ผลของการอบอุ่นร่างกายในเวลา 15 นาทีต่อการเปลี่ยนแปลงอุณหภูมิแกนกลางร่างกายและสมรรถภาพการวิ่งเร็วระยะสั้นในนักกีฬาฟุตบอลหญิงทีมชาติไทย

นางสาว ลดาวัลย์ ชุติมากุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2549

EFFECTS OF 15-MINUTE WARM UP ON CORE TEMPERATURE CHANGES AND SPRINT PERFORMANCE IN THAI FEMALE NATIONAL SOCCER PLAYERS

Ms. Ladawan Chutimakul

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Sports Medicine
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Thesis Title	EFFECTS OF 15-MINUTE WARM UP ON CORE TEMPERATURE CHANGES AND SPRINT PERFORMANCE IN THAI FEMALE NATIONAL SOCCER PLAYERS
By	Ladawan Chutimakul
Field of Study	Sports Medicine
Thesis Advisor	Assistant Professor Sompol Sanguanrungsirikul, M.D.
Thesis Co-advisor	Associate Professor Juraiporn Somboonwong, M.D.

Accepted by the Faculty of Medicine, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master 's Degree

P. Kamolratanakul .... Dean of the Faculty of Medicine

(Professor Pirom Kamolratanakul, M.D.)

THESIS COMMITTEE

.... Chairman

(Associate Professor Prasong Siriviriyakul, M.D.)

Sompol Sanguanrungsirikul .... Thesis Advisor

(Assistant Professor Sompol Sanguanrungsirikul, M.D.)

Juraiporn Somboonwong .... Thesis Co-advisor

(Associate Professor Juraiporn Somboonwong, M.D.)

Onanong Kulaputana .... Member

(Assistant Professor Onanong Kulaputana, M.D., Ph.D.)

P. Watanatada .... Member

(Pasakorn Watanatada, M.D., Ph.D.)

ลดาวัลย์ ชุติมากุล : ผลของการอบอุ่นร่างกายในเวลา 15 นาทีต่อการเปลี่ยนแปลงอุณหภูมิแกนกลางร่างกายและสมรรถภาพการวิ่งเร็วระยะสั้นในนักกีฬาฟุตบอลหญิงทีมชาติไทย. (EFFECTS OF 15-MINUTE WARM UP ON CORE TEMPERATURE CHANGES AND SPRINT PERFORMANCE IN THAI FEMALE NATIONAL SOCCER PLAYERS) อ.ที่ปรึกษา : ผศ. นพ. สมพล สงวนรังศิริกุล, อ.ที่ปรึกษาร่วม : รศ. พญ. จุไรพร สมบุญวงค์ 58 หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของการอบอุ่นร่างกายในเวลา 15 นาทีต่อการเปลี่ยนแปลงอุณหภูมิแกนกลางร่างกายและสมรรถภาพการวิ่งเร็วระยะสั้นในช่วงรอบประจำเดือน ของนักกีฬาฟุตบอลหญิงทีมชาติไทย อาสาสมัครนักฟุตบอลหญิงทีมชาติไทยจำนวน 13 คน อายุ 18.8±1.3 ปี ส่วนสูง 161.23±4.69 เซนติเมตร น้ำหนัก 54.77±3.30 กิโลกรัม สมรรถภาพการใช้ออกซิเจนสูงสุด 53.05±6.66 มิลลิลิตร/กิโลกรัม/นาที รอบประจำเดือน 29.4±1.07 วัน ทำการอบอุ่นร่างกายในระยะเวลา 15 นาที ซึ่งประกอบด้วยการวิ่งเหยาะๆ ก้าวกระโดดร่วมกับเคลื่อนไหวขา และวิ่งเร็วสลับวิ่งธรรมดา ที่อุณหภูมิแวดล้อม 30.0-35.5°C ความชื้นสัมพัทธ์ร้อยละ 40-69 ในช่วงต้นของฟอลลิคูล่าร์และช่วงกลางของลูเทียล บันทึกอัตราการเต้นหัวใจขณะพักและระหว่างอบอุ่นร่างกาย บันทึกอุณหภูมิแกนกลางร่างกายขณะพัก ระหว่างอบอุ่นร่างกายและช่วงพักหลังอบอุ่นร่างกายระยะเวลา 45 นาที ทดสอบสมรรถภาพการวิ่งเร็วระยะสั้นเป็นค่าพื้นฐานและทดสอบหลังอบอุ่นร่างกายทั้งสองช่วงของรอบเดือนเพื่อเปรียบเทียบผลของการอบอุ่นร่างกาย ผลการศึกษาพบว่า ขณะพักอุณหภูมิแกนกลางร่างกายช่วงกลางของลูเทียล (37.11±0.16°C) สูงกว่าช่วงต้นของฟอลลิคูล่าร์ (36.79±0.21°C) อย่างมีนัยสำคัญทางสถิติ เมื่ออบอุ่นร่างกายครบ 15 นาที อุณหภูมิแกนกลางร่างกายเพิ่มขึ้น 1.26±0.41°C และ 1.18±0.33°C ในช่วงต้นของฟอลลิคูล่าร์และช่วงกลางของลูเทียลตามลำดับ อัตราการเต้นหัวใจเพิ่มขึ้นจาก 69.33±8.14 และ 73.15±6.73 ครั้ง/นาที เป็น 153.67±20.34 และ 158.38±15.19 ครั้ง/นาที ในช่วงต้นของฟอลลิคูล่าร์และช่วงกลางของลูเทียล ตามลำดับ ช่วงพักหลังอบอุ่นร่างกายพบว่าอุณหภูมิแกนกลางร่างกายค่อยๆลดลง โดยลดลงประมาณร้อยละ 50 ในนาทีที่ 20 ส่วนเวลาที่ใช้วิ่งเร็วระยะสั้นหลังอบอุ่นร่างกายในช่วงต้นของฟอลลิคูล่าร์และช่วงกลางของลูเทียล มีค่าเท่ากับ 5.52±0.13 และ 5.51±0.16 วินาที ตามลำดับ ซึ่งน้อยกว่าค่าพื้นฐาน (5.66±0.13 วินาที) อย่างมีนัยสำคัญทางสถิติ แสดงว่าการอบอุ่นร่างกายระยะเวลา 15 นาทีในสภาพอากาศร้อน สามารถทำให้อุณหภูมิแกนกลางร่างกายเพิ่มขึ้นมากกว่า 1°C และเพิ่มสมรรถภาพการวิ่งเร็วระยะสั้นของนักกีฬาฟุตบอลหญิงทีมชาติไทยได้ ส่วนอัตราการเต้นหัวใจขณะทำการอบอุ่นร่างกายและสมรรถภาพการวิ่งเร็วระยะสั้นของนักกีฬา ไม่มีความแตกต่างกันในช่วงรอบประจำเดือน

สาขาวิชา..........เวชศาสตร์การกีฬา............ ลายมือชื่อนิสิต ...ลดาวัลย์ ชุติมากุล...

ปีการศึกษา..............2549.................... ลายมือชื่ออาจารย์ที่ปรึกษา ...[signature]...

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ...[signature]...

4774771130 : MAJOR SPORTS MEDICINE

KEY WORD: WARM UP / CORE TEMPERATURE / SPRINT PERFORMANCE / FEMALE / SOCCER

LADAWAN CHUTIMAKUL : EFFECTS OF 15-MINUTE WARM UP ON CORE TEMPERATURE CHANGES AND SPRINT PERFORMANCE IN THAI FEMALE NATIONAL SOCCER PLAYERS. THESIS ADVISOR : ASST.PROF. SOMPOL SANGUANRUNGSIRIKUL, M.D., THESIS COADVISOR : ASSOC.PROF. JURAIPORN SOMBOONWONG, M.D., 58 pp.

The purpose of this study was to investigate the effects of 15-minute warm up on core temperature changes and sprint performance during menstrual cycle in Thai female national soccer players. Thirteen subjects (age 18.8±1.3 years, height 161.23±4.69 cm, weight 54.77±3.30 kg, VO_{2max} 53.05±6.66 ml/kg/min, and menstrual cycle length 29.4±1.07 days) performed 15-minute warm up consisting of jogging, skipping with moving legs in all directions and sprinting alternated with jogging, and 45-minute recovery period at ambient temperature of 30.0-35.5°C with relative humidity of 40-69% during early follicular phase and mid luteal phase of the menstrual cycle. Heart rate was monitored at rest and during warm up. Rectal temperature was recorded at rest, during warm up and recovery period every 5 minutes. Sprint performance after warm up was assessed to compare with baseline. Rectal temperature at rest in mid luteal phase (37.11±0.16°C) was significantly higher than in early follicular phase (36.79±0.21°C). Immediately after warm up, rectal temperature increased 1.26±0.41°C and 1.18±0.33°C (early follicular and mid luteal phases, respectively) from base line. Heart rate was increased from 69.33±8.14 and 73.15±6.73 bpm to 153.67±20.34 and 158.38±15.19 bpm (early follicular and mid luteal phases, respectively). The rectal temperature decreased gradually after warm up. At 20^{th} minute of recovery, rectal temperature was decreased by approximately 50%. Sprint time after warm up during early follicular and mid luteal phases (5.52±0.13 and 5.51±0.16 s, respectively) was significantly decreased from baseline (5.66±0.13 s). It is suggested that the 15-minute warm up is sufficient for Thai female national soccer players to improve performance in hot environment since the core temperature can be elevated more than 1°C. Moreover, heart rate and sprint performance did not differ during the course of the menstrual cycle.

Field of study ....Sports Medicine...... Student's signature ....Ladawan Chutimakul....

Academic year ....2006.............. Advisor's signature ....Sompol Sanguanrungsirikul....

Co-advisor's signature....Juraiporn Somboonwong....

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BBT	Basal body temperature
BMR	Basal Metabolic Rate
bpm	Beat per minute
cm	Centimeter
CNS	Central Nervous System
^{o}C	Degree Celsius
d	Day
e.g.	Exempli gratia
F	Follicular phase
FSH	Follicle Stimulating Hormone
GnRH	Gonadotrophin Releasing Hormone
h	Hour
HR_{max}	Maximum heart rate
i.e.	Id est
Kcal	Kilo calories
Kg	Kilogram
kgm	Kilogram-meters
L	Luteal phase
LH	Luteinizing Hormone

min	Minute
ml	Milligram
R	Recovery period
rpm	Revolution per minute
T_c	Core temperature
VO_{2max}	Maximum oxygen consumption
WU	Warm up

CHAPTER I
INTRODUCTION

Background and Rationale

At present, warm up is a widely accepted practice preceding nearly every athletic event. Warm up not only prevent injury, but also improve performance. Proposed benefit of warm up is stimulation of muscle metabolism and cardiorespiratory function (Robergs and Roberts, 1997). The majority of the effects of warm up have been attributed to temperature related mechanisms (decreased resistance of muscles and joints, greater release of oxygen from hemoglobin and myoglobin, speeding of metabolic reactions, increased nerve conduction rate and increased thermoregulatory strain) and non-temperature related mechanisms (increased blood flow to muscles, elevation of baseline oxygen consumption, postactivation potentiation, psychological effects and increased preparedness) (Shellock, 1983; Bishop, 2003a). Metabolic processes in the cell are temperature-regulated and there is a 13 percent increase in the metabolic rate for each degree of temperature increase (Astrand and Rodahl, 1977).

The objective of warm up in soccer is to increase body temperature, prevent injury and prepare psychology of the player (James C, 2004). The Effective warm up should increase the core temperature by $1^{o}C$ - $2^{o}C$ (Devries, 1980; Roy and Richard, 1983; Fox, 1984; Plowman and Smith, 2003). The recommended Football Association warm-up and most professional teams have suggested that warm ups include a third stage of more vigorous activity and longer hold stretches. The objective is to raise the heart rate to 160-200 beats per minute which is of high intensity level. The excellent European soccer team has suggested that heart rate that has to be reached at the end of warm up is 160-170 beats per minute (Spassov, 2005). The usual duration of warm up ranges from 5 to 30 minutes. Surprisingly, although warm up helps prevent injury it is still found that the proportion of injuries occurred during warm up is 4% (Price et al, 2004).

Information and recommendation on the warm up in Thailand is very limited. Some Thai handbooks of soccer suggest that warm up should begin with slow movement and then progress gradually from low to high intensity (Chanvit, 1991;

Prayote, 1999). In Thailand where the climate is hot and humid, the body's ability to lose heat by radiation, convection and evaporation is reduced. This inability to lose heat during exercise results in a greater core temperature and a higher sweat rate (more fluid loss) when compared to the same exercise in a moderate environment, probably leading in heat injury and dehydration.

In Thai national soccer team, the duration of warm up is variable, ranging from 10-30 minutes. There is no scientific evidence supporting the effectiveness of the warm up protocol in hot and humid environment. Moreover, in female players, the fluctuations in hormonal releases cause regular cyclic changes in a number of physiological responses including the core temperature changes across the phases of the menstrual cycle. Thus, 3 female national soccer players perform warm up in a pilot study. We found that 15-minute warm up might increase core temperature of more than 1^{o}C.

Therefore, the warm up protocol in this study was set up for 15 minutes and investigate the effects of warm up on core temperature and sprint performance during the course of the menstrual cycle in Thai female national soccer players in hot environmental conditions.

Objectives

1. To investigate the effects of warm up on core temperature changes and sprint performance in Thai female national soccer players.

2. To compare the effects of warm up on core temperature changes and sprint performance during early follicular and mid luteal phases of the menstrual cycle.

Research Question

1. What is the effects of 15-minute warm up on core temperature and sprint performance in Thai female national soccer players in hot and humid environment?

2. Are there any differences in the effects of 15-minute warm up on core temperature and sprint performance during early follicular and mid luteal phases of the menstrual cycle?

Limitation

1. This study performed in the environment where ambient temperature, relative humidity, and air velocity are not under control.

2. Air velocity is not recorded in this study because evaporation is the main mechanism of heat loss during exercise in hot condition.

3. The number of subjects is limited.

Operational Definition

1. Core temperature is defined as body temperature measured at rectum called ‘rectal temperature’.

2. Early follicular phase is defined as the phase of the menstrual cycle during 3-6 days after the onset of menstruation.

3. Mid luteal phase is defined as the phase of the menstrual cycle during 5-8 days after elevated basal body temperature of 0.5°C.

Expected Benefits and Application

1. To get knowledge of the effects of 15-minute warm up on core temperature changes and sprint performance in Thai female national soccer players in hot condition.

2. To get some information for designing an appropriate warm up protocol for Thai female national soccer players in hot conditions.

CHAPTER II

REVIEW OF THE LITERATURES

Thermoregulation

The hypothalamus contains the central coordinating center for temperature regulation. This group of specialized neurons at the floor of the brain acts as a "thermostat". Body temperature is usually set and carefully regulated at 37±1°C (98.6 °F ±1.8°F). There are two ways to activate the body's heat-regulating mechanisms: 1) thermal receptors in the skin provide input to the central control center, 2) changes in the temperature of blood that perfuses the hypothalamus directly stimulate this area (McArdle et al, 2000).

Body temperature reflects balance between heat production and heat loss. Heat production can be classified as 1) voluntary (exercise) and 2) involuntary (shivering or biochemical heat production caused by the secretion of hormones such as thyroxine and catecholamines). Since the body is at most 20% to 30% efficient, 70% to 80% of the energy expended during exercise appears as heat. Involuntary heat production by shivering is the primary means of increasing heat production during exposure to cold. Maximal shivering can increase the body's heat production by approximately five times the resting value. In addition, release of thyroxine from the thyroid gland can also increase the rate of cellular metabolism. The increase in heat production due to the combined influences of thyroxine and catecholamines is called nonshivering thermogenesis (Power and Howley, 2001). Heat loss from skin to the environment is through radiation, conduction, convection, and evaporation. Skin constantly radiates heat in all directions to the objects around it but it can also receive radiational heat from surrounding objects that are warmer. Heat conduction involves transfer of heat from one material (liquid, solid, or gas) to another through molecular contact. Convection, on the other hand, involves moving from one place to another by the motion of a gas or a liquid across the heated surface. Evaporation is the primary avenue for heat dissipation during exercise. As sweat reaches the skin, it is converted from a liquid to a vapor by heat from the skin (McArdle et al, 2000). Figure 2.1 illustrates the roles of evaporation, convection, and radiation in heat loss during constant-load exercise in a moderate environment. Estimated caloric heat loss through each mechanism compared at rest and during prolonged exercise at 70% of VO_{2max} is summarized in table 2.1 (Wilmore and Costill, 1999).

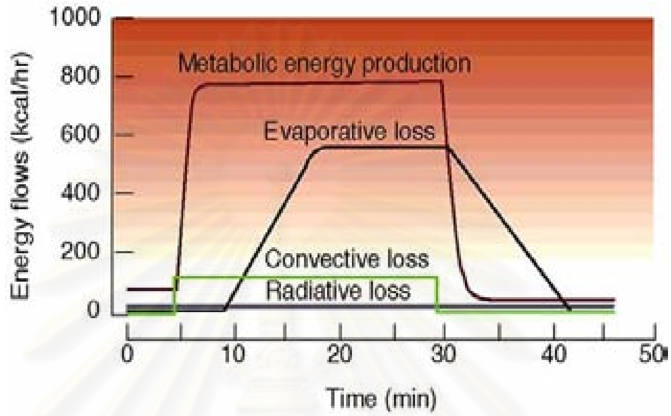

Figure 2.1 The changes in metabolic energy production, evaporative heat loss, convective heat loss, and radiative heat loss during 25-minute sub maximal exercise (Powers and Howley, 2001).

Table 2.1 Estimated Caloric Heat Loss at Rest and During Prolonged Exercise (Wilmore and Costill, 1999).

Mechanism of heat loss	Rest		Exercise	
	% total	kcal/min	% total	kcal/min
Conduction and convection	20	0.3	15	2.2
Radiation	60	0.9	5	0.8
Evaporation	20	0.3	80	12.0

Thermoregulation during Exercise in the Heat

Exercise increases the demands on the cardiovascular system. The body faces two competitive cardiovascular demands: 1) oxygen delivery to muscles must increase to sustain energy metabolism. 2) peripheral blood flow to the skin must increase to transport metabolic heat from exercise for dissipation at the body's surface (McArdle et al, 2000). To accomplish this during exercise in the heat, large part of the cardiac output must be shared by the skin and the working muscles. Blood and oxygen delivers to muscles to sustain activity, while the skin needs blood to facilitate heat loss to keep the body cool. To maintain a constant cardiac output while shunting blood to the periphery, the cardiovascular system must make some noticeable adjustments. The redistribution of blood reduces the volume of blood that returns to the heart, which reduces the end-diastolic volume. This in turn reduces the stroke volume. Cardiac output remains reasonably constant throughout a 30-minute exercise bout in a warm (36°C) or cool (20°C) temperature, despite a steady decrease in stroke volume. A gradual upward drift in heart rate compensates for the drop in stroke volume throughout exercise (Wilmore and Costill, 1999).

Heat production increases during exercise due to muscular contraction and is directly proportional to the exercise intensity. The venous blood draining the exercising muscle distributes the excess heat throughout the body core. As core temperature increases, thermal sensors in the hypothalamus sense increase in blood temperature, and the thermal integration center in the hypothalamus compares this increase in temperature with the set-point temperature and finds a difference between the two (Powers and Howley, 2001). For example, metabolism often rises 20 to 25 times above the resting level to about 20 Kcal/min during intense aerobic exercise by elite athletes; this theoretically can increase core temperature by 1°C (1.8°F) every 5 to 7 minutes (McArdle, 2000). Figure 2.2 shows that, during constant-load exercise, the core temperature increase is directly related to the exercise intensity.

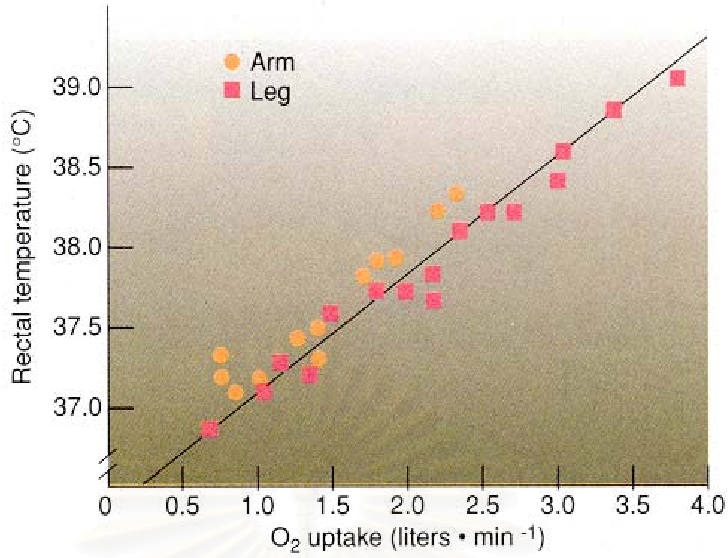

Figure 2.2 Relationship between metabolic rate and rectal temperature during constant load arm (●) and leg (■) exercise (Powers and Howley, 2001).

High heat and humidity reduce the body's ability to lose heat by radiation, convection and evaporation, respectively. This inability to lose heat during exercise in a hot, humid environment results in a greater core temperature and a higher sweat rate (more fluid loss) when compared to the same exercise in a moderate environment. Figure 2.3 shows heat exchanges during exercise in a broad range of ambient temperature and figure 2.4 shows the difference in core temperature during exercise between the hot/humid conditions and cool conditions.

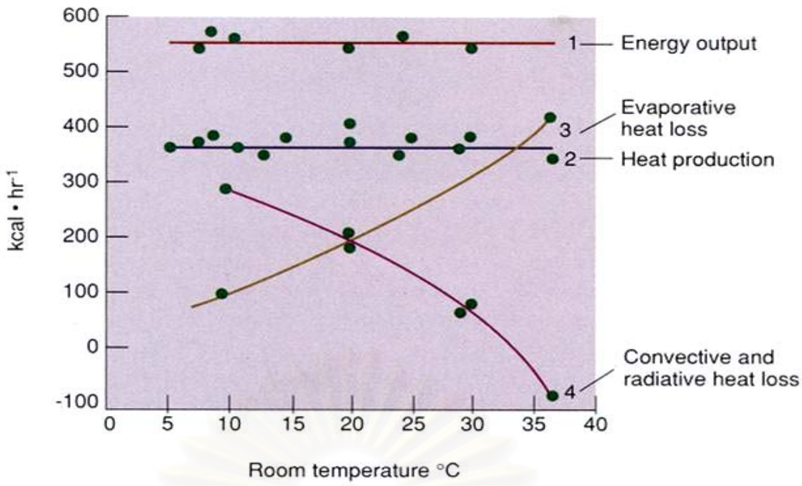

Figure 2.3 Heat exchange during exercise in a broad range of ambient temperature (Powers and Howley, 2001).

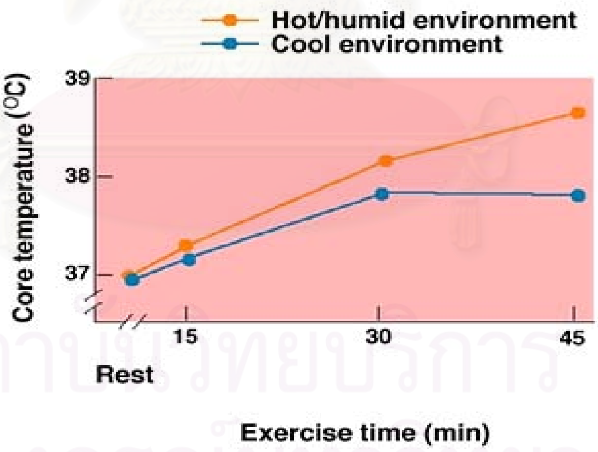

Figure 2.4 Differences in core temperature during 45-minute sub maximal exercise in a hot/humid environment versus a cool environment (Powers and Howley, 2001).

Dehydration induced by a few hours of heavy exercise in the heat can reach levels that impede heat dissipation and severely compromise cardiovascular function and exercise capacity. A large sweat output and subsequent fluid loss occur in sports other than distance running; football, basketball, and hockey players also deplete large quantities of fluid during competition. The mean sweat rate in footballers was 2.14 l/h and 1.77 l/h in the runners. Important factors that affect sweat production during exercise are physical conditioning (aerobic and anaerobic), acclimatization, hydration status, exercise intensity, physical size, and amount of clothing or equipment worn (Godek et al, 2005). Hot, humid environments impede the effectiveness of evaporative cooling (because of the high vapor pressure of ambient air) and promote large fluid losses. Figure 2.5 illustrates a linear relationship between sweat rate during rest and exercise and the air's moisture content in ambient temperature (dry-bulb) equaled 43.3°C.

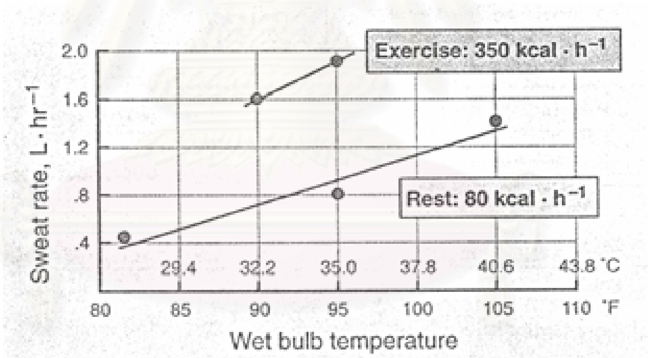

Figure 2.5 Effects of humidity (wet-bulb temperature) on sweat rate during rest and exercise in the heat (McArdle, 2001).

Menstrual Cycle

The menstrual cycle is a series of various hormone releases that coordinate the readiness of the female reproductive system for conception. The release of gonadrotropin-releasing hormone (GnRH) by the hypothalamus on day one of the cycle controls stimulation and inhibition of the release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from anterior pituitary. These hormones then regulate the release of estrogen (from ovarian follicles) and progesterone (from the corpus luteum) and coordinate progression of these events during an average cycle of 28 days (Marsh and Jenkins, 2002). Figure 2.6 shows the feedback loops to the pituitary and hypothalamus; the system is referred to as the hypothalamic-pituitary-ovarian axis. The cyclic changes in core temperature, gonadotropins and ovarian hormones levels, and endometrium lining the uterine wall are shown in figure 2.7.

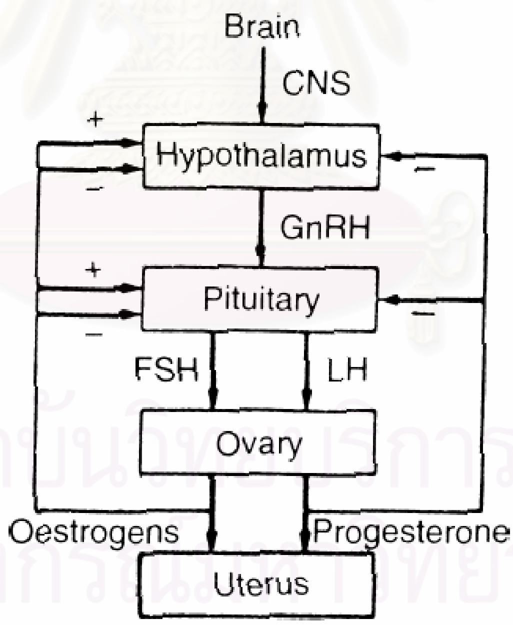

Figure 2.6 The hypothalamic-pituitary-ovarian axis. CNS = central nervous system; GnRH = gonadotrophin releasing hormone; FSH = follicle stimulating hormone; LH = luteinizing hormone (Reilly et al., 1997).

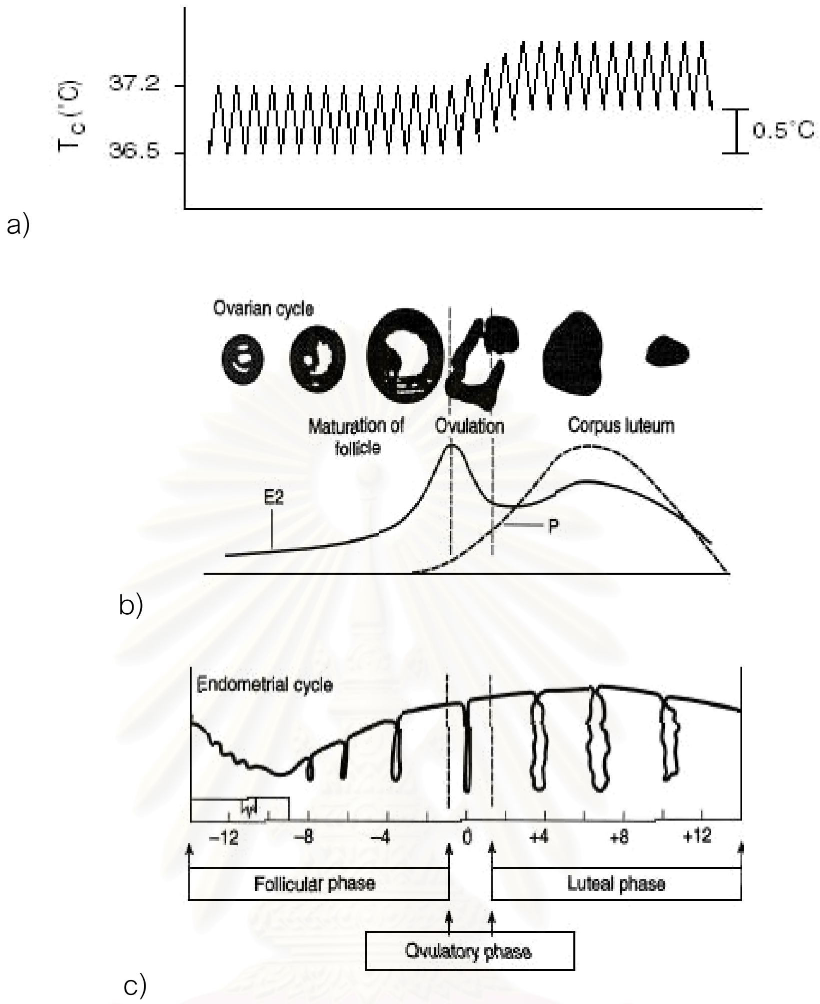

Figure 2.7 Cyclic changes during the menstrual cycle: (a) core temperature fluctuations; (b) ovarian cycle; (c) endometrium lining the uterine wall. Tc = Core Temperature; P = Progesterone; E2 = Estradiol (Reilly et al., 1997).

The first part of the cycle constitutes the follicular phase. The maturing follicle ovulates about mid-cycle (Day 14), ovulation being triggered by a sharp rise in LH and signified by an elevation of about 0.5°C in body temperature. For conception to occur, the liberated ovum has to be fertilized within 24 h. The cycle now enters the luteal phase characterized by the collapse of the ruptured follicle from which the ovum has burst to form the corpus luteum which produces increased amounts of progesterone. If implantation of the fertilized egg has not occurred, the corpus luteum usually regresses by day 21. As the main function of progesterone is to prepare the uterine wall for implantation of the fertilized ovum, progesterone falls to a low level pre-menses. Consequently the endometrium regresses and about two-thirds of its lining is shed in menstruation as the next cycle starts. The hormonal changes affecting the uterus are closely integrated with ovarian functions within the overall regulation of the menstrual cycle (Fig. 2.7). The proliferative phase of the endometrium following menses is stimulated by the steroid hormones estradiol and progesterone. Estradiol output enhances development of the endometrial surface and the spiral arteries. At ovulation progesterone causes the endometrium to develop mucous-secreting glands and endometrial cells to accumulate glycogen in anticipation of receiving a fertilized ovum. As the ovum reaches the uterus, the follicular cells now form the corpus luteum which, as explained above, secretes large amounts of estrogen (estradiol) and progesterone. Negative feedback of the levels of these hormones acts to suppress the release of GnRH, FSH and LH. Once the fertilized ovum is implanted in the uterus, progesterone protects the integrity of the endometrium and inhibits uterine contractions during pregnancy.

Events in the ovarian phases are harmonized with the thickening and subsequent shedding of the endometrial lining in a complete menstrual cycle. During the follicular phase of the ovarian cycle that follows menstrual bleeding, both FSH and LH levels remain fairly constant until a peak in estradiol secretion occurs on the day before ovulation. Estradiol acts by means of positive feedback to induce a rise in LH and GnRH which then stimulates output of both FSH and LH. The outcome is a pronounced surge in LH and a lesser rise in FSH. At onset of the luteal phase post-ovulation, progesterone levels increase further, linked to the secretory phase of the endometrial cycle. In the absence of implantation, estrogen and progesterone drop towards their lowest level as the corpus luteum regresses and GnRH, FSH and LH are no longer subject to negative feedback. The loss of endometrial lining is a result of the large drop in progesterone secretion which causes blood vessel spasms, ischemia and death of the surface cells of the endometrium. As menstruation begins, FSH promotes follicle development and the cycle gets underway again (Reilly, 2000).

Physiological Responses to Exercise between Menstrual Cycle Phases

Few, if any, changes have been found in the cardiovascular response to changing hormone levels during the menstrual cycle. The majority of studies have found no significant difference in heart rate between the phases of the menstrual cycle either at rest or during exercise. The part of plasma volume, phase-related fluctuations have not been uniformly reported. Generally, hemoglobin concentrations are higher in males, although this is compensated in females by higher levels of 2, 3-diphosphoglycerated (2, 3-DPG) which increases the availability of oxygen to tissues. Numerous studies have reported no significant changes in hemoglobin concentration over the course of the menstrual cycle. Although an increase in resting luteal hemoglobin, this did not result in a substantial increase in arterial oxygen content or any subsequent change in oxygen delivery during exercise. Similarly, decreases in luteal hemoglobin concentration were not reflected in changes in oxygen consumption (VO_2) at rest or during exercise.

The menstrual cycle has little or no significant effect on oxygen consumption (VO_2) or maximal oxygen uptake (VO_{2max}) in healthy, young females during exposure to ambient or hot conditions. Fluctuating progesterone concentrations have been implicated in changes in respiratory muscle function; increased progesterone has been shown to cause significant increases in phrenic nerve activity. As the phrenic nerve innervates the diaphragm, elevated progesterone is often associated with varying degrees of hyperventilation and hypocapnia during the luteal phase. Despite these findings, researchers are divided in stating the influence of the cycle on V_E (minute ventilation). While a number of studies have shown no significant difference in V_E between phases in normal or hot environments, others have reported significant elevations in V_E and maximal inspiratory ventilation during the luteal phase. In summary, although it has been shown that progesterone has a marked effect on phrenic nerve activity, subsequent influences of the menstrual cycle on respiratory function are not conclusive. No significant differences are generally reported in the standard measurements of VO_2 and ventilation across the phases of the menstrual cycle. Furthermore, little or no significant phase-related change is apparent during heat exposure in various respiratory responses (such as VO_2, VO_{2max} or V_E).

Previous studies have found significant differences in various parameters between menstrual cycle phases. During the luteal phase, the threshold for onset of sweating is increased while sweat rates have been shown to be elevated. The potential mechanisms responsible for the increased threshold for the onset of sweating during the luteal phase could be associated with the actions of either progesterone or estrogen as both are elevated during this time.

Exercise performance is not necessarily impaired during any stage of the menstrual cycle. In contemporary society, female participation in professional sport is widely accepted as is the principle that menses is no bar to training or competing. However, for prolonged exercise performance, the menstrual cycle may have an effect. It was found that time to exhaustion was decreased during the mid luteal phase, when body temperature is elevated. Thus, the luteal phase has a potential negative effect on prolonged exercise performance through elevated body temperature and potentially increased cardiovascular strain. It was practical implications for female endurance athletes, especially in hot and humid conditions (Reilly, 2000; Jonge, 2003).

Physiology of Soccer

Soccer is a game that involves two teams of 11 players each: 10 outfield players and 1 goalkeeper. At the most basic level, the division of positions is defenders, midfielders, and forwards (strikers). The game is nominally two 45-minute halves with a 15-minute pause. No time-outs are allowed, the clock is stopped only at the referee's discretion (e.g., injuries in which a player needs to be removed from the field), and substitution rules vary by league from very lenient (free substitution) to highly restrictive (maximum of two outfield players and one goalkeeper with no reentry) (Garrett and Kirkendall, 2000).

Distances covered at top level are in the order of 10 to 12 km for the field players, and about 4 km for the goalkeeper. Over all, professional midfielders run the most whilst strikers sprint the greatest distance. Each sprint is between 10 and 40 meters, accumulating about 800 to 1000 meters. For example, a top centre-forward has been shown to sprint 900 meters (>21 kilometers/hours) and runs 1520 meters at high intensity (14-21 kilometers/hours). Indeed players sprint on average once every 90 seconds (Stolen et al, 2005; Garrett and Kirkendall, 2000). Figure 2.8 breaks down the total distance run (11.6 kilometers) of a top level midfielder in to the percentage of time spent in different running activities (Soccer academy, 2005).

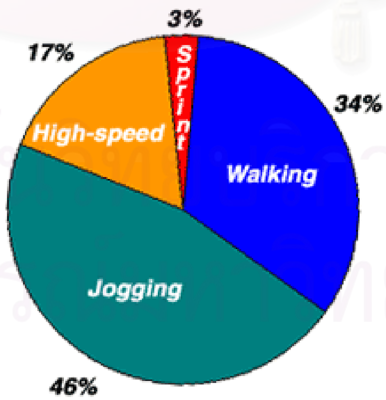

Figure 2.8 Percentage of time spent in match of a top level midfielder (Soccer academy, 2005).

There are about 850 to 1000 distinct activities, which corresponds to about one change in direction or intensity about every 5 to 6 seconds. A player sprints about once every 90 seconds and works at the higher intensities of sprinting/cruising about once every 30 seconds (Garrett and Kirkendall, 2000).

Because of the game duration, soccer is mainly dependent upon aerobic metabolism. The average work intensity, measured as percentage of maximum heart rate (HR_{max}), during a match is close to the anaerobic threshold (the highest exercise intensity where the production and removal of lactate is equal; normally between 80 to 90% of HR_{max} in soccer players). Similarly, measuring blood lactate values are useful for indicating the severity of exercise. Extremely high levels up to 12 $mmol^{-1}$ have been observed in top level play and progressively higher lactate concentrations from the fourth to the top division in Swedish professional football demonstrate the greater high-intensity nature of the game especially at the top level (Mohr et al, 2005). Body temperature offers clues on exercise intensity and energy production. Again, similar observations were made on Swedish professional football and the players from top division had the highest post-match temperatures which can again be linked to greater overall exercise intensity.

Although aerobic metabolism dominates the energy delivery during a soccer game, the must decisive action are covered by means of anaerobic metabolism to perform short sprints, jumps, tackles, and duel play, anaerobic energy release is determinant with regard to who is sprinting fastest or jumping highest. This is often crucial for the match outcome (Stolen et al, 2005).

Interestingly, there is a gender difference in physiological profile of male and female soccer players, which will be discussed below together with thermoregulation in soccer match.

1. Physiological Profile of Male Soccer Players

The data in table 2.2 shows stature and mass for elite soccer players. It is indicate that the soccer player is of rather ordinary size. What one might notice is the trend toward the taller, heavier, and leaner player (Garrett and Kirkendall, 2000). The VO_{2max} in male out-field soccer player varies from about 50-75ml/kg/min. There are so many different ways to measure strength (grip strength, maximal voluntary contraction, isokinetically, eccentrically). However, it is no standardized protocol for testing strength of soccer players exists. For example, previous research founds that male soccer player has bench press values 100 kg and squat values >200 kg. A higher level of all strength parameters would be preferable and would reduce the risk of injuries (Stolen et al, 2005).

Table 2.2 Stature and mass of male soccer players by year (Garrett and Kirkendall, 2000).

Year	Height (cm)	Weight (kg)	%Fat
1973	174.6	69.4	12.4
1975	176.3	71.3	14.9
1976	176.3	75.7	9.6
1978	178.3	72.3	9.4
1984	177.3	74.5	10.0
1991	180.4	75.0	10.0

2. Physiological Profile of Female Soccer Players

In 2002, the Football Association reported that there were 131,000 registered female players and about 1.4 million females played football at various levels of competition in England (The Football Association, 2005). In the USA, it is estimated that 5.5 million women over the age of 7 years play football (National Sporting Goods Association, 2004). However, there were very few research studies in female soccer players. Previous research suggests that both female and male players tax the aerobic and anaerobic energy system to a similar level. It is reported that a female player covers less distance in a match than a male, but the relative intensity of activity is maintained around 70% of maximal oxygen uptake (VO_{2max}), which is similar to that of males (Krustrup et al, 2005; Stolen et al, 2005). There was a reported VO_{2max} of 38.6-57.6 ml/kg/min (Stolen et al, 2005). Concerning sports injury, there is a study showing that female soccer players had a higher incidence of injury than male soccer players in youths and for elite senior players (Inklaar, 1994). Differences in physical resources, determined as strength and endurance parameters, between male and female elite soccer teams, are similar to their sedentary counterparts. It is proposed that part of sex differences may also indeed be a result of differences in priority of strength training and type of strength training performed.

3. Thermoregulation in Soccer Match and its Relation to Performance

A study on muscle and core temperatures during match play in male soccer players (figure 2.9) found that average core temperature was about 39^{o}C reached during the game. Both muscle and core temperatures decreased markedly during the half time period of a soccer match when players recovered passively. The lower body temperatures prior to the start of the second half were associated with a significant impairment in sprint performance. The decrease in muscle temperature at half time was correlated to the reduction in sprint performance during half time. Additionally, there was a study showing that top class male soccer players perform less high intensity running in the first 5 min of the second half compared with the first half. This pattern is also seen in the women’s game (Krustrup et al, 2005). Therefore, body temperature has an influence on performance, especially, the sprint performance.

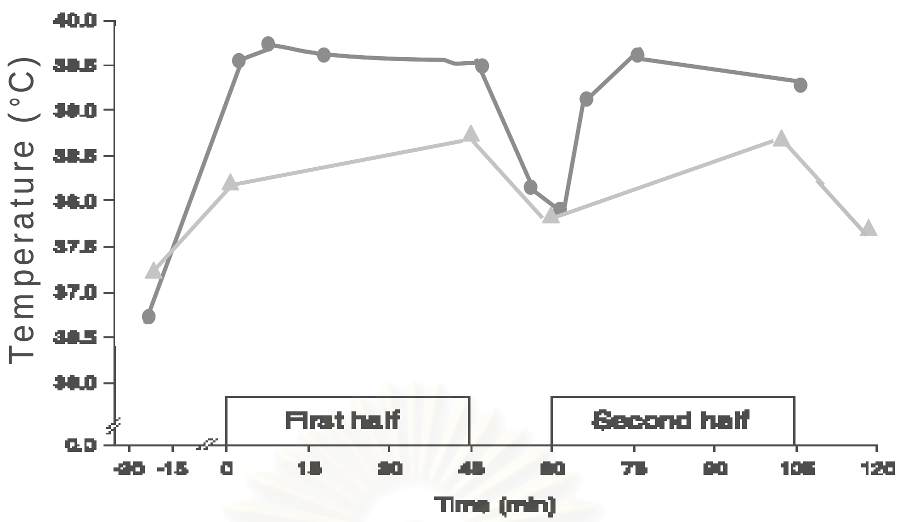

Figure 2.9 Muscle (circle) and rectal (triangles) temperatures during soccer match (Mohr et al, 2004).

Measurement of Core Temperature during Sports Activities

Core temperature is often used to indicate the efficiency of the thermoregulatory system of the body. An exact site for measurement of core temperature is a contentious issue and varies between studies. Commonly used sites include rectal, oral, esophageal and tympanic regions of the body, each yielding different values due to regional blood flow, metabolic rate of surrounding tissues and exposure to the external environment (Marsh and Jenkins, 2002).

Oral temperature does not measure accurately the deep body (core) temperature after strenuous exercise. For example, large and consistent differences occurred between oral and rectal temperatures after a 14-mile race in a tropical climate - the rectal temperature averaged 39.7^{o}C, whereas oral temperature remained a normal 37^{o}C.

This discrepancy partly results from evaporative cooling of the mouth and airways due to relatively high ventilatory volumes during and immediately high ventilatory volumes during and immediately after heavy exercise (McArdle et al, 2000). The esophagus is preferred by many as the site to measurement because of its deep body location close to the left ventricle, the aorta and to the blood flow to the hypothalamus. However, this site is undesirable in many settings because of the difficulty in inserting the thermistor, irritation to nasal passages, and general subject discomfort. Therefore, rectal temperature is the most accurately available method for monitoring core temperature during sports activites (Moran and Mendal, 2002). A linear relationship has been reported between the rectal temperature and relative workload (Saltin and Hermansen, 1966). The rectal temperature is generally uniform when the thermistor is inserted between 5 to 27 centimeters beyond the anal sphincter; the average insertion used in most studies is normally 8 to 12 centimeters for the comfort of participants (Marsh and Jenkins, 2002).

The principle is based on a thermistor probe or thermocouple sensor that produces electronic signals that change with differences in temperature. The thermistors are constructed from heavy metals where the resistance of the metals decreases as the temperature rises and increases as the temperature decreases. The degree of resistance is converted to temperature values. Heat energy, even as a result of a small rise in temperature, is enough to release electrons, and in this way to increase conduction and reduce resistance.

The Warm Up

Generally, warm up can be divided into several categories: active versus passive, general versus specific, and submaximal versus intense. Passive warm up involves raising muscle temperature or core temperature by some external means. Active warm up involves exercise and is likely to induce greater metabolic and cardiovascular changes than passive warm up. A general warm up, such as muscle stretching and total body exercise, can provide the benefit, but it is not as effective in stimulating increased blood flow and muscle mitochondrial respiration as a specific warm up. Warm up strategies have been devised for activities that demand more neuromuscular precision than physiologic function (e.g. gymnastics, dancing, diving, ice skating, and other high skill activities) (Robergs and Roberts, 1997). The beneficial effects of warm up have been attributed to temperature related mechanism and non-temperature related mechanisms as summarized in table 2.2 (Bishop, 2003a).

Active warm up tends to result in slightly larger improvements in short-term performance (<10 seconds). However, short-term performance may be impaired if the warm-up protocol is too intense or does not allow sufficient recovery. Warm up also appears to improve long-term (> 5minutes) and intermediate performance >10 seconds, but < 5 minutes) if it allows the athlete to begin the subsequent task in a relatively non-fatigued state, but with an elevated baseline VO_2. Long term performance may be impaired if the warm up depletes muscle glycogen stores and/or increases thermoregulatory strain (Bishop, 2003b).

The objective of warm up in soccer is to increase body temperature, prevent injury and prepare psychology (James C, 2004). It is suggested that the effective warm up should increase the core temperature by 1^oC-2^oC (Devries, 1980; Roy and Richard, 1983; Fox, 1984; Plowman and Smith, 2003).

Table 2.3 The beneficial effect of warm up (Bishop, 2003a).

Mechanism	Effect
Temperature related	Decreased resistance of muscles and joints Greater release of oxygen from hemoglobin and myoglobin Speeding of metabolic reactions Increased nerve conduction rate Increased thermoregulatory strain
Non-temperature related	Increased blood flow to muscles Elevation of baseline oxygen consumption Postactivation potentiation Psychological effects and increased preparedness

Active warm up for soccer includes two parts: general and specific warm up. The general warm up is a simple physical exercise like jogging or gentle rhythmic exercise. Drills with a ball are applied during the specific part of the active warm up. The major step involved in the process of warm up for soccer is shown in figure 2.10. The recommended Football Association warm-up and most professional team warm-ups include a third stage of more vigorous activity and longer hold stretches. The objectives are to raise the heart rate to 160 - 200 beats per minute (Soccer Academy, 2005).

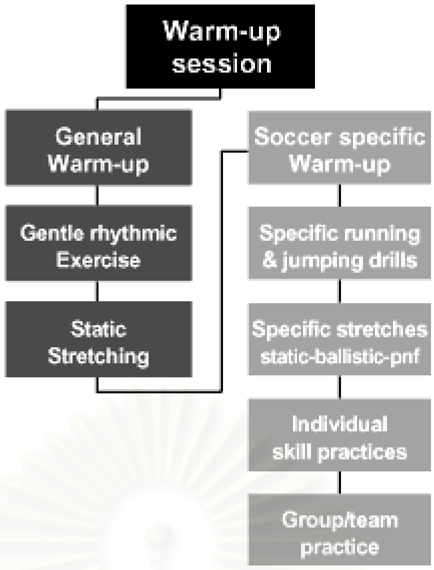

Figure 2.10 The process of warm up for soccer players (Soccer academy, 2005).

According to The European approach to warm-up in soccer, it is suggested that passive warm up can be divided in two parts: internal and external. The internal part includes drinks that the player can consume to increase their heart rate and blood circulation. The most common formulation for this purpose used by more than 90 percent of the teams in the world is hot tea with lemon, sweetened with honey. The external part is when parts of the body are rubbed with heating ointments.

There were a few details of warm up in Thai handbooks. It is briefly suggested that warm up should begin with slow movement and progress gradually, from low to high intensity (Chanvit, 1991; Prayote, 1999). Therefore, the protocol of warm up including intensity, duration and recovery depends on coach prescription.

CHAPTER III
MATERIALS AND METHODS

Materials and Equipment

1. A thermistor probe (TSD 102A, Biopac Systems Inc., Canada).

2. A biopac MP100 system with SKT100C transducer module (Biopac Systems Inc., Canada).

3. An oral digital thermometer (MT1611, Microlife®, Switzerland).

4. An ambient mercury thermometer (SK, Thailand).

5. A hygrometer (Barigo, Germany).

6. A heart rate monitors (Polar A1™, Sport Tester, Finland).

7. A stop watch (JS-306, Junso®, Chaina).

8. An AcqKnowLedge 3.8 for life science research Program (Biopac Systems Inc., Canada).

Methods

1. Subjects

There are twenty Thai female national soccer players who are preparing for the competition of 15^{th} Asian Game at Doha, State of Qatar during August to December, 2006. Thirteen subjects were voluntarily included in this protocol. The criteria of the subjects as follows:

<u>Inclusion criteria</u>

1. Healthy.

2. Normal menstrual cycle (28±3 days).

3. Informed consent.

Exclusion criteria

1. Illness that obstruct to exercise.

2. Cardiovascular diseases, hypothermia or hyperthermia.

3. Amenorrheic, oligomenorrheic.

4. Taking oral contraceptive pills.

5. Hormonal replacement.

The subjects were fully informed of any risks and discomforts associated with the experiments before giving their informed consent to participate. The studies were approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

2. Experimental Protocol

The general data of the subjects are collected including age, height, weight, oxygen consumption, and baseline sprint performance. Each subject had a normal menstrual cycle as defined by regular periodicity. To verify ovulatory menstrual cycles, daily basal body temperature (BBT; oral) was recorded by each subject on awakening. Data from an entire the menstrual cycle were collected before inclusion in the study to determine whether BBT increased after ovulation.

All experimental trials were conducted in the afternoon following a minimum of 2 h without heavy physical activity. Upon arrival at the field, subjects were clothed in soccer uniform and shoes. Ambient temperature and relative humidity were recorded at margin of the field and 80 centimeters above the ground. Each subject performed 2 experimental trials. Baseline resting data were collected for a 15-minute period. Before starting the experiment, subjects performed 5-minute muscle stretching. Then they performed 15-minute warm up, consisting of 5 minutes of jogging and 5 minutes of skipping with moving legs in all directions (i.e., kicked leg to front – behind, flexed knee with rotated to internal - external, as shown in figure3.1), and 5 minutes of sprinting combined with jogging in 50 meters (including jogging 15 meters, sprint for 20 meters and jogging 15 meters, sprint was 75% of maximal speed), followed by 45 minute recovery. Subjects could drink water through the experimental trials. Rectal temperature was recorded at rest, every 5 minutes during warm up and recovery period. In addition, heart rate was recorded at rest and every 5 minutes during warm up.

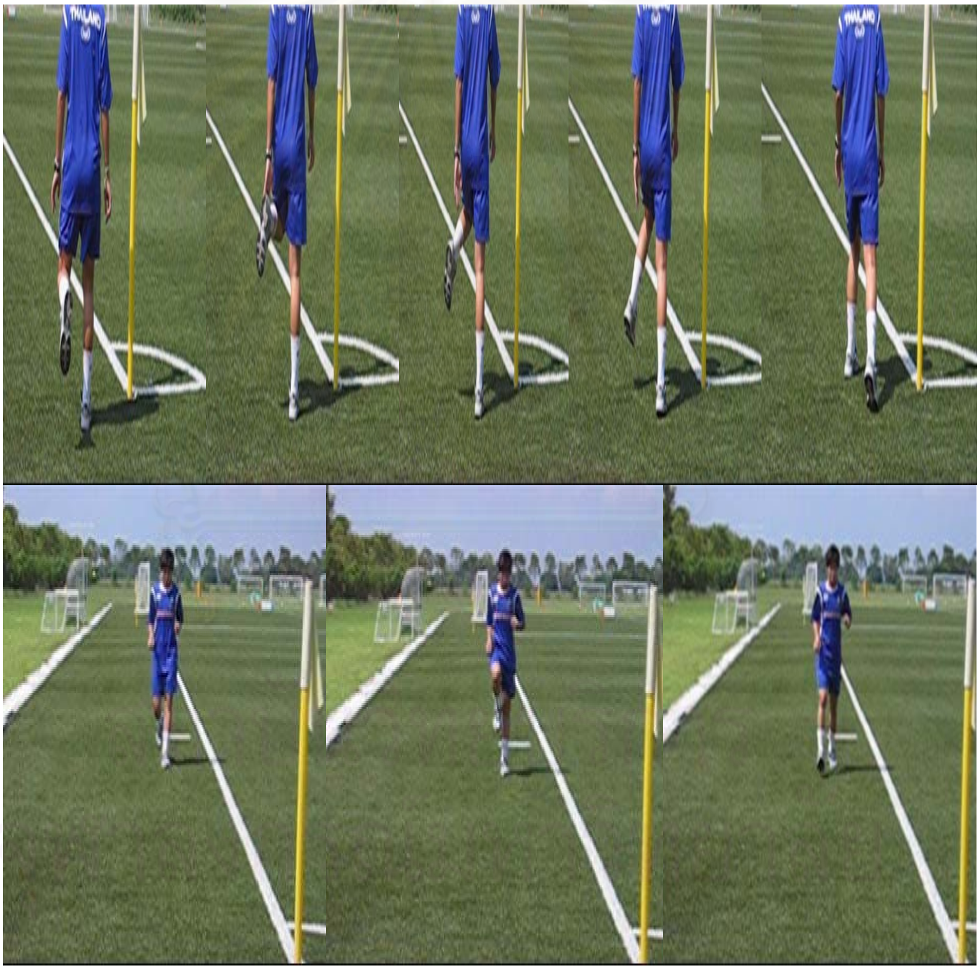

Figure 3.1 The example of skipping during warm up.

3. Sprint Test

Sprint test was performed at least 2 days before or after experiment for a baseline data and immediately after warm up during both phases of the menstrual cycle. The test consists of three 40-yard (36.6m) sprints and recovery for 3 minutes. Sprint times were recorded by using stop watch (JS-306, Junso®, China), having a precision of 0.01 s (chronograph up to 23 hours, 59 minutes, and 59 seconds). The best sprint time was represented for sprint performance.

4. Measurements

4.1 Core Temperature and Heart Rate

Core temperature was measured using a Biopac MP100 system with SKT100C transducer module (Biopac Systems Inc., Canada) (figure 3.2), and a thermistor probe (TSD102A, Biopac Systems Inc., Canada) which 1.7 mm. of diameter. The thermistor probe was wrapped by plastic film (figure 3.3) and lubricant gel was applied before inserting to the rectum at a depth of 10 cm, then thermistor probe was stabilized behind the left thigh (figure 3.4). The software program for collecting data was AcqKnowLedge 3.8 for life science research Program (Biopac Systems Inc., Canada). Heart rate was recorded by means of wireless transmission (Polar A1™, Sport tester, Finland). Heart rate monitor was placed on the chest of the subject (figure 3.5).

Figure 3.2 Biopac MP100 system with SKT100C transducer module.

Figure 3.3 The thermistor probe was wrapped by plastic film.

Figure 3.4 The subject who had taken the thermistor probe.

Figure 3.5 The subject with heart rate monitor.

4.2 Calibration of the Equipment

A thermistor probe is connected to an SKT100C amplifier with a gain setting of 5^{o}/Volt, an output set to channel 1. For this acquisition, the signal from the transducer was expressed in terms of degrees Celsius. To calibrate the transducer, it was brought to two known temperatures, against a mercury thermometer. At the first temperature, a voltage was taken reading by selecting show input values from the MP menu. At 32.2^{o}C, a read of 0 Volts will be got. The transducer is then brought to a temperature of 35^{o}C, and read of 1 Volts will be got.

The input Volts and scale value boxes reflect the value of the incoming signal and how it will be plotted on the screen, respectively. AcqKnowLedge program will perform linear extrapolation for signal levels falling outside this range, as well as, will perform similar interpolation for values between this range. These numbers in the change scaling box, type in “degree C” for units, and click the OK button (figure 3.6).

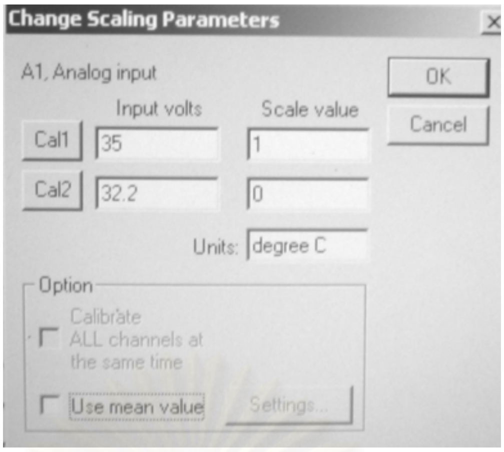

Figure 3.6 Change scaling parameters (Kremer, 2006).

5. Predicted Maximal Oxygen Consumption: Astrand Bike Test

Subject was tested for maximal oxygen consumption on 5th July, 2006 by Sports Authority of Thailand. The Astrand bike test predicts maximal oxygen consumption based upon the steady-state heart rate of a person exercising at a submaximal power level for 6 minutes. The rationale is dependent upon the direct relationships between power level, oxygen consumption, and heart rate. The equipment consists of bicycle ergometer, stethoscope, and stop watch. Subject was adjusted seat before testing, slight bend in knee when ball of foot was on pedal at bottom of pedal stroke and straight leg when heel was on pedal. When subject had set on the bike already, heart rate was auscultated for resting heart rate value. The initial power level was set at 300 kgm/min. Subject began cycling at 50 rpm, auscultate and count 30 heart beat at 1.30 min of the test and every 1 min through the last minute (sixth) of the test. The power level was readjusted after the third minute as shown in table 3.1. After complete 6 min, subject continued cycling for cool down at force level of 150 kgm/min until the heart rate was less than 100 bpm. The maximal oxygen consumption was interpreted and reported by Sports Authority of Thailand.

Table 3.1 Power adjustments of the Astrand bike test (Adam, 1994).

Heart rate	Power		Force	
	kgm/min	Watt	kg	N
Raise power level by				
<110	450	75	1.5	15
110-129	300	50	1.0	10
130-139	150	25	0.5	5
Lower power level by				
150-159	300	25	0.5	5
>160	150	50	1.0	10

Data Analysis

All values were presented as mean ± standard deviation (SD). Rectal temperature was reported at rest, during 15-minute warm up, and 45-minute recovery period decreased to baseline. Heart rate was reported at rest and during 15-minute warm up. Sprint time was reported at baseline and after 15-minute warm up during both phases of the menstrual cycle.

The result of rectal temperature, heart rate and sprint time were compared between early follicular and mid luteal phases of the menstrual cycle by Wilcoxon signed ranks test. Additionally, sprint time was compared between baseline and immediately after 15-minute warm up during both phases of the menstrual cycle by Wilcoxon signed ranks test. The significance is set at the 0.05 level of confidence.

Statistical analyses were performed using computer software SPSS version 13.0 for windows (SPSS, Chicago, IL, USA).

CHAPTER IV
RESULT

Characteristics of Subject

Thirteen Thai female national soccer players volunteered to participate in this study. One subject performed the experiment only in mid luteal phase. The characteristics of the subjects was shown in table 4.1. All subjects performed the study at ambient temperature of 32.5±1.63°C (30.0-35.5°C) with relative humidity of 53.57±10.18% (40-69%).

Table 4.1 The characteristics of the subjects (N=13).

Characteristics	Mean±SD (Min-Max)
Age (yr)	18.8±1.3 (17-21)
Height (cm)	161.23±4.69 (153-168)
Weight (kg)	54.77±3.30 (50-60)
VO_{2max} (ml/kg/min)	53.05±6.66 (41.18-66.21)
Menstrual cycle length (d)	29.4±1.07 (28-31)

Rectal Temperature

This study was divided into two trials: during early follicular and mid luteal phases of the menstrual cycle. The number of subjects in early follicular and mid luteal phases of the menstrual cycle was 12 and 13, respectively. Rectal temperature was recorded at rest, during 15-minute warm up and 45-minute recover period. As depicted in table 4.2, baseline resting rectal temperature in early follicular and mid luteal phases were 36.79±0.21°C and 37.11±0.16°C, respectively. Resting rectal temperature in mid luteal phase was significantly higher than in early follicular phase.

During warm up, the rectal temperature increased continuously. At the end of warm up, it was significantly elevated above the baseline level in early follicular and mid luteal phases (38.05±0.38°C and 38.29±0.30°C, respectively). The total increase in rectal temperature during early follicular and mid luteal phases of the menstrual cycle was 1.26±0.41^{o}C and 1.18±0.33^{o}C, respectively. The rectal temperatures were graphically presented in figure 4.1 and 4.2.

Subsequently, the rectal temperature decreased gradually after warm up. At 20th minute of recovery, rectal temperature was decreased by approximate 50%, i.e., 0.58±0.26^{o}C and 0.57±0.26^{o}C during early follicular and mid luteal phases, respectively.

Table 4.2 Mean ± SD of rectal temperature and difference temperature between phases of the menstrual cycle at rest, during warm up and 45-minute recovery period.

Period	Minute at	Rectal temperature (^{o}C)		
		Early follicular phase (N=12)	Mid luteal phase (N=13)	Diff. (#) (N=12)
Rest		36.79±0.21	37.11±0.16	0.32±0.29*
Warm up	5	37.26±0.29	37.46±0.26	0.21±0.36
	10	37.50±0.28	37.68±0.24	0.18±0.37
	15	38.05±0.38	38.29±0.30	0.27±0.38
Recovery	5	37.91±0.31	38.15±0.32	0.27±0.36
	10	37.78±0.29	38.02±0.33	0.27±0.38
	15	37.63±0.29	37.84±0.31	0.25±0.40
	20	37.47±0.28	37.71±0.30	0.27±0.42
	25	37.31±0.28	37.53±0.22	0.25±0.36
	30	37.09±0.24	37.41±0.19	0.34±0.34
	35	36.97±0.22	37.30±0.16	0.35±0.28
	40	36.86±0.22	37.17±0.19	0.33±0.31
	45	36.79±0.21	37.11±0.16	0.33±0.29

The difference value (#) is the mean difference in rectal temperature between mid luteal phase and early follicular phase using Wilcoxon signed ranks test.

* Significant difference between both phases, $P<0.05$.

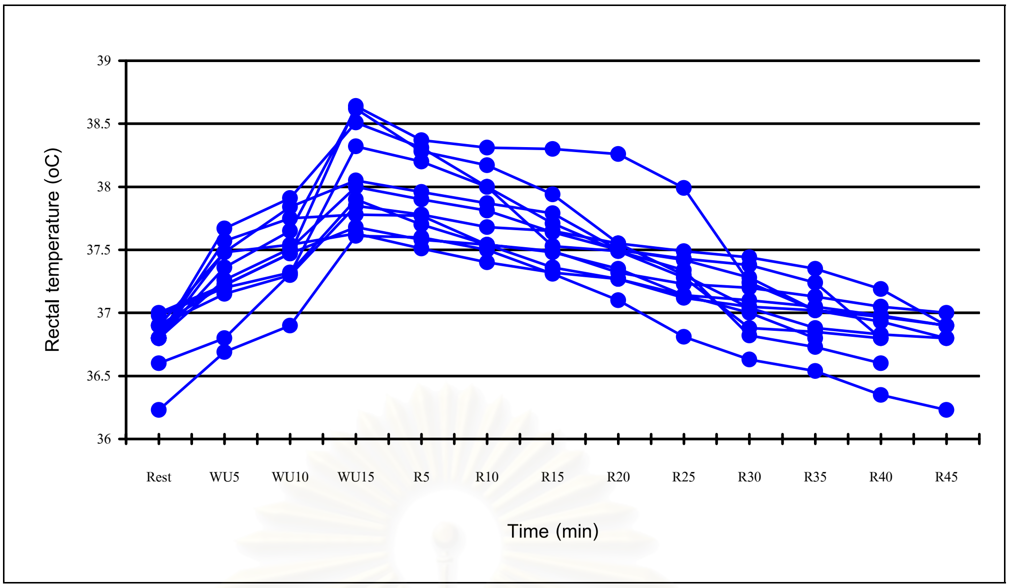

Figure 4.1 Rectal temperature at rest, during warm up (WU), and recovery period (R) in early follicular phase (●) of the menstrual cycle.

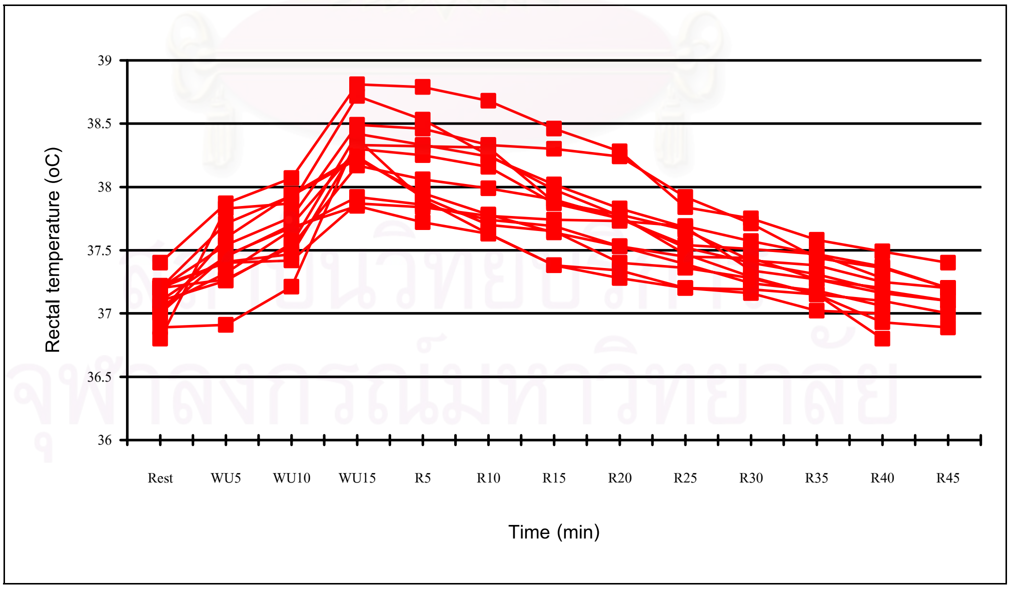

Figure 4.2 Rectal temperature at rest, during warm up (WU), and recovery period (R) in mid luteal phase (■) of the menstrual cycle.

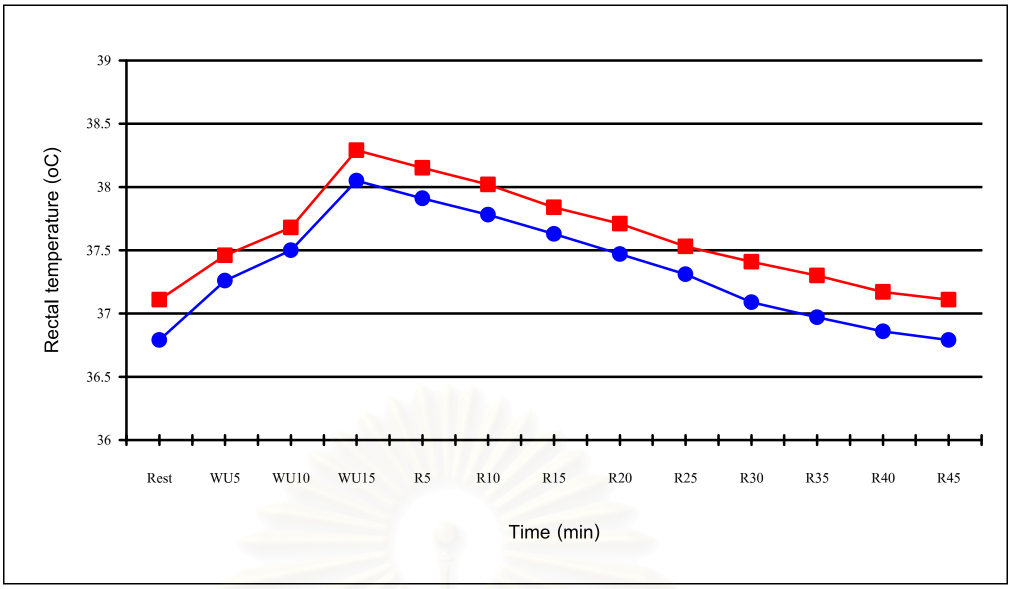

Figure 4.3 Mean rectal temperature at rest, during warm up (WU), and recovery period (R) in early follicular phase (●) and mid luteal phases (■) of the menstrual cycle.

In figure 4.3, the mean±SD of rectal temperature during early follicular phase of the menstrual cycle at rest, during 15-minute warm up and recovery period tended to be higher than early follicular phase of the menstrual cycle.

Heart Rate

Resting heart rate in mid luteal phase was significantly higher than in early follicular phase (73.15±6.73 beats/min and 69.33±8.14 beats/min, respectively). However, heart rate was similar in early follicular and mid luteal phases during warm up. The data was shown in table 4.3.

Table 4.3 Heart rate at rest and during warm up during early follicular and mid luteal phases of the menstrual cycle.

Period	Minute at	Heart rate (beats/min)	
		Early follicular phase	Mid luteal phase
Rest		69.33±8.14	73.15±6.73*
Warm up	5	122.08±15.97	117.46±10.08
	10	130.33±16.96	135.31±17.36
	15	153.67±20.34	158.38±15.19

Compared between phases of the menstrual cycle using Wilcoxon signed ranks test.

* Significant different from early follicular phase, $P<0.05$.

Immediately after warm up during early follicular phase, heart rate was 153.67±20.34 beats/min (76.34±9.96% of HR_{max}), and mid luteal phase was 158.38±15.19 beats/min (78.69±7.37% of HR_{max}).

Sprint Performance

The subject performed three sprints. The mean±SD of best sprint time in baseline and after 15-minute warm up during early follicular and mid luteal phases of the menstrual cycle were shown in table 4.4. The data was presented in histogram in figure 4.4. The mean sprint time after warm up of both phases of the menstrual cycle were reduced ($P<0.05$) by 0.15±0.19 seconds and 0.15±0.15 seconds (early follicular and mid luteal phases, respectively) compared with baseline. However, the mean sprint time was not different between early follicular and mid luteal phases of the menstrual cycle.

Table 4.4 Mean±SD of sprint time in baseline and after 15-minute warm up during early follicular and mid luteal phases of the menstrual cycle.

Period	Baseline	After 15-minute warm up	
		Early follicular phase	Mid luteal phase
Time (seconds)	5.66±0.13	5.52±0.13	5.51±0.16

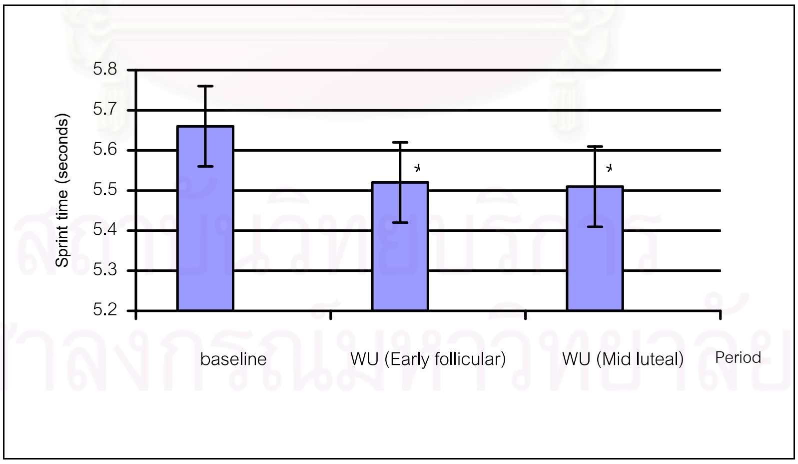

Figure 4.4 Mean ± SD of sprint time compared at baseline and after warm up (WU) in early follicular and mid luteal phases of the menstrual cycle. The comparison was alone by using Wilcoxon signed ranks test. * Significant difference between baseline, $P<0.05$.

CHAPTER V
DISCUSSION AND CONCLUSION

Discussion

The purpose of this study was to investigate the effects of 15-minute warm up on core temperature changes and sprint performance during early follicular and mid luteal phases of the menstrual cycle in Thai female national soccer players in hot and humid condition. Thirteen female national soccer players volunteered to participate in this study with informed consents. The characteristics of the subjects in table 4.1 showed that the maximal oxygen consumption was high. This indicated that the subjects represented those who were high in cardiovascular fitness.

The warm up protocol in the present study is the active warm up without ball or general warm up which is usually performed in Thai female national soccer team. The protocol was set up for 15 minutes, consisting of jogging, skipping and sprinting. The intensity of procedure was determined by heart rate monitor during warm up. The mean maximum intensity of both phases was 77.57±8.61% of HR_{max}. Warm up resulted in an increase in rectal temperature of 1.26±0.41°C (from 36.79±0.21°C to 38.05±0.38°C) and 1.18±0.33°C (from 37.11±0.16°C to 38.29±0.30°C) during early follicular and mid luteal phases of the menstrual cycle, respectively. The result showed that the 15-minute warm up in hot and humid condition (ambient temperature of 32.5±1.63°C with relative humidity of 53.57±10.18%) could increase core temperature more than 1°C. This result of increased core temperature was similar to a study in male Danish soccer players whose core temperatures at rest were elevated from 37.2±0.1°C to 38.2±0.1°C after 35-minute warm up in cold condition (Mohr et al, 2004). The present study showed that the duration of warm up in hot and humid condition should be less than that of cold environment because heat and high humidity reduce the body's ability to lose heat. Therefore, this 15-minute warm up protocol is sufficient for Thai female soccer player in a hot and humid environment.

During recovery period, rectal temperature gradually decreased. Within 20 minutes, the temperature was decreased by 46.03% and 49.15% (early follicular and mid luteal phases, respectively). Finally, rectal temperatures returned to baseline within

45 minutes. On the contrary, a study on esophageal temperature response on post-exercise found that in both exercise trials (moderate exercise: 70%VO_{2max} and intense exercise: 93%VO_{2max}), the temperatures decreased immediately during the first 5 minutes of recovery, reaching stable elevated values within the subsequent 10-minute period (Kenny and Niedre, 2002). However, there was a difference in ambient temperature and humidity. They controlled a constant ambient temperature of the chamber at 29^{o}C with a relative humidity of 50% but in this study the experiment was performed in soccer field where ambient temperature was 32.5±1.63^{o}C (30.0-35.5^{o}C) with relative humidity of 53.57±10.18% (40-69%). Generally, the main mechanism of heat loss at rest is radiation. Heat radiates more from the body where the ambient temperature was low. Therefore, the rate of decreased core temperature was different when compared between the two study.

Regarding the phases of the menstrual cycle, the result showed that resting rectal temperature during mid luteal phase was significantly higher than during early follicular phase (37.11±0.16^{o}C and 36.79±0.21^{o}C, respectively). This result confirmed the majority of the studies that resting rectal temperature was significantly elevated during the luteal phase, especially in ambient and hot conditions (Kolka and Stephenson, 1997; Tladi et al., 2003). The mechanism for this elevation is associated with a thermogenic action of progesterone, of which the concentration is maximal during the luteal phase. Recently, it was reported that estrogen administration can attenuate the thermoregulatory effects of progesterone and lower the hormonally increased setpoint temperature. Furthermore, it has been suggested that core temperature could depend on the ratio of progesterone to estrogen (Marsh and Jenkins, 2002).

The result of this study revealed that rectal temperature at rest, during 15-minute warm up and 45-minute recovery tended to be elevated in mid luteal phase. Agreed with most studies, the thermoregulation strain was affected by the menstrual phase (Kolka and Stephenson, 1997; Charkoudian and Johnson, 2000; Tladi et al, 2003). In previous study, it was found that esophageal temperature at rest and during exercise was 0.3±0.1^{o}C higher in mid luteal phase than in early follicular phase at ambient temperature of 35^{o}C with relative humidity of 22%.

Moreover, thermoregulatory effector function can also be assessed by measuring skin blood flow and sweat rate. As core temperature increases during exercise or heat stress, blood flow to the cutaneous vasculature increases proportionately. Another previous study found that during exercise, forearm blood flow was increased when the core temperature was elevated of greater than 37.5^{o}C during the mid luteal phase compared with early follicular phase and 40-50% higher during mid luteal phase experiments (Kolka and Stephenson, 1997). Interestingly, there was a study that investigated what extent oral contraceptives could modify the thermoregulatory responses to exercise. They found that intake of oral contraceptives reduced the differences in the gains for sweating, making the thermoregulatory responses to exercise more uniform (Grucza et al, 1993).

Regarding hemodynamics response during recovery period, it was suggested that post exercise hemodynamics, including arterial pressure, systemic vascular conductance, and femoral vascular conductance are unaffected factors associated with the menstrual (Lynn et al., 2007).

In this study, the subjects performed 40-yard sprint according to an instruction of test. The 40-yard sprint represented the typical punt-coverage distance of the soccer. The test consisted of three trials and 3 minutes of recovery between trials. There should be no more than three trials if the time difference between trials is not greater than 0.20 seconds. The 3-minute recovery is adequate to avoid injury and allow restoration of the phosphates (Adams, 1994). The best time of the test is used as the individual's score. The data presented in table 4.4 showed that sprint time after 15-minute warm up during both phases of the menstrual cycle (5.52±0.13 and 5.51±0.16 seconds: early follicular and mid luteal phase, respectively) was significantly decreased when compared to baseline (5.66±0.13 seconds). The decrease in sprint time (0.15±0.19 and 0.15±0.15 seconds: early follicular and mid luteal phase, respectively) seems to be of little extent but it is very considerable in the soccer match. A player will reach a ball first if he can run faster than another one even if the time difference is in the twinkling of the eyes. Interestingly, the 15-minute warm up protocol could improve the sprint performance. This result agreed that sprint performance was related to core temperature. Similarly, there was a study on relationship between muscle temperature and sprint performance.

It was shown that decrease in muscle temperature at half-time of soccer match was correlated (r=0.6., $P<0.05$) to the reduction in sprint performance during half-time (Mohr et al, 2004). The mechanism of warm up to improve short term performance was temperature related. It has been reported that increase in temperature may improve performance via a decrease in the viscous resistance of muscles, a speeding of rate-limiting oxidative reactions and an increase in oxygen delivery to muscles (Bishop, 2003a).

With regards to effects of the menstrual cycle on exercise performance. This study showed no difference in sprint performance across the menstrual cycle. According to a study on catecholamines response to sprint exercise during phases of menstrual cycle, it was found that catecholamines concentrations were not significantly different in the follicular and luteal phase. This suggested that the menstrual cycle phase did not alter performance (Botcazou et al., 2006). In another sports, such as repeated swimming time trials, incremental, high-intensity and intermittent treadmill running and maximal cycle protocols, it was also found that performances did not change between phases of menstrual cycle (Marsh and Jenkins, 2002). Previous studies suggested that regularly menstruating female athletes, competing in strength-specific sports and intense anaerobic/aerobic sports, do not need to adjust for menstrual cycle phase to maximize performance (Reilly, 2000; Jonge, 2003).

There was a significant difference in heart rate between the phases of the menstrual cycle at rest. Heart rate during mid luteal phase was higher than during early follicular phase. In contrast, there was no difference in heart rate during warm-up between phases of menstrual cycle. Most researches have reported no changes over the menstrual cycle for many determinants, including heart rate, maximal oxygen consumption (VO_{2max}), lactate response to exercise, body weight, plasma volume, hemoglobin concentration, and ventilation (Kolka et al, 1997; Marsh and Jenkins, 2002; Jonge, 2003; Lynn et al, 2007). However, there was a conflicting data in a study, which showed significant difference between phases, with heart rate during the luteal phase being significantly higher both at rest and during exercise (Stoney et al, 1986; Hessemer and Bruck, 1985; Tladi et al, 2003).

Conclusions

In view of the submission that effective warm up should be able to raise the rectal temperature by 1°C - 2°C, these data demonstrate that warm up for 15 minutes can elevate the core temperature of more than 1°C in hot and humid environment. Additionally, the 15-minute warm up can improve sprint performance. Hence, this warm up procedure was sufficient and effective for Thai female national soccer players. Concerning recovery period, this study suggested that recovery period should be no longer than 10 minutes before the next match or training so as to maintain the increment in core temperature of approximately 1°C. If the players take a rest of more than 20 minutes, the rectal temperature will decline by nearly 50%. Moreover, heart rate and sprint performance did not differ during the course of the menstrual cycle.

However, warm up for soccer is more complicated. It is important to set up a warm up protocol that is sufficient in intensity and duration, followed by an appropriate recovery period, in order to increase body temperature to an optimal level, but neither to deplete muscle glycogen stores nor to increase thermoregulatory strain.

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APPENDICES

APPENDIX A

Descriptive of one cycle of basal body temperature during experimental.

เลขที่ วันที่	1	2	3	4	5	6	7	8	9	10	11	12	13
1	35.7	36.1	36	36.2	36	36.1	35.8	36	35.9	36	35.9	35.8	36
2	35.8	36.2	36.1	36.2	36	36.1	35.9	36.2	35.8	36.1	36	35.9	36.1
3	36	36.2	36	36.2	35.8	36.2	36	36.2	35.9	36.1	36.1	36	36
4	36	36.1	35.9	36.1	36.1	36	36.1	36.1	36	36.2	36.2	36	35.9
5	36.1	36	36.1	36	35.9	36.1	36.1	36.2	35.8	36.1	36.1	35.9	36
6	36	36.1	36.2	36.1	36	36	36	36.2	35.5	36	36	36	36.2
7	36.1	36	36.2	36	36.1	35.9	35.9	36.1	35.7	36.2	36	36.2	36.1
8	36	36	36.1	36.2	36.1	36.2	36	36	35.8	35.9	36.3	36.1	36.1
9	36.1	36.1	36	36.1	36.2	36.1	36.1	36	35.9	36	36	36	36
10	36.1	36.1	36.1	36.2	36.1	36	36	36.1	35.8	36.1	36.2	36.2	35.9
11	36.1	36	36.1	36.1	35.7	36	35.9	36	35.4	36.3	36	36	36
12	36	36.1	36.1	36	35.9	36.1	36	**36.4**	35.9	36.4	35.9	36.1	36
13	36	36.1	36.2	36.1	36	36	35.8	36.3	35.9	36.3	36	**36.4**	36.2
14	**36.4**	36	36.1	36	36	35.9	**36.2**	36.4	35.8	36.3	36.1	36.4	36.1
15	36.4	**36.3**	36	36	**36.4**	36.1	36.3	36.5	35.8	36.2	36.3	36.5	36
16	36.5	36.4	**36.5**	35.9	36.3	36	36.5	36.5	35.9	**36.6**	**36.7**	36.6	**36.4**
17	36.4	36.4	36.6	**36.4**	36.4	**36.4**	36.5	36.6	**36.4**	36.7	36.6	36.5	36.5
18	36.6	36.6	36.5	36.4	36.5	36.5	36.6	36.5	36.5	36.8	36.7	36.4	36.7
19	36.5	36.5	36.4	36.6	36.6	36.6	36.5	36.5	36.5	36.7	36.6	36.4	36.6
20	36.5	36.4	36.4	36.7	36.6	36.5	36.4	36.7	36.4	36.6	36.5	36.5	36.6
21	36.5	36.5	36.6	36.9	36.5	36.4	36.4	36.6	36.4	36.7	36.4	36.6	36.5
22	36.5	36.6	36.5	36.5	36.4	36.3	36.6	36.6	36.3	36.7	36.4	36.6	36.5
23	36.4	36.5	36.5	36.7	36.4	36.3	36.5	36.5	36.4	36.8	36.6	36.5	36.4
24	36.3	36.4	36.4	36.4	36.5	36.4	36.5	36.4	36.3	36.9	36.5	36.7	36.4
25	36.4	36.5	36.5	36.5	36.4	36.5	36.4	36.5	36.3	36.8	36.5	36.6	36.5
26	36.4	36.5	36.5	36.5	36.3	36.4	36.3	36.7	36.4	36.6	36.4	36.5	36.6
27	36.5	36.4	36.4	36.4	36.4	36.4	36.3	36.6	36.3	36.4	36.5	36.5	36.5
28	36.4	36.3	36.4	36.3	36.5	36.3	36.1	36.5	36.3	36.3	36.6	36.4	36.5
29	36.4.	36	36.3					36.4	36.3		36.5	36.5	36.4
30		35.8	36					36.4	36.2		36.4	36.4	36.4
31		35.8	36						36				

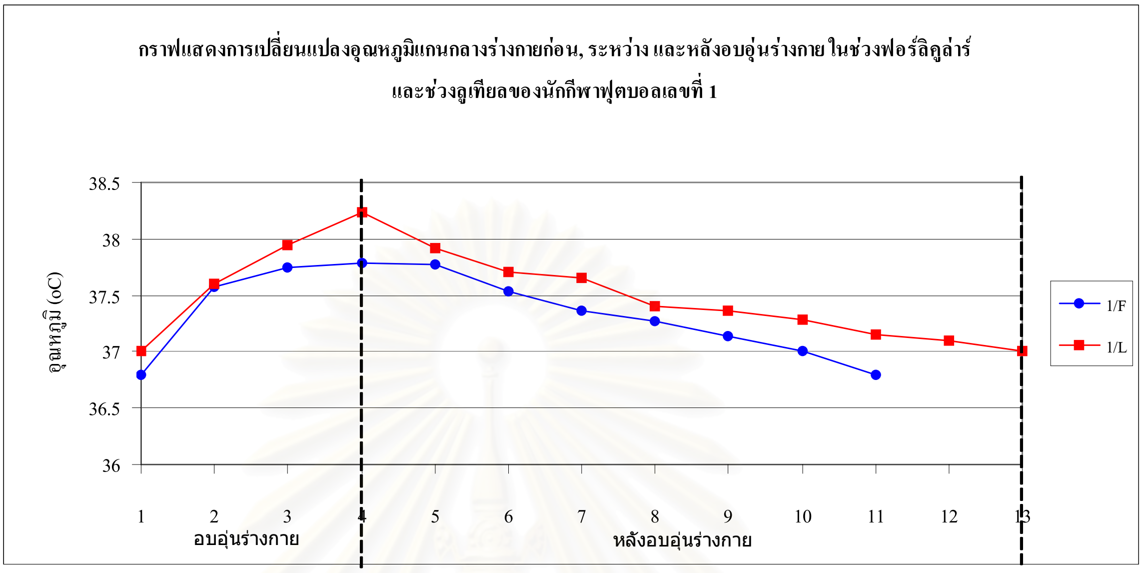
ปล. เริ่มนับวันที่เริ่มมีประจำเดือนเป็นวันที่ 1

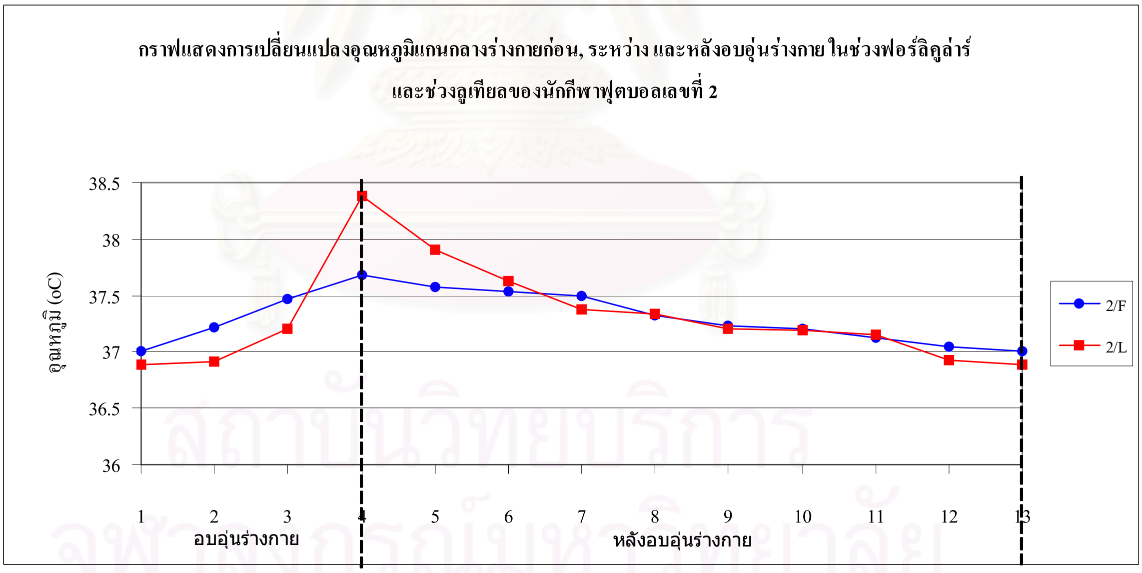
APPENDIX B

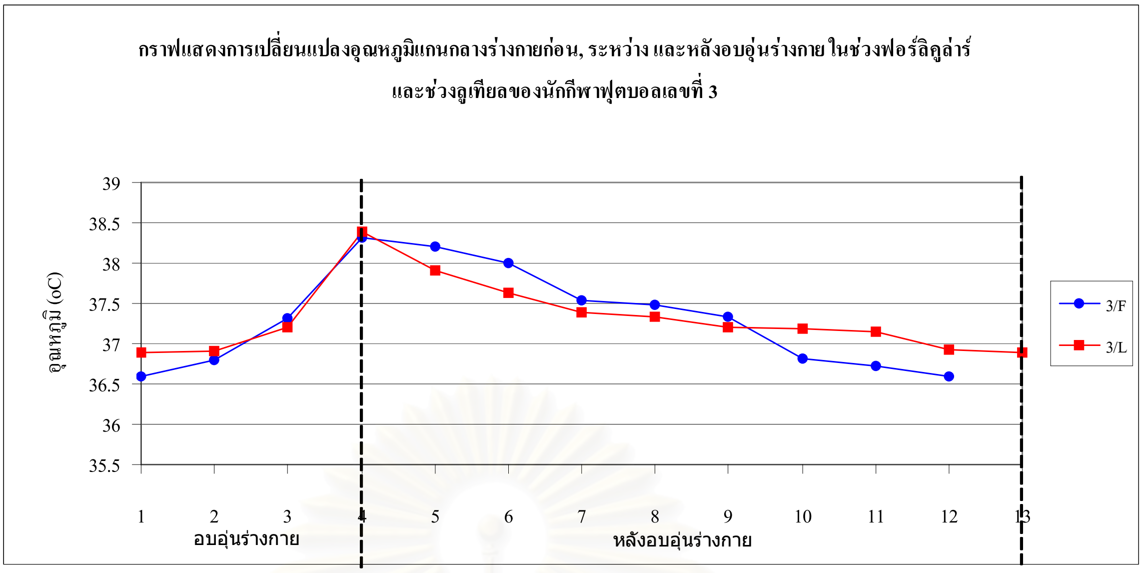
Descriptive of rectal temperature before, during warm up and 45-minute recovery period divided to early follicular phase (F) and mid luteal phase (L) of all subject.

เลขที่	ขณะพัก	ระหว่างอบอุ่นร่างกาย นาทีที่			หลังอบอุ่นร่างกาย นาทีที่									
		5	10	15	5	10	15	20	25	30	35	40	45
1/F	36.8	37.57	37.75	37.78	37.77	37.54	37.36	37.27	37.14	37	36.8	36.8	36.8
2/F	37	37.22	37.47	37.68	37.58	37.54	37.49	37.32	37.23	37.2	37.13	37.05	37
3/F	36.6	36.8	37.31	38.32	38.2	38	37.53	37.49	37.34	36.82	36.73	36.6	36.6
4/F	36.9	37.22	37.47	38.64	38.37	38.31	38.3	38.26	37.99	37.24	37.02	36.97	36.9
5/F	36.8	37.36	37.65	38.62	38.28	38.17	37.94	37.55	37.3	37.04	36.88	36.83	36.8
6/F	36.8	37.67	37.91	38.51	38.31	38	37.71	37.49	37.28	36.88	36.85	36.8	36.8
7/F	36.98	37.2	37.32	37.9	37.7	37.54	37.48	37.35	37.14	37.1	37.05	36.98	36.98
8/F	36.9	37.48	37.54	37.63	37.51	37.4	37.32	37.27	37.12	37.05	37.02	36.98	36.9
9/F	36.23	36.69	36.9	37.61	37.6	37.5	37.31	37.1	36.81	36.63	36.54	36.35	36.23
10/F	36.9	37.15	37.3	37.85	37.78	37.68	37.65	37.55	37.49	37.44	37.35	37.19	36.9
11/F	36.8	37.48	37.84	38.05	37.96	37.87	37.79	37.5	37.43	37.38	37.24	36.8	36.8
12/F	36.8	37.26	37.51	38	37.9	37.81	37.64	37.5	37.42	37.28	37.02	36.93	36.8
1/L	37	37.6	37.94	38.24	37.92	37.7	37.65	37.4	37.36	37.28	37.15	37.1	37
2/L	37.2	37.27	37.53	38.17	38.06	37.99	37.9	37.75	37.54	37.51	37.47	37.37	37.2
3/L	36.89	36.91	37.21	38.38	37.9	37.63	37.38	37.34	37.2	37.19	37.15	36.93	36.89
4/L	37.2	37.41	37.47	38.33	38.32	38.31	37.88	37.78	37.66	37.42	37.38	37.25	37.2
5/L	36.8	37.83	37.87	38.72	38.53	38.25	37.98	37.77	37.47	37.29	37.15	36.8	36.8
6/L	37.2	37.54	37.76	38.49	38.46	38.33	38.3	38.24	37.92	37.71	37.44	37.36	37.2
7/L	37.06	37.32	37.66	37.92	37.86	37.74	37.69	37.53	37.39	37.24	37.18	37.06	37.06
8/L	37.22	37.4	37.42	37.87	37.84	37.77	37.74	37.73	37.69	37.57	37.47	37.28	37.22
9/L	37.4	37.87	38.07	38.81	38.79	38.68	38.46	38.28	37.84	37.75	37.58	37.49	37.4
10/L	37.1	37.26	37.55	38.42	38.33	38.24	38.02	37.83	37.68	37.34	37.27	37.16	37.1
11/L	37.2	37.71	37.93	38.22	37.95	37.78	37.64	37.53	37.45	37.44	37.27	37.2	37.2
12/L	37	37.46	37.68	37.85	37.72	37.63	37.38	37.28	37.2	37.16	37.02	37	37
13/L	37.1	37.45	37.7	38.3	38.25	38.16	37.87	37.75	37.52	37.4	37.31	37.18	37.1

The rectal temperature before, during warm up and 45-minute recovery period of each subject was graphically presented in figure 1-13.



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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 3
อุณหภูมิ (oC)
39
38.5
38
37.5
37
36.5
36
35.5
1
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6
7
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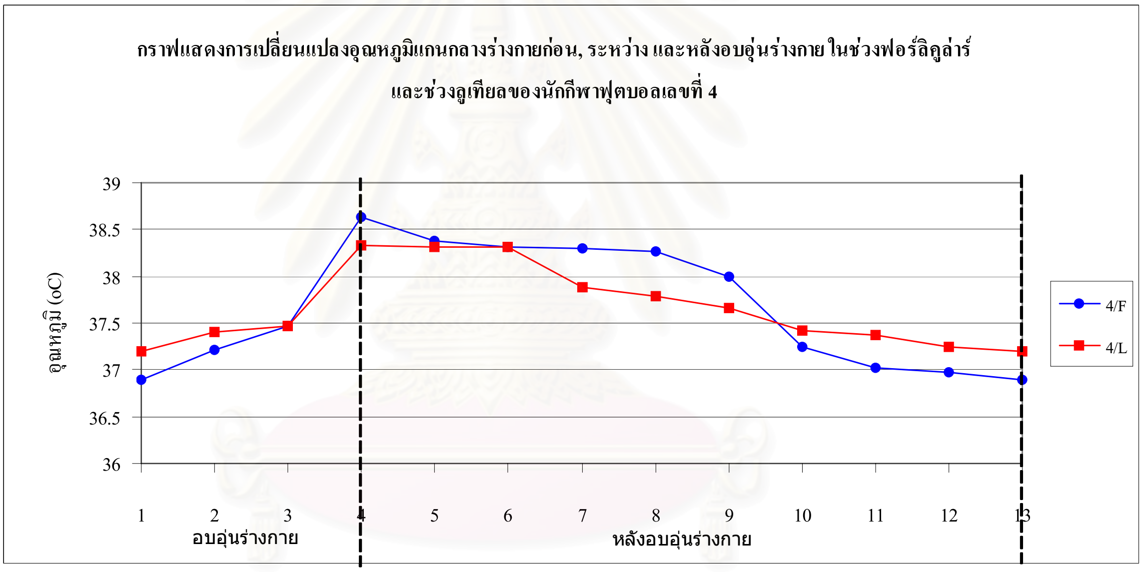
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
3/F
3/L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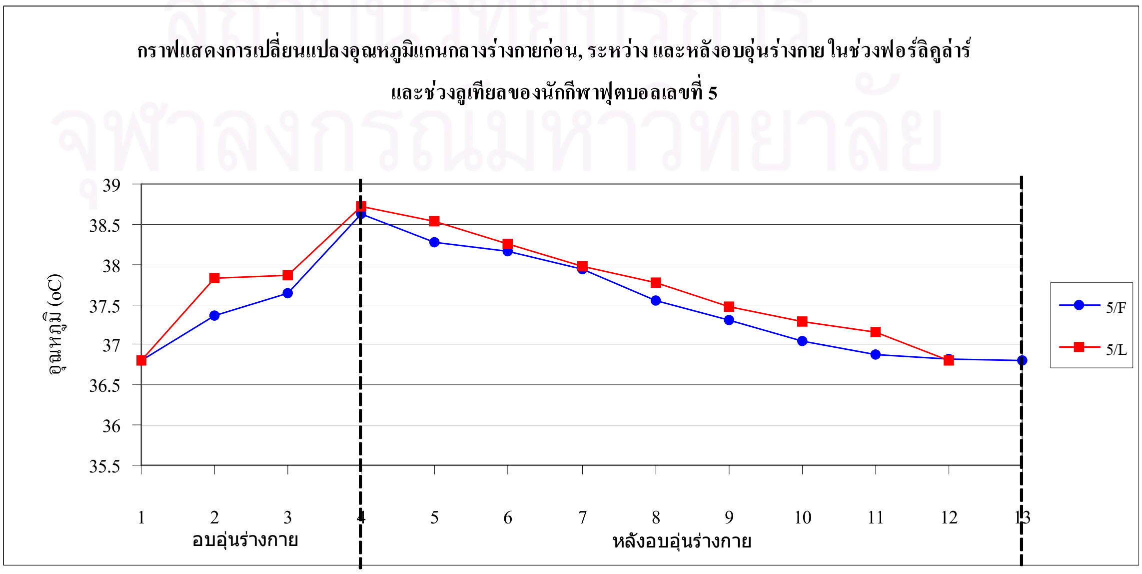
และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 4
อุณหภูมิ (oC)
39
38.5
38
37.5
37
36.5
36
1
2
3
4
5
6
7
8
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
4/F
4/L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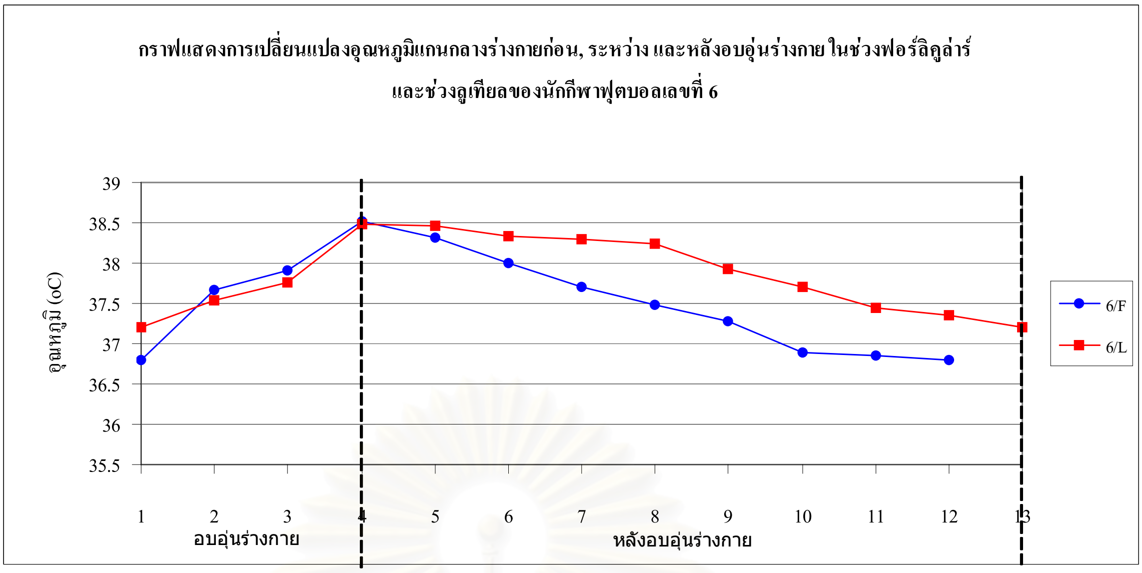
และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 5
อุณหภูมิ (oC)
39
38.5
38
37.5
37
36.5
36
35.5
1
2
3
4
5
6
7
8
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
5/F
5/L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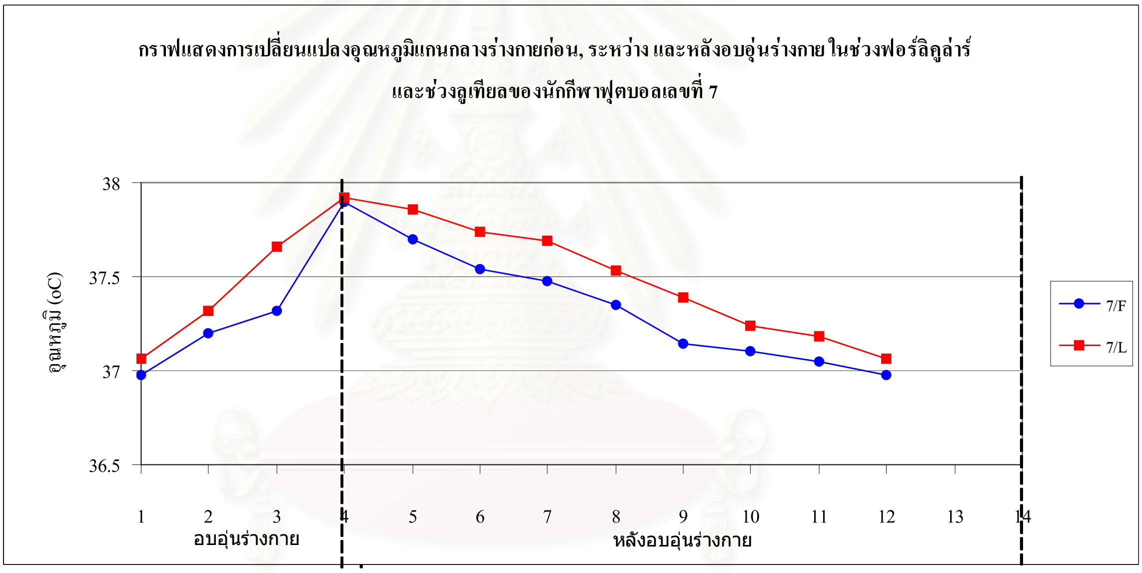
และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 6
อุณหภูมิ (oC)
39
38.5
38
37.5
37
36.5
36
35.5
1
2
3
4
5
6
7
8
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
6/F
6/L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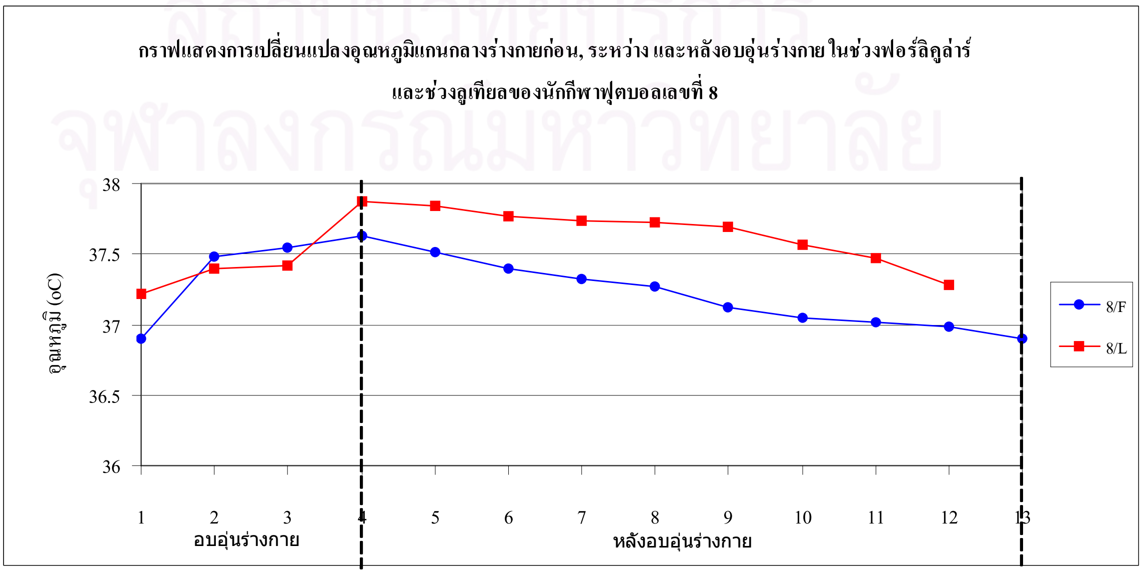
และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 7
อุณหภูมิ (oC)
38
37.5
37
36.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
7/F
7/L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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 8
อุณหภูมิ (oC)
38
37.5
37
36.5
36
1
2
3
4
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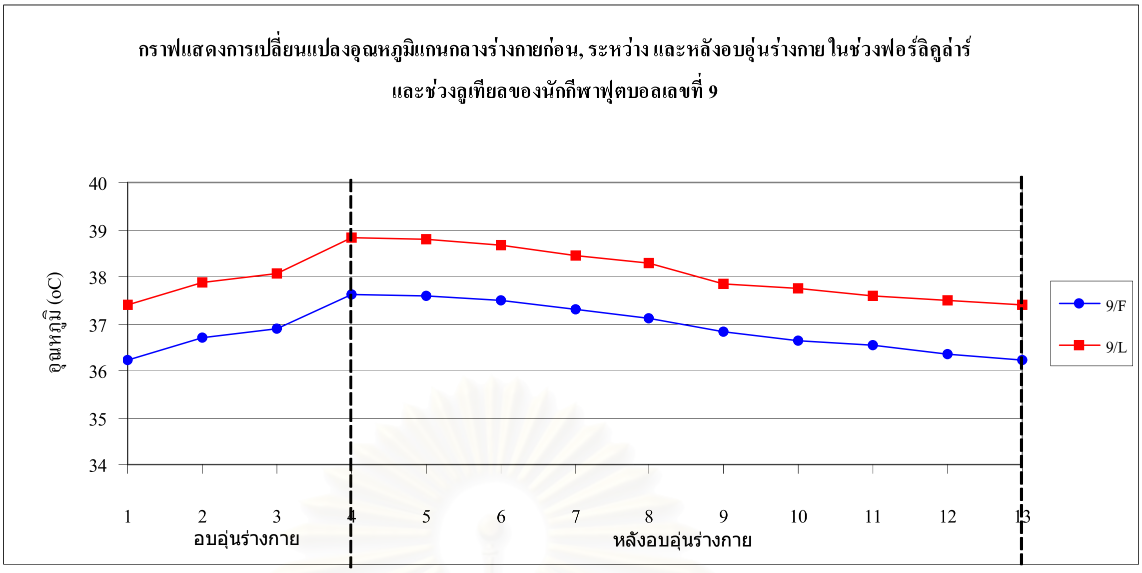
6
7
8
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
8/F
8/L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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 9
อุณหภูมิ (oC)
40
39
38
37
36
35
34
1
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3
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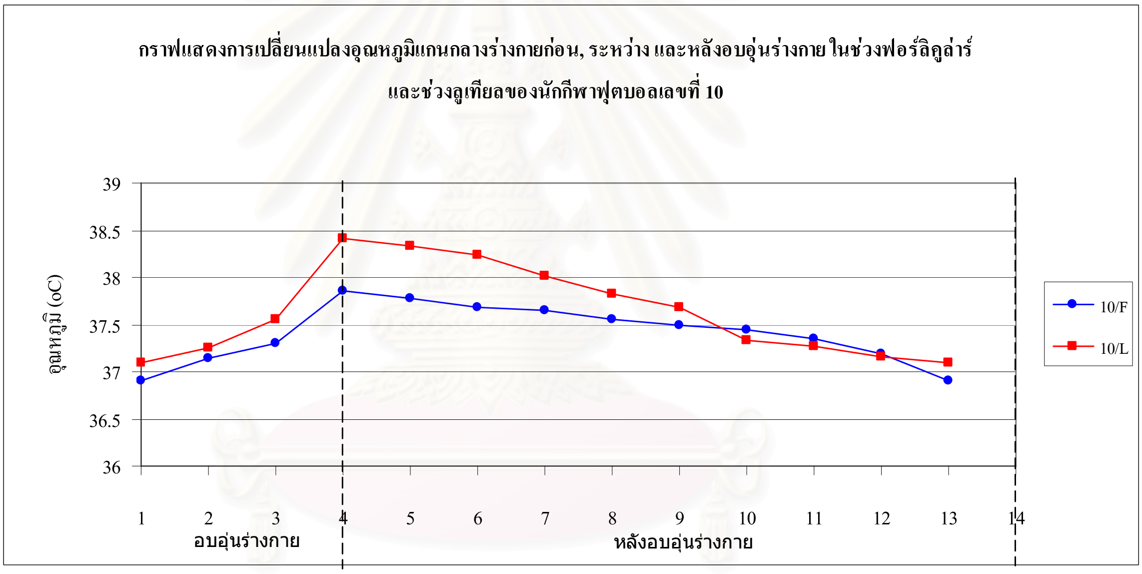
8
9
10
11
12
13
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
9/F
9/L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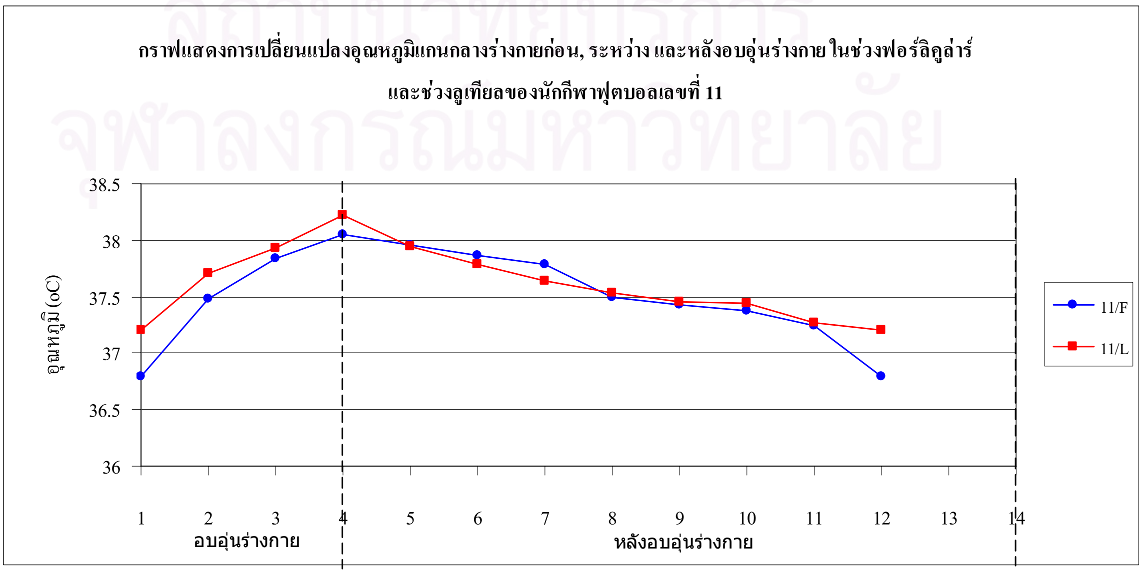
และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 10
อุณหภูมิ (oC)
39
38.5
38
37.5
37
36.5
36
1
2
3
4
5
6
7
8
9
10
11
12
13
14
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
10/F
10/L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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 11
อุณหภูมิ (oC)
38.5
38
37.5
37
36.5
36
1
2
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4
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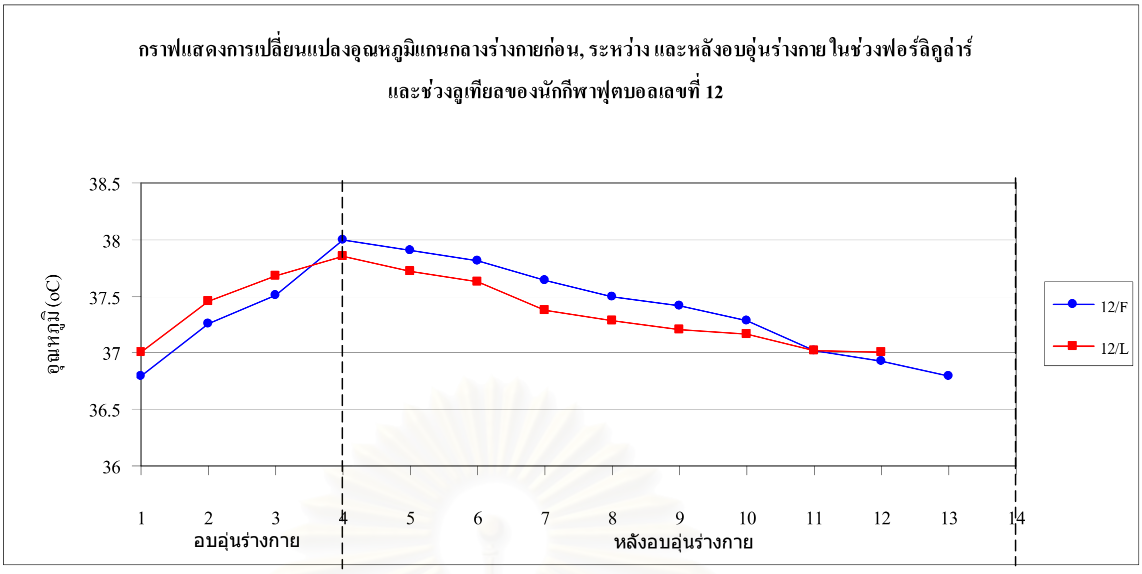
6
7
8
9
10
11
12
13
14
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
11/F
11/L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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 12
อุณหภูมิ (oC)
38.5
38
37.5
37
36.5
36
1
2
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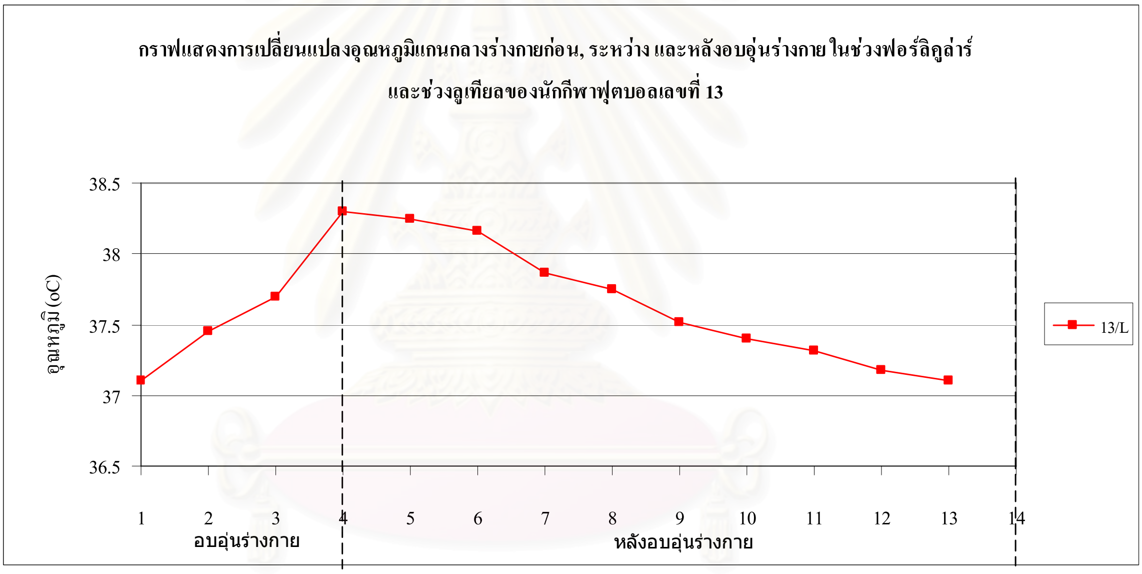
7
8
9
10
11
12
13
14
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
12/F
12/L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และช่วงลูเทียลของนักกีฬาฟุตบอลเลขที่ 13
อุณหภูมิ (oC)
38.5
38
37.5
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36.5
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14
อบอุ่นร่างกาย
หลังอบอุ่นร่างกาย
13/L

Descriptive of heart rate at rest and during warm up divided to early follicular phase and mid luteal phase of 13 Thai female soccer players.

No.	Early follicular phase (bpm)				Mid luteal phase (bpm)			
	At rest	During warm up			At rest	During warm up		
		5^{th}	10^{th}	15^{th}		5^{th}	10^{th}	15^{th}
1	59	117	109	184	73	120	154	175
2	58	110	126	140	70	104	136	148
3	78	115	134	148	80	121	145	173
4	78	136	142	171	78	125	168	171
5	71	152	160	177	83	116	154	172
6	71	150	158	170	78	127	133	156
7	77	119	135	168	82	134	134	156
8	56	107	109	120	67	103	113	141
9	67	118	120	135	67	124	115	130
10	79	118	127	144	71	126	142	162
11	70	122	131	156	70	105	114	178
12	68	101	113	131	72	115	134	156
13	-	-	-	-	60	107	117	141

Descriptive of three sprint time baseline and after warm up in 13 Thai female national soccer players.

No.	Baseline (seconds)			After 15-minute warm up (seconds)					
				Early follicular phase			Mid luteal phase		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
1	5.86	5.78	**5.74**	5.53	**5.44**	5.5	5.41	**5.36**	5.5
2	5.79	**5.77**	5.81	5.63	**5.62**	5.72	5.68	**5.65**	5.71
3	5.84	5.80	**5.73**	5.46	**5.22**	5.49	5.3	5.32	**5.27**
4	5.71	**5.66**	5.78	5.65	5.48	**5.42**	5.56	5.6	**5.53**
5	5.65	**5.61**	5.69	5.9	6.06	**5.66**	5.91	**5.87**	6.03
6	5.77	**5.74**	5.79	5.66	**5.53**	5.76	5.39	**5.37**	5.42
7	5.80	5.75	**5.71**	5.86	5.8	**5.77**	5.45	**5.43**	5.51
8	**5.60**	5.64	5.66	5.9	**5.56**	5.58	5.74	5.7	**5.63**
9	5.37	**5.34**	5.43	5.7	**5.53**	5.85	5.61	5.73	**5.46**
10	**5.71**	5.77	5.82	5.58	5.73	**5.51**	5.55	**5.44**	5.62
11	5.56	5.58	**5.53**	**5.47**	5.69	5.78	**5.43**	5.62	5.74
12	5.64	**5.60**	5.67	5.5	**5.41**	5.54	5.6	**5.55**	5.63
13	5.90	5.89	**5.87**	5.59	**5.56**	5.61	5.72	**5.61**	5.85

BIOGRAPHY

Name	Ms. Ladawan Chutimakul
Date of birth	29th July 1981
Place of birth	Bangkok, Thailand
Instructions attended	Chulalongkorn University (1999-2002)
	Bachelor of Science (Physical Therapy)