LOWER BODY IMMERSION AT DIFFERENT WATER TEMPERATURES DURING RECOVERY PERIOD ON THERMOREGULATORY PROFILES AND PERFORMANCE IN SOCCER PLAYERS.

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ABSTRACT

The objectives of this study were to identify effect of lower body immersion, at different water temperatures (ambient, cold and warm) during 15-min recovery period on thermoregulatory profiles and the subsequent performance in soccer players. Twenty-eight soccer players were voluntarily participated in the study. To simulate soccer game conditions, the subjects were asked to complete 2 sets of 45-min intermittent sprint-cycling activities. Various recovery methods during the 15 min half-time period were randomly intervened with a control (rest without water immersion) and water immersions in ambient (27 °C), warm (39 °C) and cold (15 °C) water temperatures. After recovery intervention the subjects performed a 5-min warm up and repeated the same protocol during another 45-min intermittent sprint-cycling test. The experimental parameters were measured and recorded every five-minutes until the end of the experiment. For data analysis, ANOVA will be used for comparison among groups at specific time. Group comparison was employed using Repeated-Measured ANOVA at different time periods on the same group. The two physical performances, pre- and post-intervention, will be compared using Student t-test. Level of significance is set at $p < 0.05$.

Rectal temperature in all groups of water immersion showed significantly lower than the control at the end of each trial ($p<0.05$). The rating perceived of exertion (RPE), thermal sensation, peak power, heart rate, systolic and diastolic blood pressures showed no difference from the control ($p<0.05$). Blood lactate in ambient and warm water immersions showed significantly lower values than in control group ($p<0.05$). Lower body immersion during 15 min half-time period prevented excessive rectal temperature in the end of second half but did not improve performance during second half of soccer bout.

KEY WORDS : WATER IMMERSION / WATER TEMPERATURES / THERMOREGULATION / PERFORMANCE

78 pages

การแช่น้ำครึ่งตัวที่มีผลต่อการควบคุมอุณหภูมิในร่างกายและสมรรถภาพในนักฟุตบอล
(LOWER BODY IMMERSION AT DIFFERENT WATER TEMPERATURES DURING RECOVERY PERIOD ON THERMOREGULATORY PROFILES AND PERFORMANCE IN SOCCER PLAYERS.)

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของการแช่น้ำครึ่งตัวที่มีผลการควบคุมอุณภูมิร่างกาย (อุณหภูมิแกนกลางและอุณหภูมิผิว) และผลต่อสมรรถภาพ ในนักกีฬาฟุตบอลผู้มีสุขภาพแข็งแรง ภายหลังการแช่น้ำที่มีอุณหภูมิต่าง ๆ กัน อาสาสมัครจำนวน 28 คน โดยแบ่งกลุ่มแบบสุ่ม กลุ่มละ 7 คน กลุ่ม 1 กลุ่มควบคุม (นั่งพัก) กลุ่ม 2 น้ำอุณหภูมิปกติ (27 องศาเซลเซียส) กลุ่ม 3 น้ำร้อน (39 องศาเซลเซียส) และกลุ่ม 4 น้ำเย็น (15 องศาเซลเซียส) โดยมีอายุเฉลี่ย 19±0.58, 19±1.0, 19.4±0.79 และ 18.9±0.69 ปีตามลำดับ อาสาสมัครต้องปั่นจักยานแบบหนักสลับเบาจำนวน 2 ครึ่ง ครึ่งละ 45 นาที และพักระหว่างครึ่ง 15 นาที โดยในกลุ่ม 1 อาสาสมัครจะนั่งพักเฉยๆ กลุ่มที่ 2, 3 และ 4 อาสาสมัครจะนั่งแช่น้ำครึ่งตัวที่ระดับสะดือ และหลังจากพัก 15 นาทีอาสาสมัครจะปั่นจักรยานแบบหนักสลับเบาอีกครั้ง โดยที่ผู้วิจัยจะวัดและบันทึกค่าตัวแปรต่าง ๆ ดังกล่าว ทุก ๆ 5 นาที

ผลการทดลองปรากฏว่าทุกกลุ่มของการการแช่น้ำทำให้อุณหภูมิแกนกลางมีค่าน้อยกว่ากลุ่มควบคุมเมื่อสิ้นสุดการออกกำลังกาย การแช่น้ำ 15 นาที ที่อุณหภูมิแตกต่างกันไม่ทำให้อัตราการเต้นของหัวใจและความดันโลหิตมีความแตกต่างกันทั้งระหว่างกลุ่มแช่น้ำและระหว่างกลุ่มแช่น้ำกับกลุ่มควบคุม กรดแลกติกหลังการออกกำลังกายพบว่าในกลุ่มแช่น้ำที่อุณหภูมิ 27 และ 39 องศาเซลซียส ที่ค่าน้อยกว่ากลุ่มควบคุม จากการศึกษาการแช่น้ำที่อุณหภูมิที่แตกต่างเป็นเวลา 15 นาที ไม่ได้ช่วยทำให้สมรรถภาพในนักฟุตบอลเพิ่มขึ้นในครึ่งหลัง

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LIST OF ABBREVIATIONS

min	=	minute
kg/m^2	=	kilogram per square meter
L	=	liter
°C	=	degree Celsius
RH	=	relative humidity
bpm	=	beat per minute
CT	=	control group
AW	=	ambient water temperature (27°C)
WW	=	warm water temperature (39°C)
CW	=	cold water temperature (15°C)
Tr	=	rectal temperature
Tsk	=	mean skin temperature
SBP	=	systolic blood pressure
DPB	=	diastolic blood pressure
HR	=	heart rate
RPE	=	rating of perceived exertion
TS	=	thermal sensation
BMI	=	body mass index
SEM	=	standard error of the means
SD	=	standard deviation

CHAPTER I
INTRODUCTION

Post-exercise recovery is an important step of many programmed sports where athletes train extremely hard with less recovery time. That completed post-recovery can lead to over reaching, burnout or poor performance (Mackinnon and Hooper, 1991). High metabolic activation during physical activity brings about physiological adjustment including post-exercise thermoregulatory and energy substrate replenishment (Bahr and Maehlum, 1986). Following exercise, the body processes do not abruptly improve to resting condition. Ideally, full recovery of body function is expected, however this is not easily achieved since many factors involve. For example the isometric handgrip endurance capacity after complete fatigue fully recovered after 40 min (Funderburk, 1974), but the recovery after distance running required considerable longer time (McArdle and co-worker, 2007).

Effective recovery is essential to ensure optimal performance in a subsequent event or match. Recently a lot of emphasis has been placed on speeding up the recovery process so that athlete can proceed to do successive bouts of training or competition without the associated fatigue or burn out effect. Previous investigations reported on various interventions on recovery processes following different intensities of exercise. Those interventions included active and passive recovery (Hermansen and Stensyold, 1972; Weltman et al, 1979; Dodd et al, 1984; Cortes et al, 1989), water immersion (Crowe et al, 2006; Schniepp et al, 2002), manual massage (Roberton et al, 2004; Brian Hemmings et al, 2000), ice bag application (Frank Verducci, 2000, 2001). Among these techniques, water immersion is gaining popularity recovery strategies after post game or post training (Calder, 2000; Cochrane, 2004).

Water immersion has been used in some cultures for health restoration (Bender et al, 2004; Calder, 2003). A part from easily access, immersion in hot and/or cold water has been used as a therapeutic treatment for restoring physical and mental health (Bender et al, 2004; Calder, 2003). Water immersion produces similar benefits

to active recovery, such as increase blood flow and lactate removal, without the need to expend the extra energy associated with active recovery (Blyden et al, 1989; Nakamura et al, 1996; Hamlin and Magson, 2002) There are four basic modes of water immersion that can be performed 1) cold water (cryotherapy) 2) hot water (thermotherapy) 3) hot-cold water (contrast therapy) and 4) thermo-neutral water (Calder, 2003). Cryotherapy, thermotherapy, and thermo-neutral water are immersion in water at a constant temperature, whereas contrast therapy is immersion in alternating extremes of temperature.

Soccer is an intermittent team sport, require athlete to compete over prolonged periods, at relatively high intensities (65% VO2max), separated into two equal halves by a 15 min halftime break. Soccer players must perform multiple repeated vigorous sprinting during the match and with require higher energy demands (Williams, 1990), and often requires sustain exercise performance in high ambient temperature. Under these conditions elevated core and skin temperature, resulting in increased cardiovascular and metabolic loads (Kozlowski et al, 1985; Morris et al, 2000), in addition to hastening neuromuscular fatigue (Kay et al, 2005) and reducing endurance (Gonzalez-Alonso et al, 1999) and intermittent sprint (Drust et al, 2005) performance compared with normo-thermic conditions. The body temperature rises during a soccer match for environment temperatures between 20 and 25˚C. Ekblom (1986) found that the mean rectal temperature after matches was 39.5˚C for Swedish first division players, while the level were between 39 and 39.2˚C for player from lower divisions. Some players were found to have a temperature higher than 40˚C (Smodlaka, 1978).

Time motion analyses of soccer indicate that both sub-maximal and sprint performance decrease during the second half of competition. When games are played in the heat, elevated core temperature from the first half can increase the level of fatigue during the second half of competition, leading to further decreases in performance. Recently, it was observed that the performance of soccer players during the initial part of the second half was lower than that in the first half (Mohr et al, 2003). Likewise, Bangbo and co-workers (1991) reported that the distance covered within the first half was 5% greater than that in the second half. Thus, recovery time period after the first half is critical for performance during the second half. Therefore,

a strategy to reduce core temperature during halftime breaks could minimize the reduction in performance that is often observed during the second half. Classical intervention in between soccer game included active and passive re-warm-up strategies (Lovell et al, 2007). Recently, new intervention of water immersion has been introduced for improving recovery before (in term of pre-cooling) and after exercise (Castle et al, 2006; Crowe et al, 2006; Frank Verducci, 2000).

To date there are very few studies investigated effects of water immersion during recovery period between exercise bouts on subsequent performance with showed equivocal result (Schniepp et al, 2002; Crowe et al 2006; Yeargin et al, 2006; Lane and Wenger, 2004). Controversially, significant decreasing in anaerobic cycling performance (30 seconds maximum effort sprint) was reported by 15-min lower cold water immersion (12o C) compared with 15-min passive rest (Schniepp et al, 2002).

Crowe and colleagues (2006) showed that lower cold water immersion (15-min, 13-14˚C) between exercise test caused significant decrease in 30-s maximal sprint cycling performance.

Very few studies indicated that cold water immersion (12-min, 13.98˚C) after 90-min running test on hilly trails enhanced performance (6% improvement in race time) compare with passive recovery (Yeargin et al, 2006).

Lane and Wenger (2004) reported that cold water immersion (15-min, 15˚C) enhanced intermittent cycling performance when applied the intervention immediately after the exercise test with 24hr between tests.

Most of the previous studies concentrated on effect of cold water immersion on type of sport with required light to moderate physical performance. None of the previous studies indicated changes in body core and peripheral temperatures during water immersion which are reasonably reflected physiologic adjustments from such intervention and most of studies interested on water immersion in term of pre-cooling before exercise but in this study is focus in between exercise during half time period.

It is believed that water immersion under different temperatures being performed between bouts of exercise might affect both physiological recovery processes. It is also considered that changes in body temperature during water immersion might influence the succeeding performance. The present study is,

therefore, aimed to investigate effect of three water temperatures: ambient, cold and warm water on thermoregulatory processes and subsequent repeated vigorous physical performance in soccer player.

1.1 Hypothesis

The present study hypothesizes that water immersion under different temperatures after the first bout of vigorous exercise might affect both physiological recovery processes which, in turn, influence the succeeding performance.

1.2 Objectives

1. To study effect of ambient, cold and warm water immersions on thermoregulatory profiles and the subsequent performance in soccer player.

2. To compare, within the group, changes of thermoregulatory profiles and repeated performance obtained during and after ambient, cold and warm water immersions.

3. To compare, between groups, changes in thermoregulatory profiles and repeated performance.

1.3 Scopes of study

This study is specifically designed to investigate effect of recovery mode using water immersion after vigorous exercise on thermoregulatory adjustment and subsequent physical performance in athletes. Ranges of water temperatures are ambient, cold and warm temperatures with lower body immersion condition in which male soccer players represent athletic subjects for the study.

1.4 Advantages of the study

1. To achieve understanding about immediate post-exercise body adjustment on thermoregulatory control to water immersion.

2. To use as guidelines to create appropriate recovery strategies following high intensity sport with short rest period.

CHAPTER II
LITERATURE REVIEW

2.1 Body Temperature

The “normal” body temperature of an adult human is approximately 37˚C but may be as low as 36˚C or as high as 37˚C in active, healthy people. “Body temperature” usually refers to the temperature of the body core, measured under the tongue (sublingually), in the ear canal, or in the rectum. For clinical purposes, the reliable among these three techniques is the rectum, because it is least influenced by air temperature. Measurement devices range from traditional mercury-in-glass thermometers to electronic, digital readout thermistors. Nearly all such instruments are accurate to 0.1˚C.

Body core temperature depends on the time of the day, the stage of menstrual cycle in woman, the level of the person’s activity, and the individual’s age. All homeotherms maintain a circadian body temperature rhythm, with variations of approximately 1˚C. In human, body temperature is usually lowest between 3:00 to 6:00 a.m., and peaks at 3:00 to 6:00 p.m. This circadian rhytmmicity is inherent in the autonomic nervous system, independent of the sleep-wakefulness cycle, but entrained by light dark cues to a 24-h cycle

Physical activity generates excess heat as a by product of elevate metabolic rate. A portion of this excess heat remains in the body, causing core temperature to rise and triggering appropriate heat-loss responses. Core temperature remains elevated during activity and for an extend period during recovery.

2.2 Body’s Heat Production

Body’s normal metabolic processes including digestion of food, contraction of skeletal muscles, and secretion of some hormones produce heat at all time. Among these, the contraction of skeletal muscles is considered to be the major source of heat. Heat production at rest or during sleep is small but becomes during

intense exercise or hard activity. Body heat produced can be classified as (1) voluntary (exercise) or (2) involuntary (shivering or biochemical heat production caused by the secretion of hormones such as thyroxine and cathecholamine).

Thyroxine that acts by increasing the metabolic rate of all cells in the body produces a slowly developing but prolong increase. Conversely, cathecholamine like epinephrine and norepinephrine create a rapid but short-lived increase in heat production by improving the rate of cellular metabolism.

2.3 Body's heat loss

For the body heat to be transferred to the environment, the deep heat produced in the body must have to access to the outside environment by being consequentially moved by the blood from the core to the shell (the skin). Once heat approaches the skin, it can be transferred to the environment by any of these four mechanisms; (1) radiation, (2) conduction, (3) convection, and/or (4) evaporation. Temperature gradient between the skin and the environment is required for the first three heat loss processes.

2.3.1 Radiation

Electromagnetic heat wave is continually emitted from surface of object at temperature above absolute zero. Radiation is the primary method for discharging the body's excess heat at rest. It relates to the transfer of heat from the surface of one object to the surface of another without molecular contact between objects. The warmer objects generally give off the infrared rays like heat through the air to solid, cooler objects in the environment. Because of this fact, human body constantly radiates heat in all directions to the cooler objects around it similar to the sun warms the earth by radiation. At room temperature, about 60% of the heat loss occurs via radiation. Although a net loss of body heat occurs due to thermal gradient between the greater skin temperature and the lesser temperature of the surrounding objects, the body can also gain heat via radiation on a hot sunny day when the skin temperature is lower than the surface temperature.

2.3.2 Conduction

Heat conduction is heat exchange between substances or objects such as liquid, solid or gas from one molecule to another at different temperatures. In human body, generated deep heat can be conducted through adjacent tissue until it reaches the cooler surface. The amount of the heat transferred is proportionate to the temperature gradient between the skin and surrounding surface.

2.3.3 Convection

Convection is defined as the transfer of heat from one place to another by the motion of gas or liquid across the heated surface. By this method, air or water molecules are warmed and moved away from heat source and are replaced by cooler molecules. The greater the movement of the air or liquid, the greater the rate of heat loss by convection. Although conduction and convection can reduce both heat when air temperature is lower than skin temperature, the efficiency of total heat loss in air is relatively small--only about 10% to 20%.

2.3.4 Evaporation

Evaporative heat loss provides the main physiologic defense against overheating. The inner heat is continually transferred to the environment by water evaporization from the respiratory passages and skin surface. The latent heat of evaporation, energy required to convert a liter of liquid water to a vapor, is equal to 580 kcal. Because of this, evaporation accounts for approximately 25% of total heat loss at rest. As body temperature generally rises above normal during exercise. In order to lower the critical heat, much sweat is secreted onto the surface of the skin by stimulating of the nervous system on sweat glands. As sweat evaporates, heat is lost to the environment, which in turn lower skin temperature. Therefore, evaporation is the most important means heat loss during exercise.

There are three factors involved with sweat evaporation from the skin; [1] the temperature and relative humidity (RH), [2] the convective currents around the body, and [3] the amount of skin surface exposed to the environment.

The relative humidity is directly related to the rate of evaporation. In fact, high relative humidity reduces the vapor pressure differences between the skin and the

environment. On a hot humid day (RH = 80% to 90%), the vapor pressure in the air is close to the vapor pressure on moist skin. Therefore, the rate of evaporation is greatly reduced. High sweat rates during exercise in hot/high humidity environment result in useless water loss. That is, sweating *per se* does not cool the skin; it is evaporization that cool the skin. Performing exercise in a hot environment where air temperature is greater than skin temperature, the only method of losing body heat is evaporation.

2.4 Body Temperature Regulation

Physiological thermoregulation in humans comprises changes in heat dissipation (cutaneous vasodilation and sweating) and heat generation (shivering) in response to various internal and external thermal stimuli. The central control of thermoregulation is in the preoptic/anterior hypothalamus (PO/AH) in the brain. Information on internal(core) and surface (skin) temperatures is relayed to the PO/AH, which then coordinates the appropriate efferent response. Conceptually, this area of the brain can be related to a thermostat, which initiates heat dissipation responses when body temperature is sensed as “too hot” and heat conservation or heat generation when temperature is sensed as “too cold”. The component of this system are: (1) thermal sensors, (2) afferent pathways, (3) an integration system in the central nervous system (CNS), (4) efferent pathways, and (5) target organ that control heat generation and transfer, such as skeletal muscle (e.g., shivering to generate heat), circulation to the skin (to dissipate heat), and the sweat glands (to dissipate heat). Control of thermoregulatory by the PO/AH is summarized in Figure 2.1

Resting skin blood flow in thermoneutral environments is approximately 250 mL/min, which results in a heat dissipation of approximately 80 to 90 kcal/h, about the level of resting metabolic heat production.1,16 During exercise or heat exposure, increases in body temperature trigger cutaneous vasodilation and sweating.1,17 Cutaneous vasodilation increases blood flow to the skin severalfold, substantially increasing convective transfer of heat from the core to the periphery. These large increases often require increased cardiac output and redistribution of blood flow from areas, such as the splanchnic region, that demonstrate vasoconstriction. These adjustments are usually sufficient to match the demand for

increased skin blood flow, such that oxygen supply to organs such as the heart is not compromised.

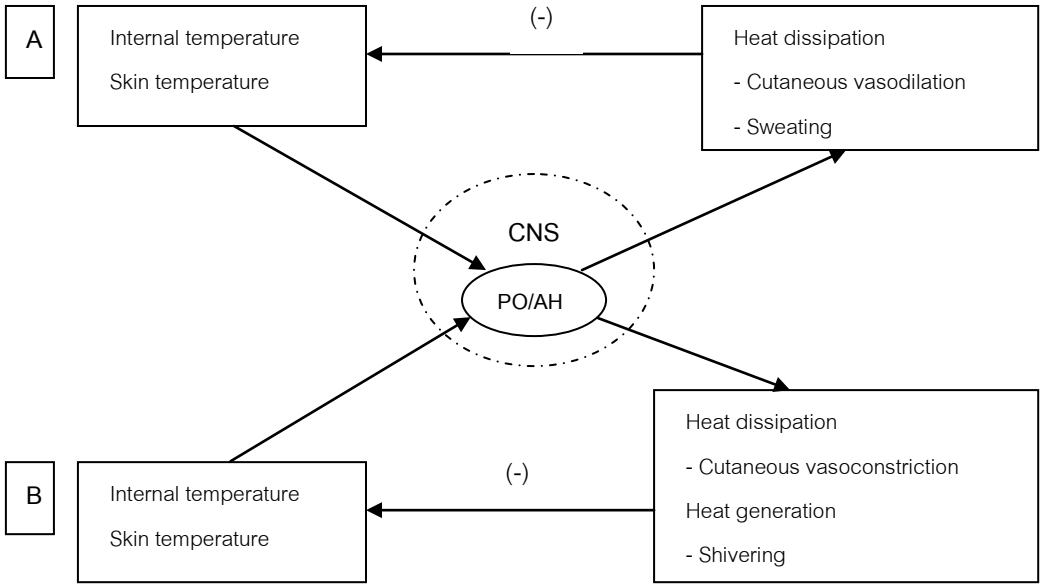


Figure 2.1 Negative feedback loops involved in physiologic thermoregulation in human. Minus sighs refer to the correction of the error signal (change in skin and/or internal temperature) by the appropriate effector response. A, Increases in internal and/or skin temperatures are sensed by the preoptic/anterior hypothalamus (PO/AH) and result in increase heat dissipation via cutaneous vasodilation and sweating, which then corrects the original increased temperature. The influence of internal temperature is several times that of skin temperature in the control of these effectors. B, Decreased skin or internal temperature cause reflex decreases in heat dissipation (cutaneous vasoconstriction) and increase heat generation (shivering) to correct the decreases in temperature that initiated those changes. CNS = central nervous system

Concurrent with cutaneous vasodilation, the evaporation of sweat decreases skin temperature, thereby cooling the blood in the dilated skin vessels before it returns to the core. In general, skin blood flow and sweating continue to increase in proportion to internal temperature until a steady state is reached at which heat dissipation and heat generation are equal, and therefore body temperature is constant, or until maximal responsiveness is reached. When internal temperature decreases toward normal, sweating stops, and skin blood flow returns to normal. In this sense, thermoregulation represents a classic negative feedback loop (Figure 2.1).

On exposure to cold environments, skin blood flow decreases via cutaneous vasoconstriction. This results in a decrease in heat dissipation from the skin surface and less convective heat transfer from the core to the surface. With further body cooling, shivering begins. The muscular contractions involved result in increased heat generation, which in combination with decreased heat dissipation helps to maintain core temperature in the face of cold exposure.

2.5 Exercise Recovery

Recovery is defined as “the sum of the processes that return the exercise to the resting state. Aerobic metabolism remains elevated in the recovery phase after exercise. Known as excess post-exercise oxygen consumption (EPOC) it assists in replenishing the body stores (Bahr and Maehlum, 1986). EPOC consist of a fast and slow component (Gaesser and Brooks, 1984). The fast component restores 70% of ATP and PCr energy stores within 30s (Hultman et al, 1967) and reloads plasma hemoglobin and muscle myoglobin (Bahr, 1992). The slow component is observed after strenuous exercise and has been associated with increased cardiac and respiratory function, elevated core temperature and removal of metabolic waste products (Gaesser and Brooks, 1984; Saltin, 1992). Dependent on the exercise intensity it may take up to 24 h for the slow component to return to its resting levels (Gaesser and Brooks, 1984). Phosphagen stores take 3-5 min to fully recover (Hultman et al, 1967) compare to an hour or more for the resting return of lactate and pH. The rise in lactate production and H^+ accumulation can disrupt the muscle contractile processes and the existing transport and metabolic pathway can become less efficient (Tomlin and Wenger, 2001). The use of passive or active recovery for replenishing fuel stores and removal of metabolic waste has implications for acceleration post recovery rates.

2.6 Processes of recovery

The processes of recovery consist of; (1) excess post exercise oxygen consumption (oxygen dept), (2) replenishment of energy stores, (3) reduction of lactic acid in blood and muscle, and (4) restoration of oxygen stores.

2.6.1. Excess post exercise oxygen consumption (oxygen dept)

The concept of oxygen debt meant that the oxygen consumed during recovery was used primary in restoring the body to its pre exercise condition, including replenishment the energy stores that were depleted and removing any lactic acid that was accumulated during exercise. Many erroneously interpret the classical term oxygen dept to mean that extra oxygen consumed during recovery is being used to replace oxygen that was “borrowed” from somewhere within the body during exercise. The oxygen consumption pattern in recovery clearly shows two major components typical of an exponential decline: a faster component and a slow component.

The time course of oxygen consumption following exhaustive exercise decreases exponentially. The rate at which oxygen is consumed is not constant throughout the recovery period. During the first two or three minutes of recovery, oxygen consumption declines very rapidly, then more slowly until a constant rate, equivalent to resting level, is reached, the initial rapid portion of recovery is now identified as the fast component (Kochan R.G. et al, 1979), whereas the slower phase is now referred to as the slow component (Margaria R. et al, 1933; Kochan R.G. et al, 1979). The slow component was formerly identified as the lactacid component, because it was observed that the oxygen consumed during this phase of recovery was quantitatively related to the removal of the lactic acid accumulated in the blood and muscle during exercise. The term alactacid was used because the oxygen consumed during the fast component of recovery was thought to be independent of the removal of lactic acid during recovery.

The elevated oxygen consumption during the fast component of recovery includes oxygen fueling the post exercise energetic need of: (1) resaturation of myoglobin with oxygen, (2) restoration of blood levels of oxygen, (3) the energy cost of elevated ventilation, (4) elevated hart activity, and probably most significantly, (5) the replenishment of phosphagens (ATP and PC) (Kochan R.G. et al, 1979).

The elevated oxygen consumption during the slow component of recovery is known to be associated with a number of physiological event including: (1) an elevated body temperature (Altman P.L. et al, 1966; Hagberg J.M. et al, 1980) involving the Q10 effect, (2) the oxygen cost of ventilation, (3) the oxygen cost of increased myocardial activity, (4) an increase in sodium and potassium pump activities (iron redistribution), (5) glycogen resynthesis, (6) the calorigenic effect of catecholamines (Barnard R.J. and M.L. Foss, 1969; Barnard R.J. et al, 1970), and (7) oxidation of lactic acid (i.e., conversion to CO2 and H2O), among other factors (Gaesser G.A. and G.A. brooks, 1979; Stainsby W.N. and J.K. Barclay, 1970).

2.6.2 Replenishment of energy stores

There are two sources of energy that are depleted to varying extents during exercise: (1) the phosphagens, or ATP and PC, stored in the muscle cells; and (2) glycogen stored in large quantities in both muscle and liver, which serves as an important dual source of fuel during most exercise activity. Several studies have shown that most of the ATP and PC depleted in the muscle during exercise is restored very rapidly (within a few minutes following exercise) (Harris R.C. et al, 1976; Hultman E. et al, 1967; Karlsson J. et al, 1975; Karlsson J. and B. saltin, 1971; Piiper J. et al, 1968; Piiper J. and P. Spiller, 1970). The ATP energy required for phosphagen restoration is provided mainly by the aerobic system through the oxygen consumed during the fast component of the recovery oxygen period (Piiper J. et al, 1968; Piiper J. and P. Spiller, 1970). The aerobic energy made available for phosphagen replenishment comes about from the breakdown of carbohydrate and fats (and perhaps a small amount of lactic acid) to CO2 and H2O via the Krebs Cycle and electron transport system. Some of the resynthesized ATP is stored directly in muscle, whereas some is broken down immediately, to resynthesize the PC that is stored in the muscle. PC can only be resynthesized in coupled reactions from the energy released when ATP is broken down. Most of the energy for phosphagen restoration arises from metabolic activity occurring during the period of the fast component of recovery. The fast component declines very rapidly and is complete in three to six minutes.

The full repletion of the muscle glycogen following exercise requires several day and depends on two major factors: (1) the type of exercise performed that caused the glycogen depletion, and (2) the amount of dietary carbohydrate consumed during the recovery period (Foss and Keteyian, 1998).

2.6.3 Reduction of lactic acid in blood and muscle

Lactate, as a metabolic product of glycolysis during exercise, has, as a principal fate, oxidation to CO2 and H2O. The concentration of lactate found in the blood at any time during either rest or activity is a function of the rate of production and the rate of degradation of this important metabolite. The lactate accumulated in blood and muscle during exercise is removed during the recovery period. The speed of lactate removal depends on whether a subject rests during recovery (passive recovery) or performs light exercise (30% to 65% VO2 max) during recovery (active recovery). Lactate is removed faster during active recovery. Blood lactate is degraded by (1) conversion to glucose and/or glycogen, (2) conversion to protein, and (3) oxidation to CO2 and H2O by the aerobic system. The blood lactate's major fate is oxidation to CO2 and water, which occurs mainly in skeletal muscle, but also occurs heart, kidney, liver, and brain tissue. Although at least part of the oxygen and ATP energy required for lactate removal probably comes from the slow component of recovery.

2.6.4 Restoration of oxygen stores

Oxygen is stored mainly in the muscle in chemical combination with myoglobin, a complex protein compound similar to hemoglobin found in the blood. Although myoglobin acts as a store for oxygen, it is also involved functionally in the actual transfer of oxygen from inside the cellular membrane to the mitochondria within the muscle cell. Thus, myoglobin has a dual role: storage of oxygen and facilitation of the diffusion of oxygen from blood to the mitochondria. The O2-myoglobin stores are small and the restoration of the O2-myoglobin stores depends mainly on the availability of oxygen. In turn, the availability of oxygen depends on its partial pressure. During heavy exercise the demand for oxygen is high. Consequently, the oxygen that was combined with myoglobin is readily given up to the mitochondria. Just the opposite is true during recovery from exercise. Here the availability of oxygen

is greatly increased, causing a recharging of myoglobin with oxygen a process requiring only a few second to complete (1971)

2.7 Recovery techniques

2.7.1 Active recovery

Active recovery is a post-game or post training exercise at an intensity that is lower than the game or training. Active cool-down is another name for active recovery. In the field it is common for coach, trainers and athlete to used for improve performance (Best and Garret, 1993; Calder, 2003). The intensity and mode of active recovery varies, but in research the intensity is normally less than the anaerobic threshold (< 65% VO2 max) and using a similar mode to the exercise that was performed (Lattier et al, 2004; Monedero and Donne, 2000; Sanders, 1996; Thiriet et al, 2004; Vaile et al, 2004; Weltman et al, 1979; Weltman et al, 1977). The duration of active recovery in research is normally between 4 and 20 minutes (Lattier et al, 2004; Monedero and Donne, 2000; Sanders, 1996; Thiriet et al, 2004; Vaile et al, 2004; Weltman et al, 1979; Weltman et al, 1977), which is approximately the duration recommended to athletes in the field.

Increase blood flow during light-intensity exercise has been postulated as the mechanism that improves recovery. Signorile and co-worker (1993) suggested that the pumping (contraction-relaxation) action for active muscles may increase the clearance of metabolic waste product. By increasing blood flow the removal of metabolites, such as lactate, and the replenishment of substrate within the muscle could be enhance (Bonen and Belcasro, 1977). Over the short term active recvery may increase the contractile ability of the muscle and over the long term aide healing (McEniery et al, 1997; Sayers et al, 2000). However, while low intensity activity may improve recovery high intensity active recovery may be contraindicative to recovery by increasing metabolic waste ad depleting nutrient stores (McEniery et al, 1997).

2.7.2 Passive recovery

Passive recovery or resting recovery means that a subject has rested throughout the duration of the recovery period (Foss and Keteyian, 1998). It is

assumed that complete inactivity might reduce the resting energy requirements and "frees" oxygen for the recovery process (McArdle et al, 2000). During passive recovery after intense exercise has produced varied results on the rate of glycogen synthesis. This high rate of glycogen synthesis id believed to be evidence for lactate reconversion to pyruvate, with a subsequent reversal of glycolysis producing glucose-6-phosphate, which can then be diverted to glycogen storage (Rogers, 1991). It was indicated that 25 minutes of rest recovery are required following maximal exercise to remove half of the accumulate lactate (Hermansen et al, 1975). In addition, the recovery from extreme muscle acidosis requires approximately 5 min during passive recovery; however, little is known of the influence of exercise duration and the severity of muscle acidosis on the kinetics of recovery from acidosis (Tomlin and Wenger, 2001). Data from Karlsson and Saltin in 1971, subject performed interval exercise at sub-maximal intensity by pedaling on cycle ergometer following passive/rest recovery (seated on the cycle). At least one hour of recovery was required to remove most of the accumulate lactate (Foss and Keteyian, 1998).

2.7.3 Water Immersion

Water immersion has been used in some cultures for health restoration (Bender et al, 2004; Calder, 2003). Recently water immersion has gained popularity as a means to improve recovery from exercise, though much for its use is based on anecdotal information (Calder, 2003). There is some basis for the use of water immersion to enhance recovery from exercise as it can produce beneficial physiological changes within the body.

There are four different methods of using water immersion in recovery; 1) cold water (cryotherapy), 2) hot water (thermotherapy), 3) hot-cold water (contrast therapy), and 4) thermo-neutral water (water immersion per se). Cryotherapy, thermotherapy, and thermo-neutral water are immersion in water at a constant temperature, whereas contrast therapy is immersion in alternating extremes of temperature.

2.8 Type of Water Immersion

2.8.1 Cryotherapy

Cryotherapy is immersion in cold water. No specific water temperature range has been determined for cryotherapy. Low and Reed (1994) state that the sensation of cold pain begins at 15°C, and some researchers have used temperatures of 15°C or less to study the effect of cold water immersion on physiological (Bonde-Petersen et al, 1992; Sramek et al, 2000) or performance changes (Burke et al, 2001; Burke et al, 2003; Lane and Wenger, 2004). In performance research the duration of immersion time varies from 15-20 minutes (Burke et al, 2003; Lane and Wenger, 2004; Clarke, 1963).

2.8.2 Thermotherapy

Thermotherapy refers to immersion in water that raises the core body temperature occurs in water temperature above 36°C (Bonde-Petersen et al, 1992; Greenleaf and Kaciuba-Uscilko, 1989; Weston et al, 1987). Little research has been conducted on the physiological or performance effect of hot water immersion. An immersion duration of 10-20 minutes has been suggested by Brukner and Khan (2001) to aide athletic recovery and rehabilitation, though this time period does not appear to be based on research.

2.8.3 Contrast therapy

Contrast therapy is a post-exercise recovery method that has recently gained popularity (Cochrane, 2004). Contrast therapy necessitates alternating temperature immersion, from a hot to cold bath and vice versa. Protocol vary but generally consist of 30 to 300 seconds of one temperature extreme, immediately followed by 30 to 300 seconds of the contrasting temperature. This is repeated a number of time for a duration of 4 to 30 minutes in total. Vascular “pumping” caused by the variation in temperature has been proposed as the mechanism that could improve recovery (Cochrane, 2004; Myrer et al, 1994; Sanders, 1996)

2.8.4 Thermo-neutral water (water immersion per se)

Thermo-neutral water both the easiest method of application in the field and, compared to the other water immersion modes, widely researched (physiologically). The temperature widely used in this mode range from cool to thermo-neutral, which this review is considered to range from 16-35 °C. Research into the physiological effect of water immersion generally has concentrated on the use of thermo-neutral immersion, and has ranged in immersion time from 5 minutes to 6 hours. This review only concentrated the effect of immersion over a maximum of 30 minutes to replicate a time similar to post-exercise recovery sessions.

2.9 The effect of water temperature

Thermo-neutrality is considered to occur in a small range (35 °C) in which subjects can maintain their core temperature for at least one hour (Craig & Dvorak, 1968). Critical cold temperatures at which can individual cannot maintain core temperature for an hour range from 30-34 °C depending on the cutaneous fat of individual (Toner et al., 1986). However, core temperatures can be maintained during chin-out immersion at temperatures as low as 18 C for up to 30 minutes (Tikuisis et al., 2000; Toner et al., 1986).

Cooler temperatures do have some effect on the physiological responses of the body. As water temperature decreases so to dose heart rate (Sramek et al., 2000; Waeton et al., 1987), which results in decreased cardiac output. Additionally, arterial blood pressure and peripheral resistance increase (Bonde-Petersen et al., 1992; Park et al., 1999; Sramek et al., 2000). The increase in peripheral resistance is due to blood being redirected from the periphery to maintain core temperature (Bonde-Petersen et al., 1992;Knight & Londeree, 1980). Oxygen consumption and metabolism also increase to maintain core temperatures (Lee et al., 1997; Park et al., 1999; Sramek et al., 2000).

Reduced permeability of cellular, lymphatic and capillary vessels due to localized vasoconstriction reduces fluid diffusion into the interstitial space (Enwemeka et al., 2001; Eston and Peters, 1999). The reduced fluid diffusion can assist in reducing

acute inflammation from muscle damage (Cote et al., 1988). This in turn can reduce pain, swelling and the lot of force generation that is also associated with inflammation (Smith, 1990). Hence, cold is often used in the treatment of inflammation to improve the rehabilitation process (Cote et al., 1988).

One metabolite that is used as a marker of muscle damage is the level of creatine kinase in blood (Rawson et al., 2001). Exercise induced injury is thought to increase the permeability of cell increasing the diffusion of myoproteins such as creatine kinase into the extracellular space (Enwemeka et al., 2001; Eston and Peters, 1999; Warren et al., 1999). Cold water immersion decrease the level of creatine kinase in the blood after exercise induced muscle damage (Eston and Peters, 1999; Howatson and Van Someren, 2003). Lower creatine levels are attributed to a decrease in cellular, lymphatic, and capillary permeability caused by vasoconstriction induced by the cold temperature (Enwemeka et al., 2001; Eston and Peters, 1999). However, caution is warranted when applying the presence of creatine kinase in the blood reflect not only creatine kinase release rate but also the removal rate. Exercise induced haemoconcentration or haemodilution and alterations of tissue clearance due to blood flow or function will affect creatine concentration in the blood. Creatine kinase may not then accurately indicate muscle damage or fatigue (Warren et al., 1999).

Neural components are also affected by the cold. Cooling of the tissue decrease the rate of transmission along neurons by decreasing the production of acetylcholine (Abramson et al., 1996) and possibly stimulates superficial inhibitory cells that regulate the impulse of pain perception to the central nervous system (Sauis, 1999). Reduction of nerve impulse transmission by cold has two effects, reduced level of pain perception (analgesia), and reduction in muscle spasm (Sauis, 1999; Washington et al., 2000). While reduction in pain may be of benefit, a reduced neural transmission may decrease muscular contractile speed (Abramson et al., 1996; Howard et al., 1994; Rutkove, 2001) and force generating ability of an athlete post application (Johnson and Leider, 1977; Rutkove, 2001; Yona, 1997). Performance may then initially inhibited if exercise is performed shortly after cold immersion.

Considering the use of thermotherapy such as hot baths in physiotherapy there is a lack of research based literature on the effect that superficial heat application

has on a person. Apart from basic physiological responses much of the literature comes from text which cite other texts or is based on anecdotal information.

Superficial application of heat increase subcutaneous and cutanous tissue temperature while tissue temperature at depths over two centimeters remains unchanged (Myer et al., 1997). An increase in superficial tissue temperature causes an increase in the cutaneous blood flow, over short durations, due to peripheral vasodilation (Bonde-Petersen et al., 1992; Knight and Londeree, 1980).

In response to hot water immersion, heart rate increase (Bonde-Petersen et al., 1992; Weston et al., 1987). This increase in heart rate may reduce stroke volume due to lack of cardiac filling time, but overall cardiac output increase compared to thermo-neutral immersion (Weston et al., 1987). The increase in cardiac output and a lower peripheral resistance allows an increase in subcutaneous and cutaneous blood flow (Bonde-Petersen et al., 1992; Weston et al., 1987; Whitney and Wickline, 2003). An increase in subcutaneous and cutaneous blood flow increase the permeability of cellular, lymphatic and capillary vessels (Roberton and Duck, 2001). Increased permeability increases metabolism, nutrient delivery and waste product removal from the cells which can increase healing (Cote et al., 1988; Michlovitz, 1996; Starkie et al., 1999). The increase in metabolism due to heat application also erodes muscle glycogen stores quicker (Starkie et al., 1999). With short duration superficial heat application any physiological changes are not likely to occur within the muscle but rather within the skin (Bonde-Petersen et al., 1992; Myer et al., 1997; Wyper and McNiven, 1976). Bonde-Petersen et al. (1992) observed that while subcutaneous blood flow increased, blood flow through the muscle may decrease with hot water immersion compared to thermo-neutral immersion. Thermo-neutral water temperatures may then have greater benefits in substrate transportation within a muscle.

Superficial heat may also increase neural transmission (Cotts et al., 2004), proprioception and improve reaction time (Burke et al., 2001). Other proposed benefits of thermotherapy include increased muscle elasticity, joint extensibility, analgesia and reduction of muscle spasm (Brukner and Khan, 2001; Coffey et al., 2004; Kaul and Herring, 1994; Michlovitz, 1996; Tonnessen, 1999; Wilk et al., 2004). While a large

amount of anecdotal support is available little research-based evidence has been found to support these claims. Of studies that have analysed the effect of the superficial application of heat, flexibility was not enhanced unless accompanied with stretching (Henricson et al., 1984; Prentice, 1982; Sawyer et al., 2003; Taylor et al., 1995). A report by Bigos et al. (1994) on back pain and thermal applications concluded that not enough data existed to recommend the use of heat in pain reduction.

2.10 Physiology of soccer

2.10.1 Energy demands of Soccer

There are three major systems available for the production of energy in the muscles: the ATP-PC system for high-intensity short bursts; the anaerobic glycolysis system for intermediate bursts of relatively high intensity (this system produces the by products of lactate ions and hydrogen ions, commonly known as lactic acid) and finally, there is the aerobic system for long efforts of low to moderate intensity. With sporting events such as cycling, swimming and running, where the intensity is constant for the duration of the event, it is possible to estimate the relative contribution of each energy system. For example, the energy for the 100 meter sprint is split 50% from the ATP-PC system and 50% from the anaerobic glycolysis system, whereas the marathon relies entirely on the aerobic system (Newsholme et al, 1992). By contrast, games such as soccer are characterized by variations in intensity. Short sprints are interspersed with periods of jogging, walking, moderate-paced running and standing still. This kind of activity has been termed "maximal intermittent exercise".

It would seem reasonable to assume that during a football game all three energy systems would be required, as intensity varies from low to very high. However, because it is not obvious just how fast, how many and how long the sprints are, and just how easy and how long the intervening periods are, it is difficult to determine which of the energy systems are most important. Most of the soccer-related research has attempted to tackle this problem. English researchers Reilly and Thomas (1976) investigated the patterns of soccer play in the old first division. They found that a player would change activity every 5 to 6 seconds, and on average he would sprint for 15 meters every 90 seconds. They found the total distance covered varied from 8 to

11km for an outfield player - 25% of the distance was covered walking, 37% jogging, 20% running below top speed, 11% sprinting and 7% running backwards. Ohashi and colleagues (1988) researching soccer in Japan, confirmed these findings, showing 70% of the distance was covered at low to moderate pace below 4m/s, with the remaining 30% covered by running or sprinting at above 4m/s. Thus, for example, if a soccer player covers 10km in total, around 3km will be done at fast pace, of which probably around 1km will be done at top speed.

The pattern of football play has also been expressed in terms of time. Apor (1988) and Ohashi and colleagues (1988) both describe soccer as comprising sprints of 3 to 5 seconds interspersed with rest periods of jogging and walking of 30 to 90 seconds. Therefore, the high to low intensity activity ratio is between 1:10 to 1:20 with respect to time. The aerobic system will be contributing most when the players' activity is low to moderate, i.e. when they are walking, jogging and running below maximum. Conversely, the ATP-PC and anaerobic glycolysis systems will contribute during high-intensity periods. These two systems can create energy at a high rate and so are used when intensity is high. The above research has described the average patterns of play during soccer and from this we can reasonably deduce when each of the energy systems is contributing most. However, now we need to establish just how important each energy system is for success.

There is evidence that the aerobic system is extremely important for football. Along with the fact that players can cover over 10km in a match, Reilly (1990) found heart rate to average 157 bpm. This is the equivalent of operating at 75% of your VO2max for 90 minutes, showing that aerobic contributions are significant. This is confirmed by the fact that various studies have shown soccer player to have VO2max scores of 55 to 65 ml/kg/min. These VO2max scores represent moderately high aerobic power. Reilly and Thomas (1976) showed that there was a high correlation between a player's VO2max and the distance covered in a game. This was supported by Smaros (1980) who also showed that VO2max correlated highly with the number of sprints attempted in a game. These two findings show that a high level of aerobic fitness is very beneficial to a soccer player.

The greater the player's aerobic power the quicker he can recover from the high-intensity bursts. These short bursts will be fuelled by the ATP-PC and anaerobic

glycolysis systems. Then, during rest periods, a large blood flow is required to replace the used-up phosphate and oxygen stores in the muscles and to help remove any lactate and hydrogen ion by-products. The quicker this is achieved, the sooner a player can repeat the high-intensity sprints, and thus cover more distance and be able to attempt more sprints. Therefore, the aerobic system is crucial for fuelling the low to moderate activities during the game, and as a means of recovery between high-intensity bursts.

As already mentioned the ATP-PC and anaerobic glycolysis systems fuel the high-intensity periods. However, if we are to optimize training programs, we need to know whether in performing the high-intensity bursts both systems contribute evenly or whether one is more important. As the sprints a player makes are mostly 10 to 25 meters in length, or 3 to 5 seconds in duration, some researchers have assumed that the ATP-PC system will be the most important. However, since soccer has an intermittent intensity pattern, just because the sprints are brief does not mean that anaerobic glycolysis does not occur; research has shown that anaerobic glycolysis will begin within 3 seconds. To determine whether anaerobic glycolysis is significant during soccer game, researchers have analysed blood lactates during match play. However, results from these studies have varied. Tumilty and colleagues (1988) from Australia cite research varying from 2 mmol/L, which is a low lactate score indicating little anaerobic glycolysis, to 12 mmol/L, which is quite a high score. Most studies seem to find values in the 4-8 mmol/L range, which suggests that anaerobic glycolysis has a role.

CHAPTER III
METHODS

3.1 Subject

Twenty eight male soccer players, Mahidol University students, volunteer in this study. Subjects will be informed for purposes, procedures, benefits and risks of the study. After completion of informed consent form, experiment will be started at the same time of the day to avoid variability attributable to the circadian rhythm of body temperature.

3.1.1 Inclusion criteria are as follows:

- Healthy, no physical or mental abnormality which may affect testing procedure
- Subject is currently trained under the same training protocol.
- Not participate with any heavy exercise
- No history of recent injuries, cardio-respiratory problems, neuromusculardiseases, chest injuries or operation, joint, muscle and bone injuries.
- Subject can participate and complete experimental project.

3.1.2 Exclusion criteria: Subject will be excluded from the study when one of the followings is met.

- Having cardiovascular disease, hypertension, or hypotension, any respiratory disease, chest injury or operation, any neuro-muscular disease, joint or muscle dysfunction which may affect the exercise test.
- Having any skin infectious diseases.
- Unable to sustained exercise test
- Unable to cope with cold and warm immersion
- Taking any medicines that affect the cardio-respiratory and metabolic system and level of consciousness within 24 hours before testing.

- Drinking alcohol or caffeine within 24 hours before testing.

3.1.3 Criteria to terminate exercise

- Exercise testing will be terminated as follows:
- Subject voluntarily aims to stop
- -Perceived exertion and vital signs approach target termination criteria as follows
    - RPE = 19 point scale
    - BP = 140/90 mmHg
    - HR = 220 – age (year)
    - Core temperature over 39.5°C (Hyperthermia) or less than 35°C (Hypothermia)
    - Any signs and symptoms of physical or mental deteriorations

3.2 Study Designs

This is a cross-sectional study with two-factorial designs; temperature and time. Factor 1 has 3 sub-levels of different temperatures, including cold, warm and ambient temperatures. Factor 2 is time series during 15 min recovery period, in which data will be collected at every 5 min interval. No other types of intervention will be added in this study.

3.3 Parameters

3.3.1. Anthropometric variables

- Age (yrs)
- Height (m)
- Body Weight (kg)
- Body mass index (BMI)

3.3.2. Vital signs: at rest, during and after exercise

- Heart rate (beat/min)
- Blood pressure (mmHg)

3.3.3 Blood chemistry: at rest, immediately after intervention and immediately after 1st and 2nd intermitten exercise

- Blood lactate (mmol/L)

3.3.4 Body temperatures: at rest, during and after exercise

- Rectal temperature (°C)
- Skin temperatures (°C) at chest, upper arm, thigh and calf

3.3.5 Participant perception

- The Borg 6-20 scale of rating perceived exertion (RPE) was used to determine the participants' perception of exercise intensity.
- 12-point thermal sensation (1 = Unbearably cold to 12 = Unbearably hot) was used to determine the participants' thermal sensation during protocol.

3.3.6 Physical Performance

- Peak power (watt/kg)

3.4 Instrumentation

1. Cycle ergometer (Monark Groningen, Sweden) (Figure 1)
2. Telemetry heart rate monitor (Polar, Finland) (Figure 2)
3. Accutrend® lactate portable lactate analyzer (Roche Mannheim, Germany) (Figure 3 No.1)
4. Softclix® blue kit (Germany) (Figure 3 No.2)
5. Accu-check® Softclix® II Lancet (Germany) (Figure 3 No.3)
6. BM-Lactate® test stip (Figure 3 No.4)
7. The modified Borg perceived exertion scale (Table 1)

8. Thermal sensation scale (Table 2)
9. Data logger (Grant Squirrel, England) (Figure 4 No.1)
10. Skin Thermistor probes (Figure 4 No.2)
11. Rectal Thermistor probes (Figure 4 No.3)
12. Digital weight scale
13. Stethoscope
14. Sphygmomanometer
15. Height scale
16. Time watch
17. 70% Alcohol solution
18. Water bath
19. Hot water conditioner
20. Plaster tape

Figure 3.1 Cycle ergometer (Monark 894E, Groningen, Sweden)

Figure 3.2 Telemetry heart rate monitor (Polar, Finland)

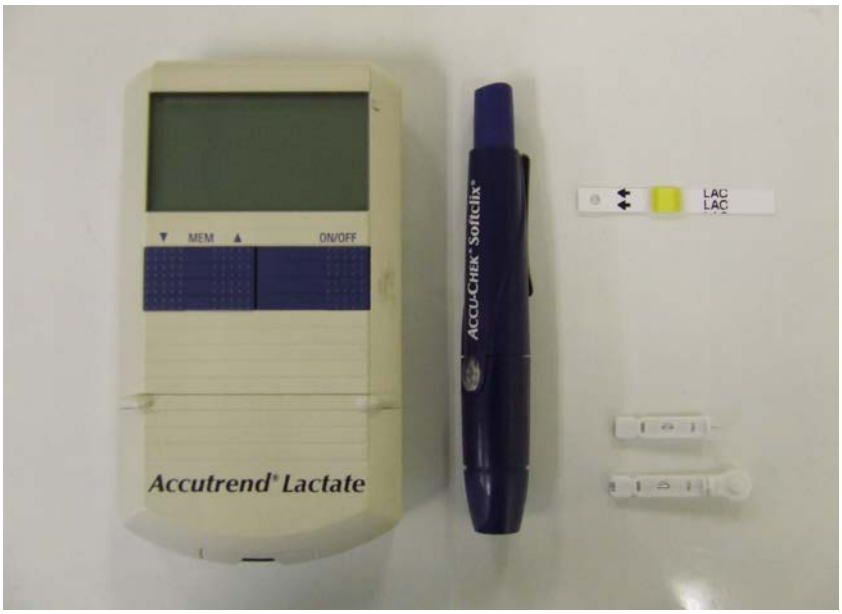


Figure 3.3 Set of instrument for determination of blood lactate concentration

Figure 3.4 Set of instrument for determination of body temperature.

Table 3.1 The Borg perceived exertion scale

Scale	Verbal expression
6	
7	Very, very light
8	
9	Very light
10	
11	Fairy light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Table 3.2 The 13-point thermal sensation scales

Scale	Verbal expression
1	Unbearably cold
2	Extremely cold
3	Very cold
4	Cold
5	Cool
6	Neutral
7	Slightly warm
8	Warm
9	Hot
10	Very hot
11	Extremely hot
12	Unbearably hot

3.5 Experimental procedure

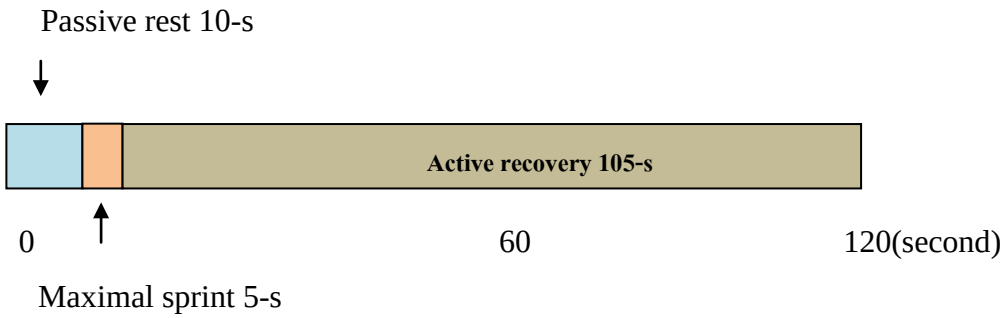
Subjects will be randomly divided in to 4 groups: group 1(passive rest : control group, CT); group 2 (ambient temperature water immersion, AW): and group 3 (cold temperature water immersion; 15°C, CW), and 4 (warm temperature water immersion; 39°C, WW). The experiment will be conducted at the 1st floor laboratory room of the College of Sport Science and Technology, Mahidol University. Daily ambient temperature will be recorded.

On the day prior to the test, subjects will be asked to rest adequately, consume their regular meals at least 1-2 h before testing, and avoid beverages containing caffeine, alcohol and smoking. No heavy physical activity is allowed. Subjects arrive to laboratory at least 1 h before the test. Subjects wear their usual soccer uniform with sock and running shoes. After 15 minutes resting baseline measurements, including body mass, height, resting heart rate, blood pressure and resting blood lactate will be monitored. To ensure euhydration status, subjects will be informed to drink ambient temperature water at 1.5% of body mass within an hour

prior to the experiment time. After baseline vital signs are achieved, a rectal thermistor probe will be self-inserted about 10 cm depth via anal sphincter. Skin temperature thermistors probe will be attached to the right side of the body on the chest, upper arm, thigh and calf. The other ends of these thermisters will be connected to data logger (Grant Squirrel, England). Heart rate monitor will be fitted to the chest. Before the 45 min intermittent cycling test subject will be performed a 5 min warm up on stationary cycle ergometer (Monark, Germany) with constant freeload.

After sitting on cycle ergometer, subject will perform a continuous 45 min cycling intermittent sprint protocol (Paul et al, 2006). The cycling intermittent sprint protocol involved 22 sets of 2 min period, consist of 10-s of passive rest, 5-s maximal sprint from a stationary start against a resistance of 7.5% body weight, follow by 105-s 0f active recovery. After completion of the first cycling test, subject will be randomly undergone a 15-min recovery intervention. After recovery intervention, subject will perform a 5 min warm up and repeat a second 45 min cycling test with the same previous.

Figure 3.5 Diagram depicting a single set of cycling intermittent sprint protocol



In recovery period subjects underwent seated water immersion up to the level of the umbilicus for 15 min at difference temperature (AWI, CWI and WWI). Maximum surface area exposure to the water was obtained by keeping the legs apart. In the control recovery condition, the same period of time was spent in seated rest at room temperature (°C).

Blood sample was obtained from the fingertip using a standard hygienic finger puncture method. The puncture was induced using Accu-check® Softclix® II Lancet (Figure 3.3). During blood collection, subject was instructed to relax the hand.

After finger selection, fingertip was cleaned with the alcohol. Drop of blood were placed on lactate test strip and then analyzed immediately using portable lactate analyzer (Accutrend® lactate, Roche Mannheim, Germany) (Figure 3 No.1). The result of blood lactate concentration was shown within 1 minute. After blood collection, blood was stopped using a brief compression and cover with plastic adhesive bandage. Series of four blood samples were collected for each protocol before and immediately after the first 45 min cycling test, after recovery intervention and immediately after repeat the second 45 min cycling test.

Heart rate, core and skin temperatures will be continuously monitored throughout the test and will be recorded every 5 min during cycling test and recovery period.

The modified Borg's scale of perceived exertion (RPE) consisted of series of 6-20 scale to indicate his total inner feeling of exertion during exercise and recovery. Thermal sensation scale (TS) has number range from 1 (Unbearably cold) to 6 (Neutral), finally to 12 (Unbearably hot) will be asked every 5 min during cycling test and recovery period.

3.6 Statistical analysis

This is a cross-sectional study with two-factorial designs: different temperatures and time series. To investigate the effect of thermoregulatory adjustments to cold, warm and ambient water temperatures during immersion, ANOVA will be used for comparison among groups at specific time series. Within the group comparison will be employed using Repeated-Measured ANOVA at different time series of the same group. Two subsequent vigorous physical performances, pre- and post-intervention, will be compared using Student t-test. Level of significance is set at $p < 0.05$.

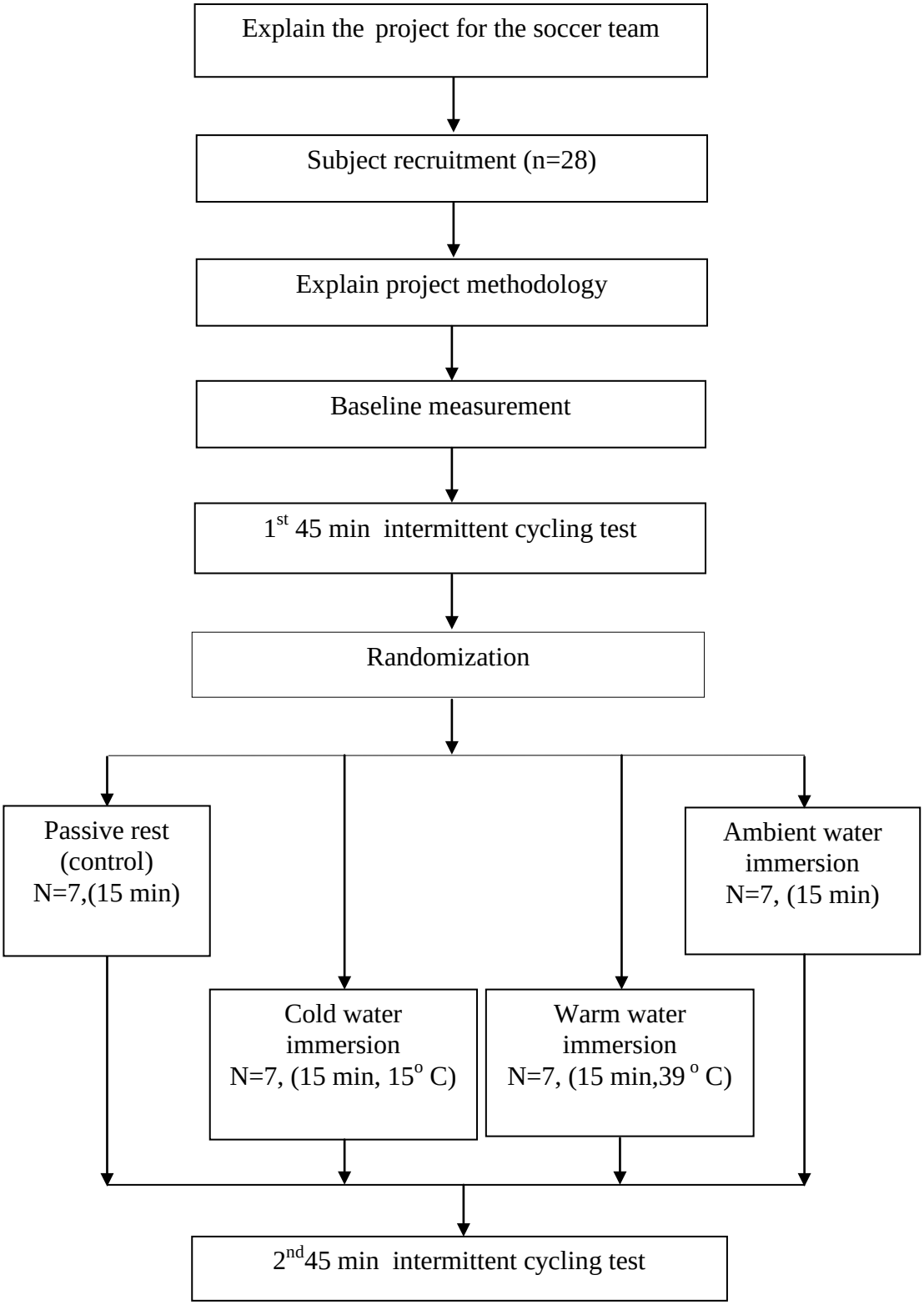
Table 3.3 Water of different temperatures immersion at different trials

Trial	Temperature of water (°C)
1	Without immersion water (CT)
2	Ambient water (AW, 28-30)
3	Warm water (WW, 39±1)
4	Cold water (CW, 15±1)

Table 3.4 Means and SD of room temperature throughout the study.

Trial	Temperature (°C)
1	32.87±0.04
2	31.69±0.06
3	27.57±0.09
4	29.79±0.04

Figure 3.6 The scheme of Experimental procedure.



CHAPTER IV
RESULTS

The objectives of this study were to investigate the physiological and thermoregulatory responses to water immersion of different temperatures: ambient, cold and warm water and to investigate the relationships between temperature of water and subsequent repeated physical performance in soccer player.

There were three temperatures of water immersion randomly experimental; ambient-temperature water (AW, 27°C), warm water (WW, 39°C), cold water (CW, 15°C). No water immersion was also included in this study as the controlled trial (PR). All results were analyzed both within and between each group using SPSS 16.0 for Window statistical package and presented as mean and standard error of the means (mean±SEM), otherwise will be stated. Significant level was set at $\alpha<0.05$.

The investigated parameters included rectal temperature, skin temperature (chest, arm, thigh, calf), heart, rate blood pressure, blood lactate, rating of perceived exertion, thermal sensation, and peak power. The results would be shown and discussed into six topics as subject characteristic, thermoregulatory responses, cardiovascular responses, blood chemistry, subject perception and physical performance respectively.

Statistical comparison within-group in this study will be presented as Table with 5 abbreviations: * represents significantly different from its corresponding initial value, ‡ represents significantly different from previous value, † represents significantly different between trial 1 and 2 at the same corresponding time, α represents significantly different between initial value trial 1 and trial 2 and β represents significantly different between final value trial 1 and trial 2. Between groups comparison will be presented as graph with 4 abbreviations: *a* represents significantly different between water immersion groups and control at the same time, *b* represents significantly different between ambient water group (AW) and warm water group (WW) at the same time, *c* represents significantly different between ambient

water group (AW) and cold water group (CW) at the same time and *d* represents significantly different between warm water group (WW) and cold water group (CW) at the same time.

4.1 Subject characteristics

Table 4.1 Subject characteristics.

Subjects' age, weight, and height were presented as mean and SD of 22.11±2.15 years, 59.83±6.69 kg, and 166.44±3.50 cm, respectively. The subject characteristics were found not significant between group (p>0.05).

Variable	Group 1(CT)	Group 2(AW)	Group 3(WW)	Group 4(CW)
Age(yrs)	19±0.58	19±1.0	19.4±0.79	18.9±0.69
Weight(kg)	63.7±7.41	63.7±6.85	63.9±7.52	63.7±7.04
Height(m)	1.69±0.04	1.75±0.06	1.73±0.06	1.71±0.01
BMI(kg/m^2)	22.08±3.36	20.86±1.21	21.23±1.34	21.87±1.95

Data are presented as mean±SD

* Significant different between group (p>0.05).

4.2 Thermoregulatory Responses

4.2.1 Rectal Temperature

Rectal temperature (Tr) between trials were illustrated in Figure 12.The subjects' rectal temperatures in CT, AW, WW, and CW were measure every 5 minutes during experimental. The room temperature in CT, AW, WW, and CW were 32.87±0.04, 31.69±0.06, 27.57±0.09 and 29.79±0.04 degree Celsius (°C), respectively.

Within at trial 1, in control shown that Tr significant increased from initial value at min 0 (subject sat on bicycle before trial) until end of trial 1 but all of water immersion groups Tr significant increased at min 5 until end of trial 1 (p>0.05). During half-time recovery all of groups were shown significant decreased from end of trial 1 but all time of half-time recovery Tr was higher than initial value (p>0.05). In trial 2 all of groups were shown increased in Tr from initial value, in control was

significant increased at min 55 to end of trial, AW was significant increased at min 60 to end of trial, WW found was significant increased at min 65 to end of trial, and CW was significant increased at min 60 to end of trial (p>0.05). In all time of trial 2 Tr significant higher from initial value in all group (p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences in all groups with Tr in trial 2 were found higher than trial 1 (p>0.05). For final value was found significant differences only in control with trial 2 was higher trial 1 (p>0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. In control was found significant differences in all corresponding time with values in trial 2 were higher than trial 1 (p>0.05). In other water immersion groups were found significant differences in some time. AW and WW were found differences in min 40-85, min 45-90 and min 35-80, min 40-85, min 45-90, respectively (p>0.05). In CW group was found differences in first 15 minutes in each trial 1 and trial 2 and after that no differences was found (p>0.05).

In between group, in trial 1 not found significant differences between all of groups (p>0.05). During half-time recovery was found significant differences between AW and WW (p>0.05) and significant differences between WW and CW at min 10, 15 (p>0.05). In trial 2 was found significant differences from control in AW and CW all time of trial 2 but in WW was found differences from control only in min 85, 90 (p>0.05). For comparison between water immersion groups was found significant differences between AW and WW from started in trial 2 until min 65 and significant differences between WW and CW from started in trial 2 until min 75 (p>0.05).

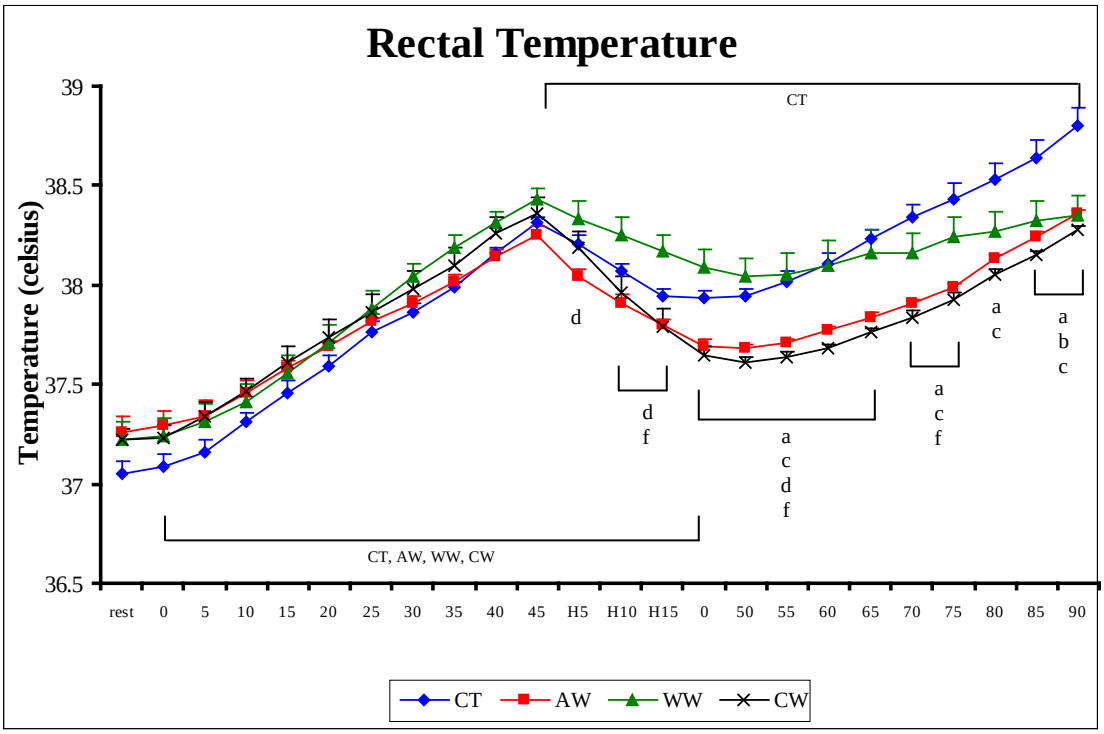


Figure 4.1 Rectal Temperature (Tr) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.2.2 Mean Skin Temperature (Tsk)

Within at trial 1, in CT, WW and CW shown that Tsk significant increased from rest until end of trial 1 but in AW shown significant in min 5, 15 (p>0.05). During half-time recovery, CT, AW and CW groups were shown significant decreased from end of trial 1 but in WW shown increase (p>0.05). In trial 2 all of groups were shown increased Tsk in different time from initial value, in control was significant increased at min 60 to end of trial, AW was significant increased at min 75 to end of trial, WW found was significant increased only min 55, and CW was significant increased at all time of trial 2 (p>0.05). In all time of trial 2 Tsk in CW significant lower than initial value at rest (p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences in CT and CW with Tsk in trial 2 were found lower than trial 1 (p>0.05). For final value was found significant differences in CT and CW with trial 2 lower than trial 1 (p>0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. In control was found significant differences in the first 10 minutes and the last 20 (p>0.05). In AW and WW were found significant differences in some time. In CW group was found differences in all time of trial (p>0.05).

In between group, in trial 1 found significant differences between CT and WW in min0- min45 and found significant differences between AW-WW, AW-CW and WW-CW in min25-min45(p>0.05). During half-time recovery was found significant differences between CT-CW, AW-CW and WW-CW (p>0.05). In trial 2 was found significant differences in CT-CW, AW-CW and WW-CW (p>0.05).

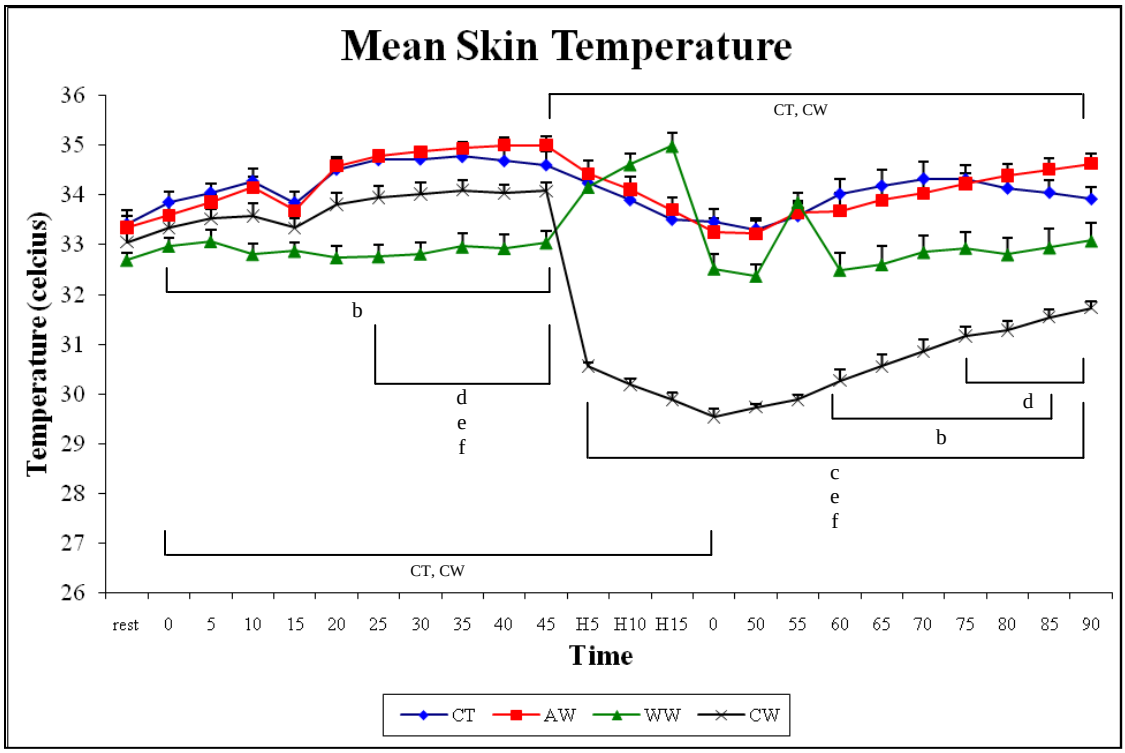


Figure 4.2 Mean Skin Temperature (Tsk) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.3 Cardiovascular Responses

4.3.1 Heart Rate

Figure 4.3 shows the heart rate (HR) influences of exercise and recovery intervention on several times. At rest Heart Rate were 65.29±3.05, 63.14±2.60, 69.57±2.51, 63.71±1.76 beat per minute (bpm) in respectively.

Within at trial 1, in all groups were shown that HR significant increased from initial value at min 0 (subject sat on bicycle before trial) until end of trial 1 (p>0.05). During half-time recovery all of groups were shown significant decreased from end of trial 1 but all time of half-time recovery HR was higher than initial value (p>0.05). In trial 2 all of groups were shown intermediately increased in HR from initial value of trial 2, In all time of trial 2 HR significant higher from initial value in all group (p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences only in WW with HR in trial 2 were found higher than trial 1 (p>0.05). For final value not found significant differences (p>0.05).

During half-time recovery HR within each group were lower than after exercise (p<0.05). The differences between group were found only min 5 in CT-CW (p>0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. In control was found significant differences in min 5 and min 10 with values in trial 2 were higher than trial 1 (p>0.05). In AW was found significant in only initial value (min 0) (p>0.05).WW was found differences in min 5-25 (p>0.05). Not found differences between trial 1 and trial 2 in CW group (p>0.05).

In between group, No significant difference between all groups was found throughout trial 1 and trial 2 (p>0.05). The significant difference between group was found only between CT and CW at min 5 during half time (p>0.05).

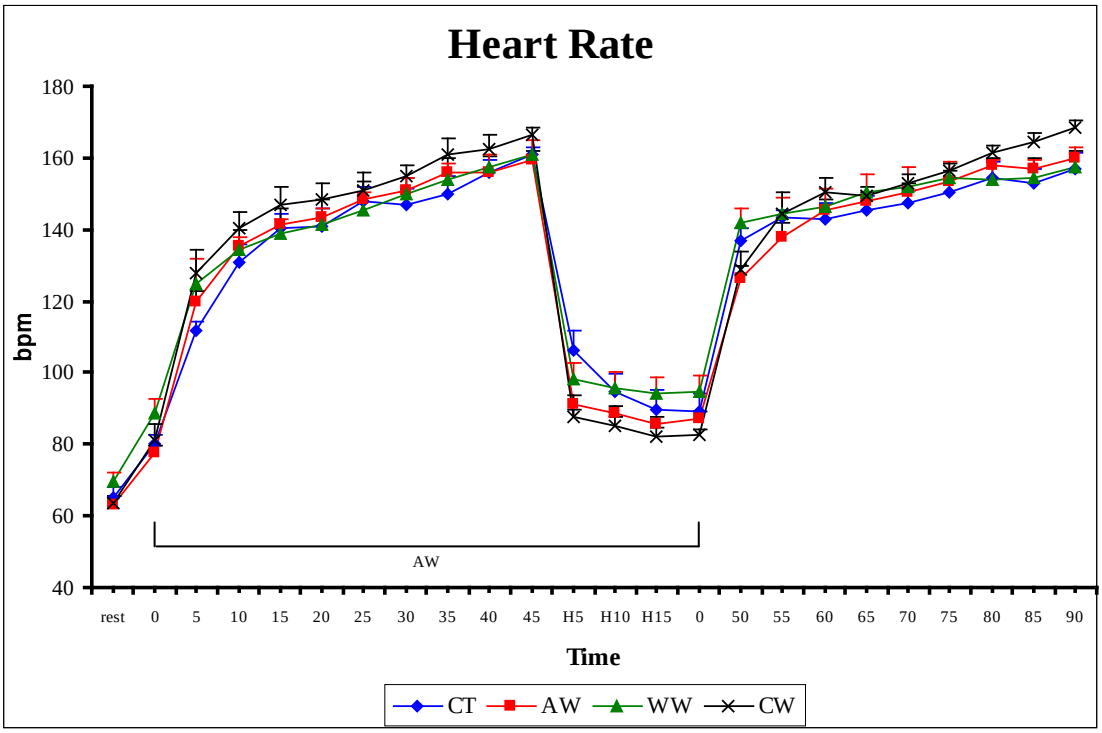


Figure 4.3 Heart Rate (HR) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.3.2 Systolic Blood Pressure

Systolic blood pressures (SBP) of the subjects obtained from four trials were showed in Figure 4.4. The measured SBP before exercise (T0 1st) were 121.43±1.43, 115.71±2.02, 121.43±1.43, 115.71±2.02 mmHg for CT, AW, WW, and CW respectively.

Within at trial 1, in all groups were shown that SBP significant increased from initial value at min 0 (subject sat on bicycle before trial) until end of trial 1 (p>0.05). During half-time recovery all of groups were shown significant decreased from end of trial 1 and no significant differences from initial value in all group (p>0.05). In trial 2 all of groups were shown rapidly increased in SBP from initial value of trial 2, In all time of trial 2 SBP significant higher from initial value in all group (p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences only in Control group, but not found significant differences in final value between trial 1 and trial 2 in all groups (p>0.05).

During half-time recovery the SBP significant decreasing from exercise min45 in all groups and the differences between group not found (p<0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. In control was found significant differences only in start trial with values in trial 1 was higher than trial 2 (p>0.05). In intervention group were found no significant between trial 1 and trial 2 (p>0.05).

In between group, No significant difference between all groups was found throughout trial 1 and trial 2 (p>0.05).

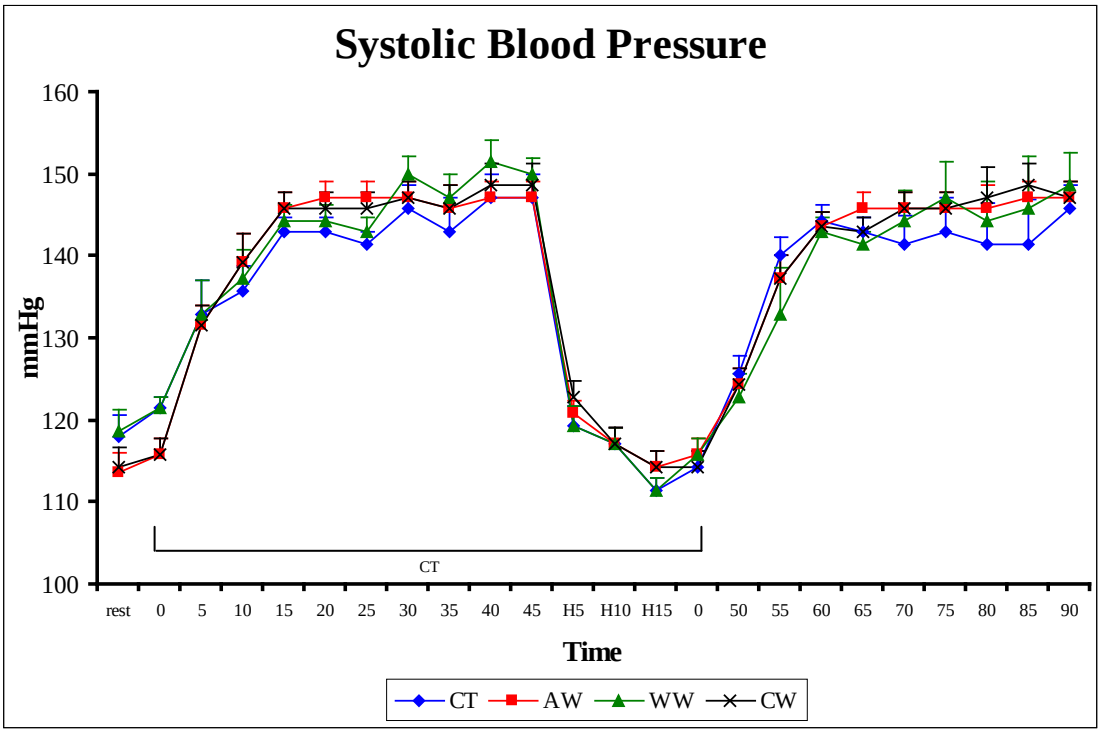


Figure 4.4 Systolic blood pressures (SBP) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.3.3 Diastolic Blood Pressure

Figure 4.5 shows diastolic blood pressure (DBP) of the subjects in each group. Subjects' DBP before exercise (T0 1st) in CT, AW, WW, and CW were 73.57±2.37, 70.00±1.89, 73.57±2.37, 70.00±1.89 mmHg respectively.

Within at trial 1, in CT and AW groups were shown that DBP began decrease from initial value at min 0 but DBP was found significant decrease in min 25 only (p>0.05). In WW group DBP significant decrease in min 20 and min 25 during trial 1 (p>0.05). In CW group was shown that DBP decrease in last 20 minutes of trial 1(p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences only in AW group, but not found significant differences in final value between trial 1 and trial 2 in all groups (p>0.05).

During half-time recovery not shown significant between groups (p>0.05).

In between groups, No significant difference between groups was found in all time trial 1 and trial 2 (p>0.05).

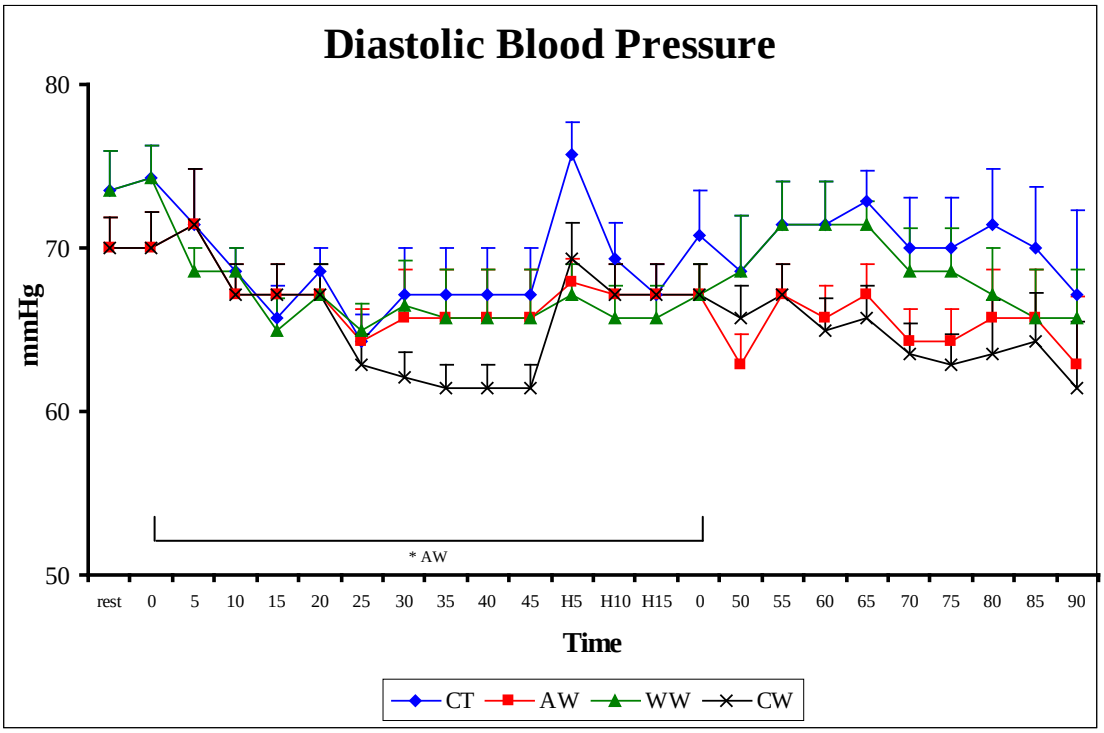


Figure 4.5 Diastolic blood pressures (DBP) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.5 Blood Lactate

Figure 4.6 shows blood lactate concentration in each trial at four difference time (at rest, after first-half exercise , after half-time recovery and after second-halve exercise).

Blood lactate at rest were 3.00±0.48, 2.24±0.16, 2.94±0.33, 3.16±0.47 for CT, AW, WW, and CW respectively and not difference between all groups (p<0.05). After first half exercise blood lactate were significant increased in all groups, and no significant between groups (p<0.05).

After intervention blood lactate were decreased in CT, WW and CW (p<0.05). In CT and AW were significant difference from resting and significant difference between CT and AW were found (p<0.05).

After second halve exercise blood lactate in AW and WW were lower than CT and no different between CT and CW (p<0.05). In all groups were differences from resting and in CT, WW and CW were increased from after intervention (p<0.05).

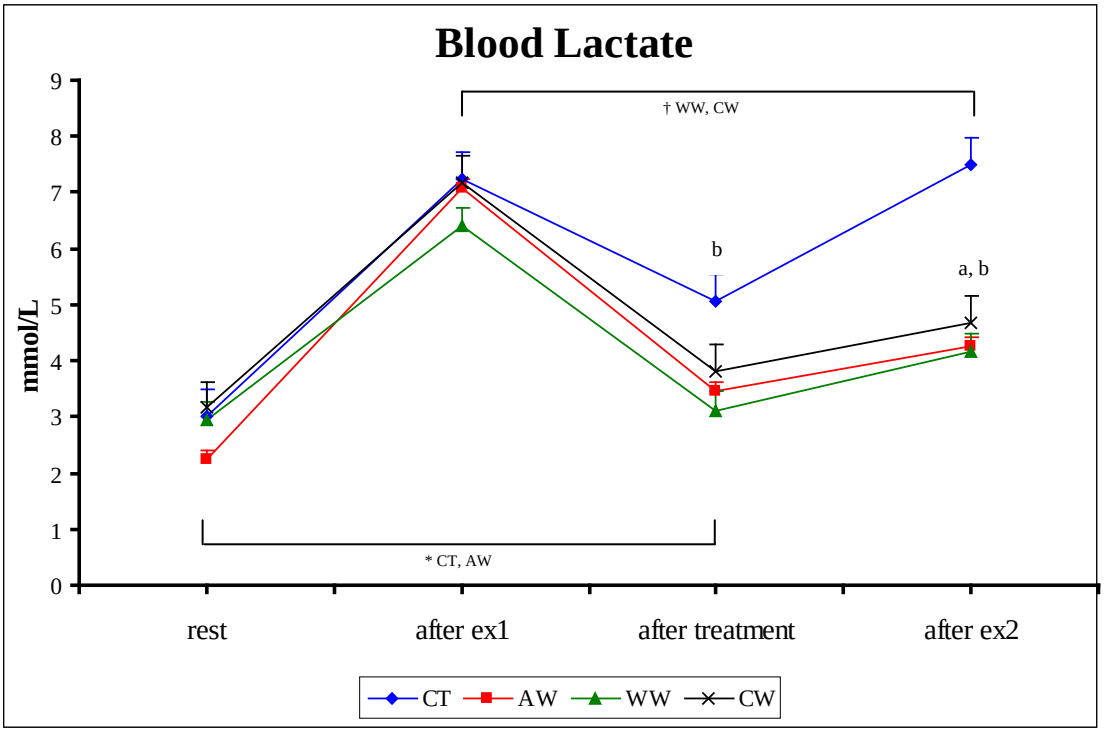


Figure 4.6 Blood lactate during experimental measured at rest, after first-half exercise, after half-time intervention and after second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.6 Subjects Perception

4.6.1 Rating of Perceived Exertion

Figure 4.7 shows rating of perceived exertion (RPE) from all subjects in four trials. At rest, RPE in CT, AW, WW and CW were 6.14±0.14, 6.14±0.14, 6.00±0.00 and 6.14±0.14, respectively.

Within at trial 1, in all groups were shown that RPE significant increased from initial value at min 0 until end of trial 1 (p>0.05). During half-time recovery all of groups were shown significant decreased from end of trial 1 and no significant differences from initial value in all group (p>0.05). In trial 2 all of groups were shown rapidly increased in RPE from initial value of trial 2, In all time of trial 2 RPE significant higher from initial value in all group (p>0.05).

For comparison initial value between trial 1 and trial 2 was found significant differences only in WW group, but not found significant differences in final value between trial 1 and trial 2 in all groups (p>0.05).

During half-time recovery the RPE significant decreasing from exercise min 45 in all groups and the differences between group not found (p<0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. Not found significant differences between trial 1 and trial 2 in all groups (p>0.05).

In between group, No significant difference between all groups was found throughout trial 1 and trial 2 (p>0.05).

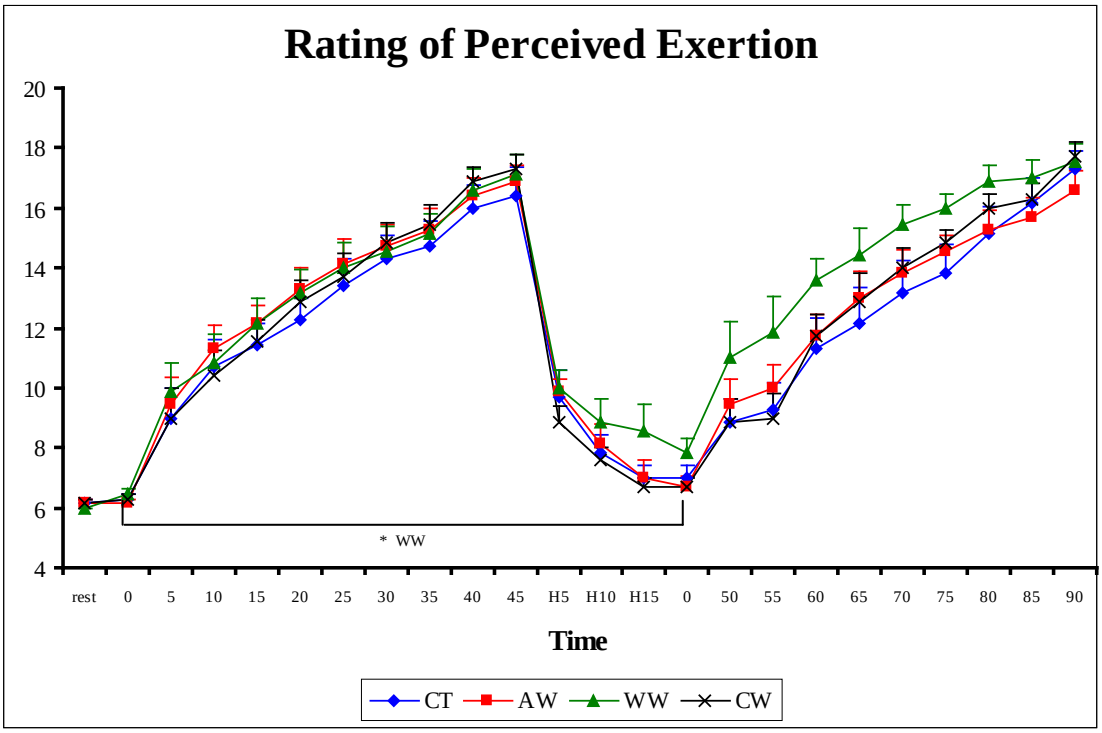


Figure 4.7 Rating of perceived exertion (RPE) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.6.2 Thermal Sensation

Thermal sensation (TS) between trials was illustrated in Figure 4.8. At rest, TS in CT, AW, WW and CW were 6.00±0.00 in all groups.

Within at trial 1, in all groups were shown that TS significant increased from initial value until end of trial 1 (p>0.05). During half-time recovery all of groups were shown significant decreased from end of trial 1(p>0.05). In trial 2 all of groups were shown increased in from initial value.

For comparison initial value between trial 1 and trial 2 was found significant differences only in WW and CW groups (p>0.05).

The comparison between trial 1 and trial 2 at the same corresponding time was observed in each group. In control was found significant differences only in min 45 with trial 2 were higher than trial 1 (p>0.05). In AW were found in min 35 between trial 1 and trial 2. In CW group was found differences in the first 10 minutes in each trial 1 and trial 2 (p>0.05).

In between group, in trial 1 not found significant differences between all groups (p>0.05). During half-time recovery was found significant differences between CT – CW, AW – WW, AW – CW, and WW – CW (p>0.05). In trial 2 was found significant differences between WW – CW in min 0 to min 55.

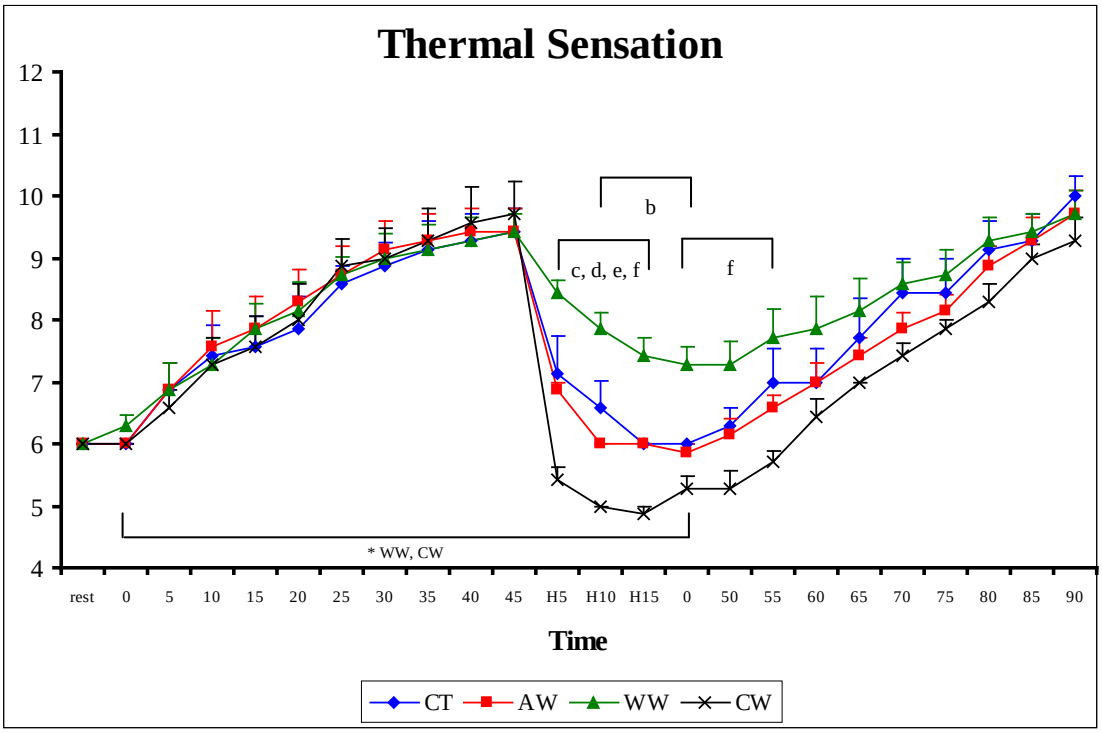


Figure 4.8 Thermal sensation (TS) at rest and during experimental measured at every 5 minutes interval, during first-half exercise, half-time intervention and second-halve exercise.

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

4.7 Peak Power

Figure 4.9 shows peak power during two halves exercise in each group. During exercise peak power was record every 2 minutes. Peak power during exercise was slightly decrease thought out exercise. No significant differences between group were found (p<0.05).

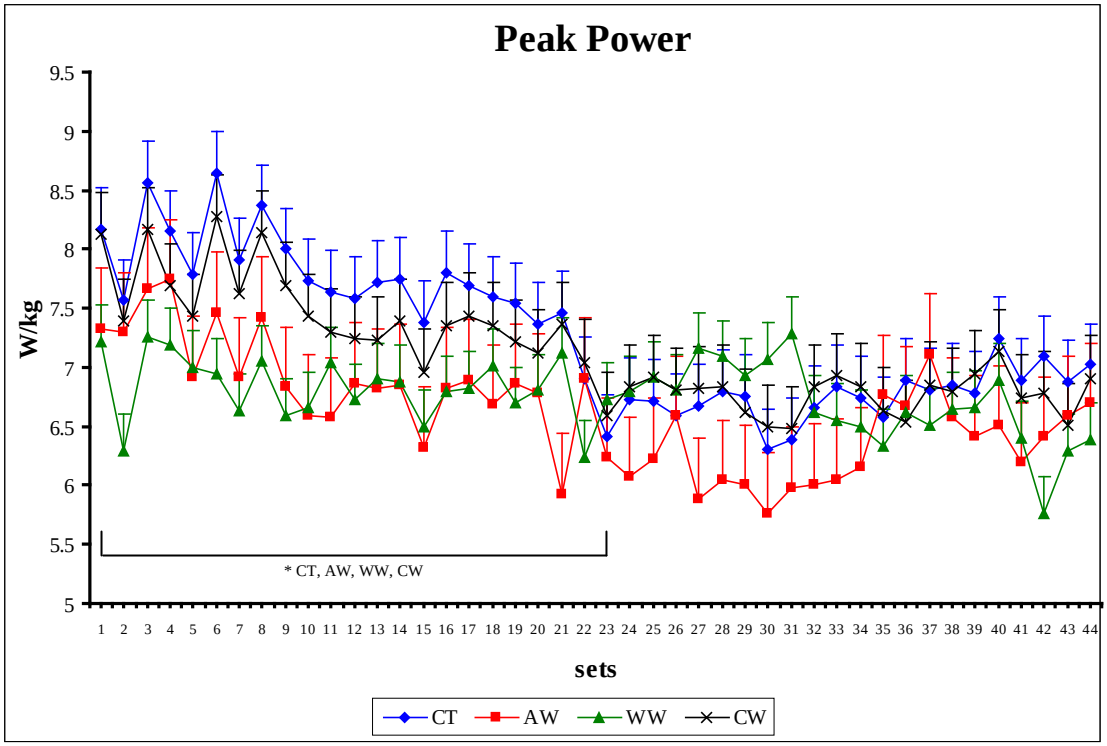


Figure 4.9 Peak Power (PP) during experimental measured at every 2 minutes interval, during first-half exercise (set 1-22) and second-halve exercise (set 23-44).

* Significant different between T0 1st and T0 2nd (p<0.05)

† Significant different between T45 and T90 (p<0.05).

a Significant different between CT and AW at the same time (p<0.05).

b Significant different between CT and WW at the same time (p<0.05).

c Significant different between CT and CW at the same time (p<0.05).

d Significant different between AW and WW at the same time (p<0.05).

e Significant different between AW and CW at the same time (p<0.05).

f Significant different between WW and CW at the same time (p<0.05).

CHAPTER V
DISCUSSION

The aim of this investigation was to study effect of lower water immersion at difference water temperature during 15 min half-time recovery on thermoregulatory and physical performance. It was hypothesizes that water immersion might effect both thermoregulatory and improve physical performance.

Recently, the use of various forms of water immersion such as cold water immersion, warm/hot water immersion, and contrast water therapy a post-exercise recovery strategy has become increasingly popularity and are now a common practice within the elite sporting environments (Cochrane 2004; Vaile et al, 2007).

Water immersion techniques used in the past have included whole body immersion (Bergh and Ekblom, 1979; Bolster et al, 1999; Booth et al, 1997; Gonzalez-Alonso et al, 1999), lower body immersion (White et al, 2000; Crowe et al 2006; Schniepp et al, 2002). Previously, cold water immersion has been used as a method of pre-cooling before exercise in an attempt to improve performance in hot and humid environmental condition. Various studies have shown cold water immersion (Eston and Peters, 1999; Merrick et al, 1999) and pre-cooling (Yanagisawa et al, 2004; Kay et al, 1999; Marsh and sleivert, 1999) to be effective, providing positive results for recovery and/or subsequent performance.

A few studies investigated cold water immersion between bout of exercises (Lane and Wenger, 2004; Crowe et al 2006; Schniepp et al, 2002; Susan et al, 2006). The present study interested the water immersion intervention as a post-exercise recovery strategy rather than a pre-cooling strategy, and observed the effect of different water temperature (15˚C, 30˚C, 39˚C). Lower body water immersion was selected for this study because more practical that can be applied during a common field game.

Main physiological effects resulting from immersion in cold water induces a fall of internal body temperature (Cannon and Keatinge, 1960; Craig and Dvorak, 1966; Holmer and Bergh, 1974; Sloan and Keatinge, 1973), localized vasoconstriction

and decreased blood flow that may be reduce edema (Meeusen and Lievens, 1986), decreased perception of pain (Cheung et al, 2003; Meeusen and Lievens, 1986). Hot water has been shown including an increase in blood flow, heart rate, and cardiac output, tissue temperature, decrease in peripheral resistance, and may enhance the inflammatory response (Wilcock et al, 2006). For ambient water showed increase stroke volume, cardiac output (4), and in some study show decrease heart rate and systolic and diastolic blood pressure (5).

5.1 Performance

The first important finding was that in the study showed that peak power during intermittent cycling test was not positively affected by water immersion when performance tests were 15 min apart. The findings were a significant decrease in peak power in all groups. The second finding all group of water immersion prevents excessive rectal temperature during second halves. The third immersion in ambient and warm temperature was reduced blood lactate concentration in second-halves.

The main finding indicated that water immersions not improve exercise performance in second halves compared to control. The negative effect of water immersion in current study support previous studies were maximum and average power significantly decreased when maximal 30-s cycling sprints were separated by 15 min of CW (12˚C) compared to passive rest (13). Similary, Crowe and colleagues (2006) showed that lower cold water immersion (15-min, 13-14˚C) between exercise tests caused significant decrease in 30-s maximal sprint cycling performance. In contrast, Lane and Wenger (2004) reported 15 min of cold water immersion (14˚C) after 90 min of running in the heat can significantly improve subsequent 2 mile running time trial performance, this finding imply that a rectal temperature reduction of approximately 0.5˚C may be needed to elicit improvements in performance under hot conditions. Cold water immersion (15 min, 15˚C) has been reported to enhance recovery for intermittent cycling compared to passive rest when 24 hours elapsed between performance tests. However, methodologies were different from this study with second-halves exercise test performed immediately after immersion.

Decreased muscle temperature and decreased core and muscle temperatures have been shown to significantly decrease muscle strength and power.

Crowe and colleagues (2006) indicate that athlete needs to allow sufficient time for muscle re-warming if cold water immersion is employed between match. Similarly, In AW and WW groups showed decrease in peak power, but there is limited research investigating the physiological effect of ambient (thermo-neutral) and warm/hot water immersion its role on enhance subsequent performance. A few studies used hot water (38˚C) immersion investigate the functional symptom of delayed onset muscle soreness post exercise.

5.2 Thermoregulatory Profiles

Rectal temperature was the major physiological variable that was observed because rectal temperature is one of the factors that have been shown to limit exercise performance (Adams et al, 1975). It is therefore suggested that a reduction in body temperature at the start of exercise influences exercise performance (Ref). Rectal temperatures significant increased from resting and higher than 38˚C after first-half exercise in all groups, but no significant difference between groups. Water immersion at different water temperature in half-time has shown different thermoregulatory adjustment. All groups of trail showed significant decreased in rectal temperature after half-time intervention, but were found significant difference between AW-WW and CW-WW. Lower body immersion in half-time prevented excessive rectal temperature in second-halves and not significant between T45 and T90 in AW (38.35±0.02vs.38.25±0.05), WW (38.43±0.06vs.38.35±0.10), and CW (38.24±0.03˚C vs.38.36±0.07˚C). Rectal temperature in CT rapidly increase during second-halve exercise and the end of second-halves was shown significance higher than other groups and significance higher than first-half (38.80±0.09 vs. 38.31±0.03). In this study indicated that 15 minutes half-time insufficient to allow body heat transfer from 45-min intermittent exercise to resting state. However, the results of the present study indicated that all water immersion groups effectively prevented excessive rectal temperature increases during subsequent 45-min intermittent exercise compared with passive rest.

5.3 Cardiovascular responses

There was no significant different was found in heart rate, systolic and diastolic blood pressure between groups throughout exercise test and during recovery period.

Several of investigation suggested that water immersion at differences water temperature shown difference in cardiovascular changes. Thermoneutral water induced bradycardia and decreased blood pressure, while cold water stimulate increase heart rate and blood pressure (5). In response to hot water immersion, heart rate increase (Bonde-Petersen *et al*., 1992; Weston *et al*., 1987).

Result in this study not supported by previously investigation 1) most of previous investigation observed effect of water immersion during rest or pre-cooling with use head-out water immersion, in contrast, our study use lower body water immersion and use between heavy intermittent exercises. A few study use water immersion between bouts of exercise. Crowe et al (2006) investigate effect of lower body immersion (15 min, 13-14˚C) between 30-s maximum cycling, but was not observed in cardiovascular variables during immersion.

5.4 Blood Lactate

Lactate is a metabolic product of anaerobic glycolysis during exercise. The concentration of lactate found in the blood at any time during either rest or activity is a function of the rate of production and the rate of degradation of this important metabolite. The lactate accumulated in blood and muscle during exercise is removed during the recovery period. Elevated concentrations of skeletal muscle and blood lactate are associated with impaired muscle function and exercise performance. (Andrews, Godt, & Nosek, 1996; Hogan, Gladden, Kurdak, & Poole, 1995; Minshull, Gleeson, Walters-Edwards, Eston, & Rees, 2007; Sahlin & Ren, 1989;Westerblad & Allen, 1992).

In this study, found that lactic acid increased after first 45 minutes when compared resting state within groups and not found different between groups. The accumulation of lactate might associate with 5-s maximal sprint in each set of exercise (total 110 seconds). In each all-out sprint anaerobic power was used. It is clear that

anaerobic glycolysis provides energy by the breakdown of glucose without oxygen for short, high-intensity bursts of activity. When the rate of demand for energy is high, lactate is produced faster than the ability of the tissues to remove it, so lactate concentration begins to rise. The increased lactate produced can be removed in a number of ways, including oxidation to pyruvate by well-oxygenated muscle cells, which is then directly used to fuel the Krebs cycle and conversion to glucose via gluconeogenesis in the liver and release back into the circulation.

After each sprint subjects must cycling for free load at 60 rpm, 115 seconds. During cycling for free load is mean active recovery from maximal sprint and might benefit for subjects for lactate clearance. Reported from Crowe (2006) shown that after 30 seconds maximal sprint blood lactate increased to 18.8±0.8 mmol/L. In this present study exercise test was different from period which exercise test combined maximal sprint (5-s) and free load cycling (115-s) and after 45 minutes intermittent cycling blood lactate was 6.98±2.62 mmol/L. Cycling with free load between maximal sprint should be effect to lactate removal.

Previous studies shown that active recovery clears blood lactate faster than passive recovery and shown that active recovery for clearing lactate may be most effective in the range 25–63% of VO2max, where the top end of that range approaches 80–100% of lactate threshold. After 15 minutes lower body immersion blood lactate decreased from after exercise in CT, WW and CW, but was found significances only in WW compared with CT. Effect of warm or hot water temperature shown increased in cardiac output and a lower peripheral resistance allows and increase in subcutaneous and cutaneous blood flow. An increase in subcutaneous and cutaneous blood flow increases the permeability of cellular, lymphatic and capillary vessels. Increased permeability increases metabolism, nutrient delivery and waste removal from the cells. Increase blood flow might support clearance of lactate from the blood to other muscles fibers for oxidation and it is transported via the blood to the liver for converted lactate to pyruvate in the presence of oxygen, which can then be converted into glucose.

Effect of cold water temperature decrease cardiac output, increase peripheral resistance (vasoconstriction). In present study cold water immersion not improved lactate removal after exercise when compared with control.

Post exercise blood lactate in WW group was still significant lower than control and in AW group shown lower than control same with warm water but, not found in CW group. In cold water lacked of data to explain effect of cold temperature associated with blood lactate. In previous reported that 15 minutes lower cold water immersion between 2 x 30-s maximal sprints shown significant decreased blood lactate.

5.5 Subject Perception

In the present study, rating of perceived exertion in all trials rose steeply after T0 until T45. No differences between trials were found during first half and second half exercise. During half time recovery, rating of perceived exertion slightly decrease in all group and no difference between group. Rating of perceived exertion before each exercise test no difference in CT, AW, and CW except WW. In WW rating of perceived exertion before second half higher than before first half exercise.

Thermal sensation values during first half exercise like RPE but significant differences between trials were observed during haft time to min 55. Half time period thermal sensation in CW was lower than other group and lower than before first half exercise, but in second half not difference from other group after min 55 to the end of experiment. The lower thermal sensation during half time period in CW may be the effect of body cooling with cold water, on the other hand, in WW group the thermal sensation was higher than AW and CW during half time except CT, and higher than before first half exercise. After min 55 to end of exercise not difference in thermal sensation between groups.

CHAPTER VI
CONCLUSION

The present study of influences of different temperatures of lower water immersion on thermoregulatory, cardiovascular, blood lactate, physical performance, and Psychological Responses during exercise and half time recovery between bout of 45 min intermittent cycling test can be concluded as following;

1. Cold water immersion (15°C) and ambient water immersion (27°C) can significantly decrease rectal temperature and prevent excessive rectal temperature by lowering initial rectal temperature early second halve exercise compared to passive rest (p<0.05). Warm water immersion (39°C) is similar prevent rise in rectal temperature in the end of exercise compared to passive rest (p<0.05) by attenuated increases rectal temperature during second halve.

2. There are no significant differences between group of water immersion and control on peak power (p>0.05). It means that lower body water immersion 15-min immediately after exercise does not improve performance during second halves exercise.

3. Rating of perceived exertion (RPE) does not difference throughout experimental in all conditions (p<0.05), but thermal sensation (TS) during water immersion show significant difference (p<0.05). During half-time recovery there were differences in TS between cold water immersion compared with other condition in half-time recovery (p<0.05), in second-halve exercise were found differences between WW-CW in H50-H55 (p>0.05).

4. During water immersion at difference water temperatures, heart rate, systolic and diastolic blood pressure no significant difference (p<0.05) with control conditions.

5. Blood lactate significant increased by first-half exercise in all group and no difference between group were found (p<0.05), after recovery intervention there

are significant decreased in CT, WW and CW (p<0.05). In CT and AW were significant difference from resting (p<0.05).

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APPENDIX

Data collection worksheet in Thesis

Lower Body Immersion at Different Water Temperatures during Recovery Period on Thermoregulatory Profiles and Performance in Soccer Players.

Subject Code…….Date……
Age…….years Weight…….kg Height……cm
BMI……..... Group of Intervention……..Position in Soccer Team……...

Table A Baseline data (Resting)

Variables	
Core temperature	
Rectal	
Skin temperature	
Chest	
Upper arm	
Thigh	
Calf	
Cardiovascular index	
Heart rate	
Blood pressure	
Blood chemistry	
Lactate	

Subjective evaluation	
RPE	
Thermal sensation	
Thermal discomfort	

Table B During Exercise (first 45 mins)

Variables	T0	T5	T10	T15	T20	T25	T30	T35	T40	T45
Core temperature										
Rectal										
Skin temperature										
Chest										
Upper arm										
Thigh										
Calf										
Cardiovascular index										
Heart rate										
Blood pressure										
Blood chemistry										
Lactate										
Peak power										
Subjective evaluation										
RPE										
Thermal sensation										
Thermal discomfort										

Table C During ☐ **Passive Rest** ☐
Intervention……

Variables	T5	T10	T15
Core temperature			
Rectal			
Skin temperature			
Chest			
Upper arm			
Thigh			
Calf			
Cardiovascular index			
Heart rate			
Blood pressure			
Blood chemistry			
Lactate			
Subjective evaluation			
RPE			
Thermal sensation			
Thermal discomfort			

Variables	T5	T10	T15
Water temperature			

Table D During Exercise (second 45 mins)

Variables	T0	T5	T10	T15	T20	T25	T30	T35	T40	T45
Core temperature										
Rectal										
Skin temperature										
Chest										
Upper arm										
Thigh										
Calf										
Cardiovascular index										
Heart rate										
Blood pressure										
Blood chemistry										
Lactate										
Peak power										
Subjective evaluation										
RPE										
Thermal sensation										
Thermal discomfort										

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