite, is accidentally took place.

Evaporation

Evaporative heat loss is defined as heat loss via water evaporation from the respiratory passages and skin surface. It accounts for approximately 25% of the total heat loss at rest. But during exercise this heat loss is the most important mode of cooling about 80% of the overall mode. In this mode, heat is transferred from the body to water on the skin surface. When water on the surface of the skin gains sufficient energy, it is converted to gas (water vapor) for prevent overheating by taking the heat away from the body. Body loses 0.58 kcal of heat/ml of water that evaporates. Therefore, evaporation of 1L of sweat causes heat loss of 580 kcal. The upper body included head responsible for the majority of evaporative heat loss. Thus wearing a hat and shirt or coat can interfere with evaporative cooling (Charkoudian, 2003). Thus sweat glands play major role in evaporation. Sweat gland itself is a tubular structure consisting of 2 parts: a deep (subdermal) coiled portion the secretes sweat (precursor

secretion) and a duct portion that passes through the dermal and epidermal layers of the skin and terminates in a pore (Foss & Keteyian, 1998). Numbers of over 2-3 millions sweat glands in a person living in a temperate climate, sweat glands are controlled or regulated by the sympathetic nervous system. Stimulation of the anterior hypothalamus preoptic area of the brain by an increased temperature in the blood circulating through this area leads to sweating. Impulses from the hypothalamus travel down nerves in the spinal cord and then through the sympathetic outflow to the skin. These nerves activate sweat glands through the release of acetylcholine. Sweat glands can also be stimulated by epinephrine and norepinephrine (adrenaline and noradrenaline) that is circulating in the blood. During exercise, elevated metabolism causes higher body temperature which stimulates sweat glands to secrete sweat onto the surface of the skin then lowers skin temperature.

Evaporation of sweat from the skin depends on three factors: 1) the temperature and relative humidity (RH), 2) the convection currents around the body, and 3) the amount of skin surface exposed to the environment (Powers & Howley, 1997). High environment humidity interferes with evaporative heat loss, thereby effectively increasing heat load on the body (Hensel, 1981). It is indicated that higher humidity will reduce potential evaporation and thus effects heat loss. In fact, vapor pressure is influenced by both temperature and relative humidity (Table 1). At any given temperatures, a rise in relative humidity results in increase vapor pressure. For example, when exercising on a hot/humid day (e.g. air temperature = 30°C; RH = 100%) it might have a mean skin temperature about 33-34°C. Air vapor pressure is 32 mmHg and vapor pressure on the skin is 35 mmHg. Vapor pressure gradient between skin and air are small (3 mmHg) and would permit only limited evaporation. Therefore small cooling will be occurred. On the other hand, if air temperature is 10°C; RH = 50% mean skin temperature = 30°C. The vapor pressure gradients under these conditions are 28 mmHg (32-4 = 28) (Table1). Therefore, the rate of evaporation is greatly. In summary, performing exercise in a hot environment where air temperature is higher than skin temperature evaporation is the only means of losing body heat.

Table 2.1 The relation between temperature and relative humidity (RH) on vapor pressure (Powers & Howley, 1997)

TABLE 12.1		The Relationship Between Temperature and Relative Humidity (RH) on Vapor Pressure	
50% RH			
Temperature °C	Vapor Pressure (mm Hg)		
0	2.3		
10	4.6		
20	8.8		
30	15.9		
75% RH			
Temperature °C	Vapor Pressure (mm Hg)		
0	3.4		
10	6.9		
20	13.2		
30	23.9		
100% RH			
Temperature °C	Vapor Pressure (mm Hg)		
0	4.6		
10	9.2		
20	17.6		
30	31.9		

In summary, thermoregulatory system is carried out via the following components (Figure 2.6): 1) *thermal regulatory center* located in the central nervous system that coordinates incoming sensory information with outgoing regulatory action; b) *Thermal receptors or sensors*, which are sensitive to thermal stimuli (heat and cold) and provide input to the coordinating center located in the nervous system; and c) *Thermal effectors organ*, which are directed by the coordinating center to produce regulatory or corrective changes.

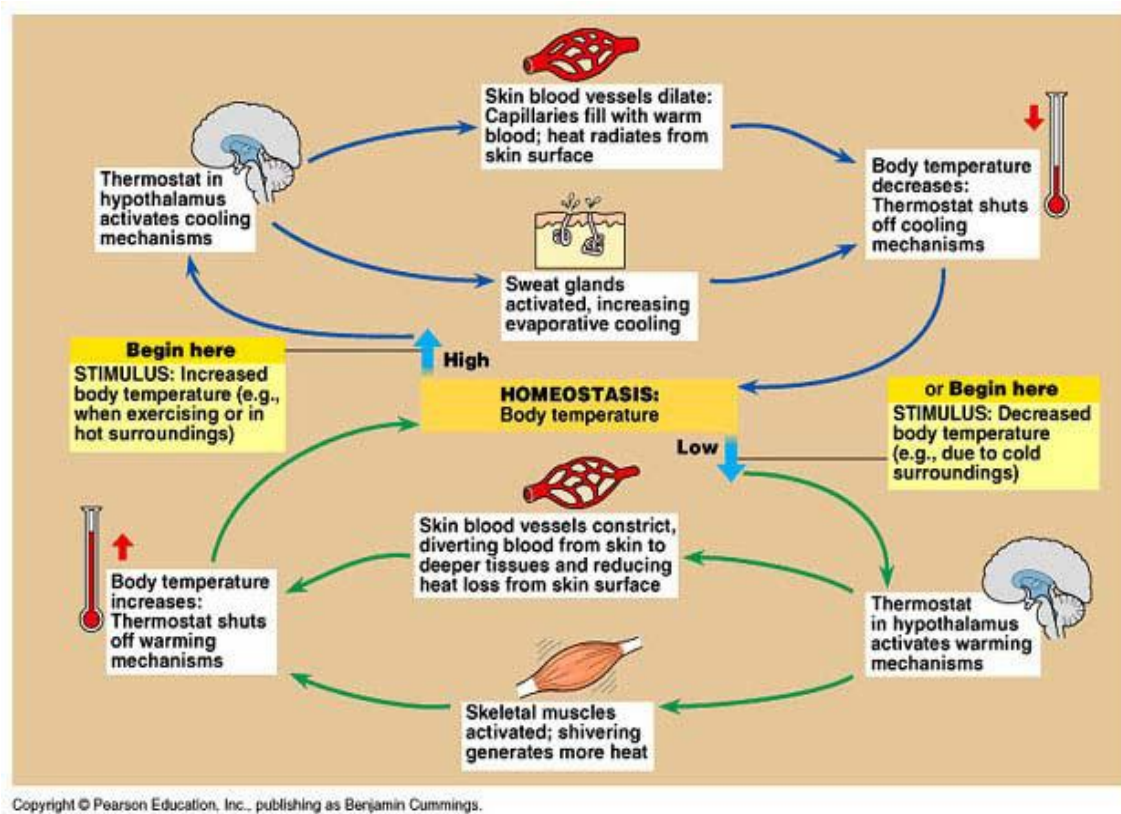


Figure 2.6 The thermoregulatory centre sends impulses to several different effectors to adjust body temperature. (Homeostasis, 2006)

2.5 The Thermal Regulatory Center

The thermal regulatory center is located in a subcortical area of the brain called hypothalamus. The role of this center is somewhat analogous to that a thermostat of air-conditioned room. The temperature of the room (internal body temperature) is measured by a thermometer (receptor organs or sensors) and compare with a set point (T_{set} , 37°C). If the measured temperature deviates from T_{set} , the thermostat (hypothalamic center) automatically relays information to the heating or cooling systems (thermal effectors), which correct the room (body) temperature to the T_{set} value. The return to T_{set} then automatically shuts off the effectors system.

2.5.1 Thermal Receptors

Human body has at least three major thermal receptor areas: these are located in the *anterior hypothalamus* (central receptors), the *skin* (peripheral

receptors), and the *spinal cord/abdominal viscera/great veins* (deep body receptors). In the anterior hypothalamus there are a large number of heat and cold sensitive neurons. The ratio of heat-sensitive to cold-sensitive neurons is 3 to 1 in which all of them sensitive to small temperature fluctuations (0.2 to 0.5°F) from incoming arterial blood. These heat-sensitive neurons increase their firing rate as the temperature of the blood passing through the anterior hypothalamus falls (Foss & Keteyian, 1998).

Thermal changes on the skin, resulted from fluctuations of environmental temperature, are sensed by at least three types of sensory receptors: cold, warmth, and pain receptors. Cold and warmth receptors are located just underneath surface of the skin, each serving an area that is approximately 1 mm in diameter. Along with cold or warmth receptors, the pain receptors respond to “freezing cold” or “burning hot”. Throughout different areas of the body there are 3 to 10 times more numbers of cold than warmth receptors. As a result, these receptors mainly detect cold rather than warmth. Cold sensitive nerve ending has been identified as a small myelinated nerve ending that extends into the bottom of the basal epidermal cells of the skin. The exact nature of the warmth fiber has not been identified. It is thought to consist mainly of free nerve ending (Foss & Keteyian, 1998).

Both of central receptors located in the hypothalamus and the other receptors are neutrally connected to a regulatory or control center in the posterior hypothalamus. Sensory input to this area triggers involuntary reflexes that will eliminate or conserve heat as needed. It is known that skin receptors and other sensory inputs (e.g., vision) provide information to the central cortex. Thus there are cortical connections/contributions available for voluntary or behavioral regulation, such as seeking shaded or sunny areas, initiating or avoiding physical exercise, removing or adding clothing, and stretching out or curling up in warm or cool environment, respectively (Foss & Keteyian, 1998).

The central and peripheral receptors are usually coordinated to provide accurate information to the hypothalamus. However, there are instances when the input can be misleading. For example, after prolonged exercise events that evoke excessive sweating (and evaporation), the skin may feel cool even though core temperature is still elevated (hyperthermic). This is why thermal wraps are provided to participants following prolonged endurance events such as a marathon. Doing so

warms the surface of the skin and appropriate signal to the temperature regulatory center.

The internal body temperature is dynamically compared with T_{set} –usually 37°C or 98.6°F. As a result of this comparison, adjustments are made by the body that lead to heat loss or heat conservation. T_{set} , however, can be changed according to the role of the peripheral receptors. For example, when the skin is warmed, T_{set} is reduced. This causes sweating, cutaneous vasodilation, and body cooling. The opposite is true when the skin is exposed to cold- that is, T_{set} is increased so that responses that lead to heat conservation or heat production occur sooner (Foss & Keteyian, 1998).

2.5.2 Thermal Effector Organs

The major thermal effector organs include *skeletal muscles*, *smooth muscles encircling the arterioles* that supply blood to the skin, the *eccrine sweat glands*, and certain *endocrine glands*. These are the sites that carry out physiologic actions to correct/restore core temperature. These major thermal effector organs actions are conducted via both somatosensory and autonomic nervous systems in a feedback regulatory fashion (Figure 7). In a warm or hot environment, the arterioles supplying blood to the skin dilate (cutaneous vasodilation), and sweating occurs to facilitate heat loss. On the other hand, in a cold environment, the skeletal muscles contribute to shivering, which increases metabolic heat production. The mechanism of shivering occurs when the body temperature falls (as sensed in the hypothalamus) just below a critical level. Under this condition, motor neurons are activated to increase muscle tone throughout the body, to the extent that shivering is noticed. During maximal shivering body heat production can rise 4 to 5 times above normal. At the same time cutaneous vasoconstriction occurs, which contributes further to heat conservation (Foss & Keteyian, 1998).

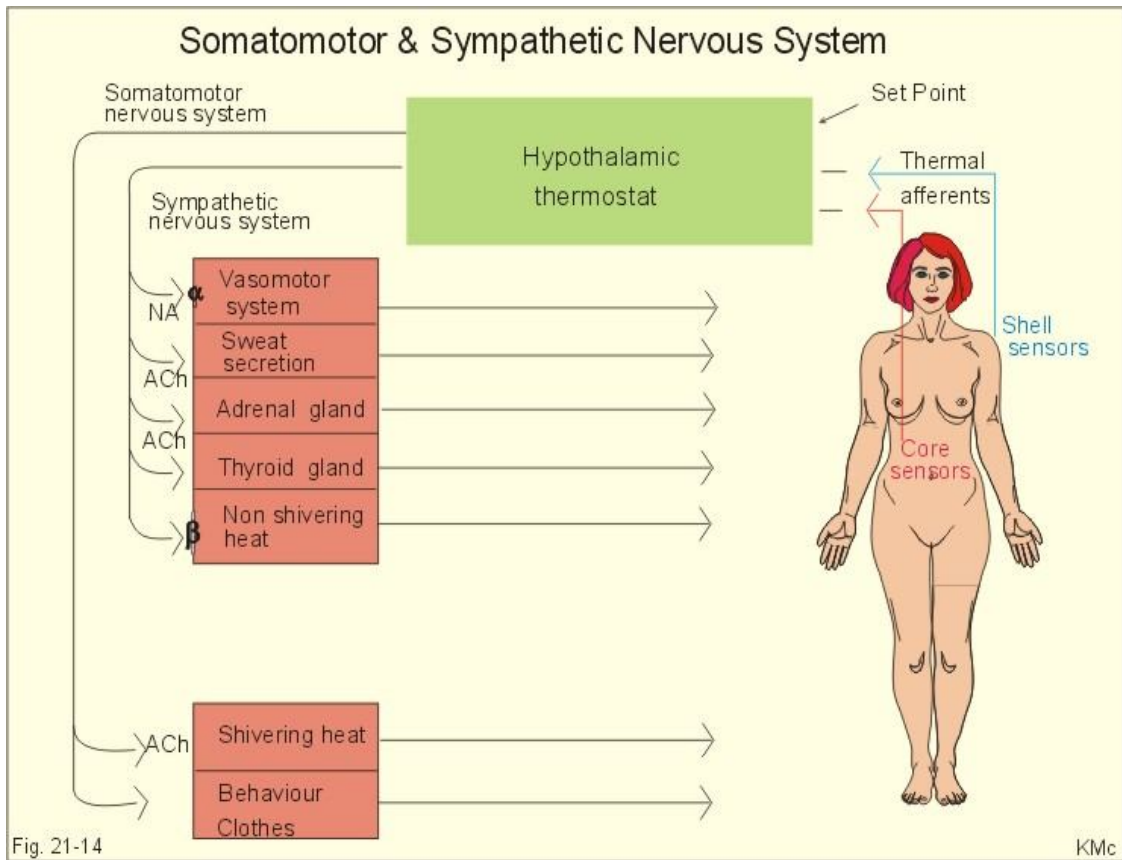


Figure 2.7 thermoregulatory feedback systems. Sympathetic and the somatomotor nervous system participate in thermoregulation. (Paulev, 2000)

The important action of vasomotor control (Table 2.2), of either dilation or constriction, of the arterioles supplying blood to the skin is achieved from the fact that heat from the body core must first be transported, by circulatory conduction and convection, to the surface before it can be lost to the environment by conduction, convection, radiation, and evaporation. With cutaneous vasoconstriction, blood flow to the skin is reduced and, hence, so is the transfer of heat from the body core (heat conservation). The opposite is true for cutaneous vasodilation; where increased blood flow to the skin allows for increased dissipation of deep body heat to the environment (Foss & Keteyian, 1998)

Table 2.2 Responses to low and high temperatures from thermal effector organs (Homeostasis, 2006)

Effectors	Response to low temperature	Response to high temperature
Smooth muscles in arterioles in the skin.	Vasoconstriction. Less heat is carried from the core to the surface of the body, maintaining core temperature. Extremities can turn blue and feel cold and can even be damaged (frostbite).	Vasodilation. More heat is carried from the core to the surface, where it is lost by convection and radiation (conduction is generally low, except when in water). Skin turns red .
Sweat glands	No sweat produced.	Sweating onto surface of skin, where it evaporates . High humidity , and tight clothing reduce the ability of the sweat to evaporate.
Erector pili muscles in skin (attached to skin hairs)	Muscles contract , raising skin hairs and trapping an insulating layer of still, induces warm air next to the skin.	Muscles relax , lowering the skin hairs and allowing air to circulate over the skin, encouraging convection and evaporation.
Skeletal muscles	Shivering: Muscles contract and relax repeatedly, generating heat by friction and from metabolic reactions.	No shivering.
Adrenal and thyroid glands	Glands secrete adrenaline and thyroxine respectively, which increases the metabolic rate in different tissues , especially the liver, so generating heat.	Glands stop secreting adrenaline and thyroxine.

The endocrine glands involved in temperature regulation contribute to both short-term and long-term heat production. During cold exposure, level of *epinephrine* and *norepinephrine* arise from the adrenal medulla and subsequently produce heat via increasing cellular metabolic rate. The extent of this chemical or nonshivering

thermogenesis is directly related to the amount of brown fat that exists in the animal's tissues. In adult humans, very little brown fat is present; therefore, heat production via this method of chemical thermogenesis is limited to a 10% to 15%. In newborn infants, however, some brown fat is present, which contributes to the maintenance of normal body temperature. Over several weeks of exposure to cold, metabolic heat production is also increased because of higher level of thyroxine from the thyroid gland. Thyroxine increases the rate of cellular metabolism, representing another form of chemical thermogenesis (Foss & Keteyian, 1998).

2.6 Heat Storage in the Body during Exercise

During exercise, heat gain is derived from higher metabolism of working muscles. This heat is not promptly lost must rather be temporarily stored in muscle and surrounding tissues. Therefore, the amount of heat gain in the body during exercise is computed as the difference between heat production and heat loss:

$$\text{Body heat gain during exercise} = (\text{heat produced} - \text{heat loss})$$

It is documented that there is no gender different in thermal responses to maximal exercise or in the relationship of hyperthermia to reductions in $\dot{V}O_{2\max}$ and physical performance at high temperature (Arngrimsson et al., 2004). However, the amount of heat energy required to raise body temperature depends upon the size of the individual (i.e., body weight) and a characteristic of body tissue called specific heat. The term specific heat for the human body is 0.83 kcal/kg of body mass. Therefore, the amount of heat required to elevate the body temperature by 1 °C can be computed as follows:

$$\text{Heat required to raise body temperature by } 1^{\circ}\text{C} = (\text{specific heat} \times \text{body mass})$$

For example, using the equation above, the amount of heat required to increase body temperature by 1°C in a 70 kg individual can be computed by multiplying the specific heat of the body (0.83 kcal/kg) by the individual's body weight (70 kg). Therefore, the heat required to increase body temperature by 1°C would be 58.1 kcal (i.e., 0.83 kcal/kg × 70 kg = 58.1 kcal) (Powers & Howley, 1997).

2.7 Body-responses to heat

Sweat secretion. Three million sweat glands produce sweat at a rate of up to 2 litres *per hour* or more during exercise in extreme warm conditions. If not compensated by drinking or cooling, such high sweat rates lead to circulatory failure and shock. Sweat resembles a dilute ultrafiltrate of plasma. Healthy humans cannot maintain their body temperature, if the environmental air reaches body temperature and the air is saturated with water vapor. Primary sweat is secreted as an osmotic fluid into the sweat duct, and subsequent NaCl reabsorption results in the final hypo-osmotic sweat. *Thermal sweating* is abolished by atropine, proving that the postganglionic fibers are cholinergic. Cholinergic drugs provoke sweating just as adrenergic agonists do.

Evaporation of water on the body surface eliminates 2428-2436 J g⁻¹ at mean shell temperatures of 30-32°C. Evaporation of a large volume of sweat per time unit (V°_{sweat}) implies a substantial loss of heat according to equation below:

Evaporation of water on the body surface eliminates 2430 J g⁻¹. Evaporation of large volume rates of sweat (V°_{sweat}) implies a substantial loss of evaporative energy (J/min) according to the equation:

$$\Delta H_{\text{EVAPORATION}} (\text{J min}^{-1}) = 2430 (\text{J g}^{-1}) \times V^{\circ}_{\text{sweat}} (\text{g min}^{-1}).$$

Normally, muscle and core temperatures rise in the parallel fashion where skin temperature falls with increasing work intensity, because the sweat evaporation cools the skin (Figure 2.8). Danger occurs when the average skin temperature and the body core temperature converge towards the same value.

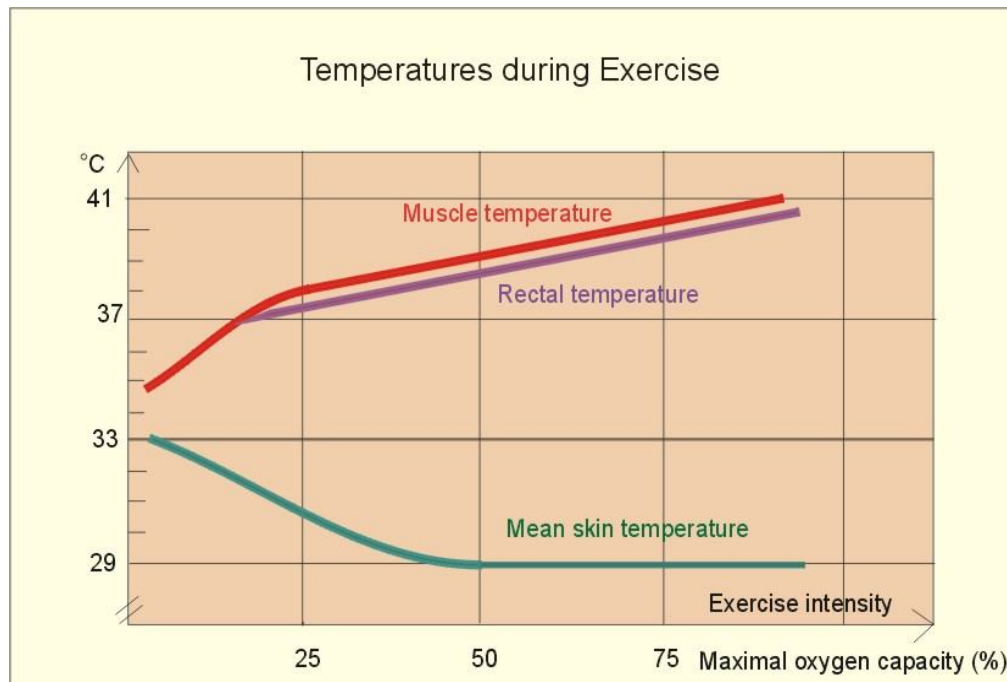


Figure 2.8 Muscular and oesophageal temperature during steady state exercise. The levels of exercise range from zero to 100% of the maximum oxygen uptake. (Paulev, 2000)

Condensation of water on the skin gains heat energy, which is stored in the body. This is what happens in a Sauna. *Vasodilatation of skin vessels* in warm environments results in increased cardiac output. The counter-current heat exchange is governed via *arterio-venous anastomoses* (Figure 2.9.) in the hands and feet, which are open, and blood flow can rise up to at least 10 folds. Skin blood flow of extremities mainly determines the amount of heat energy being accumulated or dissipated.

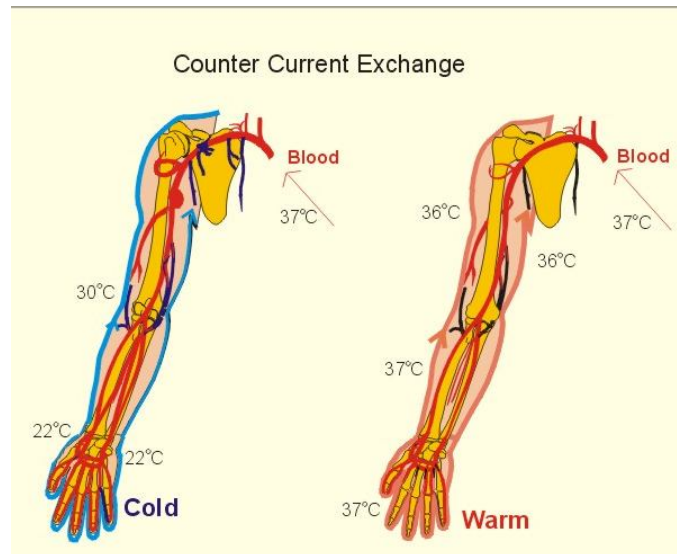


Figure 2.9 Counter-current exchange in a human arm conserving heat energy in a cold climate (left). Superficial venous cooling eliminates heat energy in a warm climate (right). (Paulev, 2000)

CHAPTER III

MATERIALS & METHODS

Taekwondo athletes received medical examination by a medical doctor in order to find out limitations that may occur while performing the test. All athletes signed informed consent document and filled questionnaires.

This study was a non-invasive experiment which measured changes in 8 skin temperatures and a core temperature with three conditions: self recovery, cooling only with RTX recovery, and cooling combine sub-atmospheric pressure with RTX recovery.

3.1 Subjects

Ten male-taekwondo athletes, age range between 15-20 years, voluntarily participated in this study. All subjects in the present study have been currently practiced taekwondo regularly at Baan Bua Thong Gym. They participated in three randomized trails; control, cooling without and with sub-atmospheric pressure. After an interview, subject filled in questionnaire for personal medical history, physical activity condition and other necessary information. Inclusion and exclusion criteria were specifically set for this experimental as follows:

3.1.1 Inclusion criteria

- Being trained under same protocol from same trainer.
- Age between 15-20 years.
- Had about 1 year of training experiences.
- Trained regularly Taekwondo, for 1 hr, at least three times a week
- Ability to understand verbal instruction on laboratory maneuver.
- To eliminate any effect of gender differences, only male subjects were recruited.

3.1.2 Exclusion criteria

- Neuromuscular or skeletal disorders, cardio respiratory problem or else that might affect on testing procedures.
- Currently smoking or history of heavy smoking (more than 20 cigarettes/day, longer than 5 years)
- Taking any medicine that might effect the thermo-regulatory system
- Taking caffeine and/or Alcohol-containing beverages within 24 hours prior to the study

3.2 Design of the study

This study was an experimental study designed to investigate the effects of body heat reduction during post-simulated competition using Rapid Thermal Exchange Unit on recovery performance in Taekwondo Athletes.

Parameters of the study

1. Anaerobic energy system
 - Anaerobic power
 - Anaerobic capacity
2. Cardiovascular system
 - Heart rate (HR)
 - Blood pressure (BP)
 - Forearm blood flow
3. Thermoregulatory system
 - Skin temperatures
 - Core temperature
 - Thermal sensation scale (TSS)
4. Blood chemistry
 - Lactate concentration ([La])
5. Subjective evaluation
 - Rating of Perceived Exertion (RPE)

3.3 Instrumentations

3.3.1 Monark cycle ergometer (Ergomedic 894 E, Sweden : Modified Wingate Anaerobic test 2 min) (Figure 3.1)



Figure 3.1 Standard Monark cycle ergometer for Wingate Anaerobic test.

3.3.2 Telemetry heart rate monitor

Continuous heart rates were monitored using Polar Accrue x Plus heart rate monitor (Polar Electro-series S810, Kempele, Finland). (Figure 3.2)



Figure 3.2 Telemetry heart rate monitor with sensor and receiver.

3.3.3 Stopwatch (Japanese CMOS & 3.0V lithium battery CR2032)

(Figure 3.3)

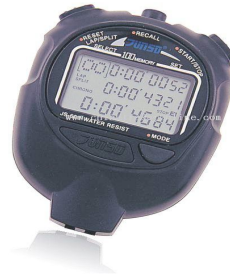


Figure 3.3 Stopwatch

3.3.4 RTX CoreControl™ (Rapid Thermal Exchange System)

For reduce core body temperature (AVAcore Technologies, Series A, Inc 333 Parkland Plaza Dr.Suite 700 Ann Arbor, MI 48103, USA) (Figure 3.4)



Figure 3.4 RTX CoreControl with hand chamber and cold water reservoir

3.3.5 Measured Body Temperature:

- Thermistors for skin temperature (Data logger LT8A, Japan): for measured skin temperature 8 points (Forehead, Chest, Back, Upper arm, Lower arm, Hand, Upper leg, Lower leg) (Figure 3.5 left)
- Tympanic Infrared Ear Thermometer (Kendall Genius 2, US): for measured core temperature (Figure 3.5 right)



Figure 3.5 Thermistors for skin temperature [data logger (left)] and Tympanic Infrared Ear Thermometer (right)

3.3.6 Thermal sensation scale (TSS) (Gagg *et al.*, 1976).

3.3.7 Rating of Perceived Exertion (RPE) (Borg, 1962)

3.3.8 Vascular Assist Ultrasound Doppler (Huntleigh, UK) (Figure 3.6)



Figure 3.6 Vascular Assist Ultrasound Doppler

3.3.9 Sphygmomanometer (AIL, KII, Japan) (Figure 3.7)

3.3.10 Stethoscope (Hico Medical Co.Ltd., Japan) (Figure 3.7)



Figure 3.7 Sphygmomanometer (left), Stethoscope (right)

3.3.11 Instruments of Blood lactate testing

For measured Blood lactate concentration the instruments were included:

(Figure 3.8)



Figure 3.8 Lactate Scout Assistant

1. Lactate Scout Assistant portable lactate analyzer(EKF Senslab GmbH, Germany)
2. Add Pack - set of Accessories: This set of accessories, supplied in a Belt Case, contains: Lancing Device; Control Solution (2,5ml); 25 x lancets; 30 x alcohol pads; Spray Bottle.
3. Comfort-Lancing Device: FELIX for standard lancets.
4. SaniSafe Waste Bottle: Compact waste box for lancets, capillaries and test strips.
5. Test strips

3.3.12 Refractometer (model 300CL Atago Inc., Japan) (Figure 3.9)



Figure 3.9 Urine specific gravity determined using refractometer

3.3.13 Weight meter (NAGATA S/N C112882, TAIWAN)

3.3.14 Height scale (NAGATA S/N C112882, TAIWAN)

3.3.15 Omron (Figure 3.10)



Figure 3.10 Body fat and composition device (Omron)

3.4 Experimental procedure

Each subject was clearly explained about benefits, possible risks of the study. All testing procedures were also clarified prior to the study.

Pre- Exercise Protocol Assessment

Standardization of the test was controlled using subject instruction as follows:

1. Hydration Status: To control hydration status, 1) amount of drinking water was determined 24 hrs before the experimental period and 2) checking of urine

specific gravity before test. Water supplement was allowed during the test where amount of water was taken into account for the test.

2. Physical Activity: Subject was asked to avoid vigorous physical activity before the experimental day.

3. Subjects wore their own Taekwondo uniforms, body protector, and headgear to control heat dissipation. In addition, experiment was conducted within the same time of the day where ambient temperature and humidity were recorded.

4. Experimental procedure was conducted in an air-conditioned room.

5. All equipments were calibrated prior to the test.

Procedure

Each subject participated in 3 randomized trials. Exercise trails were performed in counterbalanced order on 3 days, separated by at least 3 days to avoid learning effects. All subjects were completely exposed with:

-Control condition trail: where all subjects had been tested and recovery with a normal routine practice. This trial was intervened with no cooling.

-Cooling condition trail 1: where all subjects had been tested and recovery using cooling device (RTX) without sub-atmospheric pressure application.

-Cooling condition trail 2: where cooling (RTX) combined with sub-atmospheric pressure condition during recovery was treated.

3.4.1 Vital sings

Heart rate was determined using a telemetry heart rate monitor and blood pressure was measured using sphygmomanometer and stethoscope.

3.4.2 Anthropometric measurements

Subject's weight and height were estimated using digital weight scale and height meter and then, BMIs were calculated. Percent fat and muscle were estimated using Touch (Omron) based on Bi-method (Bioelectrical Impedance Method) in approximately seven seconds interval.

3.4.3 Blood lactate testing

Blood samples from fingertip were collected under a standard hygienic finger puncture method (Declan *et al.*, 2003). Tiny puncture was performed using Accu-Chek[®] Softclix II Lancet device. During blood collection, subject was recommended in the relaxing position. Then selected finger was cleaned with 70% alcohol. Drop of blood was placed directly on lactate test strip without touching the skin. After blood collection, clean the finger with 70% alcohol and stop bleeding using compression with cotton for few seconds. Lactate was analyzed immediately using portable lactate analyzer (Lactate Scout Assistant). The results of blood lactate level were shown within 15 seconds. Blood samples were sequentially collected 5 times: at rest, within 1 minute rest period of each bout, after 5 minutes, and 30 minutes recovery after the 3rd bout.

3.4.4 Urine specific gravity measurements

Urine specific gravity was measured at rest to determine hydration status before the test using a clinical refractometer (model 300CL Atago Inc., Japan). Calibration of the clinical refractometer was performed prior to the first sample following manufacturer's instructions. Urine specific gravity and urine color were recorded (Armstrong, 2000).

3.4.5 Psycho-physiological variables

Subjective variables were quantified prior to each experimental protocol, between 1 minute rest into three bouts, after 5 minutes, and 30 minutes rest in third bouts.

Thermal sensation scale (TSS) was modified from previous study (Gagg *et al.*, 1976). Meanings for TSS scale form 1 to 13 were as follows: 1 = unbearable cold; 13 = unbearable hot. Similar question of "How does the temperature of your body feel?" were asked for self determination on TSS.

Table 3.1: The 13-point thermal sensation scale

<u>Scale</u>	<u>Verbal expression</u>
13.....	Unbearably hot
12.....	Extremely hot
11.....	Very hot
10.....	Hot
9.....	Warm
8.....	Slight warm
7.....	Neutral
6.....	Slight cool
5.....	Cool
4.....	Cold
3.....	Very cold
2.....	Extremely cold
1.....	Unbearably cold

Rating of perceived exertion (RPE) or effort sensation was obtained for the whole body, and fractionated for the chest, and legs. Before experimental procedures data at rest, between 1 minute rest into three bouts, after 5 minutes, and 30 minutes rest in third bouts were recorded. The question was asked: “How hard do you feel you are exercising your whole body/chest/legs?” Subject determined on a scale of 6 to 20 (Borg, 1962).

Table 3.2: The Borg’s Scale Rating of Perceived Exertion

Rating of Perceived Exertion (RPE)	
6	No exertion at all
7	Extremely light
8	Very light
9	Light
10	Somewhat hard
11	Hard (heavy)
12	Very hard
13	Extremely hard
14	Maximal exertion
15	
16	
17	
18	
19	
20	

3.4.6 Thermoregulatory variables

1. Skin Temperature: Skin temperatures were recorded from 8 sites of the body (Forehead, Chest, Back, Upper arm, Forearm, Hand, Thigh, Calf) by using data logger (Japan) and download data to computer with Lte software program. The mean skin temperature was calculated using modified Kenney formula in 1988 as follows:

$$\text{Mean } T_{\text{sk}} = (T_{\text{forehead}} + T_{\text{chest}} + T_{\text{back}} + T_{\text{upper arm}} + T_{\text{forearm}} + T_{\text{hand}} + T_{\text{thigh}} + T_{\text{calf}}) / 8$$

2. Core Temperature: Core temperature was estimated via tympanic temperature.

3. Mean body temperature: Mean body temperature (MBT) was estimated from core and mean skin temperatures with a formula proposed by Burton in 1935:

$$\text{MBT} = 0.64 T_{\text{Core}} + 0.36 T_{\text{Skin}}$$

4. Thermistor calibration: All thermistor was calibrated prior to each test following manufacturer's instruction.

3.4.7 Cardiovascular variables

1. Cardiac frequency: Heart rate was monitored using a Polar Accrued x Plus heart rate monitor (Polar Electro-series S810, Kempele, Finland). Heart rate was recorded every 5 seconds immediately before and after 30 minutes of experimental procedure and downloaded data to computer with Polar Precision Performance SW Program.

2. Forearm blood flow: Circulating blood flow was determined non-invasive technique using Ultrasound Doppler (Huntleigh, UK) on the anterior part of elbow. Data were collected between 1 minute rest between bouts, after 5 minutes, and 30 minutes rest of the final bout.

3. Blood pressure: Systolic blood pressures (SBP) and diastolic blood pressure (DBP) were routinely recorded using a stethoscope and sphygmomanometer before test, between 1 minute rest into three bouts, after 5 minutes, and 30 minutes rest in third bouts. Resting mean arterial pressure (MAP) was determined according to the following formula;

$$\text{MAP} = [(\text{SBP} - \text{DBP})/3] + \text{DBP}$$

3.4.8 Anaerobic power and capacity

Each subject was properly positioned on a Monark cycle ergometer (Ergomedic 894 E, Sweden). Seat height was adjusted to suit the subject and foot clips were used to prevent the feet from slipping off the pedals, and hands in proper position on the handlebars. From pilot trials, subjects performed for a total of 19 minutes on a Monark cycle ergometer and 29 minutes resting in a seated position on comfortable chair including:

- Sat on cycle ergometer 5 minutes.
- Warmed up free load 5 minutes by control 55-60 reps/min.
- Modified Wingate Anaerobic test was conducted. In order to enable subject to perform 3 repeated-2 min anaerobic bouts, workload was recalculated using $0.06/5 \times \text{Body Weight (Kilograms)}$ which properly induced heart rate up to 90% HRmax (result from pilot study). To exhibit near maximal performance, subject was asked to pedal as fast as possible for all 3 bouts.
- Post-modified 3-Wingate bouts data collection was conducted while subject in a seated position on cycle ergometer.

3.4.9 RTX CoreControl™ (Rapid Thermal Exchange System)

To test the reduction of core body temperature, RTX (AVAcure Technologies, Series A, Inc 333 Parkland Plaza Dr. Suite 700 Ann Arbor, MI 48103, USA) was employed during 1 minute rest period in each bout, 5 and 30 minutes recovery after 3rd bout with cooling only and cooling combine sub-atmospheric pressure.

Setting and Process of Experimental

1. This study was conducted in the Sports Physiology Laboratory, College of Sports Science and Technology, Mahidol University (Salaya campus).
2. Prior to the exercise the subjects were fully informed for the procedures and the applications of equipments.
3. To prevent injury during the experiment, the subjects were asked to perform 5 minute warm up and sip water before exercise.

Experimental protocol:

To avoid circadian variation, this study was conducted only in the morning. To imitate the competitive environment, exercise on cycle ergometer was conducted to bring up pulse rate up to the previously estimated peak (from the data at the initial assesses at training field / competition field). Three repeated modified Wingate Anaerobic program, to imitate 3 rounds of 2 minutes period with 1 minute recovery, were conducted. The cooling trails were performed using RTX during 1 minute rest period in each bout, 5 and 30 minutes recovery after 3rd bout (Figure 3.11).

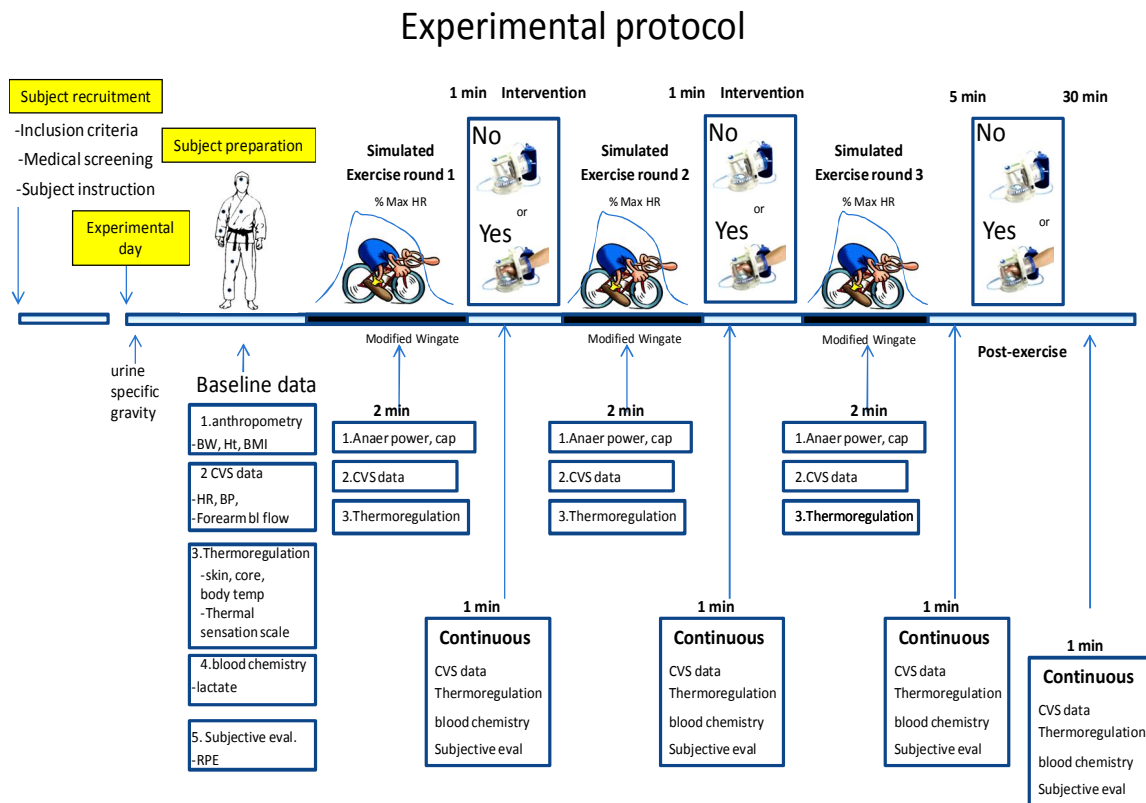


Figure 3.11 Experimental protocol and data collection in Taekwondo athletes.

Performance measurement was based on anaerobic test in that Taekwondo had to move fast, made immediate jump and turned around. These actions could not be measured in real condition, so the researcher used Modified Wingate anaerobic test. Test was started and sustain for 2 minutes at $0.06/5 \times$ body weight (kilograms) workload where maximum revolution numbers for 2 minutes was performed. This method accelerated pulse rates to values previously determined from the initial survey.

3.5 Statistical Analysis

The statistical analysis was obtained for between-group and within-group effects using GLM Repeated measures, SPSS version 16. The statistical significance was set at *p-value* less than 0.05 ($p < 0.05$).

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effects of rapid palm cooling (RTX Core Control method) in male Taekwondo athletes during 1 min of recovery period of 3 rounds simulated competition, and at 5 and 30 min after the final round. Ten male-taekwondo athletes, age range between 15-20 years, voluntarily participated in this study. Designed of the study included three randomized trails, separated by a week of control, cooling without (no vacuum) and with negative (vacuum) pressure interventions, whilst subjects performed 3 repeated (2 min anaerobic bouts with 1-min rest) using Modified Wingate Anaerobic test, loaded at $0.06/5 \times$ body weight (kg). Changes of cardiovascular system (HR, BP, forearm blood flow), thermoregulation (skin and core body temperatures, thermal sensation scale), blood chemistry (lactate concentration) and subjective evaluation (RPE) between 3 groups were measured. Comparisons of performance, including anaerobic power and capacity, of 3 rounds were investigated for effectiveness of RTX.

4.1 Characteristics of Subjects

All subjects randomly performed three trails; control, RTX with vacuum, and RTX with no vacuum in air-conditioned room (mean \pm SD, temperature = $25.1 \pm 0.5^\circ\text{C}$, relative humidity = $46.3 \pm 3.9\%$). Informed consent was obtained from all subjects, and approved by Ethics Committee on Human Experiment of Mahidol University. Physical characteristics were tabulated in Table 4.1.

Table 4.1 Characteristics of Taekwondo athletes (n=10). Values are means and standard deviations.

Variables	Mean ± SD
Age (yr)	16.5 ± 1.1
Weight (kg)	60.1 ± 9.0
Height (cm)	172.9 ± 2.9
BMI (kg/m ²)	20.1 ± 2.6
Body fat (%)	11.0 ± 3.8
Urine specific gravity	1.018 ± 0.009

4.2 Effects of rapid palm cooling method on subsequently changes of anaerobic energy system.

Anaerobic variables, including peak anaerobic power (watts, w), average anaerobic power (w), and anaerobic power drop (w) during 3 consecutive anaerobic tests, were presented in Figure 4.1. These variables were separately described as follows.

4.2.1 Peak anaerobic power (w)

Initial peak anaerobic power values were 291.4±29.6, 302.9±40.5, and 279.1±33.9 watts in control, RTX with no vacuum, and RTX with vacuum groups respectively. All groups comparison showed that there was no significant different of peak anaerobic power (Figure 4.1) between control, RTX with no vacuum, and RTX with vacuum groups for all 3 rounds ($p>0.05$). As consecutive exercise tests were conducted, remarkable changes of either within or between groups were found.

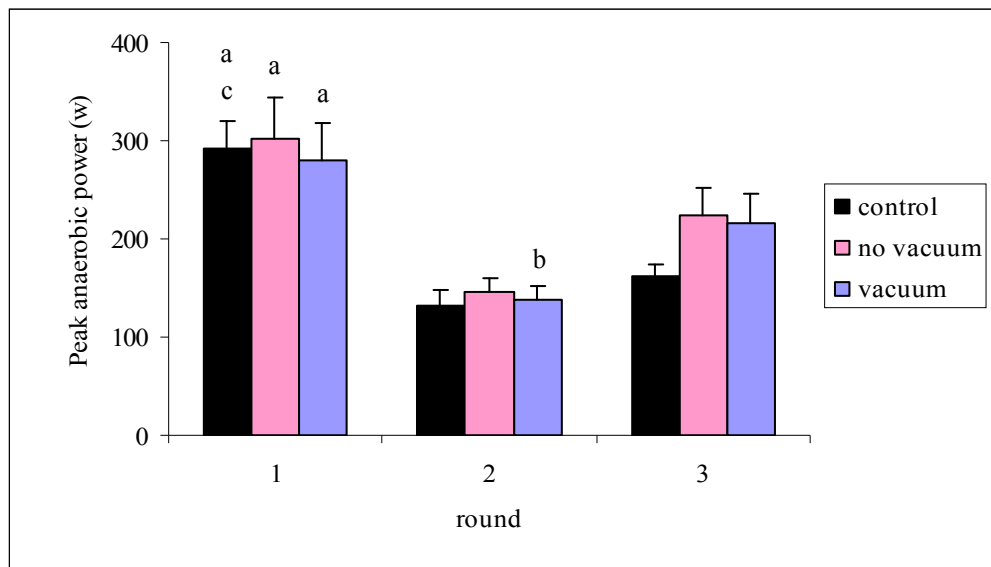


Figure 4.1 Peak anaerobic power (w) in 3 rounds of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- a: Significantly different within the same group between bout 1-2 at $p<0.05$.
- b: Significantly different within the same group between bout 2-3 at $p<0.05$.
- c: Significantly different within the same group between bout 1-3 at $p<0.05$.
- ☆ Significantly different between control and RTX with no vacuum group at $p<0.05$
- ♥ Significant different between control and RTX with vacuum group at $p<0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p<0.05$

Within group comparison, data showed that there were significant reduction of peak anaerobic power only in control group from round1 to round2 ($p<0.05$) and round1 to round3 ($p<0.05$). In RTX with no vacuum and RTX with vacuum group, there were significant reduction of peak anaerobic power from round1 to round2 ($p<0.05$). RTX with vacuum group showed significant increase of peak anaerobic power from round2 to round3 ($p<0.05$) which was not found in RTX with no vacuum group.

4.2.2 Average anaerobic power (w)

Initial average anaerobic power values were 95.7 ± 7.5 , 90.6 ± 5.6 , and 94.5 ± 7.2 watts in control, RTX with no vacuum, and RTX with vacuum groups respectively. All groups comparison showed that there were no significant different of

initial average anaerobic powers (Figure 4.2) between control, RTX with no vacuum, and RTX with vacuum groups for all 3 rounds ($p>0.05$). Repeated exercise tests induced changes in average anaerobic power within group only.

Within group comparison, data showed that there were similar significant reduction of average anaerobic power within control, RTX with no vacuum, and RTX with vacuum groups in that from round1 to round2 ($p<0.05$) and round1 to round3 ($p<0.05$).

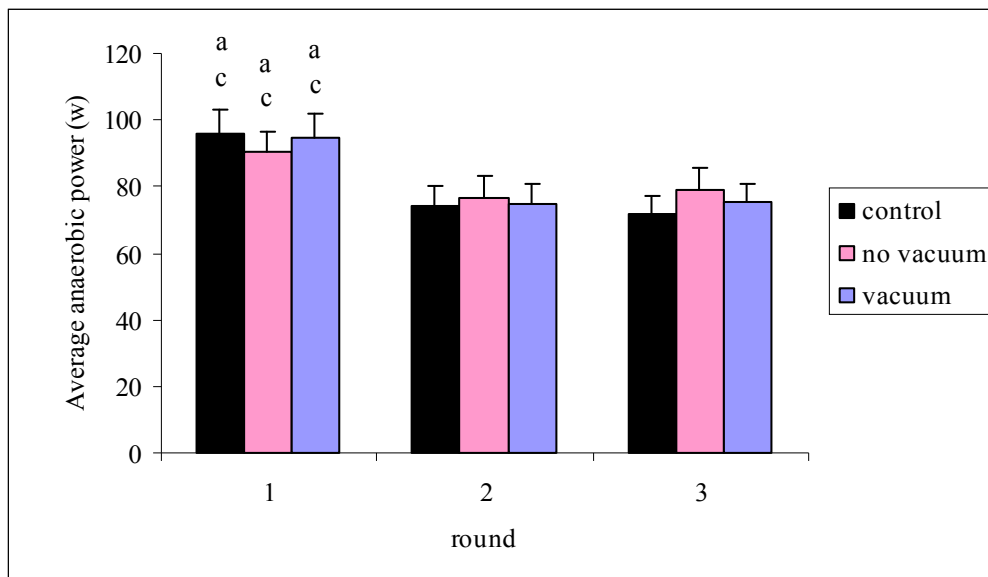


Figure 4.2 Average anaerobic power (w) in 3 rounds of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- a: Significantly different within the same group between bout 1-2 at $p<0.05$.
- b: Significantly different within the same group between bout 2-3 at $p<0.05$.
- c: Significantly different within the same group between bout 1-3 at $p<0.05$.
- ☆ Significantly different between control and RTX with no vacuum group at $p<0.05$
- ♥ Significant different between control and RTX with vacuum group at $p<0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p<0.05$

4.2.3 Anaerobic power drop (w)

In the present study, anaerobic power drops were defined as differences in numbers of peak power performed between each consecutive bout. All three groups showed similar tendencies of anaerobic power drop as exercises were consecutively

done. Initial anaerobic power drops values were 267.3 ± 41.5 , 292.0 ± 54.3 , and 237.9 ± 56.3 watts in control, RTX with no vacuum, and RTX with vacuum groups respectively.

Between groups comparison showed that there were no significant different of anaerobic power drop (Figure 4.3) between control, RTX with no vacuum, and RTX with vacuum groups for all 3 rounds ($p > 0.05$).

Within group comparison, data showed that there were significant reduction of anaerobic power drop in control group from round1 to round2 ($p < 0.05$) and round1 to round3 ($p < 0.05$). In RTX with no vacuum group, there was significant reduction of anaerobic power drop from round 1 to round 3 ($p < 0.05$). In RTX with vacuum group, there was significant reduction of anaerobic power drop from round2 to round3 ($p < 0.05$).

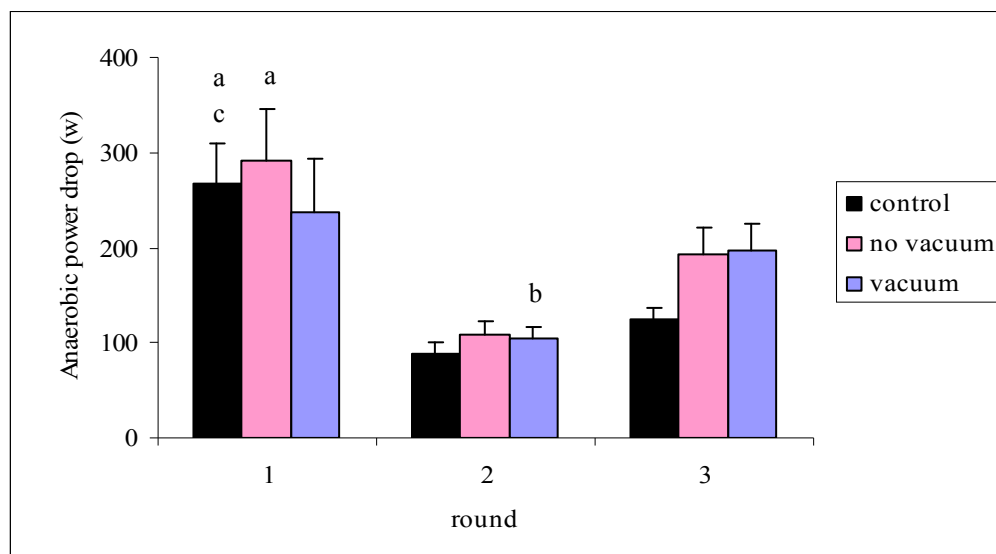


Figure 4.3 Anaerobic power drop (w) in 3 rounds of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- a: Significantly different within the same group between bout 1-2 at $p < 0.05$.
- b: Significantly different within the same group between bout 2-3 at $p < 0.05$.
- c: Significantly different within the same group between bout 1-3 at $p < 0.05$.
- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

4.3 Effects of rapid palm cooling method on cardiovascular system.

Similar changes in cardiovascular variables, including heart rate, blood pressure (mean arterial pressure, systolic and diastolic blood pressure), and forearm blood flow, were presented during, 1-min post, 5 and 30 min-recovery periods. Details of these variables were described in Figure 4.4, 4.5 and Table 4.2.

4.3.1 Heart rate (beat/min)

Heart rates in all groups showed similar patterns of alteration during the study. Initial heart rates were 71.5 ± 2.5 , 70.1 ± 2.8 , and 71.8 ± 2.7 bpm in control, RTX with no vacuum, and RTX with vacuum groups respectively. No significant difference of heart rate between groups comparison (Figure 4.4) between control, RTX with no vacuum, and RTX with vacuum groups was detected ($p > 0.05$).

Within group comparisons of control, RTX with no vacuum, and RTX with vacuum groups for all of measurement had significant higher than the corresponding resting values during exercise and recovery period of either between or post exercise bouts ($p < 0.05$).

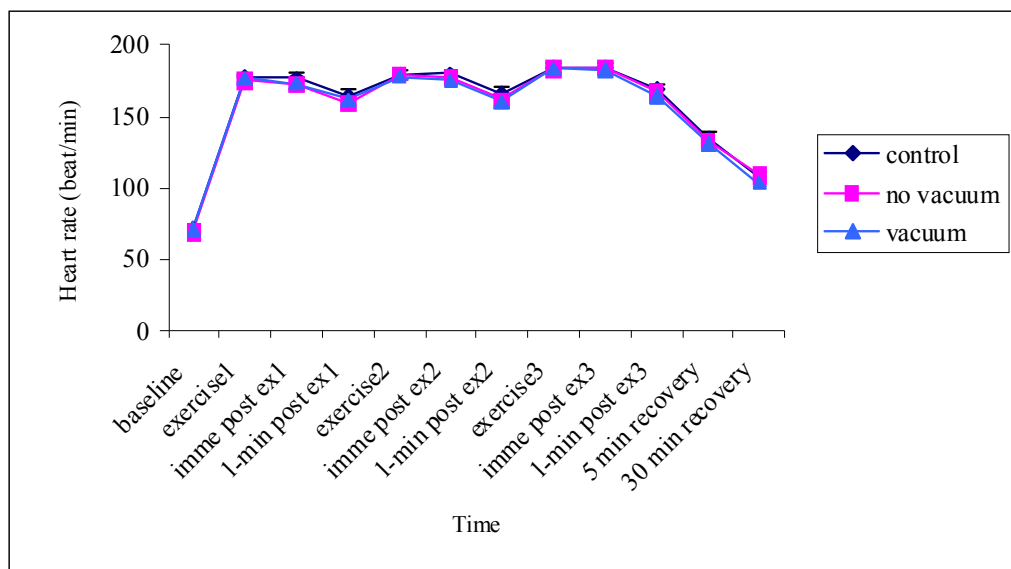


Figure 4.4 Heart rate (beat/min) of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

4.3.2 Blood pressure (mmHg)

Cardiovascular variables including systolic, diastolic and mean arterial blood pressures (mmHg) and blood flow (ml/min) were presented as resting (baseline), 1-min post exercise 1, 2, 5 and 30 min recovery (Table 4.2).

Baseline mean arterial, systolic and diastolic blood pressures, in control, RTX with no vacuum, and RTX with vacuum groups, were 84.0 ± 2.5 , 83.3 ± 2.0 , and 87.5 ± 1.8 , were 108.8 ± 2.2 , 112.0 ± 3.2 , and 114.5 ± 2.4 , and were 71.6 ± 2.8 , 69.0 ± 1.9 , and 74.0 ± 2.0 respectively. Similar changes in mean arterial, systolic and diastolic blood pressures and blood flow were observed in that these variables increased during 1-min post exercise 1 and 2 and declined at 5- and 30-min recovery.

All groups comparison showed that there were no significant different of mean arterial blood pressure, systolic and diastolic blood pressures between control, RTX with no vacuum, and RTX with vacuum groups for all experiment ($p > 0.05$).

Within group comparison in control group showed that mean arterial pressure had significantly higher than its corresponding resting value only at 1-min post exercise bout 1 and 2 ($p < 0.05$). This variable returned to resting value at 5 and 30 min recovery ($p > 0.05$). Systolic blood pressure in control group showed significantly higher than its corresponding resting value at 1-min post exercise bouts of both after round 1 and 2 and at 5-min recovery ($p < 0.05$). Systolic blood pressure in control group was, therefore, recovered at 5 min after exercise was terminated. Diastolic blood pressure in control group showed significantly higher than its corresponding resting value at 1-min post exercise bouts of both after round 1 and 2 ($p < 0.05$). Blood flow in control group showed significantly higher than its corresponding resting value at 1-min post exercise bouts of both after round 1 and 2 ($p < 0.05$).

Within group comparison in RTX with on vacuum showed that mean arterial, systolic, and diastolic blood pressures significantly increased at post-exercise ($p < 0.05$) and returned to the corresponding resting values within 5 min of recovery.

Table 4.2 Cardiovascular Variables (Mean \pm SEM)

Variable	Condition	baseline	1-min post ex1	1-min post ex2	5 min Recovery	30 min recovery
Mean Arterial Pressure						
	Control	84.0 \pm 2.5	109.4 \pm 2.0 *	106.5 \pm 2.8 *	87.8 \pm 1.9	82.7 \pm 2.4
	No vacuum	83.3 \pm 2.0	107.7 \pm 2.8 *	110.3 \pm 2.4 *	92.1 \pm 2.6 *	82.7 \pm 2.7
	Vacuum	87.5 \pm 1.8	110.2 \pm 2.8 *	105.9 \pm 3.0 *	91.9 \pm 1.8	81.1 \pm 2.4 *
Systolic Blood Pressure						
	Control	108.8 \pm 2.2	166.2 \pm 4.9 *	161.2 \pm 5.9 *	123.8 \pm 3.9 *	106.2 \pm 3.0
	No vacuum	112.0 \pm 3.2	163.8 \pm 6.2 *	165.6 \pm 4.3 *	127.4 \pm 4.1 *	108.2 \pm 2.9
	Vacuum	114.5 \pm 2.4	165.8 \pm 5.4 *	160.6 \pm 5.3 *	127.0 \pm 3.0 *	106.4 \pm 2.6 *
Diastolic Blood Pressure						
	Control	71.6 \pm 2.8	81.0 \pm 2.1 *	79.2 \pm 2.1 *	69.8 \pm 1.9	71.0 \pm 2.2
	No vacuum	69.0 \pm 1.9	79.6 \pm 3.1 *	82.6 \pm 2.7 *	74.4 \pm 2.3 *	70.0 \pm 2.8
	Vacuum	74.0 \pm 2.0	82.4 \pm 2.3 *	78.6 \pm 2.5 *	74.4 \pm 2.0	68.4 \pm 2.6
Blood Flow (ml/min)						
	Control	122.7 \pm 4.7	159.2 \pm 10.1 *	179.8 \pm 13.1 *	165.5 \pm 9.0 *	133.2 \pm 6.8
	No vacuum	114.6 \pm 2.6	160.2 \pm 8.4 *	172.7 \pm 10.3 *	142.4 \pm 8.3 *	119.3 \pm 4.3
	Vacuum	110.9 \pm 3.1	157.7 \pm 7.3 *	175.1 \pm 4.0 *	148.1 \pm 5.9 *	129.1 \pm 6.0 *

* Significant different from baseline within the same group at $p < 0.05$

☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$

♥ Significant different between control and RTX with vacuum group at $p < 0.05$

♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

In RTX with vacuum group, comparison within the group showed that mean arterial, systolic blood pressures showed significantly increased at post-exercise ($p < 0.05$) and throughout the 30-min recovery period. These variables remained higher than its corresponding initial values even at 30-min recovery with the exception of diastolic blood pressure which recovered immediately at the end of exercise bout 2.

4.3.3 Forearm blood flow (ml/min)

All groups comparison showed that there were no significant different of forearm blood flow (Figure 4.5) between control, RTX with no vacuum, and RTX with vacuum groups for all experiment ($p > 0.05$)

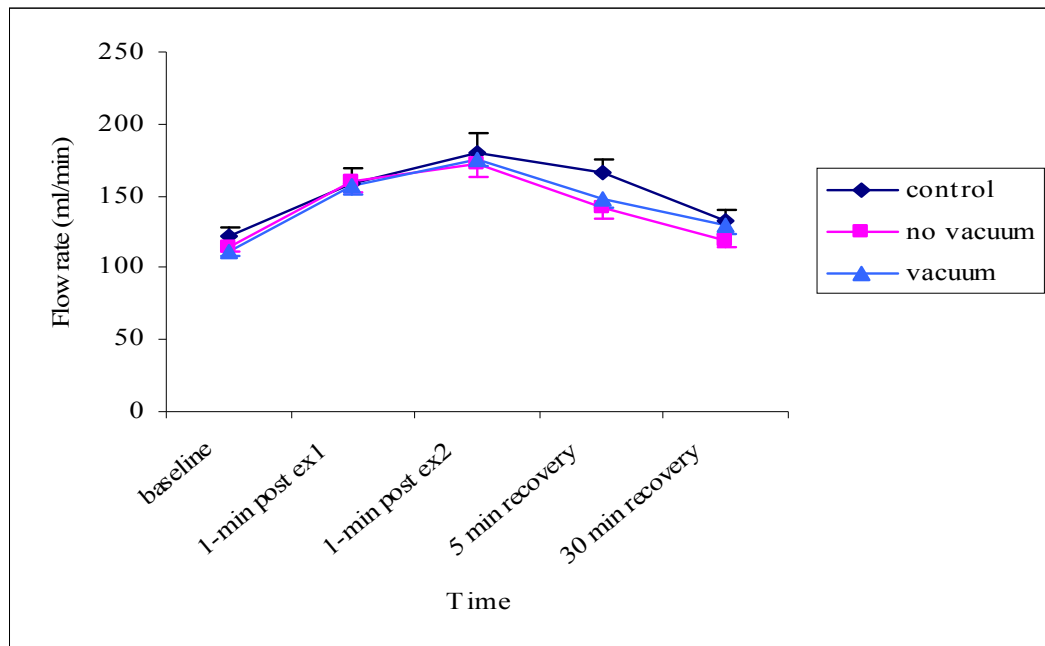


Figure 4.5 Forearm blood flow (ml/min) of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

Within group comparison of forearm blood flow (Table 4.2) of control, RTX with no vacuum, and RTX with vacuum groups showed significant higher than their corresponding resting values ($p < 0.05$) for all experimental protocols. Blood flows in control and RTX with no vacuum groups at 30-min recovery showed non-significant result with initial values. With the exception of RTX with vacuum group which showed significant higher than in resting value even at 30-min recovery.

4.4 Effects of rapid palm cooling method on thermoregulatory system.

Thermoregulatory variables including 8 points skin temperatures, mean skin temperature, core temperature (Tympanic temperature), mean body temperature, and Thermal sensation scale were grouped and presented separately as 8 points

including trunk (forehead, chest, and back temperatures), upper limb (upper arm, forearm, and hand temperatures), and lower limb temperatures (thigh and calf temperatures).

4.4.1 Skin temperatures

4.4.1.1 Trunk temperature (Figure 4.6)

Forehead temperature: Initial forehead temperatures in control, RTX with no vacuum, and RTX with vacuum were 35.3 ± 0.1 , 34.9 ± 0.4 , and 35.2 ± 0.1 °C respectively. All groups showed similar changing pattern during exercise bouts and recovery (Figure 4.6). Between groups comparison showed that there were significant different of forehead temperatures between control and RTX with no vacuum groups as exercise was continuously extended to the 3rd round and 1 minute post exercise round 3 ($p < 0.05$).

Within group comparison of *Forehead temperature* (Table 4.3) for control, RTX with no vacuum, RTX with vacuum groups (value are mean \pm SEM; 35.3 ± 0.1 , 34.9 ± 0.4 , 35.2 ± 0.1 respectively) data showed significant different from baseline for all experiment ($p < 0.05$)

Chest temperature: Initial chest temperatures in control, RTX with no vacuum, and RTX with vacuum were 35.7 ± 0.3 , 35.5 ± 0.2 , 35.3 ± 0.2 °C respectively. All groups showed similar changing pattern during exercise bouts and recovery with the lowest values at 30-min recovery (Figure 4.6 B). Data showed that there was no significant different between control, RTX with no vacuum, and with vacuum groups ($p > 0.05$).

Table 4.3 Within group comparison of skin temperatures obtained from forehead, chest, back, upper arm, forearm, hands, thigh and calf with mean skin temperature. Values were presented as mean ± SEM.

Condition	Baseline	exercise 1	1-min post ex1	exercise 2	1-min post ex2	exercise 3	1-min post ex3	5 min recovery	30 min recovery
Forehead temperature									
Control	35.3±0.1*	34.8±0.2*	34.3±0.2*	34.1±0.2*	34.1±0.2*	34.4±0.2*	34.3±0.2*	34.2±0.3*	32.8±0.4*
No vacuum	34.9±0.4*	34.2±0.4*	33.6±0.4*	33.2±0.4*	33.2±0.4*	33.2±0.4*	33.1±0.5*	33.5±0.3*	33.6±0.3*
Vacuum	35.2±0.1*	34.6±0.2*	34.2±0.2*	33.8±0.2*	33.7±0.2*	33.9±0.3*	33.9±0.3*	33.9±0.3*	33.6±0.3*
Chest temperature									
Control	35.7±0.3	35.6±0.3	35.7±0.3	35.5±0.4	35.6±0.4	35.7±0.5	35.8±0.5	36.5±0.2*	34.8±0.4
No vacuum	35.5±0.2	35.2±0.2	35.0±0.3	34.8±0.3	35.0±0.3	34.9±0.3	34.9±0.4	35.6±0.5	34.6±0.4*
Vacuum	35.3±0.2	35.1±0.2	34.9±0.3*	34.8±0.2*	35.0±0.3*	35.0±0.3	35.1±0.4	35.9±0.3	34.7±0.3
Back temperature									
Control	35.0±0.2	35.1±0.2	35.1±0.2	34.6±0.2*	34.5±0.2*	34.5±0.2*	34.4±0.3	34.5±0.2	33.7±0.4*
No vacuum	34.7±0.2	34.7±0.3	34.6±0.3	34.2±0.3	34.1±0.4	33.9±0.4*	33.9±0.4*	34.1±0.3	34.4±0.7
Vacuum	34.9±0.3	35.1±0.3	34.7±0.3	34.6±0.3*	34.5±0.3*	34.4±0.3*	34.2±0.4*	34.3±0.4*	34.0±0.6
Upper arm temperature									
Control	34.2±0.2	34.1±0.2	34.1±0.2	33.9±0.2	33.8±0.2*	33.5±0.3*	33.2±0.4*	33.1±0.2*	32.2±0.3*
No vacuum	33.5±0.4	33.3±0.4	33.3±0.4	33.0±0.5	33.0±0.4	32.6±0.5*	32.6±0.4*	33.0±0.4	31.5±0.3*
Vacuum	33.9±0.2	33.9±0.1	33.3±0.3*	33.4±0.2*	33.3±0.2*	33.2±0.2*	33.2±0.2*	33.3±0.3	31.4±0.4*
Forearm Temperature									
Control	32.7±0.3	32.7±0.3	32.5±0.3	32.1±0.3*	32.2±0.3*	31.9±0.3*	31.8±0.4*	32.1±0.3*	32.7±0.5
No vacuum	32.2±0.3	32.1±0.2	31.9±0.2	31.6±0.3*	31.4±0.3*	31.1±0.4*	30.9±0.4*	31.2±0.4*	31.0±0.4*
Vacuum	32.3±0.2	32.3±0.1	31.9±0.4	31.7±0.3*	31.7±0.3*	31.3±0.3*	31.3±0.3*	31.6±0.4*	31.0±0.3*
Hand temperature									
Control	29.2±0.4	28.8±0.4*	28.6±0.3*	28.4±0.3*	28.4±0.3*	28.3±0.4*	27.8±0.4*	29.6±0.6	33.0±0.5*
No vacuum	29.9±0.8	29.0±0.7*	29.1±0.6*	28.5±0.6*	28.5±0.6*	28.0±0.6*	28.0±0.6*	28.6±0.7*	29.2±0.9
Vacuum	29.2±0.7	28.6±0.6*	28.5±0.6*	28.1±0.5*	28.1±0.5*	27.6±0.5*	27.5±0.6*	27.3±0.6*	28.3±0.7*
Thigh temperature									
Control	32.8±0.4	32.7±0.5	33.1±0.5	33.0±0.5	33.3±0.5*	33.1±0.5	33.2±0.5*	34.0±0.5*	33.7±0.3*
No vacuum	32.9±0.3	32.8±0.3*	33.1±0.3	32.9±0.3	33.1±0.4	32.9±0.3	33.0±0.3	33.4±0.2*	32.6±0.5
Vacuum	33.3±0.4	32.9±0.4*	33.3±0.5	33.1±0.4	33.6±0.5*	33.4±0.4	33.5±0.4	34.2±0.5*	32.7±0.4*
Calf temperature									
Control	32.6±0.3	32.2±0.3*	32.6±0.3	32.2±0.3	32.5±0.3	32.2±0.3*	32.2±0.2	32.6±0.2	32.4±0.3
No vacuum	32.4±0.4	31.9±0.4*	32.1±0.3*	32.0±0.3*	32.2±0.3	31.9±0.3*	32.1±0.3*	32.3±0.4	32.3±0.3
Vacuum	32.2±0.4	31.6±0.3*	31.9±0.3	31.7±0.3*	32.1±0.3	31.5±0.3	31.6±0.3	32.1±0.2	32.8±0.2
Mean skin temperature									
Control	33.4±0.2	33.2±0.2 *	33.3±0.2 *	33.0±0.2 *	33.1±0.2 *	32.9±0.3 *	32.8±0.3 *	33.3±0.2	33.2±0.2
No vacuum	33.3±0.2	32.9±0.2 *	32.8±0.2 *	32.5±0.2 *	32.6±0.2 *	32.3±0.2 *	32.3±0.2 *	32.7±0.1	32.4±0.2
Vacuum	33.3±0.2	33.0±0.2 *	32.8±0.2 *	32.0±0.2 *	32.7±0.2 *	32.6±0.2 *	32.5±0.2 *	32.8±0.2	32.3±0.2

* Significant different from baseline within the same group at p<0.05

Within group comparison showed that control group had significantly higher chest temperature than its baseline (35.7 ± 0.2) at 5-minute recovery (36.5 ± 0.2 °C). Data from RTX with no vacuum group showed significantly lower chest temperature than its baseline (35.5 ± 0.2) at 30-minute recovery (34.6 ± 0.4). For RTX with vacuum group, data showed significant lower than its baseline (35.3 ± 0.2) at 1-minute post exercise round 1 (34.9 ± 0.3), exercise round 2 (34.8 ± 0.2), and 1-minute post exercise round 2 (34.9 ± 0.3) ($p < 0.05$).

Back temperature: Initial back temperatures in control, RTX with no vacuum, and RTX with vacuum were 35.0 ± 0.2 , 34.7 ± 0.2 , 34.9 ± 0.3 °C respectively. All groups showed similar changing pattern during exercise bouts and recovery period in that back temperatures slightly declined throughout the study (Figure 4.6 C). Data showed that there was no significant different between control, RTX with no vacuum, and with vacuum groups ($p > 0.05$).

Within group comparison (Table 4.3) showed that back temperature in control group were significantly declined than its resting value during 2nd round, 1-minute post exercise round 2, during 3rd round, and at 30-minute recovery ($p < 0.05$). In RTX with no vacuum group data showed significant lower than its resting value during 3rd round and 1-minute post exercise round 3 ($p < 0.05$). For RTX with vacuum group data showed significant lower than its resting value during 2nd round, 1-minute post exercise round 2, during 3rd round, 1-minute post exercise round 3, and 5-minute recovery ($p < 0.05$).

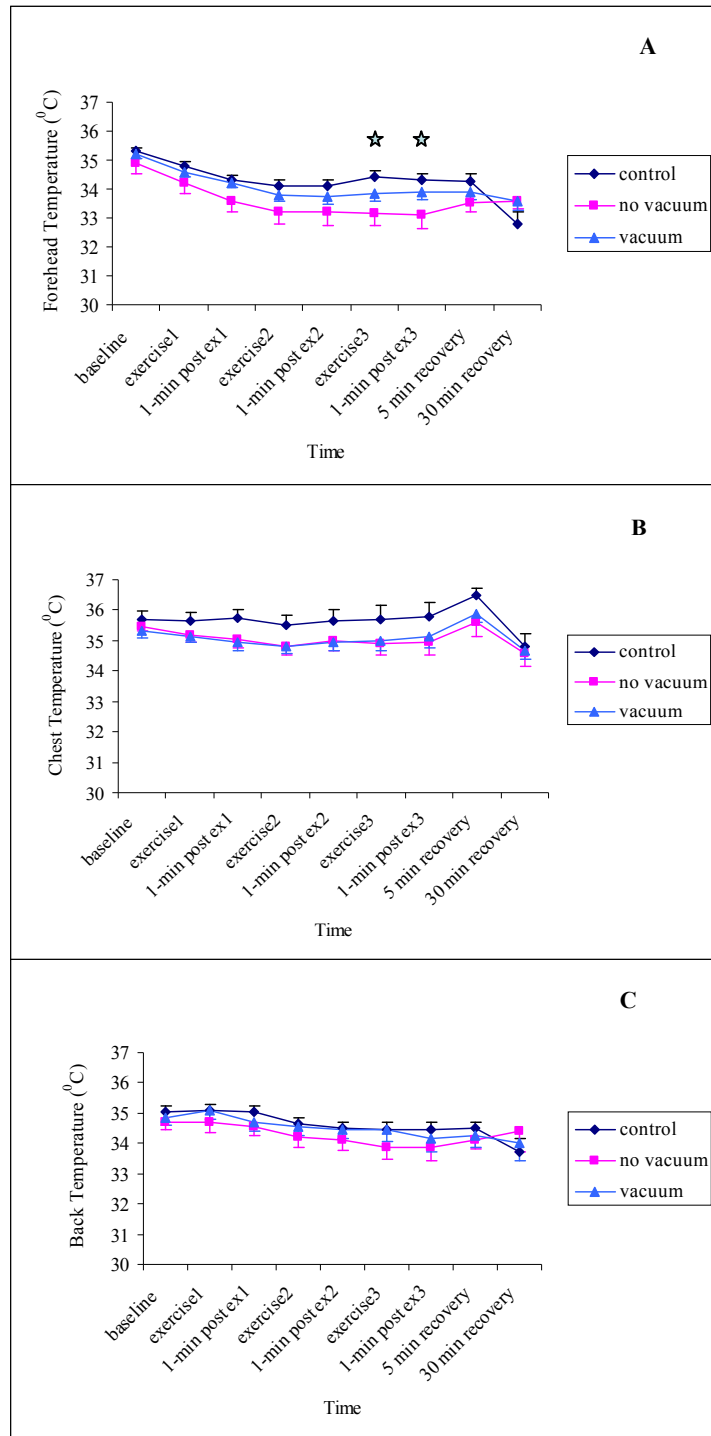


Figure 4.6 Between group comparisons of trunk temperature included A: Forehead temperature, B: Chest temperature, and C: Back temperature.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

4.4.1.2 Upper limb temperature (Figure 4.7)

Upper arm temperatures: Resting temperatures of upper arm in control, RTX with no vacuum, and RTX with vacuum were 34.2 ± 0.2 , 33.5 ± 0.4 , 33.9 ± 0.2 °C respectively. Between groups comparison showed that there were no significant different of upper arm temperatures (Figure 4.7 A) between control, RTX with no vacuum, and RTX with vacuum groups ($p > 0.05$). Forearm temperature (Figure 4.7 B) of control group was higher than those of RTX with no vacuum ($p < 0.05$) and RTX with vacuum groups ($p < 0.05$) at 30-minute recovery. Hand temperature (Figure 4.7 C) of control group was higher than that of RTX with vacuum ($p < 0.05$) at 5-min recovery. In addition at 30-minute recovery, hand temperature of control group was higher than those of RTX with no vacuum ($p < 0.05$) and RTX with vacuum groups ($p < 0.05$) at 30-minute recovery.

Within group comparison of upper arm temperatures: Control group (Table 4.3) showed that there were significant decreased of upper arm temperatures from resting value at 1-min post exercise round 2, during 3rd round, 1-minute post exercise round 3, 5-minute and 30-minute recovery ($p < 0.05$). Within group comparison in RTX with no vacuum group, there were significant decreased of upper arm temperatures from resting value during 3rd round, 1-minute post exercise round 3, and at 30-minute recovery ($p < 0.05$). Within group comparison in RTX with vacuum group showed significant decreased of upper arm temperatures from resting value at 1-minute post exercise round 1, during 2nd round, 1-minute post exercise round 2, during 3rd round, 1-minute post exercise round 3, and 30 minute recovery ($p < 0.05$).

Within group comparison of forearm temperatures:

Control group (Table 4.3) had significant decreased from its baseline during 2nd round, 1-minute post exercise round 2, during 3rd round, 1-minute post exercise round 3, and 5-minute recovery ($p < 0.05$). In RTX with no vacuum group showed significant decreased from its resting value of either during and post-exercise condition throughout the studying period ($p < 0.05$) with the exception of during and post-exercise 1 ($p > 0.05$). For RTX with vacuum group showed significant decreased from its resting value throughout the experimental study ($p < 0.05$).

Within group comparison of hand temperatures:

Control group (Table 4.3) showed significantly decrease from its resting value during 1st round, 1-minute post exercise round 1, during 2nd round, 1-minute post exercise round 2, during 3rd round, 1-minute post exercise round 3 and significantly increased from resting value at 30-minute recovery ($p < 0.05$). RTX with no vacuum group showed significant decreased from its baseline throughout the experiment ($p < 0.05$) with the exception only at 30-minute recovery ($p > 0.05$). For RTX with vacuum group, there were significant increased of hand temperatures from its baseline for the entire period of the study ($p < 0.05$).

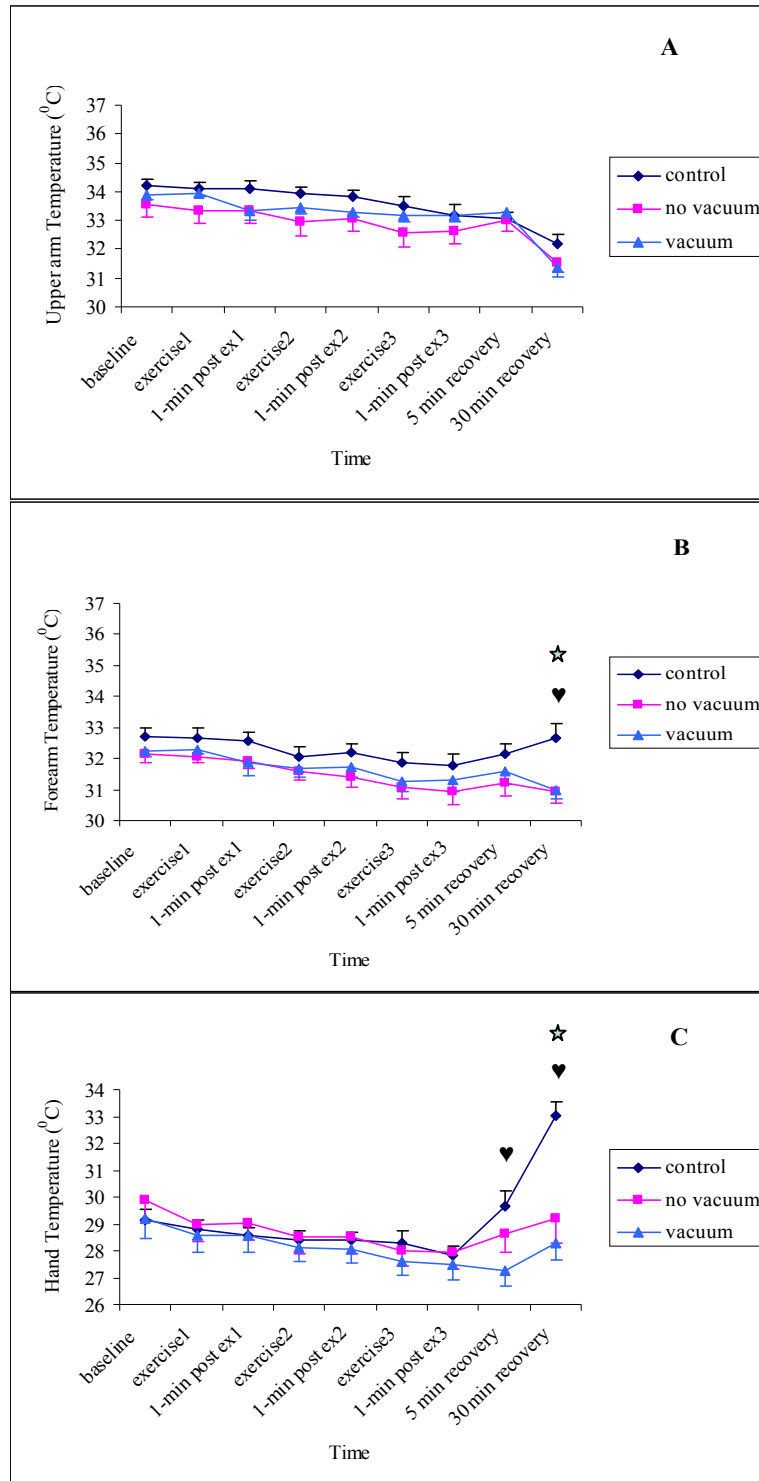


Figure 4.7 Between group comparisons of upper limb temperature included A: Upper arm temperature, B: Forearm temperature and C: Hand temperature.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

4.4.1.3 Lower limb temperatures

Thigh and calf temperatures: Resting temperatures of thigh temperatures in control, RTX with no vacuum, and RTX with vacuum were 32.8 ± 0.4 , 32.9 ± 0.3 , 33.3 ± 0.4 °C respectively. Resting calf temperatures in control, RTX with no vacuum, and RTX with vacuum were 32.6 ± 0.3 , 32.4 ± 0.4 , 32.2 ± 0.3 °C respectively. Between groups comparison (Figure 4.8) showed that there was no significant different of either thigh or calf temperatures for all experiment ($p > 0.05$).

Within group comparison (Table 4.3), control group showed significant increased of *thigh temperature* from its baseline at 1-minute post exercise round 2, 1-minute post exercise round 3, 5-minute recovery, and 30-minute recovery ($p < 0.05$). In RTX with no vacuum group compared with its baseline data showed significant decreased only during 1st round and increased at 5-minute recovery ($p < 0.05$). For RTX with vacuum group compared with its baseline data showed significant decreased during 1st round and 30-minute recovery and increased at 1-minute post exercise round 2 and 5-minute recovery ($p < 0.05$).

Within group comparison (Table 4.3) showed that *calf temperature* of control group had significant reduction from its baseline during 1st and 3rd round. In RTX with no vacuum group showed significant decreased from baseline at 1st round, 1-minute post exercise round 2, 2nd round, 3rd round, and 1-minute post exercise round 3 ($p < 0.05$). For RTX with vacuum group, data showed significant reduction from baseline during 1st and 2nd rounds ($p < 0.05$).

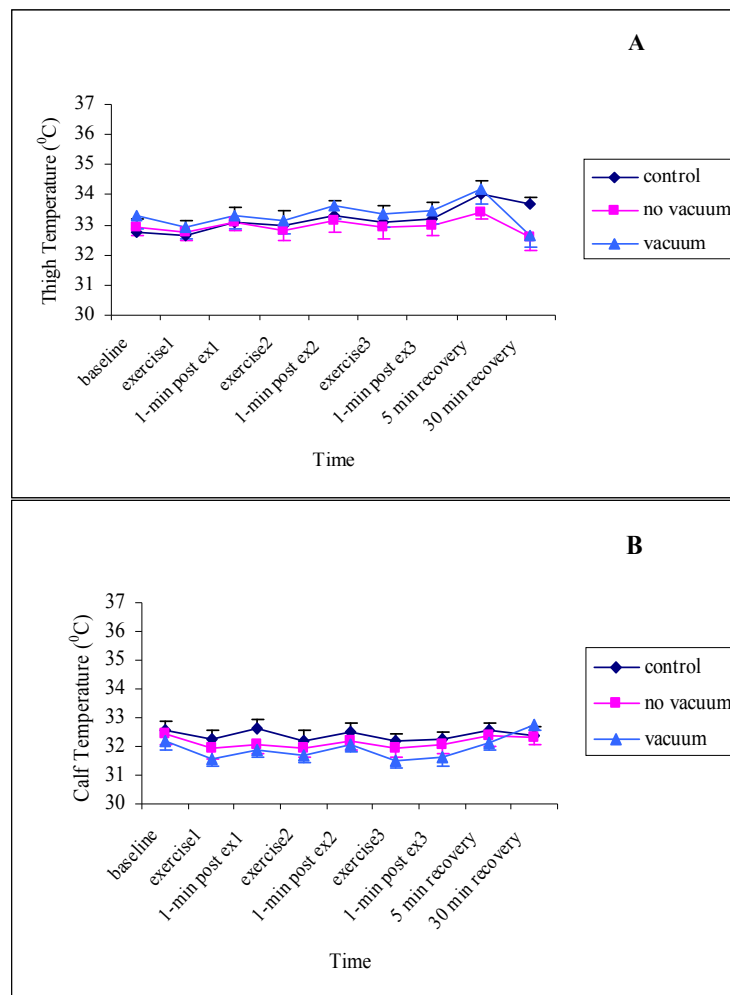


Figure 4. 8 Between group comparisons of lower limb temperature included A: Thigh temperature and B: Calf temperature.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

4.4.2 Mean skin temperature

Resting mean skin temperatures (Figure 4.9) in control, RTX with no vacuum, and RTX with vacuum were 33.4 ± 0.2 , 33.3 ± 0.2 , 33.3 ± 0.2 °C respectively. Similar changes of reduction of mean skin temperatures in all groups were observed during the experiment. Comparison showed that there was no significant different of mean skin temperatures in all groups except between control and RTX with vacuum group at 30-minute recovery ($p < 0.05$).

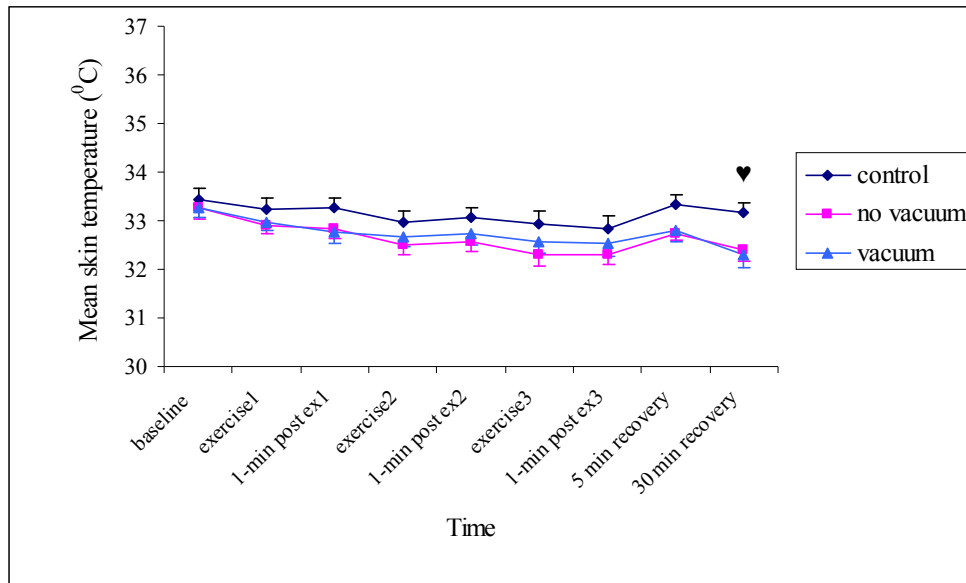


Figure 4.9 Mean skin temperature in degrees Celsius of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

Within group comparison (Table 4.3), control group showed significant reduction of mean skin temperature throughout experiment ($p < 0.05$) only 5-minute and 30-minute recovery had no significant different from baseline ($p > 0.05$). In RTX with no vacuum and with vacuum groups, there were significant reduction from baseline throughout exercise and recovery period ($p > 0.05$).

4.4.3 Core temperature

Accordingly, none of subjects agreed to have rectal probe insertion. Therefore, core temperature in the present study was represented via tympanic membrane. Since the variations in tympanic temperature, all values were presented as changes from initial values. Between groups comparison data showed that there were significant different of tympanic temperature (Figure 4.10) between control and RTX with no vacuum groups at 30-minute recovery ($p < 0.05$).

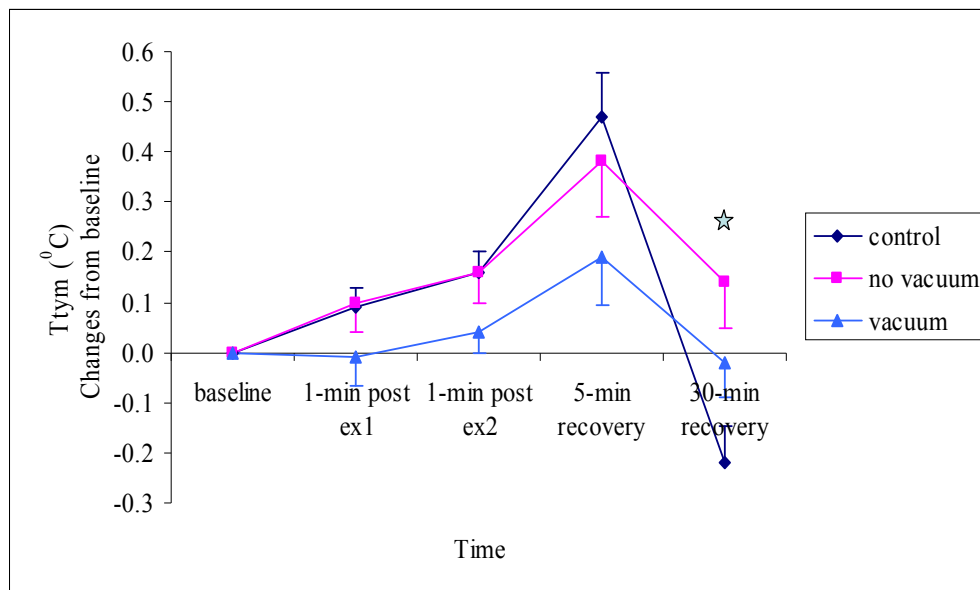


Figure 4.10 Tympanic temperature calculated as change from baseline in degrees Celsius of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

Within group comparison (Figure 4.10) between the corresponding baseline values of control group showed significant increased ($p < 0.05$) of changes of tympanic temperature from baseline (0.09 ± 0.03 , 0.16 ± 0.04 , 0.47 ± 0.09 °C, for 1-min post exercise round 1, 1-minute post exercise round 2, and 5-minute recovery, respectively) which the significantly declined at 30-minute recovery (-0.22 ± 0.07) ($p < 0.05$). RTX with no vacuum group showed significant increased from baseline only at 1-minute post exercise round 2 (0.16 ± 0.06) and 5-minute recovery (0.38 ± 0.11) ($p < 0.05$). For RTX with vacuum group, there was no significant different of tympanic temperatures from baseline throughout recovery period ($p < 0.05$).

4.4.4 Mean body temperature

All Resting mean body temperatures, calculated using $MBT = 0.64 T_{Core} + 0.36 T_{Skin}$ equation, of control, RTX with no vacuum, and RTX with vacuum groups were 35.5 ± 0.1 , 35.7 ± 0.1 , and 35.8 ± 0.1 respectively. Between groups comparison

showed that there were no significant different of mean body temperatures (Table 4.4) for all experiment ($p>0.05$).

Within group comparison of control group showed significant increased in mean body temperature from baseline at 5-minute recovery and decreased from baseline at 30-minute recovery ($p<0.05$). In RTX with no vacuum group showed significant decreased from baseline only at 1-minute post exercise round 1 and 1-minute post exercise round 2 ($p<0.05$). For RTX with vacuum group, there was significant decreased from baseline at 1-minute post exercise round 1, 1-minute post exercise round 2, and 30-minute recovery ($p<0.05$).

4.4.5 Thermal sensation scale

Subjective thermal sensation scale was estimated at rest, during, post exercise and during recovery. Resting thermal sensation scales of control, RTX with no vacuum, and RTX with vacuum groups were 6.7 ± 0.2 , 6.7 ± 0.2 , and 6.6 ± 0.3 respectively. All groups comparison showed that there was no significant different of thermal sensation scale (Table 4.4) for all experiment ($p>0.05$).

Table 4.4 Thermal sensation scale and mean body temperature of control, RTX without and RTX with vacuum intervention (Mean \pm SEM)

Variable	Condition	baseline	1-min post ex1	1-min post ex2	5 min recovery	30 min recovery
Thermal Sensation Scale						
	Control	6.7 ± 0.2	$9.1 \pm 0.5 *$	$10.0 \pm 0.5 *$	$9.6 \pm 0.5 *$	$7.4 \pm 0.3 *$
	No vacuum	6.7 ± 0.2	$8.3 \pm 0.7 *$	$8.9 \pm 0.7 *$	$8.6 \pm 0.6 *$	6.9 ± 0.3
	Vacuum	6.6 ± 0.3	$8.0 \pm 0.6 *$	$8.8 \pm 0.7 *$	$8.3 \pm 0.6 *$	6.5 ± 0.3
Mean Body Temperature ($^{\circ}$C)						
	Control	35.5 ± 0.1	35.5 ± 0.1	35.5 ± 0.1	$35.8 \pm 0.1 *$	$35.3 \pm 0.1 *$
	No vacuum	35.7 ± 0.1	$35.6 \pm 0.1 *$	$35.5 \pm 0.1 *$	35.7 ± 0.1	34.2 ± 1.3
	Vacuum	35.8 ± 0.1	$35.6 \pm 0.1 *$	$35.6 \pm 0.1 *$	35.8 ± 0.2	$35.4 \pm 0.1 *$

* Significant different from baseline within the same group at $p<0.05$

☆ Significantly different between control and RTX with non vacuum group at $p<0.05$

♥ Significant different between control and RTX with vacuum group at $p<0.05$

♣ Significant different between RTX with no vacuum and vacuum group at $p<0.05$

Within group comparison from resting value in control group showed significant increased thermal sensation scale at 1-minute post exercise round 1, 1-minute post exercise round 2, 5-minute recovery, and 30-minute recovery ($p<0.05$). In

RTX with no vacuum and vacuum groups showed significant increased from baseline at 1-minute post exercise round 1, 1-minute post exercise round 2, and 5-minute recovery ($p<0.05$).

4.5 Effects of rapid palm cooling method on blood chemistry.

Blood lactate concentration

Resting blood lactate levels in control, RTX with no vacuum, and RTX with vacuum groups were 1.9 ± 0.2 , 1.7 ± 0.2 , and 1.8 ± 0.1 respectively. As exercise bouts were repeatedly performed, blood lactate concentrations in all groups showed the similar fashion which had peaks at 5-min recovery. Between groups comparison (Figure 4.11) showed that there was no significant different of blood lactate concentration for all experiment ($p>0.05$).

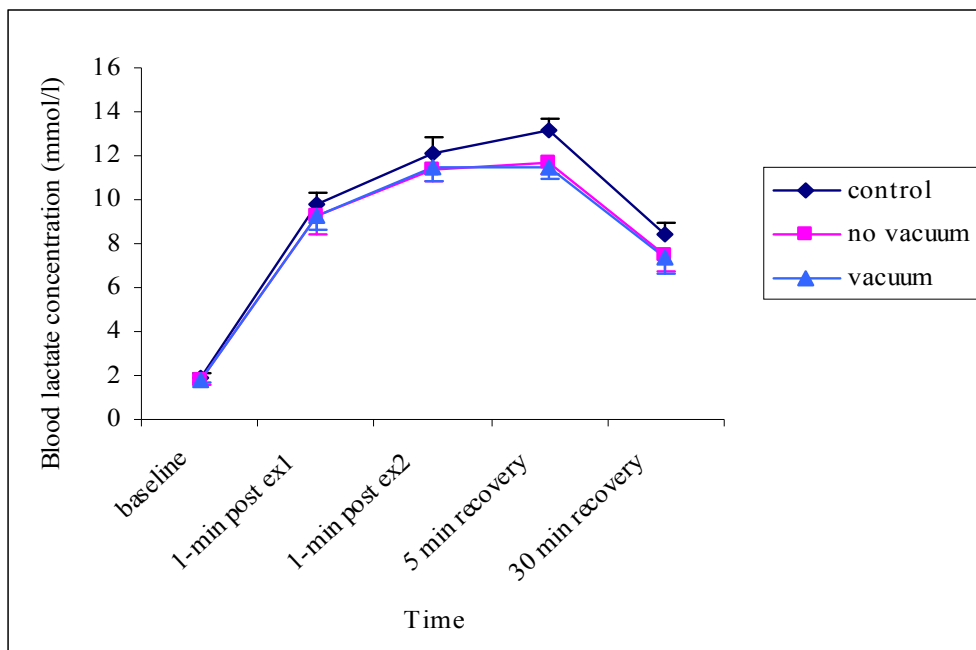


Figure 4.11 Blood lactate concentration (mmol/l) of Taekwondo athletes ($n=10$) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with non vacuum group at $p<0.05$
- ♥ Significant different between control and RTX with vacuum group at $p<0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p<0.05$

Within group comparison (Table 4.5) from its corresponding baseline in control , RTX with no vacuum, and RTX with vacuum groups showed significant increased of blood lactate concentrations from baseline at 1-minute post exercise round 1, 1-minute post exercise round 2, 5-minute recovery, and 30-minute recovery ($p<0.05$).

Table 4.5 Within group comparison on blood lactate concentrations (mean \pm SEM).

Condition	baseline	1-min post ex1	1-min post ex2	5 min recovery	30 min recovery
Control	1.9 \pm 0.2	9.7 \pm 0.6 *	12.1 \pm 0.8 *	13.2 \pm 0.5 *	8.5 \pm 0.5 *
No vacuum	1.7 \pm 0.2	9.3 \pm 0.8 *	11.4 \pm 0.5 *	11.7 \pm 0.5 *	7.5 \pm 0.7 *
Vacuum	1.8 \pm 0.1	9.3 \pm 0.6 *	11.5 \pm 0.7 *	11.5 \pm 0.5 *	7.3 \pm 0.6 *

* Significant different from baseline within the same group at $p<0.05$

4.6 Effects of rapid palm cooling method on subjective evaluation.

Rating of perceived exertion

Resting values of rating of perceived exertion (RPE) in control, RTX with no vacuum, and RTX with vacuum were 6.0 ± 0.0 , 6.0 ± 0.0 , and 6.0 ± 0.0 respectively. RPE in all groups changed in the similar pattern which showed peak values at 5-min recovery. Between groups comparison (Figure 4.12) showed that there was significant different of rating of perceived exertion between control and RTX with vacuum groups only at 5-minute recovery ($p<0.05$).

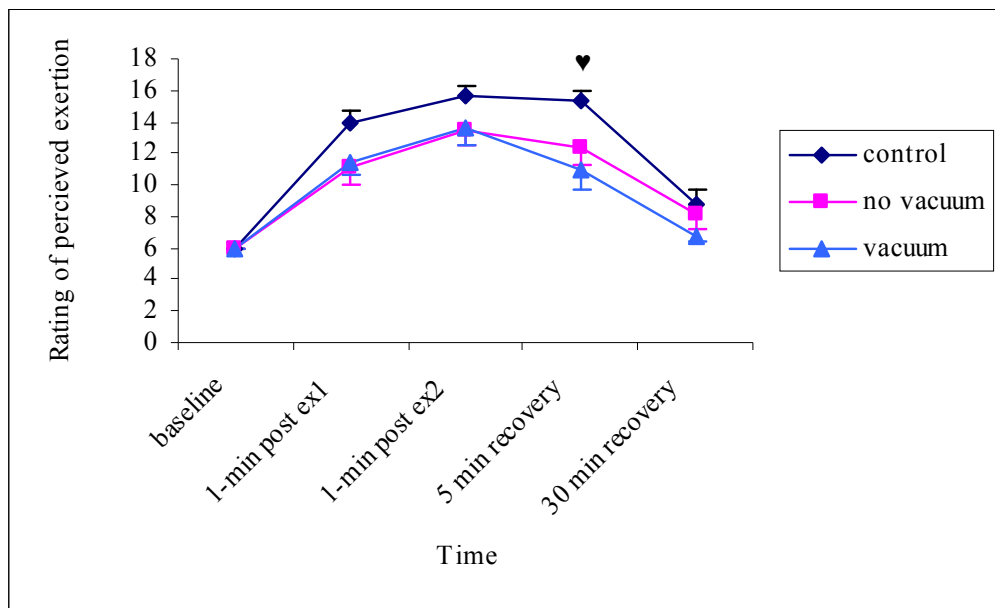


Figure 4.12 Rating of perceived exertion of Taekwondo athletes (n=10) between control, RTX with no vacuum, and RTX with vacuum groups. Values are means and SEM.

- ☆ Significantly different between control and RTX with no vacuum group at $p < 0.05$
- ♥ Significant different between control and RTX with vacuum group at $p < 0.05$
- ♣ Significant different between RTX with no vacuum and vacuum group at $p < 0.05$

Within group comparison (Table 4.6) between baseline and data of control, RTX with no vacuum, and RTX with vacuum groups showed significant increased in RPE from baseline at 1-minute post exercise round 1, 1-minute post exercise round 2, 5-minute recovery, and 30-minute recovery ($p < 0.05$) only 30-minute recovery of RTX with vacuum group had no significant different from baseline ($p > 0.05$).

Table 4.6 Within group comparison of Rating of Perceived Exertion (mean \pm SEM).

Condition	baseline	1-min post ex1	1-min post ex2	5 min recovery	30 min recovery
Control	6.0 \pm 0.0	13.9 \pm 0.7 *	15.7 \pm 0.6 *	15.3 \pm 0.6 *	8.8 \pm 0.9 *
No vacuum	6.0 \pm 0.0	11.1 \pm 1.1 *	13.5 \pm 0.9 *	12.4 \pm 1.1 *	8.1 \pm 0.8 *
Vacuum	6.0 \pm 0.0	11.5 \pm 0.8 *	13.6 \pm 1.0 *	10.9 \pm 1.1 *	6.7 \pm 0.3

* Significant different from baseline within the same group at $p < 0.05$.

CHAPTER V

DISCUSSION

5.1 Characteristic of Subjects

All subjects in the present study have been currently and regularly practiced taekwondo at Baan Bua Thong Gym at least 1 year under the same coach and protocol. Physical characteristics including age (yr), weight (kg), height (cm), body mass index (BMI), and body fat (%) were in normal ranges of age range between 15-20 years (National Growth, 1999). Subject's instruction for additional vigorous physical activity and hydration status were controlled prior to the test. Urine specific gravity is in normal range (1.0002-1.030) (Bazari, 2007). No significant difference in statistic of these parameters between subject groups in this study. All subjects randomly completed three trails; control, RTX with vacuum, and RTX with no vacuum. During each experimental, all subjects were similarly stimulated for maximal voluntary performance during the test using verbal and visual feedbacks which are known to influence on force production (Perrin, 1993).

5.2 Effects of rapid palm cooling method on subsequently changes of anaerobic energy system.

5.2.1 Peak anaerobic power (watt)

Anaerobic power absolutely uses stored energy within muscles with no oxygen expenditure. Two energy systems, which responsible for these types of power, are known phosphogens and lactic acid system. Human uses this form of energy in short bursts activity that cannot be sustained for longer than about two minutes (di Prampero & Mognoni,1981) To initiate all rapid movements, the body requires conversion of certain amount of immediate energy stored within muscle known as "anaerobic alactic component". This ability is a prime determining factor for athletic success since it is an initial important component in the overall physical fitness.

Estimation of these anaerobic power and capacity are relevant to athletes whose sports require a significant contribution of the immediate anaerobic energy production in very short but intensive muscular exertion, such as sprinting, jumping, throwing and lifting etc. This process of anaerobic source for mechanical energy of muscular work is exhausted in a few seconds owing to its small capacity and high rate. Theoretically, the maximum rate of energy conversion at highest intensity can be reached within 3 to 5 seconds. This is derived from the maximum rate of splitting of ATP (adenosine triphosphates) and CP (Creatine phosphate) stored within the muscle at limited amount. As activity is sustained, this immediate energy becomes depleted and lactic anaerobic (fast glycolysis) energy source accounts for energy supply (Bouchard *et al.*, 1991).

Taekwondo is an intermittent sport, characterized by short duration of 2 min intense activity. It requires significant anaerobic fitness and operates within a well-developed aerobic system. This sport is estimated to be 70-80% anaerobic and 20-30% aerobic which requires 2:1 work:rest period (Brooks & Fahey, 1985). At the beginning of high intense exercise, the speed of splitting of high-energy phosphates is determined by the specific enzymatic activity in the muscles which is genetically specific. Maximum anaerobic power is, therefore, reached during the first few seconds where the highest speed takes place. Such activity is sustained for another 4 to 6 seconds. After that the mechanical output declines progressively because of the decreased ATP and CP content in the working muscles (McArdle *et al.*, 1996). The development of power, performance of work expressed per unit of time, is related to the contribution of the ATP-CP and lactic acid system. The term anaerobic power is more preferable than “explosive power”. The present explanation will concentrate on ATP-CP system rather than lactic acid system. The latter inhibits on muscular function. However, there is no solely anaerobic or aerobic energy system contributes for such activity (Astrand *et al.*, 1986).

Anaerobic capacity can be indirectly estimated using Wingate test, where subject is forcefully pedaled at maximal speed on a mechanical braked cycle for 30 seconds. This is an all-out cycling test of short duration used to estimate the power and capacity of the anaerobic energy system (McArdle *et al.*, 1996). Wingate test uses an exercise bike that can be weighed with resistance based on a percentage of body

weight for an all out 30 second sprint. This specific test was introduced in the mid-1970s, by the Wingate institute in Israel, to assess peak muscle power, local muscle endurance, and fatigability. It has also been used to analyze physiologic and cognitive responses to supramaximal exercise (Bar-Or *et al.*, 1996) because of its high reliability, sensitivity and validity. To simulate competitive condition in taekwondo, subject had to sustain and able to complete 3 repeated bouts of 2 min maximal pedaling (Kui Lu *et al.*, 2008). Thus workload of this cycling test is re-adjusted. It is documented that modifications of Wingate anaerobic tests have been currently performed to fit with types of sports and physical activity (Lakomy, 1986). British Olympic Medical Center modified this test for middle and long distance runners (MacDougall *et al.*, 1991). According to pilot study, modified Wingate was introduced with lower workload, which made it possible for all subjects to successfully complete the exercise trials.

Replenishment of the above anaerobic energy storages appear differently according to types, intensity, duration and work-rest ratio of such activity (McArdle *et al.*, 1996). For example, replacement of ATP-CP system up to 70% might appear within 30 sec to 2 min due to the intensity and duration of physical activity while that of anaerobic lactic system emerges within 30 min (Dunford & Doyle, 2008). Another investigation indicated that stores of ATP and CP after intense exercise are replenished, with time constants of 2-6 min (Spurway, 1992). Therefore, it is not possible for complete recovery to be taken place, for ATP-CP and anaerobic lactic system, with 1 min recovery in simulated Taekwondo competition. It is no doubt that incomplete recovery of the previous bout will affect performance of the subsequent bouts. As a result, the declines of performance in the second and third bouts were detected in the present study.

While these anaerobic energy systems are repeatedly utilized, the body uses more energy than it can be replenished. This can lead to various signs and symptoms: ranged from decline of anaerobic peak power, cramping, fatigue and lactic acid buildup (Spurway, 1992). However, anaerobic performance in this study showed the changes of anaerobic energy with the highest at the 1st round and slightly decline in the second round after that increase in the last round. Although recover occurs, this progress is not yet fully achieved within 1 minute. Interventions with RTX during 1-

min rest period between bouts exert some physiologic effect to accelerate recovery in the last phase, 3rd bout. Similar to other cooling methods during exercise (Ranalli *et al.*, 2010; House *et al.*, 1997), RTX exhibits positive effect on both aerobic and anaerobic performance. It is proposed that cooled blood in the hands flowed directly to the body's core via the superficial veins to lower heat strain to higher center (House *et al.*, 1997). In addition, cooler blood is shunted from superficial part, to the deeper veins, to be heated by deeper warm arterial blood, therefore protecting the deeper part from extremely heated temperature; this has been referred to as countercurrent heat exchange (Livingstone *et al.*, 1989). RTX, like other palm cooling method (Goosey-Tolfrey *et al.*, 2008), reduces both core and periphery temperatures and preserving blood flow toward working muscles which enables muscles to sustain its contractions.

Peak anaerobic power was estimated as the highest power output reached over a five second interval (Vandewalle *et al.*, 1987; Melhim, 2001). The current study found that local palm cooling treated with RTX with vacuum improved peak anaerobic power in Taekwondo athletes particularly on the 3rd round. Possibly palm cooling related to a decreased central fatigue response or to a peripheral counter-irritation effect which increased exercise repetitions and exercise volume (Kwon, 2009). In contrast to results obtained from control group (no cooling), which had significant reduction in peak anaerobic power from round to round. The results strongly recommend that local cooling had beneficially improved anaerobic performance no matter RTX with or without vacuum was applied.

Sub-atmospheric pressure, of 4 mmHg, was known to induce remarkably fluid filtration into joints (Levick, 1979). Local application of sub-atmospheric pressure induced no vasoconstriction of limb segment in myocardial patients (Skagen, 1982) and enhanced blood flow (Olsen *et al.*, 2008). The absence of a vasoconstrictor response to locally applied subatmospheric pressure could not be due to decreased venous distensibility. The underlying mechanism may be neuronal inhibition, probably antidromic, in sympathetic fibres (Skagen, 1982). In the present study, it is also observed that when sub-atmospheric pressure was applied along with palm cooling. Thus RTX with vacuum demonstrated that peak anaerobic power was further increased from round 2 to round 3 which indicated that local cooling with vacuum can additionally improve performance in Taekwondo athletes. Like results obtained from

previous investigations which concluded that local cooling in combination with sub-atmospheric pressure had beneficial to improve exercise performance (Tenforde, 2003; Whitish *et al.*, 2003; Grahn & Heller, 2004; Grahn *et al.*, 2005; Whitmore *et al.*, 2007; Kwon, 2009). The present study believes that blood flow is effectively drawn to cooling palm with this negative pressure which might partly lower body temperature. Few studies had been similarly mentioned (Heller *et al.*, 1998). It is considered that accumulation of heat stress in Taekwondo who must wear protective garments that limitation of heat dissipation and increase in core body temperature, subsequently, this decreases an athlete's ability to tolerate causes rise in body temperature and increases the probability for heat-related injuries (Oppliger & Bartok, 2002). At the present time RTX has been used in sports research to lower core temperature that affects the recovery of anaerobic function (Whitish, *et al.*, 2003) and reduces recovery time from virtually aerobic (Elliott *et al.*, 2003).

5.2.2 Average anaerobic power (watt)

Whitish and co-workers (2003) reported the effects of the Rapid Thermal Exchange on power output in that RTX cooling had little influence on power output during maximal repeated bouts of cycling. Similar this study, we found that RTX treated with and without vacuum, exert no effect on average power in Taekwondo athletes as RTX treated would be too short to improve anaerobic fitness.

Moreover, repeated simulated Taekwondo competition causes significantly lower average anaerobic powers in the second round with no further dropped in the last round. Like a study of Thomas *et al.* (2008) and Duffield *et al.* (2003), who that suggested longer periods of cooling may be necessary to produce a change of any variables.

5.2.3 Anaerobic power drop (watt)

Power drop is defined as different between peak power and lowest power during 2 minute anaerobic test. Even though RTX enabling to sustain Peak anaerobic power during the 3rd round, this group showed greater % power drop than in control from 2nd to 3rd round. Fatigue index, the decrease in force development, had been proposed when repeated muscle contractions were performed (Gibson & Edwards,

1985). In this study, when skeletal muscle fiber had been activated at maximal pedal speed on Monark cycle ergometer, this will reduce relaxation phase. This type of muscle action, when velocity of contraction gradually increases whilst the duration of contraction oppositely decreases, leads to the reduction in force being produced. From the study of Davies et al. (2009), they found that the decrease tetanus relaxation rate was positively associated fatigue index.

We, therefore, conclude that the uniqueness of this study is that application of local cooling media on area far away from working muscle enhances anaerobic performance on the consecutive bouts in Taekwondo athletes.

5.3 Effects of rapid palm cooling method on cardiovascular system.

5.3.1 Heart rate and blood pressure

In high intense sports, like Taekwondo (TKD), heat transferring ability can be reduced from specific sports uniforms (dobok), body armour (hoegul) and associated protective body pads, all of which diminish heat exchange surface areas (Gavin, 2003). Under these circumstances, physiologic body responses might be affected. It is well known that physical conditioning and aerobic capacity in particular, depend upon 4 important elements: maximal oxygen consumption, anaerobic threshold, work economy and recovery (Howley *et al.*, 1995; Wisloff *et al.*, 2002). To maintain good performance throughout the competitive phase this physiological base must be maintained (Bompa, 1999). Schneider and co-workers (2006) study the differences of body cooling between no cool, water bath, and RTX cooling method, they discovered that heart rate during water bath and RTX test were similar to no cool method. In relation to this study that the rise in heart rates in all treated conditions were mainly due to workloads being performed. When work load increase, it will induce heart rate also increase allow proportion with work output and other factor such as temperature, hydration status, and etc. Which intervention had no effect when high intense exercise.

Previous study indicated that no heart rate differences between groups despite the intervention methods and the only changes of heart rate variability were detected (Anthony *et al.*, 2009).

From the results, we may concern about “cardiac drift”. During intensity exercise blood is distributed to both the active skeletal muscles and the skin. In fact, there is a slight “pooling” of blood at cutaneous level that facilitates heat transfer. All of this leads blood being returned to the heart, which leads to a decrease in left ventricular end-diastolic volume, a reduced stroke volume and, if left uncompensated, a reduced cardiac output. However, to maintain cardiac output during exercise, the drop in stroke volume is compensated for by an increase in heart rate. This incident, referred to as cardiovascular drift, explains why higher heart rates are observed when exercising (Foss & Keteyian, 1998).

In 1999, Fritzsche reported that during prolonged exercise in a neutral environment the decline in stroke volume (SV) is related to the increase in heart rate (HR) but not affected by cutaneous blood flow (Rowell, 1996). Moreover, cooling intervention may affect cardiovascular system in various ways, for example decreasing in heart rate, increasing venous return and stroke volume caused by alterations in vasomotor tone (Schnepp *et al.*, 2000). This cardiovascular drifting is the consequence of a progressive increase in cutaneous blood flow (CBF) as body temperature rises. It is thought that the rise in CBF would lead to an increase in skin venous volume, reducing ventricular filling pressure, end-diastolic volume, and thus stroke volume (Rowell, 1996). Several literatures had accepted that a progressive increase in CBF is the main cause of the decline in SV during prolonged exercise (Johnson, 1987; Mole & Coulson, 1985; Raven, 1988; Rowell, 1974). When heat accumulation in body rises thus it affects physical performance as most of blood is being sent to active muscles but diminished certain amount of blood to skin for heat dissipation. Heat conduction depends upon a temperature gradient, many studies using ice-cold water to establish a steeper thermal gradient between skin and environment (Ferris *et al.*, 1938; Donnell, 1971; Cosfrini, 1990; Armstrong *et al.*, 1996; Proulx *et al.*, 2003; Hadad *et al.*, 2004). However, aggressive skin cooling may induce shivering and peripheral vasoconstriction, impeding the cooling efficacy (Hadad *et al.*, 2004). A question has been raised regarding the optimal water temperature when using the immersion approach. Magazanik *et al.* (1980), compare cooling rates when using tap water at 15-16°C, cold water at 10-11°C or ice water at 1-3°C. They found the equal effectiveness of different water temperature, the higher thermal gradient, was

explained by the vigorous shivering during immersion in ice water, which caused additional heat production and a slow rate of cooling. Range of temperature for cooling, of 18-22°C, using in this study is known to be effective for the body heat control as indicated from previous report (Grahn *et al.*, 2005). We concluded that RTX, at 18-22°C, is useful although some cardiac variables did not change but indeed it can enhance a peak anaerobic performance in short duration, high intensity exercise.

5.3.2 Forearm blood flow (ml/min)

Forearm blood flow in this investigation proved that flow rates in all interventions still in normal ranges with RTX of 18-22°C. From study of Coles (1975) and Coles and Greenfield (1995), it is demonstrated that local sub-atmospheric pressure enhanced blood flow through the fingers and toes which resulted in more heat loss. Controversially, pressure gradient of more than 50 mmHg limits heat loss (and thus, blood flow) through the hand (Coles & Greenfield, 1956; Grahn & Heller, 1998). Greenfield and Patterson (1954) observed a local vasoconstriction in the forearm, following exposure of 50-100 mm Hg below atmospheric pressure. These reactions may represent a continuation of an increase in contractile force in the walls of the resistance vessels brought about by increased transmural pressure during venous congestion or exposure to sub-atmospheric pressure. It is possible that during the period of increased transmural pressure an increase in contractile force enables the resistance vessels more or less successfully to resist passive dilatation. While sub-atmospheric pressure expanded the blood volume into the hand, blood flow through the distended vessels could be controlled by manipulation of local skin temperatures and general skin temperatures (Coles & Patterson, 1957). These results proved that while the local application of sub-atmospheric pressure increased the standing volume of blood in vascular structures of the hand, it was the temperature manipulations that determined blood flow through the vascular structures. The temperature manipulation effects were independent from the pressure manipulation effects.

Heat extraction device used in this study has the ability to enhance heat exchange capacity via distending the venous plexus vessels through the application of sub-atmospheric pressure. Furthermore, reflex vasoconstriction of the arterio-venous anastomoses (AVAs) is possibly prevented by maintenance of a heat-sink temperature

above the threshold for local vasoconstriction (Grahn *et al.*, 2005). During recovery from heat stress where vasoconstriction threshold is reached, with some cooling method, blood flow through the hand will not be shut off (Grahn & Heller, 2004). Thus, RTX, of 15°C temperature, is the selected cooling method like other studies (Davis & Young, 1993; Mattacola & Perrin, 1993; Catlaw *et al.*, 1996; Hatzel & Gulick, 2000; Douris *et al.*, 2003; Thonley *et al.*, 2003; Richendoller *et al.*, 2006; Patterson *et al.*; 2008; Fisher *et al.*, 2009; code in Kwon, 2009)

Expectedly, applying vacuum during cooling method would increase blood flow than without vacuum. Although we did not find different between groups but in within group we found slight different in RTX with vacuum group with high forearm blood flow at 30-minute recovery than other groups. Further investigation might concern with greater negative pressure.

5.4 Effects of rapid palm cooling method on thermoregulatory system.

5.4.1 Trunk temperature

The present study shows that RTX cooling technique is an effective method to reduce metabolic heat production by manipulate skin temperature particularly when RTX was used in a short period in between extreme exercise as indicated directly by upper limb temperatures. The surface of the human body is covered by two types of skin: non-hairy and hairy parts. The skin regions are not only characterized by absence or presence of hair follicles but also by a unique set of subcutaneous vascular structures (arterio-venous anastomoses and venous plexuses) which enable large volumes of circulating blood to flow through the subcutaneous space (Greenfield, 1963; code in Grahn *et al.*, 2004). The non-hairy skin surfaces are restricted to palm area, soles of the feet and some regions of ears and face. These structures provide a pathway for blood to flow directly from the heart via arterial outflow to the body surface and back to the heart via venous return. Blood passing through these heat exchange units is delivered directly from the heart via arterial system and delivered back to the heart via venous return. Blood flow through the heat exchange vascular units is extremely variable. It has been estimated that blood flow into the venous plexuses can range from near to zero in cold stress to as much as 60%

of the total cardiac output during heat stress (Greenfield, 1983; Johnson & Proppe, 1996; code in Grahn *et al.*, 2004). Venous plexuses are arranged to allow sustained residence time of the circulating blood directly under the exposed body surfaces. Sphincter muscles in the arterio-venous anastomoses control the blood flow through the venous plexuses (Bergersen *et al.*, 1997; code in Grahn *et al.*, 2004). The dimensions of venous plexuses determine the blood volume capacity of heat exchange region while the AVAs control the blood flow through venous plexuses (Grahn & Heller, 1998)

Thus RTX methods enhanced these specialized AVAs that exist in the palm of hand for cooled body core temperature. Moreover, an airtight wrist seal creates a negative pressure in the vacuum chamber which draws more blood into the AVAs with the intent of speeding the heat exchange. Although chest temperature plays no significant role during and post-exercise in taekwondo athletes but in back temperatures declined despite types of intervention. It seems likely that body regulates heat via this body's part.

5.4.2 Upper and lower limb temperature

From finding in this study, forearm temperature especially in hand temperature was significant lower temperature than no cooling compare with palm cooling at 30-minute recovery. The results represent that local cooling is an effective way to cool the skin regions. When compare between with vacuum and without vacuum, results show slightly different but when compare no cooling and RTX with vacuum results show more different than without vacuum observe at 5-minute recovery of hand temperature. Therefore, we conclude that RTX application of slightly sub-atmospheric pressure around 35-40 mmHg is the best choice for local cooling techniques.

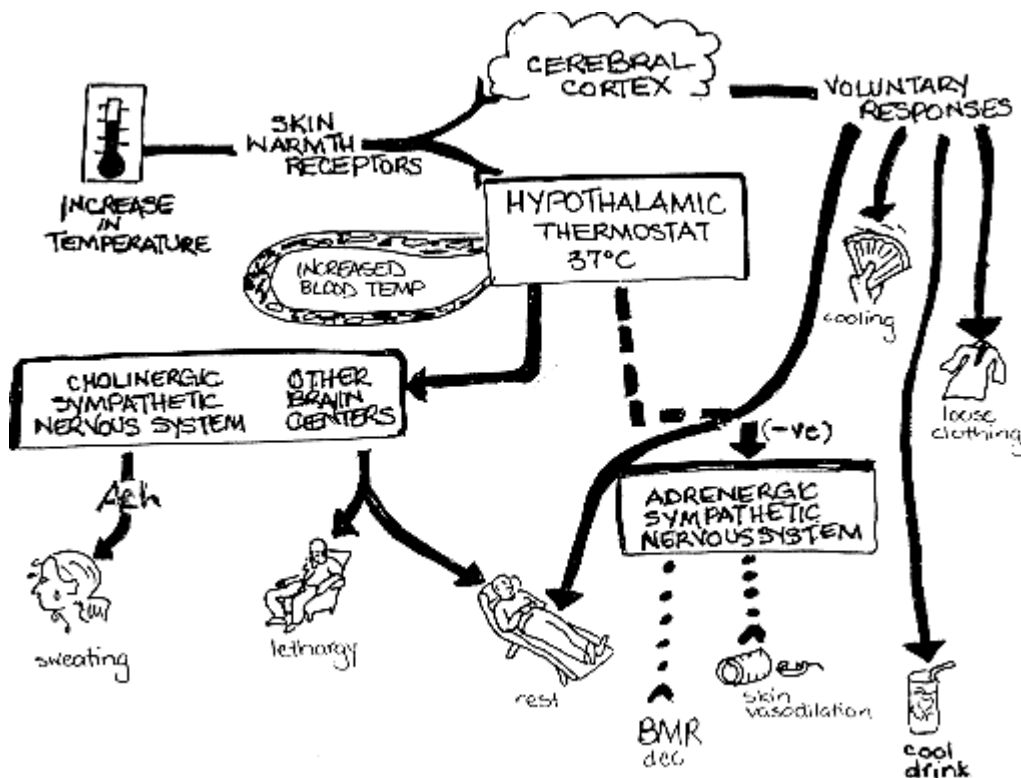


Figure 5 Neurophysiology of thermoregulation when responses to heat (Guyton, 1996).

Normally, some type of sympathetic nervous system which relevant to control thermoregulation system called “Cholinergic sympathetic fibers” will released neurotransmitter known as acetylcholine, which affects sweat rate and vasodilatation. The other sympathetic type is “Adrenergic sympathetic fibers”, which will release neurotransmitter named noradrenalin. As physical activity is continued, body temperature rises; blood conveys such temperature changes to the hypothalamic thermostat. Response mechanisms appear in different ways. This thermostat inhibits the adrenergic activity of the sympathetic nervous system, which normally controls vasoconstriction and metabolic rate. As a result of such inhibition, vasodilation of skin vessels and reducing BMR might be taken place. This primarily causes an increase in heat loss via the skin and a decrease in heat being conveyed to the core. In this condition, sweating may or may not be observed. Additionally, as heat production becomes more and more intense, by means of physical activity, then cholinergic sympathetic fibers, which innervate sweat glands release Ach (Acetylcholine), stimulating sweat. Sweating, the most effective involuntary heat elimination in man is

activated via skin warmth receptors (Guyton, 1996). From combine effect sympathetic also cholinergic and adrenergic, leads to eliminate heat accumulation in the body thus decrease in core and skin temperature together.

During palm cooling, peak anaerobic power in the last bout was even more than in the 2nd bout. Possibly cold receptors are dense (up to 10 times) than warm receptors in hand skin layers, so make more available blood send into muscles (Jones & Lederman, 2006). Cold receptors discharge the most vigorous at skin temperatures of 25°C (Guyton, 1996; Jones & Lederman, 2006) whereas, warm receptors discharge with increasing skin temperature and reaching a maximum at 45-50°C (Pierau & Wurster, 1981; code in Kwon *et al.*, 2009). Our subjects' hand temperature at 30-minute recovery during control, RTX without vacuum, and RTX with vacuum was around 33°C, 29°C, and 28°C, respectively.

In conclusion, it appears in all groups that forearm temperatures significantly responded almost throughout the studying period (RTX with and without vacuum induce lower forearm and hand temperatures at 5 min and 30 min recovery). As investigation has been explored further to the hand zone, this area plays even more significant respond with changes of skin temperatures at all steps of investigation. Therefore, heat dissipation via forearm and hand play major role in Taekwondo athletes. The greater improvement of Peak anaerobic power in the 3rd bout may have resulted from a greater number of cold receptors stimulated.

RTX with and without vacuum had no effect on lower limb temperature but more effective to manipulate in core body and nearly part of skin regions which see from part of trunk and upper limb temperatures. Possibly, blood flow to lower part of the body is slower than in upper part. Results from the study is similar to previous report (Schneider, 2006), who measured skin temperatures from eight skin sites (no cool, vest, water bath, AVA) with lower chest and back temperatures whereas no change in skin temperature in other regions.

5.4.3 Mean skin temperature

Mean skin temperature in this study was calculated from the eight skin sites as previously described. Vasomotor tone is a primary thermoregulatory effectors mechanism and vasoconstriction is the initial response to a cold challenge (Wyss *et*

al., 1974). As core temperature is reduced, input is conveyed to both central and peripheral organs. These organs, either alone or together, can elicit a vasoconstriction response (Hales *et al.*, 1985; Frank *et al.*, 1999; code in Grahn & Heller, 2004). During exercise, blood flow through active muscles transfers heat away. Similarly, blood flow through the subcutaneous space delivers heat to the skin (Grahn & Heller, 1998). Therefore, when core temperature rises, vasodilation response will be induced (Crawshaw *et al.*, 1975; Pergola *et al.*, 1996; code in Grahn & Heller, 1998) to dissipate heat.

Normally, muscle and core temperatures rise in the parallel fashion where skin temperature falls with increasing intensity, it is because the sweat evaporation cools the skin. Danger might be occurred when average skin and core temperatures converge towards the same value (Paulev, 2000). Previous study (Hascall *et al.*, 2008) found no difference of core and mean skin temperatures between RTX cooling and no cooling trials during vigorous exercise in the heat. Therefore, RTX will not clearly exert its efficiency in light exercise such as walking and running (Walker *et al.*, 2009). In study of Whitmore *et al.* (2007) where subjects walked on treadmill for 20 min and found that skin temperatures were about the same for control, RTX, and vest conditions. Even though, RTX is ineffective to thermal stress during light exercise but it improves performance via the recovery of anaerobic function (Whitish *et al.*, 2003; Kwon, 2009). Similar to results from the study, RTX treated during intermittent intense exercise is effective to improve anaerobic system and lower mean skin temperature than control (no cooling).

Clinical trials of RTX are concerned not only to able-bodied but also to reduce heat stress in patients with spinal cord injury who loss of autonomic nervous system function below the lesion. Study found that RTX can compromise thermoregulatory capacity and increase the risk of heat stress (Hagobian *et al.*, 2002). Controversially, there was no different of mean skin temperature between palm cooling and no cooling during exercise in a hot, dry environment (Schneider, 2006). Differences of these results are considerably due to different subjects' characteristics, methodologies, exercise regimes, timing and cooling periods.

The present experiment demonstrates that during subsequent exercise bouts, forehead temperatures in all groups are closely controlled in the lower ranges than initial values, no matter data were collected during, post-exercise, or recovery conditions. While changes in chest and back temperatures are scattered in the unpredicted fashion, forearm and hand temperatures response in the similar fashion to forehead and mean skin temperatures. In addition, between groups comparison demonstrates the remarkable changes of mean skin temperature in control and RTX with vacuum groups during recovery period concomitant to hand and forearm temperatures. RTX methods were treated it tends to be effective in manipulating core and skin temperature together.

5.4.4 Core temperature (Tympanic temperature)

RTX shows tendency of an effective method for rapid heat dissipation from metabolic changes during exercise in Taekwondo athletes. The present finding of palm cooling using only one hand, during brief periods between bouts, fails to lower heat from intense exercise. It is reported that both hands cooling exerts more efficiency (Grahn *et al.*, 2005). Heat extraction through the palm improves aerobic exercise endurance in hot environment (Kwon, 2009). Intermittent local cooling is a new method to improve training for higher intensity, short duration exercise. Previous results suggest the heat extraction method via palm area may provide an effective way to manipulate tympanic temperature in proper situation by lower core temperature (Kwon, 2009). The mechanism, of cooled palm induces sufficient cooling of core, relies on specialized heat exchange vascular structures as palm is main part of the non-insulated skin regions. Other areas include soles of the feet, ears, and non hairy regions of the face (Bergersen, 1993; Gemmell & Hales, 1997; Saad, 2001; code in Grahn, 1998). Model in dog's tongue, rabbit's ear, and penguin's feet reflect that these areas contain arterial venous anastomoses (AVAs) where shunting of blood, directly from arterioles to venous plexuses, takes place, which act as effective radiator (Grahn *et al.*, 1998; Kwon, 2009).

Previous studies showed cooling of these areas was an effective method of heat removal (Livingstone *et al.*, 1989; Hagobian *et al.*, 2003; Grahn *et al.*, 2005; Hsu *et al.*, 2005; Giesbrecht *et al.*, 2007; Grahn *et al.*, 2008; Khomenok *et al.*, 2008; code

in Kwon, 2009). In addition, applied sub-atmospheric pressure to this area during cooling may further enhance heat transfer by opposing a reflex vasoconstriction response which would reduce perfusion of the AVAs. In conclusion, cooling combined with negative pressure can reduce core temperature more than without negative pressure.

In the present study, none of subjects agreed to have rectal probe insertion. Therefore, tympanic membrane was unavoidably used to represent core temperature despite the fact that the remarkable variations in tympanic temperature may be taken place since this technique is always exposed to ambient temperature. So, we suggest that this technique for core temperature is not reliable and invalid and may not be a proper method for use in scientific way. For future study, other reliable techniques should be chosen for the accuracy and the most important concern is that such technique should not disturb subjects.

5.4.5 Mean body temperature

In the study on effect of palm cooling with negative pressure compared with no cooling, hand immersion, and cooling with vest (Schneider, 2006) which found significant difference between cooling condition, where vest mean skin and mean body temperature was lower than other conditions. Mean skin temperature was calculated using modified Kenney formula in 1988 in which core temperature is the main portion. With limitation on equipment in this study, core temperature measurement is inaccurate. This causes no different of mean body temperature when compare between control, RTX with and without vacuum.

5.4.6 Thermal sensation scale

Subjective heat strain, during and 30 min after vigorous exercise, was estimated in this study. In the study “Is performance of intermittent intense exercise enhanced by use of a commercial palm cooling device?” by Thomas *et al.* (2009) demonstrated that no differences in their subjective ratings of heat stress between conditions, who received RTX at 15°C during 90s rest period after 30s hard and fast running, eight intervals. However, it is suggested that modifications of intervention, for example, treated with longer periods of time (Duffield *et al.*, 2003), set subjects in

different posture (Matthew *et al.*, 2009) may enhance measurable subjective outcome during recovery period.

It was observed that cooling vest circulating 20°C water had greater effect on subjective ratings of heat stress than did use of the RTX circulating 20°C water (Balldin *et al.*, 2007). Similarly, Schneider (2006) found that cooling vest was significant lower thermal rating than no-cool method whereas water bath and palm cooling with RTX method were similar to no-cool. Previous studies (Elliott *et al.*, 2003; Whistish *et al.*, 2003; Hsu, 2005; Grahn, 2005) indicated that single hand cooling is sufficient to induce a reduction of thermal heat stress. Therefore, RTX method in this study might be an effective tool which makes athletes feel refresh and ready for the next competition, which may be very beneficial for many sports that must finished race on one day such as Taekwondo.

5.5 Effects of rapid palm cooling method on blood chemistry.

Blood lactate concentration

Lactate is an expected result of anaerobic work, and therefore should be high in short duration of maximal exertion exercise. It is stated that Taekwondo requires rapid movement from action of large muscle groups (Boutcher *et al.*, 1989). Many folds of blood lactate concentration may increase during exercise. Previous study found peak blood lactate concentration after 143 seconds of a Taekwondo fight up to 11.4 mmol/l (Heller *et al.*, 1998). The present study found similar amount of lactate concentration up to 13.2 mmol/l. It has been shown that blood lactate concentration and acidity are the reflections of intensity and duration of the Taekwondo performance (Hultman & Sahlin, 1980; code in Melhim, 2001). Acidity caused by lactate accumulation, which affects performance by inducing central fatigue. This acidity can be subsided by cooling technique which has been accepted as an ergogenic aids to improve performance in athletes during short and intense resistive exercise (Yeargin *et al.*, 2006; Verducci, 2000; Burke *et al.*, 2000; code in Kwon, 2009).

In the present study, RTX cooling method lower blood lactate concentration for all experimental conditions. In contrast, Tenforde (2003) had studied the effects of cooling core body temperature on overall strength gains and post exercise recovery, he found that the average blood lactate levels between cooling and control trials showed no major differences. RTX method had more effect to improve muscular enzyme ATPase in muscle cell. This study found that when RTX was treated it improved Peak anaerobic power in Taekwondo athletes, particularly on the 3rd round. The results seem to be consistent to a theory of a central mechanism of fatigue related to elevated temperatures cause to metabolic byproducts from intense exercise and Ca^{2+} in muscles release and uptake outside of optimal can inhibit normal muscle function. (Allen *et al.*, 2002; Kaminski & Richmonds , 2002; Lamb, 2002; Nybo & Nielsen, 2001; code in Tenforde, 2003)

5.6 Effects of rapid palm cooling method on subjective evaluation.

Rating of perceived exertion

Apart from physiological responses to metabolic heat production, previous study reported outcomes on perceived exertion in taekwondo (Bridge *et al.*, 2009) in that international level Taekwondo competition elicited near-maximal physiologic response in parallel to increased in competitors RPE across the game. In addition to expression exercise intensity via heart rate response, this subjective evaluation revealed that RTX applied under sub-atmospheric pressure may affect athletes in that they feel fresh. With no RTX intervention, like in control group, higher RPE was detected in control group. These data indicated the use of the RTX device along with sub-atmospheric together had the most effective to attenuated exhaustion feeling when recovery time in high intensity competitions. Moreover, this study may be useful when repeated competition in one day not just to Taekwondo but in other martial art sports such as in boxing, wresting, judo et al. as athletes feel ready for the next competitions. RTX was applied in progressive weights training and found that this cooling device lowered RPE during exercise when compare with no cooling. In addition, RTX can increase exercise repetitions and exercise volume (Kwon, 2009; Bridge *et al.*, 2009). In the present study, just by the end of the second exercise bout, RPE increased to the

range of “somewhat hard (13)” in RTX groups but about “hard (15)” in control. From finding in this examination, emphasize that local cooling applied with sub-atmospheric pressure had more useful for competitive sports.

5.7 Limitation of the Study

Like other studies on exercise in particular sports, the present study found some limitations as follows:

- Due to sex hormones which are known to affect on metabolism and body temperature regulatory system, only male subject were recruited. Therefore the results from this study can be explained some changes only in male athletes. In addition, RTX methods may be an effective method to reduce metabolic heat from intense exercise in men because men can sweat more and better than women (Parry, 2010).

- The present study is aimed to explore only on RTX efficiency, thus only one cooling method was tested.

- Due to different training protocols among taekwondo schools, the present study recruited only subjects being trained from one site. They were all well-trained athletes, thus this study pay attention only changes during the bouts rather than comparing between well-trained and amateur taekwondo athletes.

- Only a single hand was treated in this study because only one RTX device was available.

5.8 Further Study

Although this device contains many advantages such as it is portable, easy to use, and non-invasive. But just one unit is available, the investigation is aimed to find out the double-hands cooling on temperature control for future study. In addition, Taekwondo, and other martial art sports, usually put on gloves as compulsory rules for the games. Therefore other forms of cooling unit in which exposure of other body areas should be considered for easily cooling.

Furthermore, in this study cardiovascular and metabolic variables are unclear in recovery periods appear at 30-min recovery, then in further study we will investigate effect of RTX only post exercise and extend time more than 30 minutes in order to complete recovery for this sport and for anaerobic energy restoration results implied that intervention by used RTX with vacuum technique improved peak anaerobic power in Taekwondo athletes but still not clearly different between RTX with and without vacuum therefore, in the future should be increase sample size for clearer results.

CHAPTER VI

CONCLUSION

Peak anaerobic performance diminishes from bout-to-bout in Taekwondo competition. Without any intervention, dynamic changes of anaerobic power are proven in that anaerobic performance diminishes greatly in bout 2 and still not recover in bout 3. Similar characteristics are observed as rapid palm cooling method was intervened. However, this study expresses that RTX with vacuum involvement remarkably recovers anaerobic performance in bout 3. So, we concluded that RTX treated, during 1-min rest period, attenuates the diminution of anaerobic performance in between competition of Taekwondo athletes. This effect is dominated particularly on the 3rd round.

Cardiovascular variables mean arterial, systolic, diastolic blood pressures and blood flow, show similar alterations during three consecutive bouts despite the intervention. Faster recovery in all groups appears at 5 minute post exercise. However, these cardiovascular variables remain high at the end of 30 minutes post exercise period. Result implies that no matter which intervention had been employed there is no complete recovery of repeated 3-round Taekwondo bouts at 5 min after cessation. It is suggested that recovery period might be extended to over than 30 min for this sport.

For thermoregulatory variables, RTX with no vacuum and vacuum induce lower forearm and hand temperatures at 5 min and 30 min recovery, this area plays even more significant respond with changes of skin temperatures at all steps investigation. In addition, between groups comparison demonstrates that the remarkable changes of mean skin temperature in control and RTX with vacuum groups during recovery period are concomitant with hand and forearm temperatures. Therefore, heat dissipation via forearm and hand play major important role in Taekwondo athletes.

Subjective variables, subjective thermal variable recovers to initial values only in RTX treated groups whereas thermal sensation scale in control group remains relatively high. Rating of perceived exertion (RPE), by the end of the second exercise bout, increased to the range of “somewhat hard (RPE 13)” in RTX groups but about “hard (RPE 15)” in control

Overall conclusion, Rapid palm cooling (RTX) enhances recovery in Taekwondo athletes in between and post competition events. This technique offers better thermoregulatory changes during repeated exercise bouts. Negative pressure application during cooling had more influence to reduce heat strain than when compared to without negative pressure.

We suggest that this specific local cooling unit can induce some physiologic effect during repeated short-term intense exercise. Although palm cooling method provided significant in statistic than no cooling, its application should be determined only in some conditions while some limitation for cooling application may be technically impossible due to specific rules of the particular sport. The results of this study are of interest not just to improve athletic performance in Taekwondo athletes but also include of other competitive martial art sports.

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APPENDICES

APPENDIX A

PARTICIPANT INFORMATION

เอกสารชี้แจงผู้เข้าร่วมการวิจัย (สำหรับอายุ 15-17 ปี และผู้ปกครอง) (Participant Information Sheet)

ในเอกสารนี้อาจมีข้อความที่ท่านอ่านแล้วยังไม่เข้าใจ โปรดสอบถามหัวหน้าโครงการวิจัย หรือผู้แทนให้ช่วยอธิบายจนกว่าจะเข้าใจดี ท่านจะได้รับเอกสารนี้ 1 ฉบับ นำกลับไปอ่านที่บ้านเพื่อปรึกษากับญาติพี่น้อง เพื่อนสนิท หรือผู้ที่ท่านต้องการปรึกษา เพื่อช่วยในการตัดสินใจเข้าร่วมการวิจัย

ชื่อโครงการ การลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิชนิดเร็วในระหว่างภาวะเลียนแบบการแข่งขันเทควันโด

ชื่อผู้วิจัย นางสาวสุชาดา เสาเวียง

สถานที่วิจัย ห้องปฏิบัติการสรีรวิทยาการออกกำลังกาย ชั้น 3 อาคารสระว่ายน้ำสิรินมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล วิทยาเขต ศาลายา

สถานที่ทำงาน ห้องวิจัย ชั้น 3 อาคารสระว่ายน้ำสิรินมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล วิทยาเขต ศาลายา

หมายเลขโทรศัพท์ที่ติดต่อได้ทั้งในและนอกเวลาราชการ
02-441-4295 – 8 และ 089-148-3119

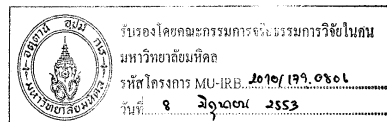
โครงการวิจัยนี้ทำขึ้นเพื่อ ศึกษาผลของการฝึกที่ใกล้เคียงกับสภาพการแข่งขันอันมีผลต่อสมรรถภาพทางกาย และระบบสมดุลอุณหภูมิภายในนักกีฬาเทควันโดไทย และเพื่อศึกษาผลของการฟื้นตัวด้านสมรรถภาพทางกาย ด้วยเครื่องระบายความร้อนชนิดเร็ว (RTX) ในช่วงพัก 1 นาที และภายหลังจากการทดลอง 30 นาทีในนักกีฬาเทควันโดไทย ซึ่งประโยชน์ที่คาดว่าจะได้รับ คือ ทราบผลการทดสอบตนเองเกี่ยวกับการทำงานและสมรรถภาพของร่างกายโดยรวมในประสิทธิภาพการทำหน้าที่ของกล้ามเนื้อ ระบบหัวใจ การหายใจและไหลเวียนในการส่งผ่านและลดความร้อนที่เกิดขึ้น เพื่อให้ร่างกายยังสามารถทำงานต่อไปได้ และเมื่อมีการหยุดพัก ร่างกายจะฟื้นตัวในลักษณะใด ซึ่งสามารถนำข้อมูลเหล่านี้มาพัฒนาทักษะ ความสามารถสูงสุดที่ใช้ในการฝึกซ้อมเทควันโดของตนเองได้ อีกทั้งสามารถนำองค์ความรู้ที่ได้ไปพัฒนาเทคนิคการคืนสภาพร่างกายในนักกีฬาเทควันโดทั้งช่วงการฝึกและการแข่งขัน เพื่อให้มีประสิทธิภาพสูงสุด

เด็กในปกครองของท่านได้รับเชิญให้เข้าร่วมการวิจัยนี้ เพราะเด็กในปกครองของท่านเป็นนักกีฬาเทควันโดที่มีประวัติการฝึกซ้อมมาอย่างต่อเนื่องนานกว่า 1 ปี เพศชาย อายุ 15-17 ปี สุขภาพดี ไม่มีประวัติการเจ็บป่วยด้วยโรคใดๆ ไม่มีการบาดเจ็บระบบกระดูก และกล้ามเนื้อของร่างกายส่วนล่างของร่างกาย

จะมีผู้เข้าร่วมการวิจัยนี้ทั้งสิ้นประมาณ 10 ท่าน

หากท่านตัดสินใจเข้าร่วมการวิจัยแล้ว จะมีขั้นตอนการวิจัยดังต่อไปนี้

- ผู้วิจัยจะขอนัด วัน เวลา ที่เด็กในปกครองของท่านสะดวกในการเข้าร่วมการวิจัย ณ ห้องปฏิบัติการสรีรวิทยาการออกกำลังกาย ชั้น 3 อาคารสระว่ายน้ำสิรินมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ศาลายา และเพื่อหลีกเลี่ยงความแปรปรวนจากอุณหภูมิสิ่งแวดล้อม จึงจะทำการเก็บข้อมูลเฉพาะในช่วงเช้า ตั้งแต่เวลา 09.00-11.00 น. เท่านั้น โดยขอให้เด็กในปกครองของท่านรับประทานอาหารเช้าและน้ำก่อนเข้าร่วมการวิจัย 2-3 ชั่วโมง



- ผู้วิจัยจะขอให้เด็กในปกครองของท่านเข้าร่วมการวิจัยทั้งหมด 3 ครั้ง ใช้เวลาในการทดสอบครั้งละประมาณ 1 ชั่วโมง ซึ่งในแต่ละครั้งจะห่างกันอย่างน้อย 3 วัน ตามรายละเอียดดังนี้

ครั้งที่ 1

- ผู้วิจัยจะขอให้เด็กในปกครองของท่านเข้ารับการตรวจร่างกายเพื่อคัดเลือกเข้าร่วมวิจัย โดย ผศ.นพ. โอภาส สิ้นเพิ่มสุขสกุล แพทย์ประจำคลินิกเวชศาสตร์การกีฬา ซึ่งทำหน้าที่เป็นที่ปรึกษาทางการแพทย์ของการวิจัยนี้
- ผู้วิจัยจะขอให้เด็กในปกครองของท่านตอบแบบสอบถาม โดยใช้เวลาในการตอบแบบสอบถามประมาณ 15 นาที ซึ่งประกอบด้วยคำถาม 2 ตอน คือ

ตอนที่ 1	ข้อมูลทั่วไป	จำนวน 3 ข้อ
ตอนที่ 2	ข้อมูลเกี่ยวกับประวัติสุขภาพ	จำนวน 12 ข้อ

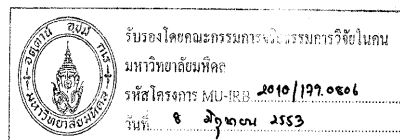
- หากเด็กในปกครองของท่านผ่านเกณฑ์การคัดเลือก ผู้วิจัยจะขอให้ท่านเข้าร่วมการวิจัยในขั้นตอนนี้
- ผู้วิจัยจะขอให้เด็กในปกครองของท่านทำการทดสอบบนจักรยานวัดงาน ด้วยโปรแกรมการทดสอบการทำงานแบบไม่ใช้ออกซิเจนด้วยวิธีวินเกต โดยมีขั้นตอนการปฏิบัติ ดังนี้
 1. นิ่งพักประมาณ 15 นาที
 2. นิ่งบนจักรยานวัดงานประมาณ 5 นาที
 3. เริ่มปั่นจักรยานเต็มที ที่ความหนัก $0.06/5 \times$ น้ำหนักตัว เป็นเวลา 2 นาที และพัก 1 นาที
 4. ทำการปั่นจักรยานจนครบ จำนวน 3 ครั้ง (เพื่อเลียนแบบการชก 3 ยกๆละ 2 นาที พัก 1 นาที)
 5. ในช่วงการพัก 1 นาที ระหว่างชุดที่ 1-2 และ 2-3 และภายหลังจากการออกกำลังกาย 30 นาที เด็กในปกครองของท่านจะไม่ได้รับการทดลองด้วยเครื่องใดๆ

ครั้งที่ 2 และ 3

- ผู้วิจัยจะขอให้เด็กในปกครองของท่านทำการทดสอบบนจักรยานวัดงาน ด้วยโปรแกรมการทดสอบการทำงานแบบไม่ใช้ออกซิเจนด้วยวิธีวินเกต เช่นเดียวกับการทดสอบในครั้งที่ 1
- ในช่วงการพัก 1 นาที ระหว่างชุดที่ 1-2 และ 2-3 และภายหลังจากการออกกำลังกาย 5 และ 30 นาที ผู้วิจัยจะขอให้เด็กในปกครองของท่านรับการทดลองด้วยเครื่องลดอุณหภูมิชนิดเร็ว (RTX) ที่ความเย็น 18-22 องศาเซลเซียส โดยให้เด็กในปกครองของท่านสอดมือเข้าไปในเครื่อง และก้านส่วนแกนกลางของเครื่องนาน 1 นาทีระหว่างพัก และ 30 นาที ภายหลังจากการทดสอบ เด็กในปกครองของท่านจะได้รับการทดสอบเครื่องนี้ใน 2 ลักษณะ คือ ขณะเครื่องทำงานโดยไม่มี และมีปั๊มสร้างแรงดูดอย่างใดอย่างหนึ่ง

ตลอดการวิจัยทั้ง 3 ครั้ง ผู้วิจัยจะขอเก็บข้อมูลจากท่านดังนี้

- ในระหว่างการทดลองผู้วิจัยจะขอเก็บข้อมูลในขณะที่เด็กในปกครองของท่านพัก-ขณะออกกำลังกาย-ขณะพักระหว่างยก และภายหลังจากการออกกำลังกาย และผู้วิจัยจะคอยดูแลให้คำแนะนำเด็กในปกครองของท่านอย่างใกล้ชิด ดังนี้
 1. ลักษณะและองค์ประกอบทางกาย น้ำหนัก ส่วนสูง เฟอร์เซนต์ไขมัน และกล้ามเนื้อ ด้วยเครื่องวัดคักซ์ไฟฟ้าจากการสัมผัส โดยให้ท่านถอดรองเท้าขึ้นบนแป้น และใช้มือทั้ง 2 ข้างกำแกนจับของเครื่องนานประมาณ 1 นาที

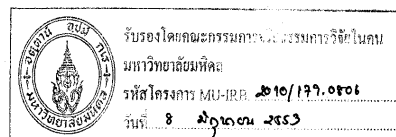


2. วัดสัญญาณชีพ ได้แก่ อัตราชีพจร ความดันเลือด
3. การไหลเวียนเลือดที่แขนวัดจากภายนอก โดยใช้เครื่องวัดการไหลเวียนที่ผิวหนังโดยใช้ระบบการสะท้อนของคลื่นเหนือเสียง (Ultrasound Doppler) วัดจากภายนอกโดยไม่มีการเจาะเข้าผิวหนัง โดยใช้การแตะเครื่องมือที่ผิวหนัง ณ ตำแหน่งข้อพับศอกของเด็กในปกครองของท่าน
4. วัดอุณหภูมิผิวจากด้านที่ถนัด โดยใช้แผ่นรับสัญญาณติดที่ผิวหนัง ณ ตำแหน่งหน้าผาก, ออก, ต้นแขน, แขนท่อนล่าง, หลัง, ต้นขา และน่อง เพื่อหาค่าเฉลี่ยอุณหภูมิกาย สำหรับอุณหภูมิแกนกลาง เป็นการวัดโดยเครื่องส่งเข้าในช่องหู
5. เก็บปัสสาวะเพื่อหาความถ่วงจำเพาะเพื่อตรวจสอบว่ามีภาวะขาดน้ำหรือไม่
6. ประเมินความเหนื่อยด้วยแบบสอบถามความรู้สึกเหนื่อยมาก-น้อยระดับต่างๆ
7. ประเมินค่าความรู้สึกร้อน-เย็นด้วยแบบสอบถามความรู้สึกร้อน-เย็นมาก-น้อยระดับต่างๆ
8. หากท่านและเด็กในปกครองของท่านอนุญาต และแพทย์ในทีมวิจัยระบุว่าปลอดภัย ผู้วิจัยจะขอทำการตรวจค่าสารแลคเตทในเลือดของเด็กในปกครองของท่าน โดยใช้เลือดจากการเจาะจากปลายนิ้ว จำนวน 5 ครั้ง ครั้งละ 1 หยดเล็กๆ รวมจำนวนในการเจาะเลือดตลอดการเข้าร่วมการวิจัยทั้งหมด 15 ครั้ง ดังนี้
 - ครั้งที่ 1 ก่อนออกกำลังกาย
 - ครั้งที่ 2 ช่วงพัก 1 นาที (ระหว่าง 15วินาทีสุดท้าย ในระหว่างพักยก 1-2)
 - ครั้งที่ 3 ช่วงพัก 1 นาที (ระหว่าง 15วินาทีสุดท้าย ในระหว่างพักยก 2-3)
 - ครั้งที่ 4 ภายหลังจากออกกำลังกายในนาทีที่ 5
 - ครั้งที่ 5 ภายหลังจากออกกำลังกายในนาทีที่ 30

ความเสี่ยงที่อาจเกิดขึ้นเมื่อเข้าร่วมการวิจัย

- การศึกษาครั้งนี้เป็นการผลของการลดอุณหภูมิร่างกายในสภาวะเลียนแบบการแข่งขันด้วยเครื่องลดความร้อนชนิดเร็ว (RTX) ซึ่งเป็นวัสดุรูปปริมาตรที่ถูกปรับความเย็น 18-22 องศาเซลเซียส จากตั้งน้ำเย็นสำรอง โดยการกำวัสดุดังกล่าวไว้ภายในระยะเวลาที่กำหนดจะมีผลต่อการลดอุณหภูมิร่างกาย ซึ่งไม่มีผลเสียกับร่างกายมนุษย์
- การวิจัยนี้มีการเจาะเลือดเพื่อวัดระดับค่าแลคเตทในเลือด โดยทำการเจาะบริเวณปลายนิ้ว และใส่แผ่นวัดระดับสารแลคเตท โดยใช้ปริมาณเลือด 1 หยดเล็กๆ จากปลายนิ้ว ซึ่งมีปริมาณน้อยมาก จึงไม่มีผลกระทบต่อและไม่ก่อให้เกิดอันตรายใดๆ ต่อเด็กในปกครองของท่าน อย่างไรก็ตามอาจเกิดการติดเชื้อที่บริเวณดังกล่าว ผู้วิจัยมีแนวทางในการป้องกัน โดยมีมาตรการการรักษาความสะอาด คือ ผู้ที่ทำการเจาะเลือดจะสวมใส่ถุงมือทุกครั้ง เช็ดแอลกอฮอล์ใช้พลาสติกปิดบริเวณที่ทำการเจาะ และใช้เข็มเจาะเลือดแบบใช้ครั้งเดียวทิ้ง ไม่มีการใช้ซ้ำ
- การศึกษานี้อาจมีความเสี่ยงจากการปั่นจักรยานด้วยความเร็วได้ ผู้วิจัยจะให้เด็กในปกครองของท่านชะลอความเร็วลงช้าๆ ด้วยตนเอง

หากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับเด็กในปกครองของท่าน นางสาวสุชาดา เสาวเรียง ซึ่งเป็นหัวหน้าโครงการวิจัย จะเป็นผู้รับผิดชอบค่าใช้จ่ายทั้งหมด หากระหว่างทำการทดสอบเกิดมีอาการผิดปกติเกิดขึ้นกับเด็กในปกครองของท่าน การทดสอบจะยุติลงทันที และจะทำการปฐมพยาบาลเบื้องต้นก่อนนำส่งคลินิกการกีฬา บริเวณชั้นล่าง วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ซึ่งมีบริการทางการแพทย์เป็นประจำ โดยหากเด็กในปกครองของท่านไม่เข้าร่วมในการวิจัยนี้ก็จะไม่มีผลกระทบใดๆ ต่อเด็กในปกครองของท่าน



การเข้าร่วมการวิจัยครั้งนี้เด็กในปกครองของท่านจะได้รับค่าชดเชยการเสียเวลาและค่าพาหนะ เป็นเงินจำนวน 500 บาท/ครั้ง ทั้งหมด 3 ครั้ง รวมเป็นเงินทั้งสิ้น 1,500 บาท และท่านไม่ต้องเสียค่าใช้จ่ายใดๆทั้งสิ้น

หากท่านและเด็กในปกครองของท่านมีข้อข้องใจที่จะสอบถามเกี่ยวข้องกับการวิจัย หรือเมื่อบาดเจ็บ/เจ็บป่วยจากการวิจัย หรือเกิดเหตุการณ์ที่ไม่พึงประสงค์จากการวิจัย ท่านและเด็กในปกครองของท่านสามารถติดต่อได้ที่ นางสาวสุชาดา เสาเวียง หมายเลขโทรศัพท์ 089-148-3119

หากมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ทราบโดยรวดเร็วไม่ปิดบัง

ข้อมูลส่วนตัวของเด็กในปกครองของท่านจะถูกเก็บรักษาไว้ ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคล แต่จะรายงานผลการวิจัยเป็นข้อมูลส่วนรวม ข้อมูลของเด็กในปกครองท่านเป็นรายบุคคลอาจมีคณะบุคคลบางกลุ่มเข้ามาตรวจสอบได้ เช่น ผู้ให้ทุนวิจัย, สถาบัน หรือองค์กรของรัฐที่มีหน้าที่ตรวจสอบ, คณะกรรมการจริยธรรมฯ เป็นต้น

เด็กในปกครองของท่านมีสิทธิ์ถอนตัวออกจากโครงการวิจัยเมื่อใดก็ได้ โดยไม่ต้องแจ้งให้ทราบล่วงหน้า และการไม่เข้าร่วมการวิจัยหรือถอนตัวออกจากโครงการวิจัยนี้ จะไม่มีผลกระทบใดๆ ต่อเด็กในปกครองของท่าน

โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนของมหาวิทยาลัย มหิดล ซึ่งมีสำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑล สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5 โทรสาร 02-849-6223 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อกับประธานคณะกรรมการฯ หรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ข้าพเจ้าได้อ่านรายละเอียดในเอกสารนี้ครบถ้วนแล้ว

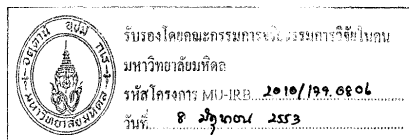
ข้าพเจ้าและเด็กในปกครองของข้าพเจ้า

- ยินยอมเข้าร่วมการวิจัย และยินยอมให้ทำการเจาะเลือด
- ยินยอมเข้าร่วมการวิจัย แต่ไม่ยินยอมให้ทำการเจาะเลือด
- ไม่ยินยอมเข้าร่วมการวิจัย

ลงชื่อ.....ผู้เข้าร่วมวิจัย

(.....)

วันที่.....



ลงชื่อ.....ผู้ปกครอง

(.....)

วันที่.....

เอกสารแจ้งผู้เข้าร่วมการวิจัย (สำหรับอายุ 18 ปีขึ้นไป)

(Participant Information Sheet)

ในเอกสารนี้อาจมีข้อความที่ท่านอ่านแล้วยังไม่เข้าใจ โปรดสอบถามหัวหน้าโครงการวิจัย หรือผู้แทนให้ช่วยอธิบายจนกว่าจะเข้าใจดี ท่านจะได้รับเอกสารนี้ 1 ฉบับ นำกลับไปอ่านที่บ้านเพื่อปรึกษาหารือกับญาติพี่น้อง เพื่อนสนิท หรือผู้ที่ท่านต้องการปรึกษา เพื่อช่วยในการตัดสินใจเข้าร่วมการวิจัย

ชื่อโครงการ การลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิชนิดเร็วในระหว่างภาวะเลียนแบบการแข่งขันเทควันโด

ชื่อผู้วิจัย นางสาวสุชาดา เสาวเวียง

สถานที่วิจัย ห้องปฏิบัติการสรีรวิทยาการออกกำลังกาย ชั้น 3 อาคารสระว่ายน้ำสิริมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล วิทยาเขต ศาลายา

สถานที่ทำงาน ห้องวิจัย ชั้น 3 อาคารสระว่ายน้ำสิริมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล วิทยาเขต ศาลายา

หมายเลขโทรศัพท์ที่ติดต่อได้ทั้งในและนอกเวลาราชการ

02- 441- 4295 – 8 และ 089 -148-3119

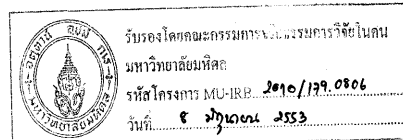
โครงการวิจัยนี้ทำขึ้นเพื่อ ศึกษาผลของการฝึกที่ใกล้เคียงกับสภาพการแข่งขันอันมีผลต่อสมรรถภาพทางกายและระบบสมดุลดอุณหภูมิภายในนักกีฬาเทควันโดไทย และเพื่อศึกษาผลของการฟื้นตัวด้านสมรรถภาพทางกาย ด้วยเครื่องระบายความร้อนชนิดเร็ว (RTX) ในช่วงพัก 1 นาที และภายหลังจากการทดลอง 30 นาทีในนักกีฬาเทควันโดไทย ซึ่งประโยชน์ที่คาดว่าจะได้รับ คือ ทราบผลการทดสอบตนเองเกี่ยวกับการทำงานและสมรรถภาพของร่างกายโดยรวมในประสิทธิภาพการทำหน้าที่ของกล้ามเนื้อ ระบบหัวใจ การหายใจและไหลเวียนในการส่งผ่านและลดความร้อนที่เกิดขึ้น เพื่อให้ร่างกายยังสามารถทำงานต่อไปได้ และเมื่อมีการหยุดพักร่างกายจะฟื้นตัวในลักษณะใด ซึ่งสามารถนำข้อมูลเหล่านี้มาพัฒนาทักษะ ความสามารถสูงสุดที่ใช้ในการฝึกซ้อมเทควันโดของตนเองได้ อีกทั้งสามารถนำองค์ความรู้ที่ได้ไปพัฒนาเทคนิคการคืนสภาพร่างกายในนักกีฬาเทควันโดทั้งช่วงการฝึกและการแข่งขันเพื่อให้มีประสิทธิภาพสูงสุด

ท่านได้รับเชิญให้เข้าร่วมการวิจัยนี้ เพราะท่านเป็นนักกีฬาเทควันโดที่มีประวัติการฝึกซ้อมมาอย่างต่อเนื่องนานกว่า 1 ปี เพศชาย อายุ 18-25 ปี สุขภาพดี ไม่มีประวัติการเจ็บป่วยด้วยโรคใดๆ ไม่มีการบาดเจ็บระบบกระดูก และกล้ามเนื้อของร่างกายส่วนล่างของร่างกาย

จะมีผู้เข้าร่วมการวิจัยนี้ทั้งสิ้นประมาณ 10 ท่าน

หากท่านตัดสินใจเข้าร่วมการวิจัยแล้ว จะมีขั้นตอนการวิจัยดังต่อไปนี้

- ผู้วิจัยจะขอนัด วัน เวลา ที่ท่านสะดวกในการเข้าร่วมการวิจัย ณ ห้องปฏิบัติการสรีรวิทยาการออกกำลังกาย ชั้น 3 อาคารสระว่ายน้ำสิริมงคล วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ศาลายา และเพื่อหลีกเลี่ยงความแปรปรวนจากอุณหภูมิสิ่งแวดล้อม จึงจะทำการเก็บข้อมูลเฉพาะในช่วงเช้า ตั้งแต่เวลา 09.00-11.00 น. เท่านั้น โดยขอให้ท่านรับประทานอาหารและน้ำก่อนเข้าร่วมการวิจัย 2-3 ชั่วโมง



- ผู้วิจัยจะขอให้ท่านเข้าร่วมการวิจัยทั้งหมด 3 ครั้ง ใช้เวลาในการทดสอบครั้งละประมาณ 1 ชั่วโมง ซึ่งในแต่ละครั้งจะห่างกันอย่างน้อย 3 วัน ตามรายละเอียดดังนี้

ครั้งที่ 1

- ผู้วิจัยจะขอให้ท่านเข้ารับการตรวจร่างกายเพื่อคัดเลือกเข้าร่วมวิจัย โดย ผศ.นพ.โอภาส สิ้นเพิ่มสุขสกุล แพทย์ประจำคลินิกเวชศาสตร์การกีฬา ซึ่งทำหน้าที่เป็นที่ปรึกษาทางการแพทย์ของการวิจัยนี้
- ผู้วิจัยจะขอให้ท่านตอบแบบสอบถาม โดยใช้เวลาในการตอบแบบสอบถามประมาณ 15 นาที ซึ่งประกอบด้วยคำถาม 2 ตอน คือ

ตอนที่ 1	ข้อมูลทั่วไป	จำนวน 3 ข้อ
ตอนที่ 2	ข้อมูลเกี่ยวกับประวัติสุขภาพ	จำนวน 12 ข้อ


- หากท่านผ่านเกณฑ์การคัดเลือก ผู้วิจัยจะขอให้ท่านเข้าร่วมการวิจัยในขั้นตอนต่อไป
- ผู้วิจัยจะขอให้ท่านทำการทดสอบบนจักรยานวัดงาน ด้วยโปรแกรมการทดสอบการทำงานแบบไม่ใช้ออกซิเจนด้วยวิธีวินเกต โดยมีขั้นตอนการปฏิบัติ ดังนี้
 1. นิ่งพักประมาณ 15 นาที
 2. นิ่งบนจักรยานวัดงานประมาณ 5 นาที
 3. เริ่มปั่นจักรยานเต็มที่ ที่ความหนัก $0.06/5 \times$ น้ำหนักตัว (ในหน่วยกิโลกรัม) เป็นเวลา 2 นาที และพัก 1 นาที
 4. ทำการปั่นจักรยานจนครบ จำนวน 3 ครั้ง (เพื่อเลียนแบบการชก 3 ยกๆละ 2 นาที พัก 1 นาที)
 5. ในช่วงการพัก 1 นาที ระหว่างชุดที่ 1-2 และ 2-3 และภายหลังการออกกำลังกาย 30 นาที ท่านจะไม่ได้รับการทดสอบด้วยเครื่องใดๆ

ครั้งที่ 2 และ 3

- ผู้วิจัยจะขอให้ท่านทำการทดสอบบนจักรยานวัดงาน ด้วยโปรแกรมการทดสอบการทำงานแบบไม่ใช้ออกซิเจนด้วยวิธีวินเกต เช่นเดียวกับการทดสอบในครั้งที่ 1
- ในช่วงการพัก 1 นาที ระหว่างชุดที่ 1-2 และ 2-3 และภายหลังการออกกำลังกาย 5 และ 30 นาที ผู้วิจัยจะขอให้ท่านรับการทดสอบด้วยเครื่องลดอุณหภูมิชนิดเร็ว (RTX) ที่ความเย็น 18-22 องศาเซลเซียส โดยให้ท่านสอดมือเข้าไปในเครื่อง และกำส่วนแกนกลางของเครื่องนาน 1 นาทีระหว่างพัก และ 30 นาที ภายหลังการทดสอบ ท่านจะได้รับการทดสอบเครื่องนี้ใน 2 ลักษณะ คือ ขณะที่เครื่องทำงานโดยไม่มี และมีปั๊มสร้างแรงดูดอย่างใดอย่างหนึ่ง

ตลอดการวิจัยทั้ง 3 ครั้ง ผู้วิจัยจะขอเก็บข้อมูลจากท่านดังนี้

- ในระหว่างการทดสอบผู้วิจัยจะขอเก็บข้อมูลในขณะที่ท่านพัก-ขณะออกกำลังกาย-ขณะพักระหว่างยก และภายหลังการออกกำลังกาย และผู้วิจัยจะคอยดูแลให้คำแนะนำท่านอย่างใกล้ชิด ดังนี้
 1. ลักษณะและองค์ประกอบทางกาย น้ำหนัก ส่วนสูง เปรอร์เซ็นต์ไขมัน และกล้ามเนื้อ ด้วยเครื่องวัดสัคย์ไฟฟ้าจากการสัมผัส โดยให้ท่านถอดรองเท้าอินบนเป็น และใช้มือทั้ง 2 ข้างกำแกนจับของเครื่องนานประมาณ 1 นาที
 2. วัดสัญญาณชีพ ได้แก่ อัตราชีพจร ความดันเลือด

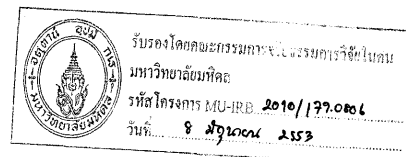
	รับรองโดยคณะกรรมการวิจัยในคน
	มหาวิทยาลัยมหิดล
	รหัสโครงการ MU-IRB 2010/129.0801
วันที่ 8 มิถุนายน 2553	2

3. การไหลเวียนเลือดที่แขนวัดจากภายนอก โดยใช้เครื่องวัดการไหลเวียนที่ผิวหนังโดยใช้ระบบการสะท้อนของคลื่นเหนือเสียง (Ultrasound Doppler) วัดจากภายนอกโดยไม่มีการเจาะเข้าผิวหนัง โดยใช้การแตะเครื่องมือที่ผิวหนัง ณ ตำแหน่งข้อพับศอกของท่าน
4. วัดอุณหภูมิผิวกายจากด้านที่ถนัด โดยใช้แผ่นรับสัญญาณติดที่ผิวหนัง ณ ตำแหน่งหน้าผาก, ออก, ต้นแขน, แขนท่อนล่าง, หลัง, ต้นขา และ น่องเพื่อหาค่าเฉลี่ยอุณหภูมิกาย สำหรับอุณหภูมิแกนกลางเป็นการวัดโดยเครื่องส่งเข้าในช่องหู
5. เก็บปัสสาวะเพื่อหาความถ่วงจำเพาะเพื่อตรวจสอบว่ามีภาวะขาดน้ำหรือไม่
6. ประเมินความเหนื่อยด้วยแบบสอบถามความรู้สึกเหนื่อยมาก-น้อยระดับต่างๆ
7. ประเมินค่าความรู้สึกร้อน-เย็นด้วยแบบสอบถามความรู้สึกร้อน-เย็นมาก-น้อยระดับต่างๆ
8. หากท่านอนุญาต และแพทย์ในทีมวิจัยระบุว่าปลอดภัย ผู้วิจัยจะขอทำการตรวจค่าสารแลคเตทในเลือดของท่าน โดยใช้เลือดจากการเจาะจากปลายนิ้ว จำนวน 5 ครั้ง ครั้งละ 1 หยดเล็กๆ รวมจำนวนในการเจาะเลือดตลอดการเข้าร่วมการวิจัยทั้งหมด 15 ครั้ง ดังนี้
 - ครั้งที่ 1 ก่อนออกกำลังกาย
 - ครั้งที่ 2 ช่วงพัก 1 นาที (ระหว่าง 15 วินาทีสุดท้าย ในระหว่างพักยก 1-2)
 - ครั้งที่ 3 ช่วงพัก 1 นาที (ระหว่าง 15 วินาทีสุดท้าย ในระหว่างพักยก 2-3)
 - ครั้งที่ 4 ภายหลังการออกกำลังกายในนาทีที่ 5
 - ครั้งที่ 5 ภายหลังการออกกำลังกายในนาทีที่ 30

ความเสี่ยงที่อาจเกิดขึ้นเมื่อเข้าร่วมการวิจัย

- การศึกษาครั้งนี้เป็นการผลของการลดอุณหภูมิร่างกายในสภาวะเลียนแบบการแข่งขันด้วยเครื่องลดความร้อนชนิดเร็ว (RTX) ซึ่งเป็นวัสดุรูปปริมาตรที่ถูกปรับความเย็น 18-22 องศาเซลเซียส จากถึงน้ำเย็นสำรอง โดยการกำวัสดุดังกล่าวไว้ภายในระยะเวลาที่กำหนดจะมีผลต่อการลดอุณหภูมิร่างกาย ซึ่งไม่มีผลเสียกับร่างกายมนุษย์
- การวิจัยนี้มีการเจาะเลือดเพื่อวัดระดับค่าแลคเตทในเลือด โดยทำการเจาะบริเวณปลายนิ้ว และใส่แผ่นวัดระดับสารแลคเตท โดยใช้ปริมาณเลือด 1 หยดเล็ก ๆ จากปลายนิ้ว ซึ่งมีปริมาณน้อยมาก จึงไม่มีผลกระทบต่อและไม่ก่อให้เกิดอันตรายใดๆ ต่อท่าน อย่างไรก็ตามอาจเกิดการติดเชื้อที่บริเวณดังกล่าว ผู้วิจัยมีแนวทางการป้องกันโดยมีมาตรการการรักษาความสะอาด คือ ผู้ที่ทำการเจาะเลือดจะสวมใส่ถุงมือทุกครั้ง เช็ดแอลกอฮอล์ ใช้พลาสติกปิดบริเวณที่ทำการเจาะ และใช้เข็มเจาะเลือดแบบใช้ครั้งเดียวทิ้ง ไม่มีการใช้ซ้ำ
- การศึกษานี้อาจมีความเสี่ยงจากการปั่นจักรยานด้วยความเร็วได้ ผู้วิจัยจะให้ท่านชะลอความเร็วลงช้าๆ ด้วยตนเอง

หากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับท่าน นางสาวสุชาดา เสาเวียง ซึ่งเป็นหัวหน้าโครงการวิจัย จะเป็นผู้รับผิดชอบค่าใช้จ่ายทั้งหมด หากระหว่างทำการทดสอบเกิดมีอาการผิดปกติเกิดขึ้นกับท่าน การทดสอบจะยุติลงทันที และจะทำการปฐมพยาบาลเบื้องต้นก่อนนำส่งคลินิกการกีฬา บริเวณชั้นล่าง วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ซึ่งมีบริการทางการแพทย์เป็นประจำ โดยหากท่านไม่เข้าร่วมในการวิจัยนี้ก็จะไม่มีผลกระทบใดๆ ต่อท่าน



การเข้าร่วมการวิจัยครั้งนี้ท่านจะได้รับค่าชดเชยการเสียเวลาและค่าพาหนะ เป็นเงินจำนวน 500 บาท/ ครั้ง ทั้งหมด 3 ครั้ง รวมเป็นเงินทั้งสิ้น 1,500 บาท และท่านไม่ต้องเสียค่าใช้จ่ายใดๆทั้งสิ้น

หากท่านมีข้อข้องใจที่จะสอบถามเกี่ยวกับการวิจัย หรือเมื่อบาดเจ็บ/เจ็บป่วยจากการวิจัย หรือเกิดเหตุการณ์ที่ไม่พึงประสงค์จากการวิจัย ท่านสามารถติดต่อได้ที่ นางสาวสุชาดา เสาวเรียง หมายเลขโทรศัพท์ 089-148-3119

ท่านมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ทราบ โดยรวดเร็ว ไม่ปิดบัง

ข้อมูลส่วนตัวของท่านจะถูกเก็บรักษาไว้ ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคล แต่จะรายงานผลการวิจัยเป็นข้อมูลส่วนรวม ข้อมูลของท่านเป็นรายบุคคลอาจมีคณะบุคคลบางกลุ่มเข้ามาตรวจสอบได้ เช่น ผู้ให้ทุนวิจัย, สถาบัน หรือองค์กรของรัฐที่มีหน้าที่ตรวจสอบ, คณะกรรมการจริยธรรมฯ เป็นต้น

ท่านมีสิทธิ์ถอนตัวออกจากโครงการวิจัยเมื่อใดก็ได้ โดยไม่ต้องแจ้งให้ทราบล่วงหน้า และการไม่เข้าร่วมการวิจัยหรือถอนตัวออกจากโครงการวิจัยนี้ จะไม่มีผลกระทบใดๆ ต่อท่าน

โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนของมหาวิทยาลัยมหิดล ซึ่งมีสำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพหลโยธิน สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5 โทรสาร 02-849-6223 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อกับประธานคณะกรรมการฯ หรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ข้าพเจ้าได้อ่านรายละเอียดในเอกสารนี้ครบถ้วนแล้ว

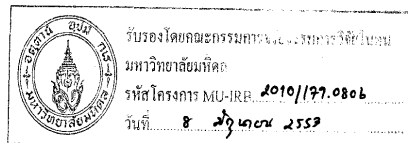
ข้าพเจ้า

- ยินยอมเข้าร่วมการวิจัย และยินยอมให้ทำการเจาะเลือด
- ยินยอมเข้าร่วมการวิจัย แต่ไม่ยินยอมให้ทำการเจาะเลือด
- ไม่ยินยอมเข้าร่วมการวิจัย

ลงชื่อ.....ผู้เข้าร่วมวิจัย

(.....)

วันที่.....



APPENDIX B

CONSENT FORM

หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ (สำหรับอายุ 15-17 ปี และผู้ปกครอง)

วันที่.....เดือน..... พ.ศ.

ข้าพเจ้า.....อายุ.....ปี อาศัยอยู่บ้านเลขที่.....

ถนน.....ตำบล.....อำเภอ.....

จังหวัด.....รหัสไปรษณีย์.....หมายเลขโทรศัพท์.....

และ ค.ช./นาย.....เด็กในปกครองของข้าพเจ้าซึ่งเกี่ยวข้องเป็น.....

ขอแสดงเจตนายินยอมเข้าร่วมโครงการวิจัยเรื่อง “การลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิขมิ้นเครือในระหว่างภาวะเลียนแบบการแข่งขันเทควันโด”

โดยข้าพเจ้าและเด็กในปกครองของข้าพเจ้า ได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัย รายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัยและความเสี่ยงที่อาจเกิดขึ้นจากการเข้าร่วมการวิจัย รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าชดเชยการเดินทางที่จะได้รับ โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการเป็นที่เรียบร้อยแล้ว

ข้าพเจ้าจึงสมัครใจให้เด็กในปกครองของข้าพเจ้าเข้าร่วมโครงการวิจัยนี้

หากข้าพเจ้าและเด็กในปกครองของข้าพเจ้า มีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดเหตุการณ์ที่ไม่พึงประสงค์จากการวิจัยขึ้นกับเด็กในปกครองของข้าพเจ้า ข้าพเจ้าและเด็กในปกครองของข้าพเจ้าสามารถติดต่อกับนางสาวสุชาดา เสาวียง ได้ที่หมายเลขโทรศัพท์ 089 -148-3119

หากเด็กในปกครองของข้าพเจ้า ได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าและเด็กในปกครองของข้าพเจ้า สามารถติดต่อกับประธานกรรมการจริยธรรมการวิจัยในคนหรือผู้แทนได้ที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑลสาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5 โทรสาร 02-849-6223

ข้าพเจ้าได้ทราบถึงสิทธิที่เด็กในปกครองของข้าพเจ้าจะได้รับข้อมูลเพิ่มเติม ทั้งทางด้านประโยชน์และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรืองดเข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบใดๆ ต่อเด็กในปกครองของข้าพเจ้า และยินยอมให้ผู้วิจัยใช้ข้อมูลส่วนตัวของเด็กในปกครองของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

ข้าพเจ้าและเด็กในปกครองของข้าพเจ้า เข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนายินยอมโดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อ.....ผู้เข้าร่วมการวิจัย

(.....) วันที่.....

ลงชื่อ.....ผู้ปกครอง

(.....) วันที่.....

ลงชื่อ.....ผู้ให้ข้อมูลและความยินยอมหัวหน้าโครงการวิจัย

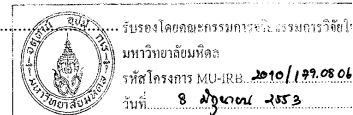
(.....) วันที่.....

ในกรณีที่ผู้เข้าร่วมการวิจัยไม่สามารถอ่านหนังสือได้ ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัย คือ

..... จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ.....พยาน

(.....) วันที่.....



หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ (สำหรับอายุ 18 ปีขึ้นไป)

วันที่.....เดือน..... พ.ศ.
ข้าพเจ้า.....อายุ.....ปี อาศัยอยู่บ้านเลขที่.....
ถนน.....ตำบล.....อำเภอ.....
จังหวัด.....รหัสไปรษณีย์.....หมายเลขโทรศัพท์.....

ขอแสดงเจตนายินยอมเข้าร่วม โครงการวิจัยเรื่อง “การลดความร้อนที่ฝ่ามือด้วยเครื่องลดอุณหภูมิ ชนิดรีวในระหว่างภาวะเลียนแบบการแข่งขันเทควันโด”

โดยข้าพเจ้าได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัย รายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัยและความเสี่ยงที่อาจเกิดขึ้นจากการเข้าร่วมการวิจัยรวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าชดเชยการเดินทางที่จะได้รับ โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการเป็นที่เรียบร้อยแล้ว

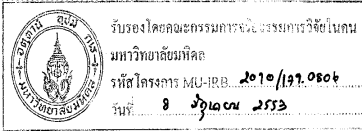
ข้าพเจ้าจึงสมัครใจเข้าร่วมโครงการวิจัยนี้
หากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หากเกิดเหตุการณ์ที่ไม่พึงประสงค์จากการวิจัยขึ้นกับข้าพเจ้า ข้าพเจ้าจะสามารถติดต่อกับ นางสาวสุชาดา เสาเวียง ได้ที่หมายเลขโทรศัพท์ 089-148-3119

หากข้าพเจ้าได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าสามารถติดต่อกับประธานกรรมการจริยธรรมการวิจัยในคนหรือผู้แทน ได้ที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑลสาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5 โทรสาร 02-849-6223

ข้าพเจ้าได้ทราบถึงสิทธิที่ข้าพเจ้าจะได้รับข้อมูลเพิ่มเติม ทั้งทางด้านประโยชน์และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรืองดเข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบใดๆ ต่อข้าพเจ้าและยินยอมให้ผู้เข้าร่วมวิจัยใช้ข้อมูลส่วนตัวของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

ข้าพเจ้าเข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนายินยอมโดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อผู้เข้าร่วมการวิจัย
(.....) วันที่.....
ลงชื่อ.....ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย
(.....) วันที่.....
ในกรณีที่ผู้เข้าร่วมการวิจัยไม่สามารถอ่านหนังสือได้ ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัยคือ..... จึงได้ลงลายมือชื่อไว้เป็นพยาน
ลงชื่อ..... พยาน
(.....) วันที่.....



APPENDIX C
THE ETHICAL COMMITTEE ON RESEARCH
INVOLVING HUMAN SUBJECT



COA. No. MU-IRB 2010/179.0806

Documentary Proof of Mahidol University Institutional Review Board

Title of Project. Palm Heat Reduction Using Rapid Thermal Exchange Unit during Simulated Taekwondo Competition
(Thesis for Master Degree)

Principal Investigator. Miss Suchada Saovieng


Name of Institution. College of Sports Science and Technology


Approval includes. 1) MU-IRB Submission form version received date 2 June 2010
 2) Participant Information Sheet version date 2 June 2010
 3) Participant Information Sheet for Child and Parent version date 2 June 2010
 4) Informed Consent form version date 2 June 2010
 5) Informed Consent form for Child and Parent version date 2 June 2010
 6) Questionnaire version received date 2 June 2010
 7) Case record form version received date 2 June 2010

Mahidol University Institutional Review Board is in full compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Date of Approval. 8 June 2010

Date of Expiration. 7 June 2011

Signature of Chairman. 
(Professor Shusee Visalyaputra)

Signature of Head of the Institute. 
(Associate Professor Sarnanee Chaiyaroj)
Vice President for Research and Academic Affairs

6. ท่านป่วยเป็นโรกระบบทางเดินหายใจ เช่น โรคภูมิแพ้ โรคหอบ โรคปอดอุดกั้นเรื้อรังหรือไม่
- ไม่ใช่ ใช่ โปรดระบุ..... เป็นมานาน.....ปี
7. ท่านป่วยเป็นโรคเกี่ยวกับกระดูก ข้อต่อ และกล้ามเนื้อ หรือไม่
- ไม่ใช่ ใช่ โปรดระบุ..... เป็นมานาน.....ปี
8. ท่านป่วยเป็นโรคเกี่ยวกับสมองและระบบประสาท เช่น โรคลมชัก ลมบ้าหมู หรือไม่
- ไม่มี มี โปรดระบุ..... เป็นมานาน.....ปี
9. ท่านเคยได้รับการผ่าตัดที่บริเวณ ทรวงอก ช่องท้อง หลัง แขน ขาและบริเวณอื่นๆ หรือไม่
- ไม่เคย เคย โปรดระบุ..... เป็นมานาน.....ปี
10. ท่านเคยได้รับอุบัติเหตุหรือ บาดเจ็บรุนแรง หรือไม่
- ไม่เคย เคย โปรดระบุ..... เป็นมานาน.....ปี
11. ท่านเคยมีอาการเจ็บหน้าอกอย่างรุนแรง หรือไม่
- ไม่เคย เคย โปรดระบุ..... เป็นมานาน.....ปี
12. ท่านเคยเป็นโรคติดต่อไปนี้ หรือไม่
- 12.1 ไวรัสตับอักเสบ ไม่เคย เคย
- 12.2 ภูมิคุ้มกันร่างกายบกพร่อง (AIDS) ไม่เคย เคย
13. ปัจจุบันท่านต้องรับประทานยาเป็นประจำ หรือไม่
- ไม่ใช่ ใช่ โปรดระบุชื่อยา..... ระยะเวลาที่ใช้.....ปี
14. ประวัติการสูบบุหรี่ และดื่มเครื่องดื่มแอลกอฮอล์
- ไม่สูบบุหรี่ สูบบุหรี่เป็นบางครั้ง
- สูบบุหรี่เป็นประจำ ระบุ..... มวน/วัน
- ไม่ดื่ม เครื่องดื่มแอลกอฮอล์ใดๆ ดื่มเครื่องดื่มแอลกอฮอล์เป็นบางครั้ง
- ดื่มเครื่องดื่มแอลกอฮอล์ใดๆเป็นประจำ ระบุ..... วัน/สัปดาห์
15. ประวัติการออกกำลังกาย (Physical activity history)
- 15.1 ท่านให้เวลากับการออกกำลังกายอย่างน้อยเพียงใด
- ไม่ได้ออกกำลังกายมาเป็นเวลามากกว่า 3 เดือน (1)
- ออกกำลังกายเป็นบางครั้ง เมื่อมีโอกาส (2)
- ออกกำลังกายเป็นประจำ ทุกครั้งเมื่อมีโอกาส (3)
- ออกกำลังกายสม่ำเสมอ (4)

เฉพาะผู้วิจัย

คะแนน ตอนที่ 2

การออกกำลังกาย: 15.1)..... +15.2)..... +15.3) +15.4) +15.60)..... =
.....

≤9 low activity

10-13 moderate activity

≥ 14 high activity

รวม..... คะแนน ระดับกิจกรรม

ความคิดเห็น

ผ่าน

ไม่ผ่าน

.....
.....
.....

APPENDIX E

DATA COLLECTION FORM

Check list for experiment

Date ID Consent from signed yes no

Body weightkg, Height cm, BMI

Resting HRbpm, BP/ mmHg Urine specific gravity

Wingate load kp Target HR

Trial.... with RTX no RTX

Arriving time Start time..... Expected finish time.....

Equipment	Calibration	Setting ready for use	Data downloaded	Remarks
Polar	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
RTX CoreControl	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
Squirrel data logger	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
Ear drum	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
Thermal sensation scale	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
Vascular Assist	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	
Wingate Test	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	<input type="checkbox"/> yes <input type="checkbox"/> no	

APPENDIX F
CHARACTERISTICS OF SUBJECTS

Table F Characteristics of subjects

Subj. No.	Variables						
	Age (yrs)	Wt (kg)	Ht (cm)	BMI (kg/m ²)	Body fat (%)	Urine specific gravity	Physical activity scores
1	17	70.9	173	23.7	14.4	1.029	18
2	19	60.0	178	18.9	6.9	1.008	15
3	15	80.5	176	26.0	20.6	1.026	17
4	15	51.0	170	17.7	9.4	1.006	18
5	17	50.2	170	17.4	10.2	1.011	15
6	17	56.1	170	19.4	9.2	1.017	19
7	17	61.6	175	20.1	10.3	1.029	19
8	16	61.1	175	20.0	9.7	1.028	20
9	16	56.5	170	19.6	9.3	1.019	18
10	16	53.5	172	18.1	9.9	1.016	19

APPENDIX G

RAPID THERMAL EXCHANGE SYSTEM

The Rapid Thermal Exchange (RTX) is used in an attempt to control body core temperature. This machine is based on the advantages of the anatomical structure of the palms, non-hairy skin, to apply cooling in combination with negative pressure to maximize skin perfusion. This hand-held device is a non-invasive and easy to use. Athlete just grasps around a conical cooling plate in the middle of a vacuum chamber. The chamber is attached by hoses to the cold water reservoir and a vacuum pump.

This technology has evolved out of many years of research at Stanford University and been scientifically validated in sports science laboratories. Other studies involving firefighters, military men and electrical workers have validated the effectiveness of this new cooling method and demonstrated remarkable results (Whitish *et al.*, 2003; Elliott *et al.*, 2003; Grahn *et al.*, 2003). For the athlete, RTX has tremendous implications for enhancing strength and endurance training. It keeps core body temperature and heart rate within normal range for optimal muscular performance (Whitish *et al.*, 2003).

Under low ambient temperature, less blood is shunted to the skin for heat conservation, making more blood available to supply working muscles in with delivery of oxygen, nutrients, and removal of metabolic byproducts to take place. RTX has been shown to enhance an athlete's work capacity during both aerobic and strength training, especially when the athlete is working at or near maximum performance levels.

RTX was originally developed on the principles of mammalian thermoregulation. All mammals have "radiators" where specific regions of the body surface designed for dissipating excess heat from the body core to the environment. Blood is preferentially pumped to body surface when metabolism increases as it does during exercise. In humans, most of these radiator surfaces are found in the palms of the hands and soles of the feet. When an athlete gets hot, blood flow naturally

increases through these skin regions to dissipate heat through specialized blood vessels called arteriovenous anastomoses (AVAs). RTX enhances heat extraction through these radiator surfaces by amplifying local blood flow using control mechanisms on temperature settings (18-22°C) and slight vacuum (35-45 mmHg).

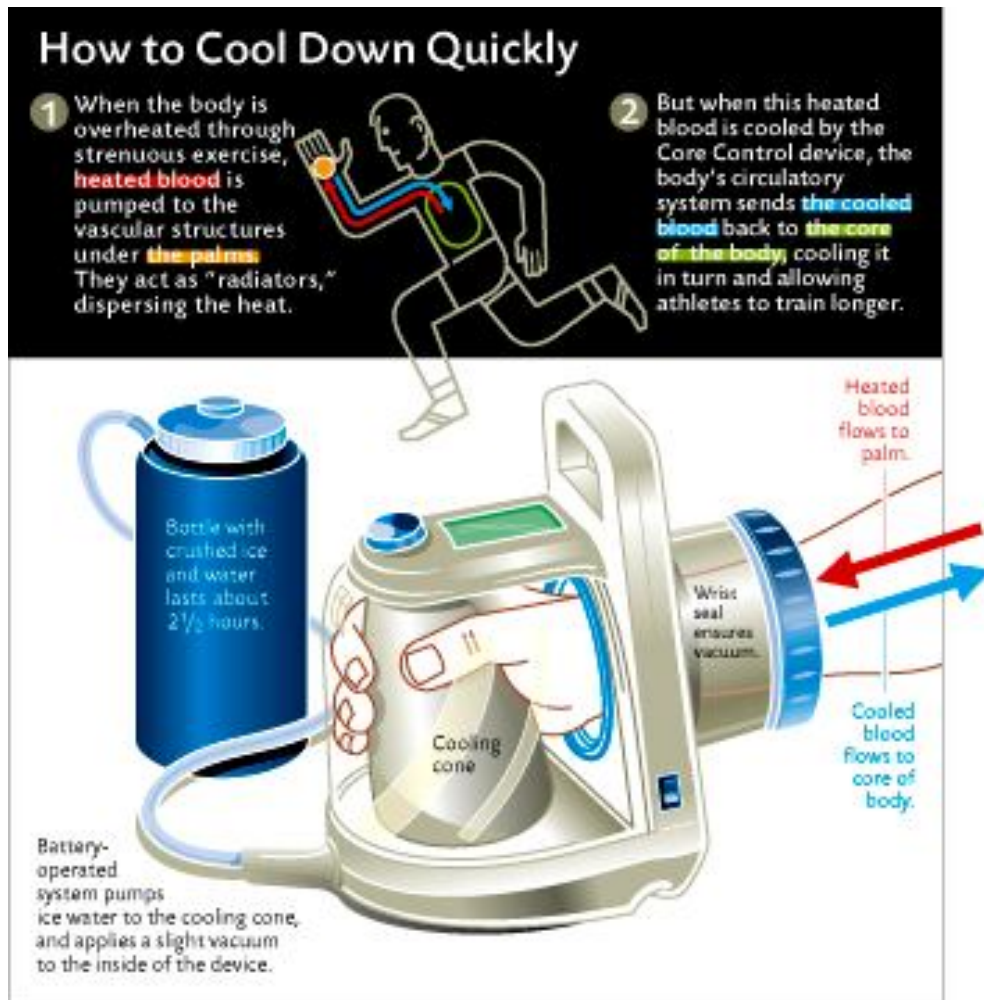


Figure G: CoreControl RTX diagram

BIOGRAPHY

NAME	Miss Suchada Saovieng
DATE OF BIRTH	14 December 1984
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Mahidol University, 2003-2006 Bachelor of Science (Sports Science) Mahidol University, 2008-2011 Master of Science (Sports Science)
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PUBLICATION/PRESENTATION

Publication

Saovieng, S., Chuanchaiyakul, R., Chentanez, T., & Widjaja, W. (2010). Rapid Palm Cooling on Physiologic Responses and Anaerobic Performance during Simulated Taekwondo Competitions. *Journal of Sports Science and Technology*, 10(2), 239-245.

Presentation

Oral Presentation: Rapid Palm Cooling on Physiologic Responses and Anaerobic Performance during Simulated Taekwondo Competitions at International Conference on Sports and Exercise Science (Pre-ASEAN University Games Conference 2010) December 10-14, 2010, Chiang Mai, Thailand.