SPORTS BRA MIGHT POSSIBLY AFFECT CARDIOVASCULAR FUNCTION IN ACTIVE WOMEN

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SPORTS BRA MIGHT POSSIBLY AFFECT CARDIOVASCULAR FUNCTION IN ACTIVE WOMEN

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ABSTRACT

The aim of this study was to investigate the effect of sports bras on cardiovascular functions at rest, during and after exercise. Thirteen young habitual active females volunteered to complete 3 randomized running trials with different bra conditions of no bra (NB), casual bra (CB) and sports bra (SB) on a motor-drive treadmill at a constant speed of 6.5 km/h, 0% grade up to 60, 70 and 80% of age-predicted maximal heart rate (MHR). Continuous cardiovascular variables, including heart rate (HR), stroke volume (SV), cardiac output (CO), cardiac index (CI), end-diastolic volume (EDV), ejection fraction (EF), systemic vascular resistance (SVR), blood pressure (BP), blood perfusion (BPF), were collected at rest, during and after exercise. Results showed that all resting cardiac variables were not significantly different between groups. As exercise was started, all three conditions showed patterns of significant increase in heart rates (HR), stroke volume (SV), cardiac output (CO) and cardiac index (CI) from its corresponding resting values ($p<0.05$). Within group comparisons, SVR showed reduction at the beginning of exercise, EDV in SB and EF in NB and SB showed no significant differences from initial resting values. Between group comparisons during exercise showed no significant differences of most of the variables with the exception of differences of SV ($p<0.05$) and CO ($p<0.05$) between SB and CB at 60%MHR. No significant differences of other variables were detected at any intensity. During recovery period, there was an immediate decline, compared between 80%MHR and 1st min, in HR in all groups ($p<0.05$), SV in CB ($p<0.05$), CO and CI in NB ($p<0.05$) and CB ($p<0.05$) (Figure1A, 1B, 1C and 1D). There was reduction in EDV in CB ($p<0.05$). During recovery period, when compared to resting values, SV and EDV in all groups had no significant difference; HR, CI and CO showed significant difference throughout 5 min period ($p<0.05$). When compared between resting values and 1st min of recovery, EF in all groups showed significant difference ($p<0.05$); SVR had significant increased in all groups ($p<0.05$); SBP in all groups showed significant difference only in NB group ($p<0.05$); DBP in NB and CB showed significant difference ($p<0.05$); blood perfusion outside the strap in all groups showed no significant differences ($p<0.05$) and lastly blood perfusion inside the strap in all groups showed significant differences only in CB ($p<0.05$). In conclusion, both central and peripheral cardiac functions including rate and contractility, systolic and diastolic blood pressures and total vascular resistance exhibit similarly as when subjects were in no bra or casual bra. Thus, it is recommended from this study that sports bras can be used safely with no cardiovascular limitations.

KEY WORDS: SPORTS BRA/CARDIOVASCULAR FUNCTIONS/EXERCISE

75 pages

การใส่เสื้อชั้นในกีฬาอาจส่งผลต่อการทำงานของระบบไหลเวียนเลือดในผู้หญิงที่ออกกำลังกายสม่ำเสมอ

SPORTS BRA MIGHT POSSIBLY AFFECT ON CARDIOVASCULAR FUNCTION IN ACTIVE WOMEN

กาญจนา เต่าทอง 5536651 SPSS/M

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คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : ไถ้ออน ชินธเนศ, Ph.D., เมตตา ปิ่นทอง, Ph.D.,รุ่งชัย ชวนไชยะกูล, Ph.D.

บทคัดย่อ

การศึกษาวิจัยครั้งนี้มีจุดประสงค์คือ เพื่อศึกษาผลของการสวมใส่เสื้อชั้นในกีฬาต่อการทำงานของระบบหัวใจและไหลเวียนเลือดทั้งในขณะพัก ขณะออกกำลังกาย และภายหลังการออกกำลังกาย อาสาสมัครเพศหญิงที่มีสุขภาพดีมีการออกกำลังกายเป็นประจำ จำนวน 13 คน เข้าร่วมการทดสอบอย่างสมัครใจ การสวมใส่เสื้อสั้นในแบบสุ่ม จำนวน 3 แบบได้แก่ เสื้อชั้นในที่สวมใส่เป็นประจำ (CB) เสื้อชั้นในกีฬา (SB) และไม่สวมใส่เสื้อชั้นใน (NB) การออกกำลังกายโดยการวิ่งบนลู่กลที่ความเร็ว 6.5 กิโลเมตรต่อชั่วโมง ในแนวราบจนกระทั่งอัตราการเต้นของหัวใจเพิ่มขึ้นถึง 60, 70 และ 80% ของอัตราการเต้นหัวใจสูงสุดตามเกณฑ์อายุ (MHR) เก็บข้อมูลขณะพัก, ที่ความหนัก 60, 70 และ 80% MHR รวมไปถึงทุกนาทีของระยะฟื้นสภาพภายหลังการออกกำลังกายเป็นเวลา 5 นาที ตัวแปรที่สำคัญได้แก่ อัตราการเต้นของหัวใจต่อนาที (Heart rate; HR), ปริมาณเลือดที่บีบออกจากหัวใจในระยะเวลา 1 นาที (Cardiac output; CO), ปริมาณเลือดที่บีบออกจากหัวใจในแต่ละครั้ง (Stroke volume; SV), ดัชนีการทำงานของหัวใจ (Cardiac index; CI), ปริมาณเลือดในหัวใจก่อนบีบตัว (End Diastolic Volume; EDV), สัดส่วนของปริมาณเลือดที่ถูกบีบออกจากหัวใจห้องล่างซ้ายในแต่ละครั้งกับปริมาณเลือดในหัวใจก่อนบีบตัว (Ejection fraction; EF), ความต้านทานของการไหลเวียนเลือดโดยรวม (Systemic Vascular Resistance; SVR), ความดันโลหิต (Blood Pressure; SBP, DBP) และการกำซาบของเลือด (Blood Perfusion, BPF) ผลการศึกษาแสดงให้เห็นว่าตัวแปรทุกตัวนั้นไม่มีความแตกต่างกันอย่างมีนัยสำคัญระหว่างกลุ่มที่ขณะพัก เมื่อเริ่มออกกำลังกายพบการเพิ่มขึ้นอย่างมีนัยสำคัญของ HR, SV, CO และ CI จากขณะพัก เมื่อเปรียบเทียบความแตกต่างภายในกลุ่มพบว่า SVR มีค่าลดลงเมื่อเริ่มออกกำลังกาย ส่วนค่า EDV ในกลุ่ม SB และค่า EF ในกลุ่ม NB และ SB แสดงให้เห็นว่า ไม่มีความแตกต่างอย่างมีนัยสำคัญจากขณะพัก อีกทั้งเมื่อเปรียบเทียบในช่วงระหว่างออกกำลังกาย ได้แสดงถึงความไม่แตกต่างกันอย่างมีนัยสำคัญของตัวแปรส่วนใหญ่ ยกเว้นเฉพาะค่า SV และ CO ระหว่างกลุ่ม SB และ CB ที่ 60%MHR ที่พบว่ามีความแตกต่างกันอย่างมีนัยสำคัญ และไม่พบความแตกต่างอย่างมีนัยสำคัญของตัวแปรอื่นๆ ที่ทุกๆความหนัก ในช่วงฟื้นสภาพจากการออกกำลังกายทันทีพบว่า มีค่าลดลงทันทีใน HR ในทุกกลุ่ม, SV เฉพาะกลุ่ม CB, CO และ CI ในกลุ่ม NB และ CB ที่นาทีที่ 1ของช่วงฟื้นสภาพเมื่อเทียบกับที่ 80%MHR ของ นอกจากนี้ยังมีการลดลงของค่า EDV ในกลุ่ม CB อีกด้วย ในช่วงฟื้นสภาพทันทีเมื่อเปรียบเทียบกับขณะพักนั้นพบว่า ค่าของ SV และ EDV ในทุกๆ กลุ่ม ไม่พบความแตกต่างกันอย่างมีนัยสำคัญ ส่วนค่า HR, CO และ CI พบว่ามีความแตกต่างกันตลอดช่วงเวลา 5 นาทีของการฟื้นสภาพ เมื่อเปรียบเทียบค่าขณะพัก และนาทีที่ 1 ของการฟื้นสภาพ พบว่า ค่า EF ในทุกกลุ่มมีความแตกต่างกันอย่างมีนัยสำคัญ ในขณะที่ SVR มีการเพิ่มขึ้นอย่างมีนัยสำคัญในทุกกลุ่ม ส่วน SBP มีความแตกต่างอย่างมีนัยสำคัญเฉพาะในกลุ่ม NB และ DBP มีความแตกต่างกันอย่างมีนัยสำคัญในกลุ่ม NB และ CB นอกจากนี้ค่าการกำซาบของเลือด (BPF) เมื่อวัดนอกสายเสื้อชั้นในพบว่าไม่มีความแตกต่างกันในทุกๆ กลุ่ม และเมื่อวัดในสายเสื้อชั้นในพบว่ามีความแตกต่างกันอย่างมีนัยสำคัญในกลุ่ม CB เท่านั้น จากการศึกษาจึงสรุปได้ว่า การทำงานของระบบหัวใจทั้งในส่วนกลางและส่วนปลายประกอบด้วย อัตราและความสามารถในการหดตัว, ความดันโลหิตขณะหัวใจบีบตัวและคลายตัว และค่าความต้านทานรวมของการไหลเวียนเลือด แสดงผลคล้ายกันทั้งใน NB และ CB ดังนั้นจึงแนะนำให้สวมใส่เสื้อชั้นในกีฬาในระหว่างการออกกำลังกายซึ่งไม่จำกัดการทำงานของระบบหัวใจและไหลเวียนเลือด

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CHAPTER I
INTRODUCTION

Exercise is a type of physical activity that has health benefits on promotion, prevention, treatment and rehabilitation (1). In addition, exercise improves some other additional functions, for example, better emotion, good personality, reducing anxiety and the enabling various organs in the body to work better such as muscles, joints, bones, etc. Exercise is used for prevention, treatment and rehabilitation purposes in various diseases and disorders of the body such as blood pressure, obesity, diabetes, arthritis, depression, high blood cholesterol and better life quality (42). Currently, lots of people pay attention to exercise with many different modes and tools such as walking, jogging, swimming, cycling, and playing sports. Nowadays there are growing numbers of either male or female participate steadily in exercises and sports. However, the growing numbers of females join in various types of physical activities, for example walking, running rather than playing popular sports such as soccer, tennis, basketball, softball, volleyball, etc. (40). When differences of anatomical and physiological underlying function between men and women including smaller muscle size, higher amount of adipose tissue, shorter arm, narrower shoulders, broader hips, as well as menstrual cycle, are considered (28), this means women may have limited exercise ability than men. As reported by Arendt et al (1999) who had claimed that women have a higher risk for anterior cruciate ligament (ACL) injuries compared to men (2), and besides ACL injury another major problem at the same time is considered as breast injuries such as breast pain, breast discomfort, and including breast cancer due to excessive swinging more than usual (41).

Female’s breast is an organ that places on pectoral region which grows at puberty. In mature female adult, size and shape will naturally change depending on many factors: a) menstrual cycle, b) pregnancy, c) types of underwear and d) menopausal period (60). Gefen and Dilmoney (2007) claimed that female’s breast contains various supporting tissues as follow: 1) the fascia of the pectoralis muscle provides support to shear, 2) the ribs support compression and 3) Cooper's ligament which shares tension load and transfer to dorsal skin (27). Although Cooper's ligament can withstand certain stretched force, but the direction and reacting forces of the stretched Cooper's ligament will be varied according to body posture. For example, in standing position Cooper's ligament will be extended, in a pose crawled four legs position Cooper's ligament at the base of the breast will be stretched vertically, in supine position Cooper's ligament is stretched but the pressure directs down vertically on the breast. Thus movements such as walking, running, jumping will make Cooper's ligament to be swung and pulled severely in vertical direction. Therefore, some type of physical activity that women repeatedly perform such as fast run, jump in volleyball or basketball, somersault in gymnastics etc, may possibly cause trouble to breast tissues. These movements can cause a severe shock to the breast (10). Therefore, to reduce risks of breast injury women should wear brassieres (bras) to support and reduce pulling force on the breast that occurred during exercise or physical activity.

Bra is a special kind of brace which contains properties that can help to support breast, maintain shape of breast, chest protection, reduce injuries around the chest, reduce tension load from playing sports, etc. There are many kinds of the bra nowadays for example common bra, sports bra, sleeping bra and so on (14).

Sports bras are divided into encapsulation and compression types. Previous studies reported that sports bra will help to reduce swinging of the breasts, reduce breast displacement, decrease the incidence of breast pain (38,55), decrease the damage that may occur to chest ligament and reduce discomfort (9) during exercise (known as exercise-induced breast discomfort) when compared with casual bras. (18,48). So sports bra is recommended that women should wear while doing various activities (38) such as walking, aerobic dancing, jogging, running especially in women with large breasts. Gehlsen and Stoner (1987) found that women with breasts size of C and D will have the chance of breast pain than women with small breasts (29).

Although sports bra has many benefits but about half of females participated in exercise ignore it. Previous study of McGhee et al (2010) found that adolescents only 13 percent wore the sports bra and the study of Bowles et al (2008) found that only 41 percent of women who love exercises chose to wear sports bras. Underlying reasons are: a) they do not believe that it can protect, b) no need to use, and c) lack of knowledge about the prevention of breast during exercise (44). Another important reason is that women thought putting sports bras can cause straining to the chest leading to breast discomfort, furrow, breast pain, respiratory limitations (11).

Cardiovascular system is one of the system's body that is very important. It is a part in maintaining the body's equilibrium of nutrients, oxygen into and out of cells, helps to maintain pH and temperature. Cardiovascular system will work harder during exercises to increase pumping blood to tissues and vital organs, while maintaining functions of other parts of the body (6). Limiting the function of this system might be derived from aging, effect of diseases, too tight clothing worn. So this study will pay specific attention on the possible changes of cardiovascular functions during exercise when sports bras are applied.

Most of previous studies concentrated on effects of sports bras on respiratory system. Bowles KA et al (2005) concluded that wearing sports bras does not cause the limitations of exercise performance and respiratory mechanics. In addition the appropriate sports bra size was recommended to support the breasts during exercise (9). Stamford (1996) had suggested that sports bra that fit will not cause a respiratory restriction which might be caused by chest strapping around respiratory apparatus. Pressure in the chest strap may cause inconvenience (57). O'Donnell et al (2000) stated that when used the chest strapping during exercise, this caused resting lung volume and exercise performance decreased significantly whereas breathing patterns were shallow with higher breathing frequency when compared to exercise without chest strapping (48). It is reported that movements of the breasts might possibly affect cardiovascular function with inelastic (canvas) strapping (38). Concomitant with putting on sports bras, it is believed that cardiac output, stroke volume and heart rate and other cardiac variables may be affected. The present study will, therefore, pay attention on effects of sports bra on the functions of the cardiovascular system compared with casual and no bras conditions.

Hypothesis

Wearing sports bra may affect the cardiovascular system at rest, during running and recovery in women.

Objectives

1. To explore the effect of sports bra on cardiovascular functions while doing constant speed exercise at rest, during and after exercise.

2. To compare the responses of the cardiovascular system in different bra conditions.

CHAPTER II
LITERATURE REVIEW

2.1 Physical Activity

2.1.1 Global Trend of Physical Activity

Regularly physical activity is associated to a wide range of health benefits, this decreased incidence of many chronic conditions, and improving health outcomes (3). Nowadays, the popularity of physical activity or exercise has more and more increased. In 2008, the percentage of English men participated with exercise or any types of physical activity increased up to 39% compared to 32% in 1997. Women, who participated with exercise or any types of physical activity, increased from 21 % to 29 % in the same period. Similarly, in Northern Ireland, women participated in physical activities increased from 26% to 35 % during 2001-2011 (61).

Currently, lots of people pay attention to exercise with many different types such as walking, jogging, swimming, cycling and playing sports. Nowadays there are numbers of either male or female participate steadily in exercises and sports. Growing trend of exercise participation had shown by numbers of females join in various types of physical activities, for example walking, running and playing sports which are popular sports such as soccer, tennis, basketball, softball, volleyball, etc. (3, 40).

2.1.2 Benefit of regular physical activity and/or exercise

Exercise is generally accepted as a type of physical activity that has benefits on promotion, prevention, treatment and rehabilitation (1). In addition, exercise improves some other benefits, for example, better emotion, good personality, reducing anxiety and the functioning of various organs in the body be able to work better such as muscles, joints, and bones etc. Thus, exercise is being used for prevention, treatment and rehabilitation in various diseases and disorders of body’s functions such as high blood pressure, obesity, diabetes, arthritis, depression and high blood cholesterol, among these benefits, exercise is also used a specific tool including to make a better life quality, however it must be done in a regular fashion (42). Apart from the fact that regular physical activity clinically raises many health-related benefits. For example, it reduces resting heart rate and blood pressure, and increases coronary blood flow (45). It also increases energy expenditure, serum high-density lipoprotein cholesterol but decreases serum triglycerides and total body fat mass. Physical activity is also well known to improve glucose tolerance and reduce insulin needs resulting in improving blood glucose handling. These blood chemical variables are all accepted as good indicators for health (45). There are some studies reported that risk of advanced prostate and lung cancers became decline in people who have reached recommenced physical activity. The effect of regular physical activity on bone has been reported that bone strength could be increased by weight-bearing and high impact activities (45). Active older people have lower risk of osteoporotic fractures, especially in activity which can improve muscle strength, coordination, and balance (45).

2.1.3 Risk related to physical activity

Because of the substantial evidences which clearly present the benefits of exercise. In the meantime, people who exercise should consider the risks that may occur from either too heavy intensity or too long exercise. This is known as or overtraining syndrome (45). Especially in people who just start a new activity, volume and intensity, and contact sports. In addition, considerable risks of injuries include dehydration, electrolyte imbalance, or cardiac arrest may be taken place. There are sports-specific risks in women including amenorrhoea and decreased bone mineral density and increase body fat. Immune system can also be affected from high level of exercise, especially in prolonged heavy exercise with environmental or competitive stress (22).

Even though, mood can be improved by moderate exercise, but too heavy exercise deteriorates our mood stage which leads to anxiety, depression, body dysmorphic disorder. As a result, exercising participants should concern about the risks above to keep away from any injuries or emergency (45).

2.1.4 Exercise causes breast discomfort

Women's breasts are unavoidably swung, laterally and vertically, during exercise which can accelerate signs and symptoms of breast discomfort depending on type and intensity of exercise (37). While jumping on the ground can accelerate breast motion of about 2-folds of gravity. Jumping on trampoline can cause acceleration on the breast up to 6-folds of gravity, which causes very severe traction and pulling on breast ligaments. However, previous studies are all conducted using an indirect estimation to support the purpose of breast plastic surgery (27).

Few evidences reported on breast motion, magnitudes and determined in term of breast displacement. It was reported that mean vertical breast displacement of female athletes (n = 40) when they performed 9.7 km/h treadmill running on a zero grade with eight different sports bras were in range from 1.37 to 7.98 cm in which the vertical breast displacement is usually in the downward direction (37). It is the matter of fact that breast motion during exercise or physical activity was relative to 3 main factors: a) nature of physical activity, for example exercise intensity; b) nature of female's breast, for example breast size and breast tissues and c) nature of supporting bra, for example stiffness of the bra's fabric (37, 43, 22, 58). Exercise is the most factors shown to be the cause of these discomforts because of the excessive breast motion which can lead to be breast pain and breast injury, respectively (12).

2.2 The Breasts

2.2.1 Structural Differences in Male and Female

Apart from menstrual cycle, differences of anatomical and physiological underlying between men and women were identified in that females have smaller muscle size, larger amount of adipose tissue, shorter limbs, narrower shoulders, but broader hips and some wider angles including Q-angle and Carrying angle (19). As reported by Arendt et al (1999), women have higher risk for anterior cruciate ligament (ACL) injuries compared to men (2). Besides ACL injury, breast injuries have been claimed as another major problem where breast pain, and discomfort were initially defined, later breast cancer due to swinging motion, of over than usual, is a big problem as well (36).

In addition, function of cardiovascular and respiratory in men and women are different. Even though maximal heart rate (HR_{max}) is generally the same in both genders, women generally exhibit higher heart rate (HR) response for any absolute level of submaximal exercise. Stroke volume (SV) is lower in women, but cardiac output (Q) is usually the same in men and women at any absolute submaximal power output (28). The higher submaximal HR response in women appears to compensate for the lower SV, allowing a similar Q for the same power output, since Q = HR x SV. The lower SV results primarily from at least two factors:

- Women have smaller hearts and therefore smaller left ventricles because of their smaller body size and possibly lower testosterone concentrations.

- Women have less blood volume than men, which is related to their sizes (lower Free Fat Mass).

Thus, on average, woman may have less aerobically conditioned (41). The above means that women may have limited exercise ability than men.

2.2.2 Anatomy of Breasts

Breast is tissue that overlays on pectoral region. It develops at puberty and the volume and shape change in menstrual cycle, pregnancy, after weaning and menopause. Breast has two main regions, the conical part with apex and the axillary tail, the extension to the armpit. Nipple in the middle is surrounded by areola containing dermal blood capillaries and nerves, this part ejects milk when it is triggered. It is red in color and darkens in pregnancy. Areola contains many tiny nodules named areolar glands that locate between sweat and mammary glands. The dermis of aerola will change, for example wrinkles and erects when nipple is aroused via cold, touch and sexual stimulations. The conical part of breast consists of large amounts of adipose and collagenous tissues, which normally determine breast size. Another tissue is called suspensory ligaments, which connect breast and dermis. They consist of 15-20 lobes which are arranged when mammary glands are developed during pregnant period (53).

2.2.2.1 Arterial supply of the breast: main arterial around breast.

Lateral (mammary) thoracic artery. This artery is a branch of axillary artery and located under pectoralis minor muscle along lateral aspect of thorax. Therefore, it supplies lateral thorax and lateral mammary glands. It runs with lateral thoracic vein and long thoracic nerve.

Internal (mammary) thoracic artery. This artery is a branch of subclavian artery and located inside thorax just later to sternum then descends vertically across intercostal spaces to supplies anterior aspect of thorax and medial mammary glands. It runs with internal thoracic vein.

Intercostal artery. This artery is branches of aorta or internal (mammary) thoracic artery and located in intercostal spaces. It supplies anterior, posterior and lateral thorax and breast. It has specific blood supply, which derived from lateral mammary branches. It runs along with intercostal vein and nerve. It has venous drainage azygos vein or internal thoracic vein.

Thoracoacromial artery. This artery is a branch of axillary artery located under pectoralis minor and anterior shoulder region.

2.2.3 Breast Growth and Volume Change

Breast grows readily in the puberty stage, from 9 to 20 yrs but development is under female's gender hormones. Lobes and lactiferous ducts are developed by the effect of estrogen, progesterone and prolactin. Breast size enlarges when adipose and fibrous tissue growth which are stimulated by glucocorticoids and growth hormones. As mentioned above, breast size is subject to change due to menstrual cycle, pregnancy, after weaning and menopause. When woman is pregnant, estrogens stimulate mammary ducts and branch to grow extensively. The breast size grows nearly twice in size with 0.9 kg out of a total of 11 kg gained in breast weight. When female gains weight, shape of breast changes as a result (53).

Menstrual cycle impacts on breast volume every month. Milligan et al (1975) investigated the correlation between breast size change in menstrual cycle and after oral contraceptives. Four 21-yr-old women were invited to measure the breast volume daily using water placement in the whole cycle. In the normal menstrual cycle, the breast volume reduced from day 1 to day 9. Starting from day 10, the volume tended to enlarge till day 25 and then decrease to normal size gradually. The breast volume is small in the mid-menstrual cycle and increases 40% before menstruation (46).

2.2.4 Breast Naturally Needs

2.2.4.1 Support

Dynamic breast motions are unavoidably created during physical activities, thus these motions may be exaggerated in certain vigorous or repeated sports. Accordingly, anatomical designed pushes various internal stretched forces applied directly to breast's tissues during exercise (55). With excessive breast motions, discomfort, pain and internal structure may potentially be damaged. Therefore, it is suggested human's breast needs some form of external support in order to reduce breast displacement and discomfort produced by external impacts (11). The situation is more serious in large breast size women which found that the number of bigger cup breast size, C and D, women having breast pain more than small breast women (29).

Gefen and Dilmoney (2007) studied breast mechanics with analytical approximation model. They assumed that Cooper's ligaments, the fascia of pectoralis muscle and the ribs, are major supporting tissues of the breast. Tension load is shared by Cooper’s ligament and transfers to dorsal skin while pectoralis fascia provides support to shear and ribs support compression (27).

Thus, research found that support is needed in all motions of breast displacement, namely vertical, medio-lateral and antero-posterior directions (54). In details, the observable views on the differences of displaced force applied on various directions revealed that vertical movement is more significant than other directions when walking (47) and such motion should be limited (43). It can be concluded that there is correlation between breast motion reduction and lowering in breast pain, in other means, achieving in breast comfort. As a result, no matter daily bra or sports bra is putting on, it should play role of reducing breast displacement in all directions, in particular during repeated physical activity.

2.2.4.2 Breast Comfort

Women wish accepted look of breast no matter what sizes they are. At the same time, they also want to enhance the look with comfort. Previous study (64) collected 250 questionnaires from bras purchases among Hong Kong Chinese females about the decision making process of intimate apparel. Results indicated that the purchasing criteria were mainly relied on aesthetic aspects, fitting and supporting, product quality and price as the top concerning reasons. For aesthetic aspect, style and store atmosphere were considered as important in innerwear purchase. Among all, fit and comfort were ranked as the most important consideration factors. Previous study revealed that female consumers’ purchase intention relied on attitude toward performing the behavior, subjective norm, controversy perception, social acceptance and fashion involvement (60). Very rare cases concerned on bras’ protective function.

2.3 Brassiere (Bras)

2.3.1 History of Bras

Brassiere, bra in short, history had been discovered since 2500 BC. At present time, bras have being developed for both aesthetics and preventive purposes. The designs include in various aspects, in forms of cup at the beginning, corset later and as sports-related.

Table 2.1 Bra History (47)

Time	Bra Style	Functions and Reasons
2500BC	Open-cup for Cretans women	Uplift and expose breast
	Mastodenton/apodesmos for Greece women	For exercise
13th - 15 th century	Long strips fabric across the shoulder and under the breast	
16th - 18 th century	Divorce corsets	Uplift and separate breast to achieve hourglass body shape
1900 - 1919	Bra	Revolution on corsets which them substituted by bra
1920 - 1939	Flat breast	Youthful and boyish look demanded by flapper girls
1940 - 1959	Cone-shaped bra, appear of bikini	Affected by Hollywood stars
1960 - 1979	Soft bra	Affected by small breast models, such as Twiggy, and natural looks raise up
1980 - 1999	Wonderbra (padded bra), sports bra	Affected by supermodel, like Cindy Crawford, push up is emphasized and demand of function bra increased
2000+	Corset, T-shirt bra, seamless bra, strapless bra, adhesive bra, one-piece bra, maximizer, mininizer	Cater for different needs, such as invisible under outerwear, lighter to reduce shoulder pain and good to health

2.3.2 Functions

Bra is considered as kind of brace that can help to support and maintain the shape of female's breast. It, therefore, plays role in chest protection, reduce injuries around the chest, and expectedly reduce tension load from playing sports etc. There are many kinds of the bra nowadays for example common bras, sports bras, breastfeeding bras, seamless bras, nursing bras, sleeping bra and many more from industrial companies (17).

2.3.3 Bra Sizing and Measurements

Several studies showed that around over 70% respondents wore incorrect size of bra and did not fit properly. This results in discomfort, pinching, muscle tension, fatigue and pain. Besides, bra functions may not be performed appropriately as it was designed. In some circumstance, it was designed just to provide shape, support and tightly limits breast displacement (8). Thus, correct measurement for the best fitting becomes critical factor to bring back female's breast prevention during exercise. Learning of bra size and selection is now a social issue.

The most common method is to measure the bust and underbust circumferences crossing the back. The underbust measurement is used to determine the band size. Cup size is estimated by the underbust circumference deducted by bust circumference (Figure 2.1, 30).

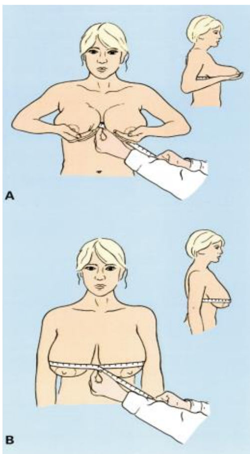


Figure 2.1 Underbust (A) and overbust measurement (B)

Table 2.2 shown the Wacoal's sizing criteria to identify bra size that researcher used in this study, cup size B and C were determined for using to qualify subjects.

Difference of Breast Circumference (cm)	**Cup Size**
6.5-8.5	AA
9-11	A
11.5-13.5	B
14-16	C
16.5-18.5	D
19-21	DD or E
21.5-23.5	DDD or F

2.3.4 Benefits of Sports Bra

Sports bra has been developed in difference styles and using different garments (37), and can be divided into 2 types: encapsulation sports bra which acts separated supporting in each side of breasts and compression bra which has been known as "Crop top", where it performs and compress both breasts together to resist chest motion (58).

Sports bra that researchers used in the investigation is "compression bra", our sports bra's area is approximately 84 cm^2 that calculated by researchers. Typically, the chest area is about 0.3 m^2 for a 165 centimeters and weighs 63 kilograms woman with moderate cup size. Sports Bra, which occupies a half of the chest around 0.15 – 0.16 m^2 when put on (23, 49, 65). In addition, researcher explored sports bra's shoulder strap compression force and found that sports bra induced only 6 g/cm^2 when put on, from the relationship between the stress and strain that a particular material displays is known as that particular material's stress–strain curve. It is unique for each material and is found by recording the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). (5)

Previous studies reported that sports bra will help to reduce swinging of the breast, reduce breast displacement, decrease the incidence of breast pain (12,16), decrease the damage that may occur to chest ligament and reduce discomfort (22), in particular, during exercise (known as exercise-induced breast discomfort) when compared with casual bras. (24,26). Thus, sports bra is also recommended while doing various activities (12) such as walking, aerobic dancing, jogging, running especially in women with large breasts.

Although sports bra has many benefits but about half of females participated in exercise did not realize it. Previous study (McGhee et al, 2010) found that only 13 percent of adolescents wore sports bra whereas the study of Bowles et al, 2008, found that only 41 percent of women who love exercises chose to wear sports bras. Underlying reasons are:

a) They do not believe that it can really protect,

b) There is no need to use, and

c) Lack of knowledge about the prevention of breast during exercise (44).

d) Another important reason is that women thought putting sports bras can cause straining to the chest leading to breast discomfort, furrow, breast pain, respiratory limitations (10).

Several evidences assure this result it was reported that participants who wore fitted sports bra had greater breast support and pain reduction (43). Moreover, sports bra could reduce most symptoms of mastalgia in 100 patients (31). Then, women should recruit sports bra for their own benefits during exercise.

2.4 Cardiovascular System

2.4.1 Meaning and Importance

Cardiovascular system means the functions of the heart and the circulatory apparatus to provide the blood flow, as necessary, to maintain homeostasis of the various tissues of the body. This system plays critical homeostasis role, which is defined as the sum total of regulatory functions that maintain a constant environment for the cells of the tissues. It is the balance between internal and external environment of cells and tissues. Internal environment must be kept in a relatively constant condition regardless of nutrients, metabolites, oxygen and carbon dioxide, temperature, hormonal fluctuation and pH. The blood must transport rich of oxygen and nutrients to the cells, then bring out waste products (34).

Major concern in physiology of exercise, however, is the transport of oxygen and carbon dioxide. During exercise, demand of oxygen supply to tissues is the most urgent adjusted. Within the cells, oxygen cannot be stored and its supply bring about normal cell function whereas lack of it will usually the critical damaged for cell function since energy liberation, ATP, can no longer sustained. This is obviously affects when body demand is greater, for example during physical performance, in particular, endurance ability (34).

2.4.2 Structure and function of the cardiovascular system

Cardiovascular system consists heart as a pump and vessels as connecting tubes. This system delivers blood to various organs in the body where the amounts are varied according to metabolic needs. This system can be viewed as two connected pipe circuits of systemic and pulmonary circulations, in which the blood flows will be adequately and identically transferred, even though the circuit to the lungs is structurally smaller than the large circuit that services the rest of the body. The two systems are interconnected by a central pump, the heart. A thick muscle wall separates the heart into two discrete cardiac myocytes. Each half of the heart is further divided into the atrium, which receives blood returning to the heart, and a main chamber, the highly muscular named as ventricle. The right ventricle pumps blood to the small circuit named as pulmonary circulation. The left ventricle pumps blood throughout the whole body known as systemic circulation. Thus, resistances within these two circulations will affect cardiac functions and vice versa (34).

Left ventricle pumps blood via aorta which is the body's largest blood vessel. Aorta transfers blood to the serially enormous branches of smaller arteries. At the fine capillaries network, they contain very thin-walled which is the readily site for gas exchange. Oxygen, carbon dioxide, nutrients and other substances are exchanged between the blood in the capillary network, known as capillary beds, within the tissues and organs and the body cells. The thin capillary walls contain special property which makes exchange very efficient. After exchanging processes via capillaries, blood is then flowed back towards the heart, first through the thin venules, which join to form larger and thicker veins. Two large veins carrying blood from the lower and the upper body join just before entering the right side of the heart (34).

Blood that returns from the tissues to the right side of the heart has a lower concentration of oxygen and higher concentration of carbon dioxide than arterial side. This difference is due to cell metabolism, reflect biochemical processes in cells, in which oxygen is consumed and carbon dioxide is produced. Blood is then pumped via the small circuit through the lungs, where carbon dioxide is released out and oxygen is absorbed into pulmonary capillaries. The oxygenated blood then returns to the left side of the heart and is pumped via the systemic circuit to the tissues. The heart also has its own blood supply through the coronary arteries, which branch off the aorta close to the heart. The cardiac veins converge into a common vein that drains into the right atrium.
The amount of blood that the heart pumps out per minutes is called the cardiac output. The magnitude of the cardiac output depends on two variables: the volume of blood that the heart pumps out per contraction, stroke volume; and rhythm of the heart pumping, heart beats per minute – the heart rate. Thus:

Cardiac output (L/min) =Stroke volume (ml/beat) x heart rate (beats/min)

The cardiac output depends mainly on ageing, cardiac contractility and rhythm, body size and level of physical activity. Other factor is called venous return, the volume of blood returning to the heart via two big veins. This also significantly and sequentially affects stroke volume. Women's hearts are generally smaller than those of men. Therefore, women have smaller maximum stroke volumes and, consequently, lower maximum cardiac outputs. The contractile function of the heart also affects stroke volume and cardiac output. During exercise, HR, SV and CO may increase at submaximal intensity, however, these cardiac variables will finally diminish at near maximum level and remarkably drop at exhaustion (25).

2.4.3 Cardiovascular responses to exercise

Numerous interrelated cardiovascular changes occur during dynamic exercise. The primary goal of these adjustments is to increase blood flow to working muscles, however, cardiovascular control of virtually every tissue and organ in the body is also altered. Changes in all components of the cardiovascular system from rest to exercise are described.

2.4.3.1 Heart Rate

Heart rate (HR) is one of the simplest physiological responses to exercise, and yet one of the most informative in terms of cardiovascular stress and strain. Measuring HR involves simply taking the subject’s pulse, usually at the radial or carotid artery. Heart rate is a good indicator of relative exercise intensity.

Resting heart rate averages are about 60 to 80 beats/min (bpm) in most individuals. In endurance trained athletes, resting HR, as low as 28 to 40 bpm have been reported. This is mainly due to an increase in parasympathetic (vagal) tone that accompanies endurance exercise training. Resting heart rate can also be affected by environmental factors; for example, it increases with extremes temperature and altitude. Anticipatory response of higher HR may be exhibited just before the start of exercise, which is mediated through release of the neurotransmitter norepinephrine from the sympathetic nervous system and epinephrine from the adrenal medulla. While vagal tone probably also decreases. Because pre-exercise HR is elevated, reliable estimates of the true RHR should be made only under conditions of total relaxation.

When exercise begins, HR increases directly in proportion to the increase in exercise intensity, until near-maximal exercise is achieved. As maximal exercise intensity is approached, HR begins to plateau even as the exercise workload continues to increase. This indicates that subject is approaching maximum heart rate (HR_{max}). This maximum value can be estimated based on subject’s age by subtracting one's age from 220. A more accurate equation has been developed to estimate exercise intensity from HR_{max}.

When the rate of work is held constant at a submaximal intensity, HR increases fairly rapidly until it reaches a plateau. This plateau is the steady-state heart rate, and it is the optimal HR for meeting the circulatory demands at that specific rate of work. For each subsequent increase in intensity, HR will reach a new steady-state value within 2 to 3 min. However, the more intense the exercise, the longer it takes to achieve this steady-state value.

2.4.3.2 Stroke Volume

During systole, most, but not all, of the blood in the ventricles is ejected. This amount of blood being ejected is known as stroke volume (SV) of the heart. The unit is the volume of the blood pumped per beat (contraction). To understand stroke volume, one must consider the amount of blood in the ventricle before and after contraction. At the end of diastole, just before contraction, the ventricle has completed filling of blood from venous return. The volume of blood it now contains is called the end-diastolic volume (EDV, resting value is approximately 100 ml). At the end of systole, just after contraction, the ventricle has completed its ejection phase, but not all the blood is pumped out of the heart. The volume of blood remaining in the ventricle is called the end-systolic volume (ESV) and is approximately 40 ml under resting conditions. Stroke volume is simply the difference between EDV and ESV; that is, SV = EDV – ESV (example: SV = 100 ml – 40 ml = 60 ml) (41).

Stroke volume (SV) also changes during acute exercise to allow the heart to meet the demands of exercise. At near-maximal and maximal exercise intensities, SV is a major determinant of cardiorespiratory endurance capacity. Stroke volume is determined by four factors:

a) The volume of venous blood returned to the heart

b) Ventricular distensibility

c) Ventricular contractility

d) Aortic or pulmonary artery pressure

The first two factors influence the filling capacity of the ventricle, determining how much blood is available for filling the ventricle and the ease with which the ventricle is filled at the available pressure. This is referred to as preload.

The last two factors influence the ventricle's ability to empty, determining the force with which blood is ejected and the pressure, or afterload, against which it must be expelled into the arteries. These four factors directly control the alterations in SV in response to increasing exercise intensity (41).

Stroke volume increases above resting values during exercise. Most researchers agree that SV increases with increasing rates of work, but only up to exercise intensities somewhere between 40% and 60% of maximal capacity. At that point, SV typically plateaus, remaining essentially unchanged up to and including the point of exhaustion. However, other researchers have reported that SV continues to increase up through maximal exercise intensities.

When the body is in an upright position, SV can almost double from resting to maximal values. For example, in active but untrained individuals, SV increases from about 60 to 70 ml/beat at rest to 110 to 130 ml/beat during maximal exercise. In highly trained endurance athletes, SV can increase from 80 to 110 ml/beat at rest to 160 to 200 ml/beat during maximal exercise. During supine exercise, such as recumbent cycling, SV also increases but usually by only about 20% to 40%--not nearly as much as in an upright position.

When the body is in the supine position, blood does not pool in the lower extremities. Blood returns more easily to the heart in a supine posture, which means that resting SV values are higher in the supine position than in the upright position. Thus, the increase in SV with maximal exercise is not as great in the supine position as in the upright position because SV starts out higher. Interestingly, the highest SV attainable in upright exercise is only slightly greater than the resting value in the reclining position. The majority of the SV increase during low to moderate intensities of exercise in the upright position appears to be compensating for the force of gravity that causes blood to pool in the extremities (41).

2.4.3.3 Ejection Fraction

The fraction of the blood pumped out of the left ventricle in relation to the amount of blood that was in the ventricle before contraction is called the ejection fraction (EF). This value is determined by dividing the stroke volume by EDV (SV/EDV). EF is generally expressed as a percentage, average about 60% at rest. Thus, 60% of the blood in the ventricle at the end of diastole is ejected with the next contraction is often used clinically as an index of the pumping ability of the heart (41).

2.4.3.4 Cardiac output

Cardiac output (Q), is the total volume of blood pumped by the ventricle per minute. It is the product of heart rate and stroke volume (CO=HR x SV). This variable predictably increases with advancing exercise intensity. Resting cardiac output is approximately 5.0 L/min but varies in proportion to the size of the person. Maximal cardiac output varies between less than 20 L/min (sedentary person) and 40 L/min (elite endurance athlete) and is a function of both body size and endurance training. The linear relationship between cardiac output and intensity of exercise is predictable because the major purpose of the increase in cardiac output is to meet the muscles' increased demand for oxygen (41).

2.4.3.5 Cardiac Index

Cardiac index (CI), the ratio between cardiac output (CO) and body surface, is the hemodynamic parameter which relates cardiac performance to the size of individual, is an important clinical parameter that used to assess patients with heart disease as well as critically ill patients and patients under anesthesia. Since body surface area is constant, thus increasing in CI is mainly due to increasing in CO. CI is also of interest in pharmacological studies (26) and the decline in CI was used to indicate that patients may have heart failure.

Cardiac index in healthy subjects did not different between males and females but there was a slight decrease of CI with age. Similarly, age but not gender was a significant variable for CI, the slight decrease of CI with age was explained by a decrease in SV with age. (15)

2.4.3.6 End-Diastolic Volume

End-diastolic volume (EDV) is the amount of blood in a ventricle immediately before the contraction, at the end of diastole. According to the Frank–Starling principle, the strength of cardiac contraction is related to the muscle fiber length at end of diastole. An increase of EDV means an increase of preload on the heart and, finally, it increases the stroke volume. The EDV is closely related to venous compliance because nearly two thirds of the blood in the systemic circulation is stored in the venous system. Increasing venous compliance elevates the capacitance of the veins, reducing venous return and therefore end-diastolic volume. Decreasing venous compliance has the opposite effect. (7)

When start exercise, the increased preload stretches the myocardium and causes it to contract more forcibly in accordance with the Frank-Starling law of the heart. Contractility of the myocardium is also enhanced by the sympathetic nervous system, which is activated during physical activity. Thus, an increase in the left ventricular end–diastolic volume and a decrease in the left ventricular end–systolic volume (LVESV) account for the increase in stroke volume during light to moderate dynamic exercise (50).

2.4.3.7 Systemic Vascular Resistance

Systemic vascular resistance (SVR) refers to the resistance to blood flow offered by all of the systemic vasculature, excluding the pulmonary vasculature. This is sometimes referred as total peripheral resistance (TPR). SVR is therefore determined by factors that influence vascular resistance in individual vascular beds. Mechanisms that cause vasoconstriction increase SVR, and those mechanisms that cause vasodilation decrease SVR. Although SVR is primarily determined by changes in blood vessel diameters, changes in blood viscosity also affect SVR. SVR can be calculated if cardiac output (CO), mean arterial pressure (MAP), and central venous pressure (CVP) are known. (11)

SVR = (MAP – CVP)/CO; CVP is normally near 0 mmHg: SVR = MAP/CO

SVR decreases owing to vasodilation in the active muscles during exercise. The vasodilation of vessels in the active muscles is brought about primarily by the influence of local chemical factors (lactate, K^+, and so on), which reflect increased metabolism. The decrease in total peripheral resistance has two important implications. First, the vasodilation in the active muscle that causes the decrease in resistance has the effect of increasing blood flow to the active muscle, thereby increasing the availability of oxygen and nutrients. Second, the decrease in resistance keeps mean arterial pressure from increasing dramatically. The increase in mean arterial pressure is 110 mmHg 15 L·min1 determined by the relative changes in cardiac output and total peripheral resistance. Since cardiac output increases more than resistance decreases, mean arterial pressure increases slightly during dynamic exercise.

However, the increase in mean arterial pressure would be much greater if resistance did not decrease.

2.4.3.8 Blood Pressure

Blood pressure is the pressure exerted by heart pump on the vessel walls, and the term usually refers to arterial blood pressure. It is expressed by two numbers: the systolic blood pressure (SBP) and the diastolic blood pressure (DBP). The higher number is the SBP; it represents the highest pressure in the artery that occurs during ventricular systole. Ventricular contraction pushes the pulsatile blood volumes through the arteries with tremendous force, and that force exerts high pressure on the arterial walls. The lower number is the DBP and represents the lowest pressure in the artery, corresponding to ventricular diastole when the ventricle is filling.

Mean arterial pressure (MAP) represents the average pressure exerted by the blood as it travels through the arteries. Since diastole takes about twice as long as systole in a normal cardiac cycle, mean arterial pressure can be estimated from the DBP and SBP as follow (41):

$$MAP = 2/3\ DBP + 1/3\ SBP \text{ or } MAP = DBP + [0.333 \times (SBP - DBP)]$$

During exercise, mean arterial blood pressure increases substantially. However, systolic and diastolic blood pressures do not increase in the similar patterns. With whole-body endurance exercise, systolic blood pressure increases in direct proportion to the increase in exercise intensity. However, diastolic pressure does not change significantly, and may even decrease.

Increased systolic blood pressure results from the increased cardiac output that accompanies increasing rates of work. This helps to facilitate the higher blood flow through the vasculature. Also, blood pressure (that is, hydrostatic pressure) determines how much plasma leaves the capillaries, entering the tissues and carrying needed supplies. Thus increased systolic pressure aids substrate delivery to working muscles.

Blood pressure reaches a steady state during submaximal steady-state endurance exercise. As work intensity increases, so does systolic blood pressure. If steady-state exercise is prolonged, the systolic pressure might start to decrease gradually, but diastolic pressure remains constant. The slight decrease in systolic blood pressure, if it occurs, is a normal response and simply reflects increased arteriole dilation in the active muscles, which decreases the total peripheral resistance or TPR (since blood pressure = cardiac output x total peripheral resistance).

Diastolic blood pressure changes little during submaximal dynamic exercise; however, at maximal exercise intensities, diastolic blood pressure increases slightly. Diastolic blood pressure reflects the pressure in the arteries when the heart is at rest (diastole). With dynamic exercise there is an overall increase in sympathetic neural tone to the vasculature, causing overall vasoconstriction. However, this vasoconstriction is blunted in the exercising muscles by the release of local vasodilators. Thus, there is a balance between vasoconstriction to inactive regions and vasodilation in the active skeletal muscle; therefore diastolic pressure does not change substantially.

2.4.3.9 Blood Flow

Acute changes in cardiac output and blood pressure, in concomitant with steady resistance during exercise will allow for increased total blood flow to target organs. These responses facilitate getting blood to areas where it is needed, primarily the exercising muscles. Additionally, sympathetic control of the cardiovascular system can redistribute blood so that areas with the greatest metabolic need receive more blood than areas with low demands.

Blood flow patterns change markedly in the transition from rest to exercise. Through the action of the sympathetic nervous system, blood is redirected away from areas where it is not essential to those areas that are active during exercise. Only 15% to 20% of the resting cardiac output goes to muscle, but during high-intensity exercise, the muscles may receive 80% to 85% of the cardiac output. This shift in blood flow to the muscles is accomplished primarily by reducing blood flow to the kidneys and the so-called splanchnic circulation that includes the liver, stomach, and intestines. This results in vasoconstriction in some areas which allows for more of the increasing cardiac output to be redistributed to the exercising skeletal muscles. Even though sympathetic activation takes place in the skeletal muscles, vasoconstriction still cannot overcome local vasodilating substances which are released from the exercising muscle. As a result, the overall vasodilation in the muscle is produced (34).

Many local vasodilating substances are released in exercising skeletal muscle. As the metabolic rate of the muscle tissue increases during exercise, metabolic waste products begin to accumulate with an increase in acidity and temperature within that muscle. These are some of the local changes that trigger vasodilation, and resulting in higher blood flow through that organ. Local vasodilation is also triggered by low partial pressure of oxygen in the tissue or a reduction in oxygen bound to hemoglobin and possibly other vasoactive substances (including adenosine) released as a result of skeletal muscle contraction (41).

2.4.3.10 Blood Perfusion

Perfusion is the process of a body delivering blood to a capillary bed in its biological tissue. The most common methods include evaluating a body's skin color, temperature, condition and capillary refill (39).

In this study, we measured blood perfusion using Laser Doppler Flowmetry (LDF) that have two black markers. The markers were adhered around 2 inches from right clavicle: the first marker is under the bra' shoulder strap (inside) and the second marker is outside strap. During exercise, blood perfusion was measured every 10 minutes. For accuracy, subject had to stop exercise and be measured blood perfusion within 1 minute.

2.4.3.11 RPE scale

The RPE scale measures feelings of effort, strain, discomfort, and/or fatigue experienced during training. One's perception of physical exertion is a subjective assessment that incorporates information from the internal and external environment of the body. The greater the frequency of these signals, the more intense are the perceptions of physical exertion. In addition, response from muscles and joints helps to scale and calibrate central motor outflow commands. The resulting integration of feedforward-feedback pathways provides fine-tuning of the exertional responses.

The level of perceived exertion is often measured with a 15 category scale. The Borg scale is shown below:

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

2.4.3.12 Discomfort scale

Discomfort or pain scale is measurement patient's pain intensity or other features. Pain scales are based on self-report, observational (behavioral), or physiological data. Self-report is considered primary and should be obtained if possible. (50)

The scale is an 11–point scale for patient self-reporting of pain. It is for adults and children 10 years old or older.

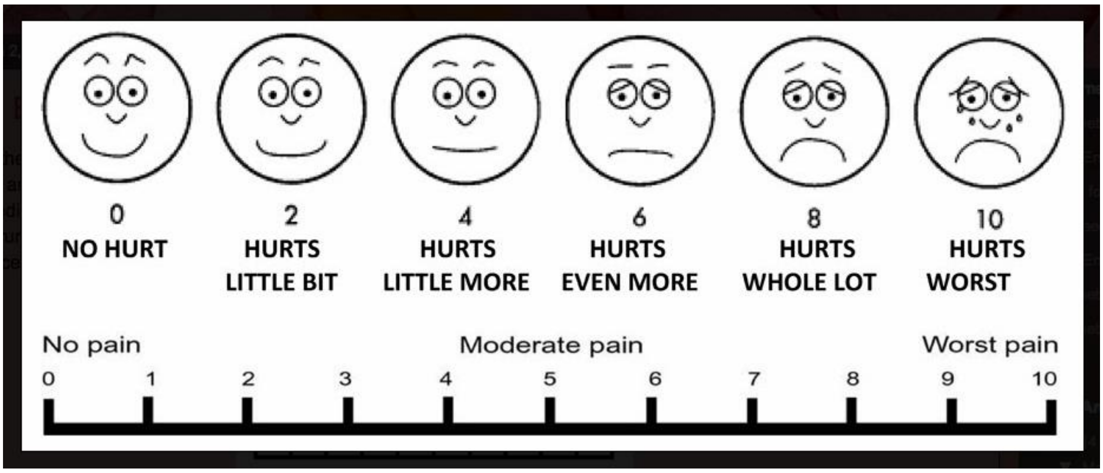


Figure 2.2 Discomfort or pain scale; 0-10 (63)

2.5 Equipment

2.5.1 Cardiac variables

PhysioFlowEnduro is an original system for non-invasive cardiac monitoring device, which provides hemodynamic parameters using analysis of thoracic electrical bioimpedance signals (TEB). TEB is a technique which quantifies heart's mechanical activity and circulation instead of its electrical activity (ECG). The fundamental theoretical principle of TEB uses direct measurement of the baseline impedance of the velocity index, the acceleration index, the ventricular ejection time and heart rate of the early diastolic function ratio. These measured parameters are used to compute other hemodynamic parameters.

PhysioFlowEnduro measures changes in impedance by inducing a high frequency alternating electrical current (66 kHz) of low magnitude (3.8 mA rms) towards the thorax between a pair of electrodes positioned on the neck and another pair positioned on xiphoid process. The use of a high frequency current eliminates the risk of interference with heart and brain bioelectrical activity. In addition, as the impedance of skin-electrodes is very low at high frequency, tissues will not endure any thermal effects and the patient feels nothing.

2.5.1.1 Functions

PhysioFlowEnduro measures the following parameters:

- Heart Rate
- Stroke Volume/Index
- Cardiac Output/Index
- Ejection Fraction
- End Diastolic Volume
- Systolic Vascular Resistance (51)

2.5.2 Blood Perfusion

2.5.2.1 Functions

Laser Doppler Flowmetry (LDF), a non-invasive method, is used to continuously measuring blood flows from target parts. It has been used to measure microcirculatory blood flow in many tissues including neural, muscle, skin, bone and intestine. The principle of laser doppler flowmetry is to measure the doppler shift - the frequency change that light undergoes when reflected by moving objects, such as red blood cells. Laser doppler flowmetry uses monochromatic light emitted from a low power laser. The light emitted and reflected is fed through optical fibers from the target to the analyzer-recorder. Measurement of the Red blood cell motion is recorded continuously in the outer layer of the tissue, with little or no influence on physiologic blood flow. This output value constitutes the flux of red cells, defined as the number of red cells times, their velocity and is reported as microcirculatory perfusion units. No direct information concerning oxygen, nutrient or waste metabolite exchange in the surrounding tissue is obtained with this technique. The relationship between the flowmeter output signal and the flux of red blood cells is linear. The beam can penetrate unbroken, non-pigmented tissue to a depth of 1-2 mm (33).

CHAPTER III
MATERIALS AND METHODS

3.1 Equipment

The following equipment was used in this study:

1. Sphygmomanometer (Spirit, Taiwan)
2. Signal Morphology-based Impedance Cardiography (PhysioFlow, France)
3. Laser Dropper Flowmetry (moorVMS-LDF,UK)
4. Gas O_2 and CO_2 analyzer (Oxycon Mobile, Germany)
5. Sports bras, Casual bras (Wacoal manufacture, Thailand)
6. Sportswears
7. Motor-drive treadmill (Marqutte, USA)
8. Electrode
9. Measuring Tape
10. 70% alcohol solution
11. Absorbent cotton
12. Digital weighing scale (AND AD-6201, Japan)
13. Stadiometer
14. Stethoscope (MDF, China)
15. Body composition monitor (Omron, Japan)
16. Borg's Perceived Exertion (from G.Borg,1982)
17. Discomfort scale (from Wong D.L., et al., 2001)
18. Physical activity questionnaires

3.2 Subjects

Thirteen healthy females (age ~ 18-30 yrs), with B and C breast cup size, voluntarily participated in this study.

Inclusion criteria: are as follow:

- Have habitually active lifestyle
- Have normal range of BMI (between 18.5 – 24.9 kg•m^2)
- Nonsmokers, Nonalcoholic
- No experience with any commercial sports bra
- No history of respiratory or cardiovascular related problems
- No injuries before the experimental day
- Have regular menstrual cycle. (Eumenorrhea)
- No previous or current pregnancies
- No major thoracic and abdominal surgery
- Free from diseases or symptoms which may limit exercise activity

Exclusion criteria: Subject will be excluded when later find that they

- Cannot exercise at the determined intensity
- Have injury which limits exercise activity
- Pregnant
- Use any contraceptive, muscle relaxant, and/ or bronchodilator pills/medication during the study period
- Cannot complete the required experimental trials

All subjects signed in consent forms before participating with the experiment after they had read and understood all the experimental protocols. The protocol was approved by the Human Research Ethics Committee of Mahidol University.

3.3 Experimental Procedure

A week before testing, participants arrived at the Laboratory (College of Sports Science and Technology, Mahidol University). All participants will initially have physical examination by physician, follow by filling in physical activity and health screening questionnaire form. Each individual will be identified for bra cup size. Then, anthropometry will be measured as follows:

- Chest, Waist, and Hip Circumferences
- Quadriceps and Cubitus angles
- Range of Motion (ROM) of back , hip, knee, and ankle
- Checked their feet shape (flatfoot)
- Vertebral column posture: Lordosis, Kyphosis, and Scoliosis

Finally, testing the peak of oxygen consumption (VO_{2peak}) on treadmill by Gas O_2 and CO_2 analyzer (Oxycon Mobile) using Bruce's Protocol (13). Until subject could not be examined.

Qualified participants would be selected and explained for the experimental protocol, procedure, possible risks/discomfort and benefits of the study before actual test. Then, they will sign informed consent forms prior to the experiment. Subjects' instructions that they have to do for 48 hours before testing are shown as follows:

- Avoided coffee, tea, alcohol, drug, or tobacco.
- Consumed the regular diet and took enough water intake.
- Get appropriated sleeping before test at least 8 hrs.
- Avoided strenuous physical activity.
- Prepared their own sports shoes.

Participants have to visit the laboratory for three random bra conditions;

- no bra (NB)
- casual bra (CB)
- and sports bra (SB)

For safety and privacy, at least two female researchers will conduct the experiment in the confidential area of Sports Physiology laboratory. They will be accepted for testing only in individuals' follicular phase of menstrual cycles to avoid the dysmenorrhea symptoms and the hormonal changes effect during menstrual period. To prevent diurnal variations, test will be done only in the afternoon. When participant arrived at laboratory on testing day, they will rest for 5 minutes and are assessed for resting vital signs, anthropometric data and set for non-invasive cardiac variables equipment (Physioflow).

3.3.1 Vital Sign Assessment

3.1.1 The manual sphygmomanometer (Spirit,Taiwan), Stethoscope (MDF, China), and wrap cuff firmly on upper arm are used for determining blood pressure.

3.1.2 Resting heart rate will be measured by Signal Morphology-based Impedance Cardiography (PhysioFlow, France).

3.3.2 Anthropometrics measurement

3.2.1 Body size

Digital weighing apparatus and a height stadiometer will be used for body weight and height measurement in each subject by the same measurer.

3.2.2 Body composition

Weight and height will be applied for Body Mass Index (BMI) calculation. The percentage of body fat mass and fat free mass will be assessed using body composition monitor (OMRON, Japan).

3.3.3 Cardiac Function test

Impact of sports bras on the function of the heart and blood volume to squeeze out time (Stroke volume, SV , ml/min) , pulse rate (Heart rate, HR, beats/minute), and volume of blood forced out per minutes (Cardiac output, CO, liters/minute) , blood pressure (BP, mmHg), blood volume when the heart relaxes(End-Diastolic Volume, EDV, ml), the ratio of the force blood out of the heart/blood volume when the heart relaxes (Ejection Fraction, EF, percentage). These variables will be continuously monitored by Signal Morphology-based Impedance Cardiography (PhysioFlow, France) and used Laser Doppler Flowmetry to measure blood perfusion (flux) either at rest or during exercise. Participant will randomly put on SB, or CB, or NB over the three exercise experiments.

3.4 Exercise protocol

They will attempt to perform running exercise up to 80% of maximum heart rate, at constant speed of 4 mph on a motor-driven treadmill at 25˚c and humidity less than 60 starting from calisthenics warm up with 2 min of static stretching and 3 minutes of 2.5 mph treadmill walking. Physiological responses of heart rate (HR), blood pressure (BP), cardiac output (CO), stroke volume (SV), ejection fraction (EF), end-diastolic volume (EDV), systemic vascular resistance (SVR), blood perfusion, RPE scales, and discomfort scale will be collected every 10 minute over exercise testing and 5 minutes of recovery. Finally, all participants cool down after finishing all data collecting. Exercise will be terminated when heart rate approaches target value. Other sign and symptoms which will terminate exercise including drop in systolic blood pressure ≥10 mmHg from baseline or high blood pressure more than 250/115 mmHg , chest pain, sever shortness of breath or wheezing and fatigue or cannot sustain pace.

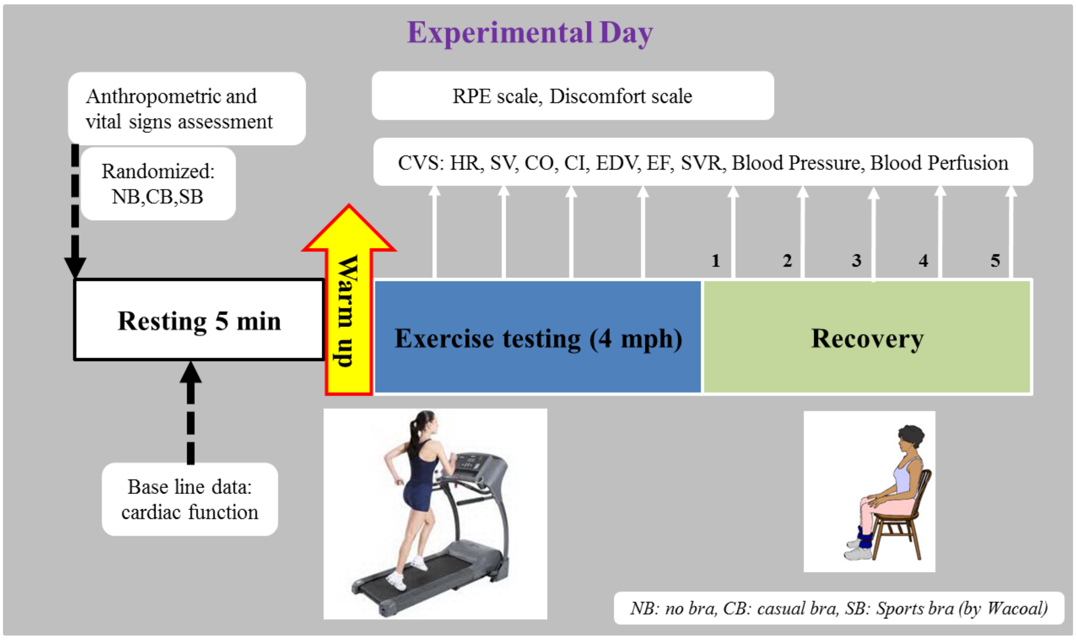


Figure 3.1 Exercise Protocol

3.5 Statistical analysis

All data will be presented as mean ±SEM otherwise will be stated. The Kolmogorov–Smirnov test (K–S test) will be used for normal distribution testing. If all cardiovascular function parameters are normal distribution, One-way ANOVA will be used for significant difference analysis, which will be accepted at p-value less than 0.05. If a significant main effect achieve, Bonferroni's post hoc test will be applied to identify the difference couple.

Flow Chart

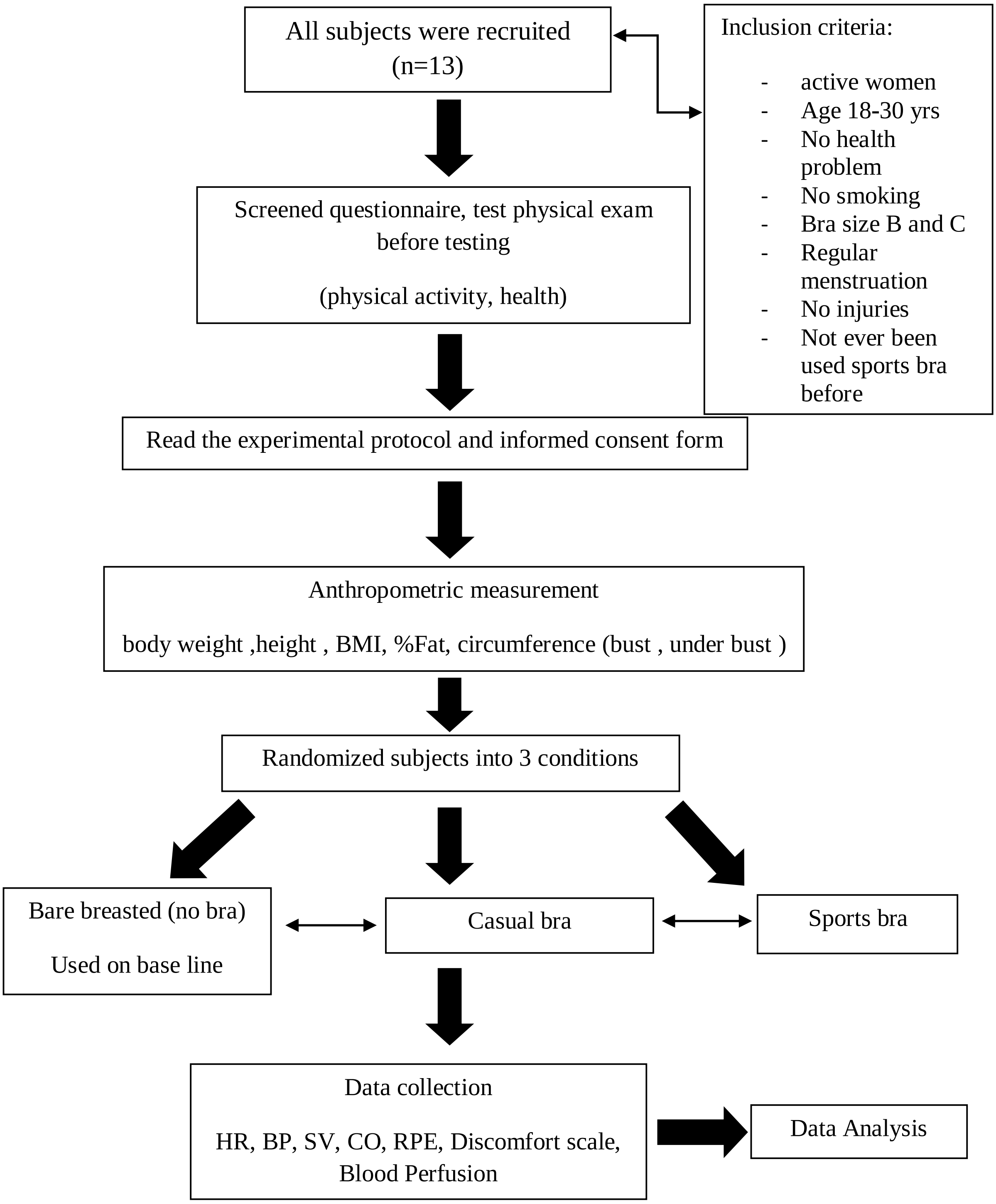


Figure 3.2 Procedure of the research

CHAPTER IV
RESULTS

The aim of this study was to explore the effects of sports bra on cardiovascular functions at rest and during constant speed running, as well as during recovery period. Sixteen female subjects were initially recruited due to inclusion criteria and completed all 3 randomized exercise conditions using no bra (NB), casual bra (CB), and sports bra (SB). All conditions were conducted in a privacy room. All variables were continuously recorded via computer programs throughout the experiments.

4.1 Characteristics of subjects

Thirteen subjects were finally completed the study. Their characteristics while participated in 3 conditions of control (no bra), casual (CB) and sports (SB) bras including anthropometric data, means and standard deviations were presented (Table 4.1). Resting heart rate (HR) and blood pressure (systolic and diastolic blood pressures, SBP and DBP) are in normal ranges of Thai population. The present study is very unique in that resting local blood perfusion (in arbitrary unit, achieved from Laser Doppler flowmeter, via), of either under or outside bra's strap, were estimated to determine whether there is any compression on local vascular circulation. No significant differences of all resting variables among three conditions were found ($p>0.05$).

Table 4.1 The characteristics of subjects in control (no bra, NB), casual (CB) and sports bras (SB) trials. Values are mean ±SD.

Variables	NB (n = 13)	CB (n = 13)	SB (n = 13)
General characteristics			
Weight (kg)	55.63 ±5.68	55.73 ±5.75	55.92 ±5.28
BMI (kg.m^{-2})	21.55 ±1.77	21.59 ±1.81	21.67 ±1.65
Body fat (%)	22.75 ±2.75	22.53 ±2.81	22.61 ±2.50
Lean body mass (%)	28.02 ±1.70	28.40 ±1.78	28.28 ±1.55
Waist (cm)	73.54 ±6.72	74.62 ±7.34	73.65 ±6.67
Hip (cm)	93.77 ±4.57	93.54 ±5.18	93.42 ±4.27
Physiologic variables			
Resting HR (bpm)	69.54 ±6.86	71.15 ±8.87	71.31 ±10.71
Resting SBP (mmHg)	104.23 ±7.49	103.85 ±12.19	106.62 ±9.41
Resting DBP (mmHg)	62.85 ±6.23	63.77 ±6.04	66.15 ±5.61
Local blood perfusion (arbitrary unit)			
Outside the strap	20.80 ±3.42	16.19 ±2.52	18.98 ±1.83
Inside the strap	20.80 ±3.42	20.69 ±4.26	26.38 ±6.42

It was noted that changes in cardiovascular variables in this study represented as graphs for between groups and tables for within group comparisons.

4.2 Effects of bra on cardiovascular variables

4.2.1 Changes in heart rate

As exercise was started, all groups showed similar patterns of changes in heart rates (HR) with significant differences from its corresponding resting values (p<0.05). These abrupt increasing in HR were immediate responses from exercise intervention: from 146.49 ±0.92 bpm (NB), 147.85 ±1.16 bpm (CB) and 147.26 ±1.23 bpm (SB) at 60% of age-predicted maximal heart rates (MHR) to 159.83 ±0.62 bpm

(NB), 161.0 ±0.73 bpm (CB) and 161.85 ±0.88 bpm (SB) at 70% MHR and 171.92 ±0.62 bpm (NB), 172.17 ±0.51 bpm (CB) and 172.90 ±0.50 bpm (SB) at 80% MHR respectively (Figure 4.1). Significant differences were detected only from initial resting values, within group comparison, but not for between groups comparisons. Remarkable declines in HR were found during the 1st min of recovery (p<0.05). HR during the rest of recovery period remained in the similar patterns with no significant differences between groups. However, all groups showed higher recovery HR than its corresponding initial values throughout 5 min period (p<0.05).

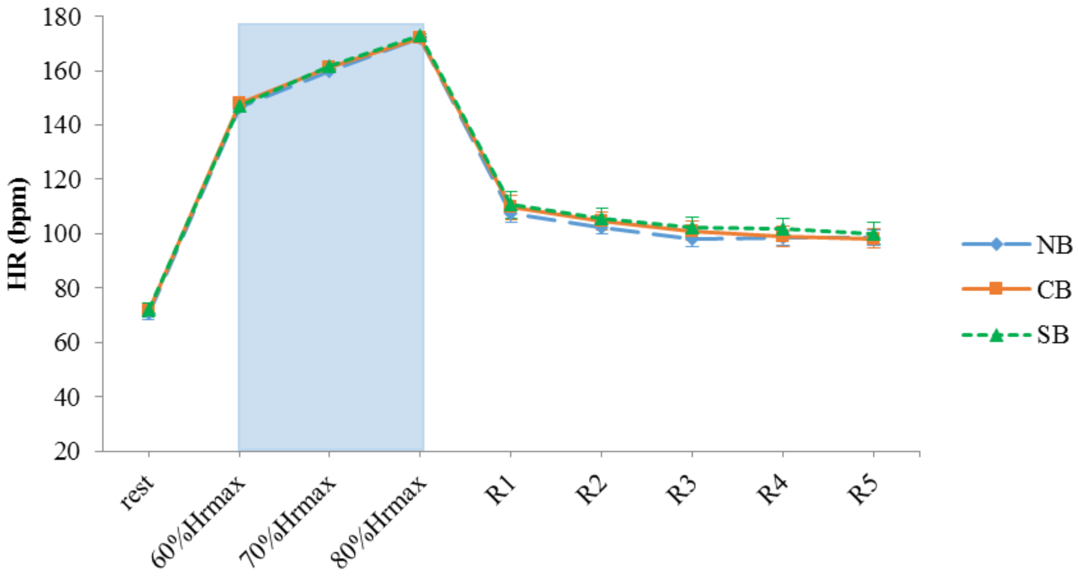


Figure 4.1 Between-groups comparisons of changes in heart rates (HR) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at p<0.05.

4.2.2 Changes in stroke volume

Resting stroke volumes of all groups, 50.72 ±2.85 ml (NB), 52.77 ±3.29 ml (CB) and 56.03 ±2.98 ml (SB), were in normal ranges. Figure 4.2 showed the result of stroke volume at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rate, all conditions changes with significant (p<0.05) from corresponding resting values. At 60% of age-predicted maximal heart rates, stroke volume increased to 73.08 ±4.37 ml (NB), 74.26 ±4.00 ml (CB) and 79.74 ±4.76 ml (SB) respectively. After that stroke volumes showed gradual change to 70 and 80% of age-predicted maximum heart rates. Between groups comparisons showed that at 60% of age-predicted maximal heart rates there was significantly different between CB and SB (p<0.05). Stroke volumes during post-exercise period remained unchanged when compared to initial values.

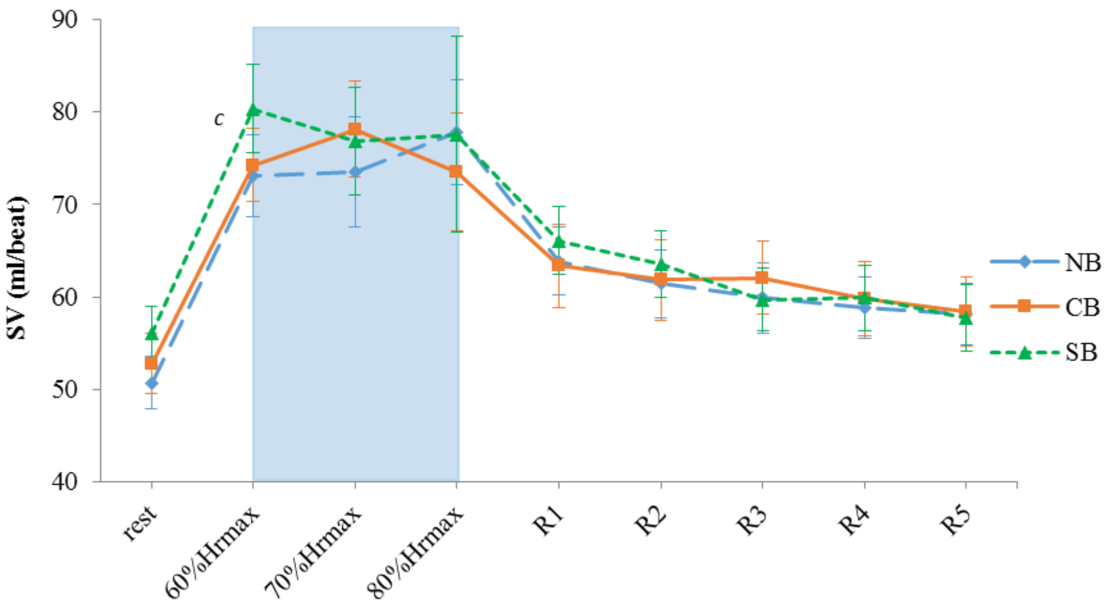


Figure 4.2 Between-groups comparisons of changes in stroke volume (SV) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at p<0.05

4.2.3 Changes in cardiac output

Resting cardiac outputs (CO) of all groups, 10.78 ±0.61 L/min (NB), 10.99 ±0.54 L/min (CB) and 11.89 ±0.66 L/min (SB), were in normal ranges (ref). From resting to 60% of age-predicted maximal heart rates, all groups showed similar patterns of changes in cardiac output with were significantly higher (p<0.05) than corresponding resting values followed by gradual increasing in CO from at 60% of age-predicted maximal heart rates to 11.84 ±0.93 L/min (NB), 12.66 ±0.79 L/min (CB) and 12.55 ±0.93 L/min (SB) at 70% of age-predicted maximal heart rates and 77.25 ±10.64 L/min (NB), 12.75 ±1.07 L/min (CB), 13.51 ±1.83 L/min (SB) at 80% of age-predicted maximal heart rates respectively (Figure 4.3). Significant difference in CO was found between CB and SB at 60% of age-predicted maximal heart rates. Remarkable declines in CO were found during the 1st min of recovery (p<0.05). CO during the rest of recovery period remained in the similar patterns with no significant differences between groups.

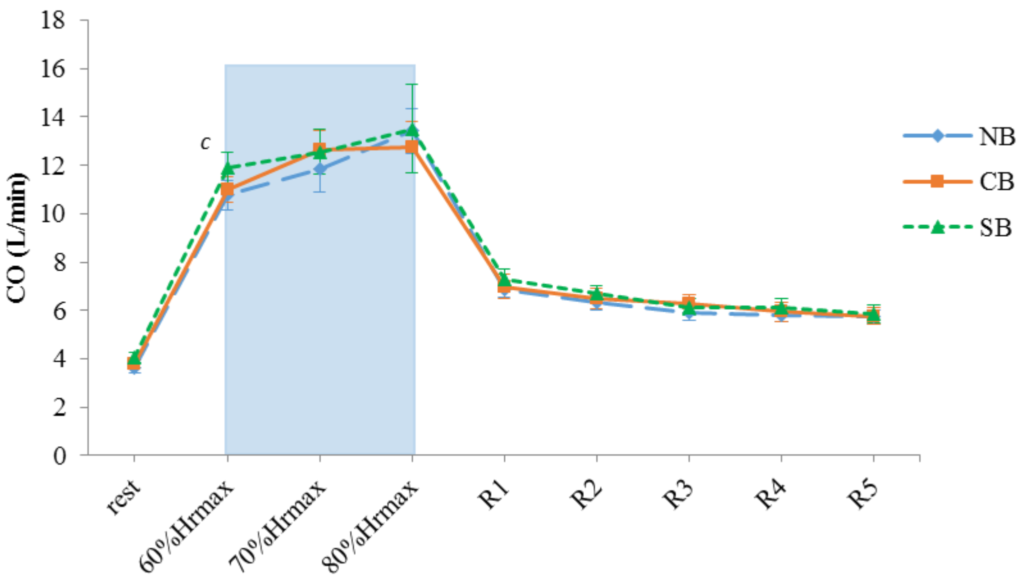


Figure 4.3 Between-groups comparisons of changes in cardiac output (CO) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at p<0.05

4.2.4 Changes in cardiac index

From resting to 60% of age-predicted maximal heart rates, all groups showed similar patterns of changes in cardiac index (CI) with significant ($p<0.05$) from corresponding resting values followed by gradual increasing in CI from 6.86 ±0.36 (NB), 6.94 ±0.27 (CB) and 7.51 ±0.36 L/min/min^2 (SB) at 60% of age-predicted maximal heart rates to 7.52 ±0.57 (NB), 8.02 ±0.42 (CB) and 7.90 ±0.49 L/min/min^2 (SB) at 70% of age-predicted maximal heart rates and 4.35 ±0.16 (NB), 4.40 ±0.27 (CB) and 4.62±0.24 L/min/min^2 (SB) at 80% of age-predicted maximal heart rates respectively (Figure 4.4). Significant differences were detected only from initial resting values, within group comparison, but not between groups. Remarkable declines in CI were found during the 1st min of recovery ($p<0.05$). CI during the rest of recovery period remained unchanged.

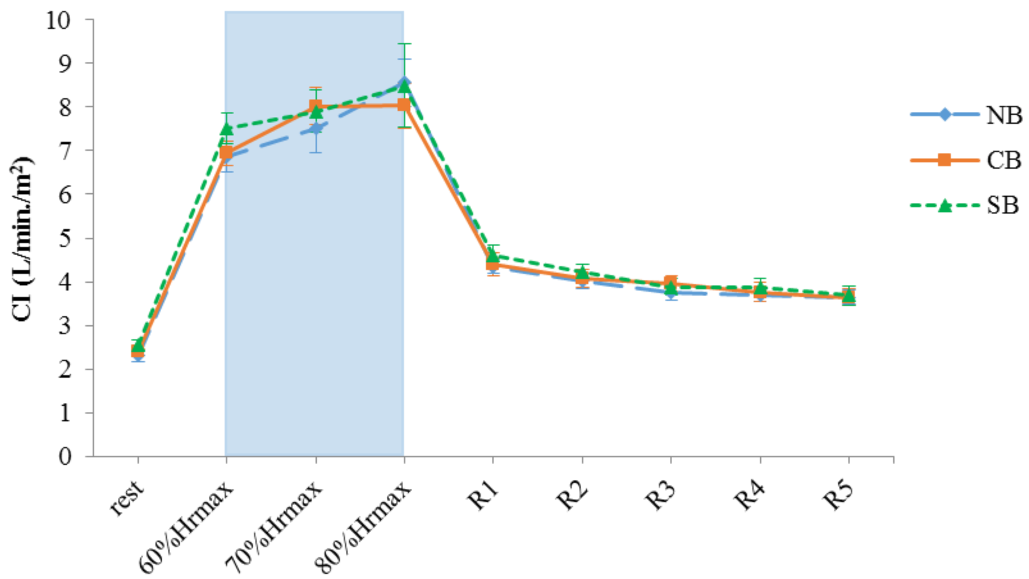


Figure 4.4 Between-groups comparisons of changes in cardiac index (CI) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at $p<0.05$

4.2.5 Changes in end-diastolic volume

End-diastolic volumes were about 109.79 ±4.95 ml, 107.36 ±6.20 ml and 113.10 ±4.34 ml in NB, CB and SB respectively (Figure 4.5) with no significance difference between groups. Exercise EDV values at 60% of age-predicted maximum heart rate were 133.33 ±6.04 ml (NB), 131.46 ±7.02 ml (CB) and 139.38 ±5.78 ml (SB), in which all groups showed similar patterns of increasing in end-diastolic volume (EDV) with no significance difference between groups was found. For within-group comparison, only SB showed significant difference ($p<0.05$) from initial values at 60% of age-predicted maximum heart rate. As exercise intensity was progressed, there were gradual increasing in EDV to 137.17 ±7.11 ml (NB), 137.61 ±9.14 ml (CB) and 137.15 ±8.79 ml (SB) at 70% of age-predicted maximal heart rates and 144.13 ±10.05 ml (NB), 136.25 ±11.74 ml (CB) and 137.14 ±12.75 ml (SB) at 80% of age-predicted maximal heart rates respectively. Remarkable declines in EDV were found during the 1st min of recovery ($p<0.05$) in CB. EDV during the rest of recovery period remained in the similar patterns in all groups with no significant difference between groups.

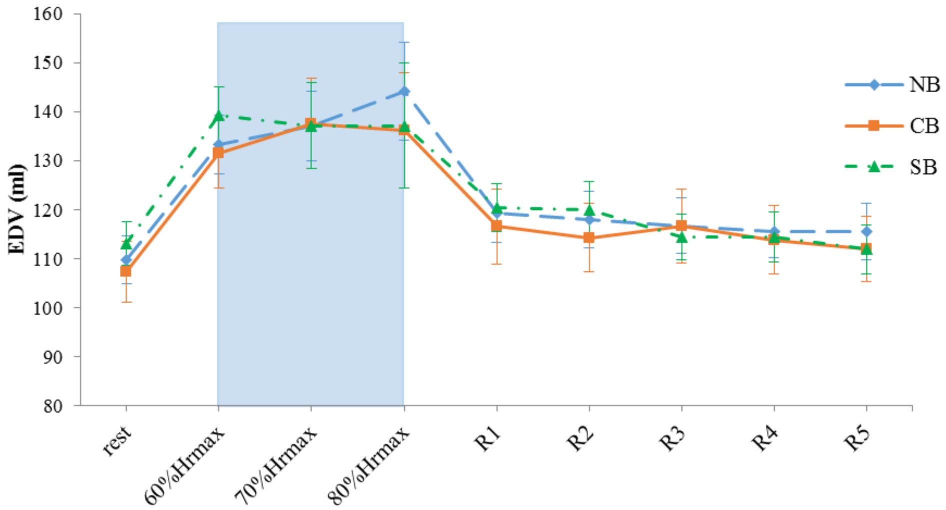


Figure 4.5 Between-groups comparisons of changes in end diastolic volume (EDV) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at $p<0.05$

4.2.6 Changes in ejection fraction

Resting EF were 46.10 ±1.97% (NB), 49.15 ±1.59% (CB) and 49.21 ±1.70% (SB) respectively (Figure 4.6). All conditions increased, when exercise was started, to 54.90 ±2.60% (NB), 56.85 ±2.18% (CB) and 57.33 ±2.43% (SB) respectively at 60% of age-predicted maximal heart rates but result showed significant increased (p<0.05) only in CB. At 60% to 80% of age-predicted maximal heart rates exercise intensities, there was no significantly different of EF among the groups. At recovery, it was found that EF gradually declined from 1st min with no significant in between groups and within group.

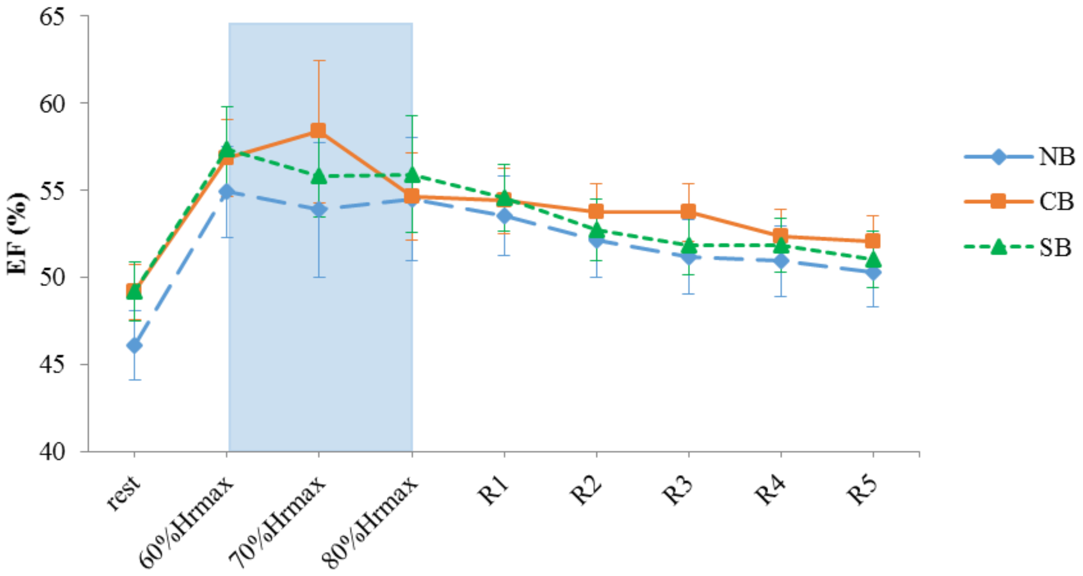


Figure 4.6 Between-groups comparisons of changes in ejection fraction (EF) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: ^{a} represents significant between NB-CB, ^{b} significant between NB-SB and ^{c} significant between CB-SB. All values are compared at p<0.05

4.2.7 Changes in systemic vascular resistance

Systemic vascular resistance (SVR) represents the rough estimation of the entire struggle in hemodynamic, but not a particular region. This study is unique to represent SVR during exercise in human. When started exercise, all groups showed similar patterns of significant reductions in systemic vascular resistance (SVR) from corresponding resting values as immediate responses (p<0.05) (Figure 4.7). These reductions, within group comparison, were detected (p>0.05) as exercise was progressed to 70 and 80% of age-predicted maximal heart rates, but not between groups (p<0.05). Higher SVR were found in all groups during the 1st min of recovery but still significant differences from initial values (p<0.05). SVR during the rest of recovery period gradually increased but remained significantly differences from initial values (p<0.05), no between groups differences were detected.

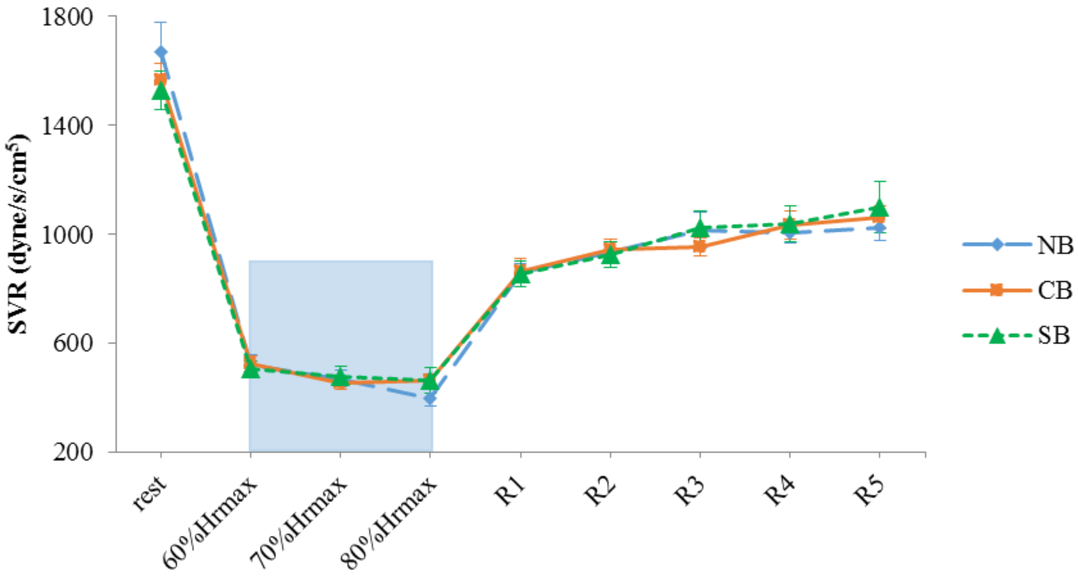


Figure 4.7 Between-groups comparisons of changes in systemic vascular resistance (SVR) at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at p<0.05

4.2.8 Changes in blood pressure

To obtain the valid blood pressures and to avoid any mechanical artifacts, investigator had to stop exercise test and kept the subject in a standstill fashion. These will more or less affect cardiovascular responses. From these difficulties, series of blood pressure were measured within less than 1 min duration of at rest, every 10 minutes of exercise on a treadmill and every minute of first 5 minutes of the recovery period (R1, R2, R3, R4 and R5).

At rest, systolic blood pressure (SBP) showed the similar values in each group, 104.23 ±2.08 mmHg (NB), 103.85 ±3.38 mmHg (CB) and 106.62 ±2.61 mmHg (SB). All groups showed similar patterns of changes in SBP from initial values when started exercise. Results showed that only CB showed significant differences from initial value ($p<0.05$) at 10 and 20 minutes of exercise (Figure 4.8 A). Only significant reduction in SBP was found in NB at the 1st min of recovery. No significant differences, between groups, in SBP during the rest of recovery period were found.

Diastolic blood pressure (DBP) at rest showed that values in each group (Figure 4.8 B), 62.85 ±1.73 mmHg (NB), 63.77 ±1.68 mmHg (CB) and 66.15 ±1.56 mmHg (SB), are in normal ranges. There were slightly increased in DBP, but no significant differences were found of both within and between groups, when exercises were started, at 10, 20 and 30 minutes. No significant differences were detected during the 1st min of recovery and the rest of recovery period.

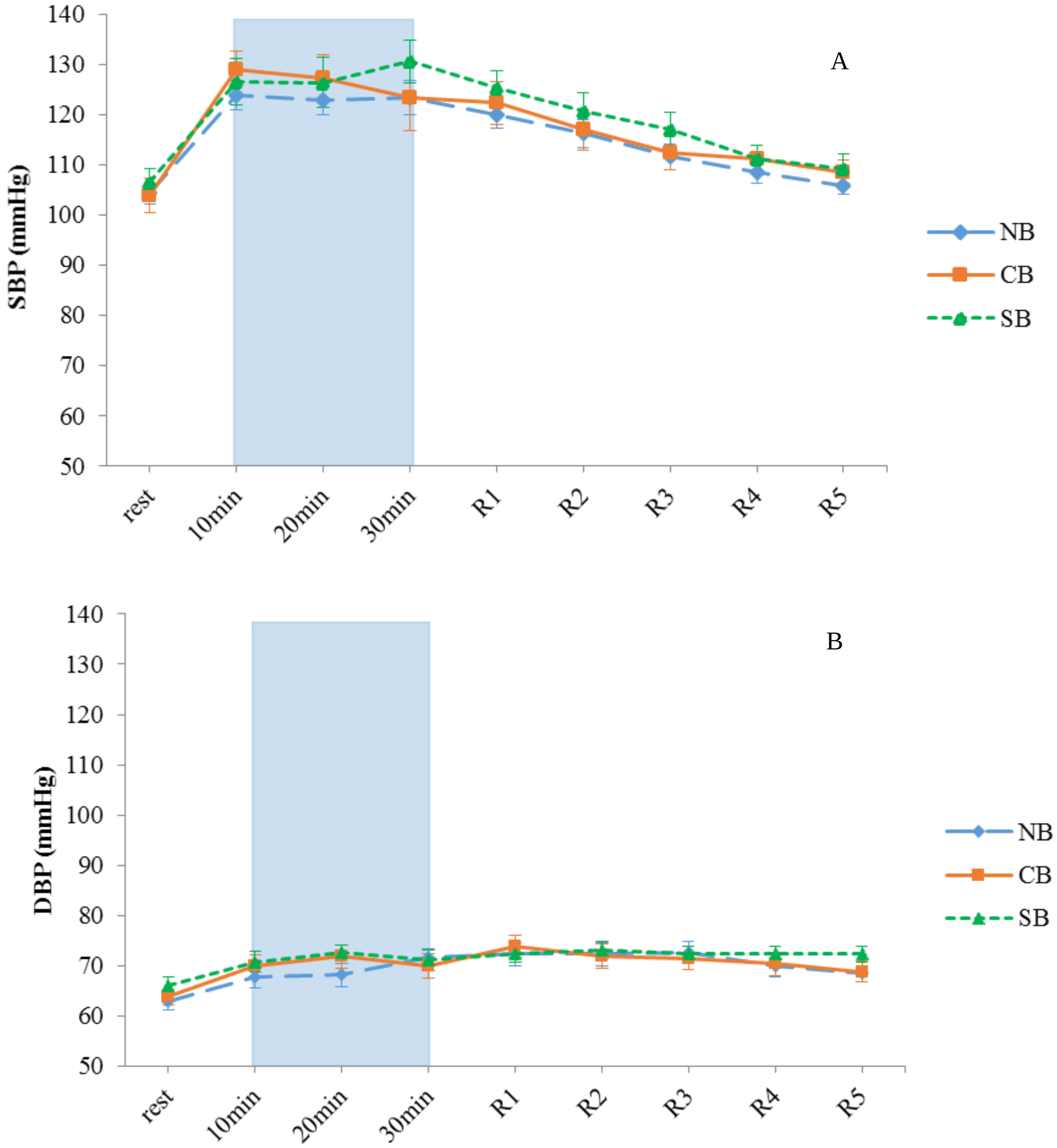
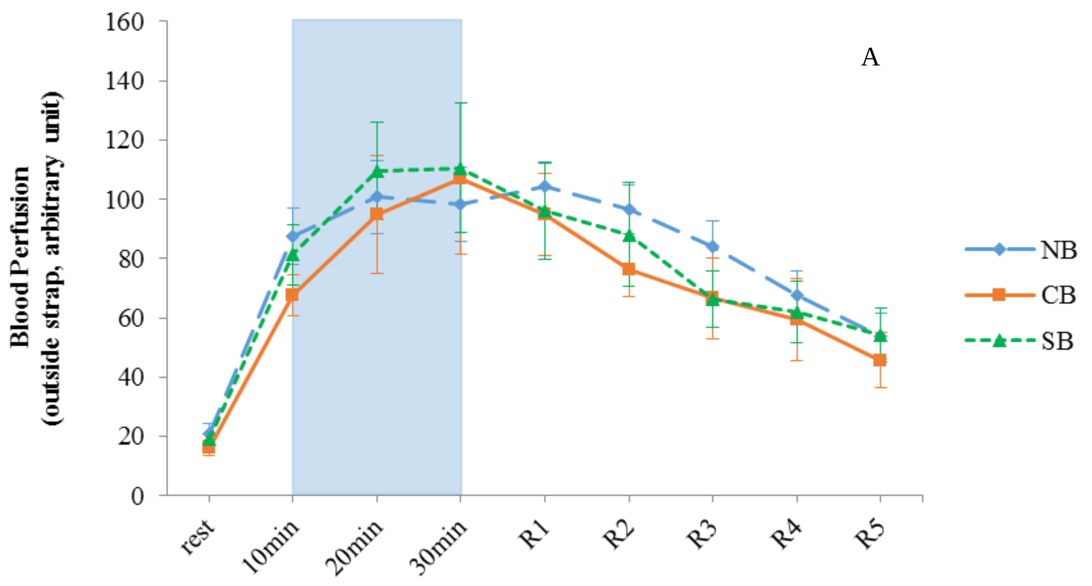


Figure 4.8 Between-groups comparisons of changes in systolic blood pressure (SBP, A) and diastolic blood pressure (DBP, B) at rest, during exercise 10, 20 and 30 min (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at $p<0.05$

4.2.9 Changes in blood perfusion

Series of blood perfusions were measured using Laser Doppler Flowmeter at skin areas outside and inside of bra's strap and can only be done in CB and SB conditions. Data were collected at rest, every 10 minutes of exercise and 5 minutes of the recovery period (R1, R2, R3, R4 and R5). Blood perfusion was then presented as arbitrary unit and statistical analysis was presented as differences between outside and inside skin areas of bra's strap on the right side about 2 inches below clavicle. Blood perfusions, outside, at rest in NB, CB and SB were 20.80 ±3.42, 16.19 ±2.52 and 18.98 ±1.83 (arbitrary unit) respectively; while blood perfusions, inside, at rest in NB, CB and SB were 20.80 ±3.42, 20.69 ±4.26 and 26.38 ±6.42 (arbitrary unit) respectively. No significant differences were detected either outside or inside bra's strap.



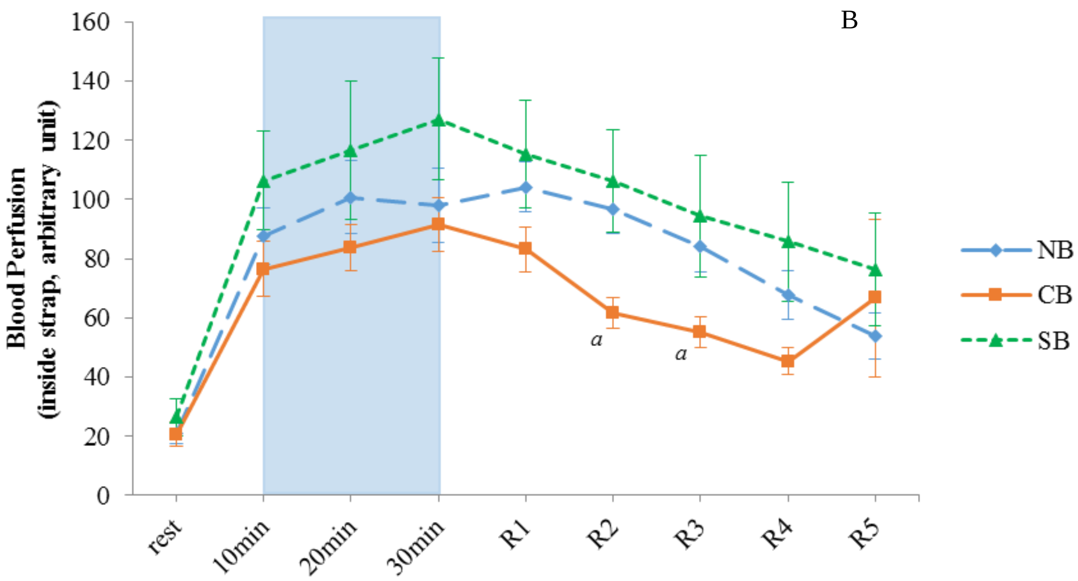


Figure 4.9 Between-groups comparisons of changes in blood perfusion outside (A) and inside strap (B) of bra at rest, during exercise 10, 20 and 30 min (shaded area), and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB) and sports (SB) bra. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at $p<0.05$

Table 4.2 Within-group comparisons of changes (mean ±SEM) in heart rate (HR), stroke volume (SV) and cardiac output (CO) of subjects at rest, during exercise at 60%, 70% and 80%MHR and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual (CB), and sports (SB) bra

Variables	HR (bpm)			SV (ml)			CO (L/min)		
conditions	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**
Rest	70.69 ±2.45	71.82 ±2.64	71.95 ±2.70	50.72 ±2.85	52.77 ±3.29	56.03 ±2.98	3.62 ±0.22	3.78 ±0.15	4.05 ±0.21
60%MHR	146.49 ±0.92*¶	147.85 ±1.16*¶	147.26 ±1.23*¶	73.08 ±4.37*¶	74.26 ±4.00*¶	80.33 ±4.76*¶	10.78 ±0.61*¶	10.99 ±0.54*¶	11.89 ±0.66*¶
70%MHR	159.83 ±0.62*¶	161.0 ±0.73*¶	161.85 ±0.88*¶	73.53 ±5.95*	78.09 ±5.18*	76.81 ±5.80*	11.84 ±0.93*	12.66 ±0.79*¶	12.55 ±0.93*¶
80%MHR	171.92 ±0.62*¶	172.17 ±0.51*¶	172.90 ±0.50*¶	77.79 ±5.67*	73.50 ±6.42*	77.57 ±10.64	13.42 ±0.93*	12.75 ±1.07*	13.51 ±1.83*
R1	107.49 ±3.08*¶	109.77 ±4.43*¶	110.69 ±4.95*¶	63.85 ±3.69	63.33 ±4.45¶	66.08 ±3.66	6.86 ±0.32*¶	6.99 ±0.52*¶	7.31 ±0.42*
R2	102.49 ±2.59*¶	104.46 ±3.32*	105.77 ±3.55*	61.41 ±3.66	61.82 ±4.41	63.49 ±3.58	6.32 ±0.31*	6.47 ±0.42*¶	6.70 ±0.30*
R3	98.26 ±3.06*	101.08 ±3.39*	102.38 ±3.67*¶	59.92 ±3.80	62.08 ±3.95	59.72 ±3.39	5.92 ±0.34*	6.28 ±0.35*	6.14 ±0.33*
R4	98.41 ±2.57*	99.00 ±3.73*	101.74 ±3.64*	58.85 ±3.36	59.82 ±4.04	59.90 ±3.51	5.80 ±0.24*	5.95 ±0.39*	6.13 ±0.36*
R5	98.38 ±2.77*	98.28 ±3.62*	100.13 ±3.93*	58.13 ±3.36	58.38 ±3.75	57.72 ±3.55	5.73 ±0.29*	5.76 ±0.36*	5.85 ±0.38*

Abbreviations * represents significant from initial (resting) value and ¶ significant from previous value at $p<0.05$

Table 4.3 Within-group comparisons of changes (mean ±SEM) in cardiac index (CI), ejection fraction (EF), end diastolic volume (EDV) and systemic vascular resistance (SVR) of subjects at rest, during exercise at 60%, 70% and 80%MHR and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual bra (CB) and sports (SB) bra

Variables	**CI (L/min./m2)**			**EDV (ml)**			**EF (%)**			**SVR (dyn·s·cm-5)**		
conditions	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**
Rest	2.31 ±0.14	2.39 ±0.08	2.56 ±0.12	109.79 ±4.95	107.36 ±6.20	113.10 ±4.34	46.10 ±1.97	49.15 ±1.59	49.21 ±1.70	1672.21 ±106.29	1566.08 ±62.03	1527.85 ±70.93
60%MHR	6.86 ±0.36*¶	6.94 ±0.27*¶	7.51 ±0.36*¶	133.33 ±6.04*¶	131.46 ±7.02*¶	139.38 ±5.78	54.90 ±2.60	56.85 ±2.18*¶	57.33 ±2.43	521.18 ±35.52*¶	523.59 ±27.01*¶	504.74 ±31.27*¶
70%MHR	7.52 ±0.57*	8.02 ±0.42*	7.90 ±0.49*¶	137.17 ±7.11*	137.61 ±9.14	137.15 ±8.79	53.87 ±3.86	58.36 ±4.06	55.85 ±2.43*	467.93 ±30.79*	452.61 ±23.88*	478.81 ±35.84*
80%MHR	8.57 ±0.55*	8.03 ±0.51*	8.49 ±0.94*	144.13 ±10.05*	136.25 ±11.74	137.14 ±12.75	54.46 ±3.54	54.63 ±2.53*	55.90 ±3.34	399.25 ±28.49*	461.79 ±26.65*	461.81 ±46.92*
R1	4.35 ±0.16*¶	4.40 ±0.27*¶	4.62 ±0.24*	119.28 ±5.93	116.54 ±7.70¶	120.38 ±4.81	53.54 ±2.28*	54.38 ±1.86*	54.56 ±1.94*	857.28 ±36.45*¶	865.51 ±43.86*¶	852.82 ±47.05*¶
R2	4.01 ±0.17*¶	4.08 ±0.22*¶	4.23 ±0.16*	118.03 ±5.79	114.26 ±6.96	120.08 ±5.56	52.13 ±2.10*	53.77 ±1.61	52.69 ±1.76*¶	932.28 ±41.32*	941.72 ±38.52*	926.90 ±46.83*
R3	3.76 ±0.20*	3.96 ±0.19*	3.88 ±0.18*¶	116.72 ±5.59	116.72 ±7.54	114.49 ±4.62	51.15 ±2.15	53.72 ±1.68	51.85 ±1.72*	1015.13 ±64.58*	953.82 ±33.71*	1022.62 ±62.85*¶
R4	3.69 ±0.14*	3.76 ±0.22*	3.87 ±0.20*	115.59 ±5.36	113.82 ±6.99	114.44 ±5.13	50.92 ±2.05	52.38 ±1.54	51.85 ±1.56*	1006.28 ±39.95*	1033.95 ±50.99*	1036.00 ±66.02*
R5	3.64 ±0.16*	3.64 ±0.20*	3.69 ±0.22*	115.56 ±5.80	112.03 ±6.69	111.92 ±4.99	50.28 ±2.01	52.08 ±1.48	51.05 ±1.63	1025.85 ±49.00*	1063.36 ±41.83*	1100.46 ±93.32*

Abbreviations * represents significant from initial (resting) value and ¶ significant from previous value at $p<0.05$

Table 4.4 Within-group comparisons of changes (mean ±SEM) in systolic blood pressure (SBP), diastolic blood pressure (DBP) and local blood perfusion outside the strap and inside the strap of subjects at rest, during exercise at 10 minutes, 20 minutes and 30 minutes and during 5 minutes of recovery period (R1, R2, R3, R4 and R5) in control (no bra, NB), casual bra (CB), and sports (SB) bra

Variables	**SBP (mmHg)**			**DBP (mmHg)**			**Blood perfusion (Outside strap)**			**Blood perfusion (Inside strap)**		
conditions	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**	**NB**	**CB**	**SB**
Rest	104.23 ±2.08	103.85 ±3.38	106.62 ±2.61	62.85 ±1.73	63.77 ±1.68	66.15 ±1.56	20.80 ±3.42	16.19 ±2.52	18.98 ±1.83	20.80 ±3.42	20.69 ±4.26	26.38 ±6.42
10minutes	123.85 ±2.90	128.85 ±3.68$^{\infty\beta}$	126.54 ±4.65	67.69 ±2.01	70.00 ±2.26	70.77 ±2.11	87.55 ±9.58	67.49 ±6.86$^{\infty\beta}$	81.22 ±10.04$^{\infty\beta}$	87.55 ±9.58	76.45 ±9.38	106.31 ±16.59$^{\infty\beta}$
20minutes	122.73 ±2.73	127.27 ±4.69	126.36 ±4.91	68.18 ±2.26	71.82 ±2.26	72.73 ±1.41	100.69 ±12.27	94.88 ±19.82	109.58 ±16.35	100.69 ±12.27	83.65 ±7.67	116.66 ±23.43
30minutes	123.33 ±3.33	123.33 ±6.67	130.63 ±4.27	71.67 ±1.67	70.00 ±2.36	71.11 ±2.00	98.12 ±12.55	107.03 ±25.46	110.58 ±21.83	98.12 ±12.55	91.54 ±8.92	127.11 ±20.66
R1	120.00 ±2.77	122.31 ±4.26	125.38 ±3.32	72.31 ±2.31	73.85 ±2.13	72.31 ±1.66	104.27 ±8.41	94.93 ±13.91	95.97 ±16.37	104.27 ±8.41	83.15 ±7.53$^{\beta}$	115.38 ±18.16
R2	116.15 ±2.90	116.92 ±3.98	120.77 ±3.62	72.31 ±2.31	71.92 ±2.50	73.08 ±1.75	96.49 ±8.11	76.38 ±9.43	88.04 ±17.56	96.49 ±8.11	61.62 ±5.09	106.24 ±17.46
R3	111.54 ±2.49	112.31 ±3.43	116.92 ±3.47	72.69 ±2.16	71.54 ±2.29	72.31 ±1.66	84.19 ±8.58	66.52 ±13.59	66.40 ±9.52	84.19 ±8.58	55.21 ±5.33	94.46 ±20.55
R4	108.46 ±2.22	111.15 ±2.78	111.15 ±2.78	70.00 ±2.26	70.38 ±2.37	72.31 ±1.66	67.75 ±8.18	59.44 ±13.95	61.91 ±10.38	67.75 ±8.18	45.29 ±4.60$^{\beta}$	85.68 ±20.28
R5	105.77 ±1.78	108.46 ±2.49	109.23 ±2.88	68.46 ±1.54	68.85 ±2.05	72.31 ±1.66	53.81 ±7.70	45.71 ±9.24	54.15 ±9.26	53.81 ±7.70	66.71 ±26.63	76.29 ±18.95

Abbreviations ∞ represents significant from initial (resting) value and β significant from previous value at $p<0.05$

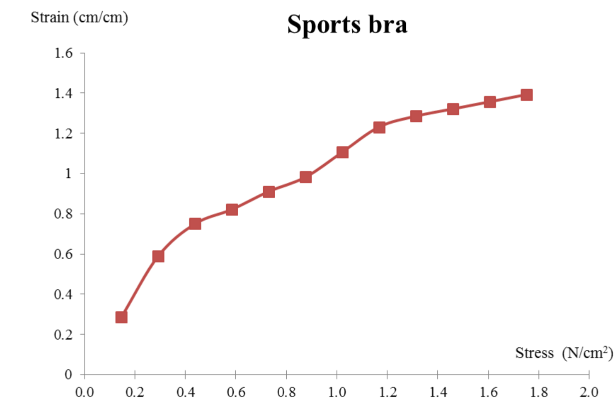
CHAPTER V
DISCUSSION

The aim of this present study was to investigate the possible effect of sports bra (SB) on cardiovascular function during running constant speed exercise at rest, during and after exercise with three different bra conditions. Thirteen healthy females who appropriated all criteria were selected to participate in this study. All characteristic data, hip and waist circumferences, hip-waist ratio and BMI showed that all subjects were in good shapes without overweight problems. Moreover, they did not show any risk in blood pressure. They were in normal ranges of Thai female population at the particular age (56). When compared between bra conditions, there were no significant different in all resting characteristics. Their VO_{2peak} levels were considered in average of Thai females at their age range (59). Thus, this study recruited normal healthy females for sports bra investigation. Apart from cardiac variables, local blood flows in this study also express some vascular characteristics.

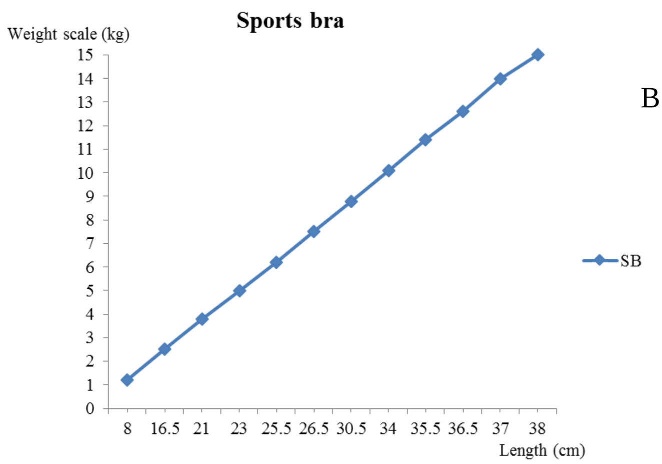
5.1 The effect of sports bra on cardiovascular function at rest, during and after exercise

This study showed that changes of most of cardiac variables were in the normal and had similar patterns during exercise no matter any types of bra or even no bra were put on. It seemed likely that the effects of exercise intensity override effects of bras. Thus, putting on sports bra does not exert any effects on cardiac function. Previous evidence indicated an increasing of ventricular contractility, which, in turn, resulting in increasing of stroke volume and cardiac output (38). However, this compensatory condition took place only when chest wall restriction was extremely high or chest wall was totally covered, where vital capacity was diminished up to 35% from elastic recoil of material used. In the present study, chest wall was not fully covered, but just partially (total area of sports bra is 0.15-0.16 m^2 (65), total area of thorax is 0.3 m^2 (23, 49). In addition, investigators explored bra's shoulder strap compressive force and found that SB induced only 6 g/cm^2 when it was put on (Figure 5.1, 5.2). Since CBs were a private property and some were used for long period of time, the present study failed to construct the similar graph to represented relationships of shoulder strap and compressive force.

Therefore, the free surface area left and low elastic recoil of bra's garment may not affect hemodynamic within the thorax. As a result, the increasing in SV and CO in SB at 60% of age-predicted MHR in present study was most likely derived from higher respiratory rates (RR), even no significant difference was detected, RR in SB 37.98 ±1.89 and in NB 35.07 ±1.59 breaths/min. Respiratory pumps from breathing cycle is known to affect cardiac function in that the more frequent RR will bring about higher SV (38). The higher SV in SB than NB conditions at 60% age-predicted MHR may be due to slight compression of sports bra on the thorax, which follows by higher respiratory rate.



A



B

Figure 5.1 Strain and stress relationships of sports bra (A) and length of bra's shoulder strap-induced compressive force (B).

It is generally known that exercise intervention will bring about higher cardiac variables including higher heart rhythm and contractility. This is similar to the phenomenon occurred during sympathetic activation (6). As exercise is commenced, sympathetic neural activation becomes the first among responses on cardiac function. This neural activity is closely related to change in blood pressure via baroreflex (18). The second responses derive from increasing in cellular oxygen requirement and later an increasing in metabolic waste products. These products from the periphery will affect centrally on the heart via both chemoreceptors and baroreceptors. As a result, heart will pump more vigorously and frequently in order to supply adequate amount of blood to working muscles, as well as fasten the removal rates of waste products (25).

Cardiac index, the ratio between cardiac output and body surface area, is the hemodynamic parameter which relates cardiac performance to the size of an individual (14). Since body surface area is constant, thus increasing in CI is mainly due to increasing in CO. This means that cardiac compensation during exercise can offer suitable hemodynamic to all body parts. In addition, this study found that it was likely intensity-dependent.

Volume of blood being ejected or remained in the heart is another unique investigation of this study. EDV depends mainly on end-diastolic duration and venous return (25). This means that the longer end-diastolic duration, the higher blood volume will be filled in heart chamber. Accordingly, heart rates and stroke volumes during exercises for all intensities were not significantly different among the groups, thus these resulted in similar EDV during exercises at any intensities in all groups. EF is a ratio between SV and EDV, normally expressed as percentage. In normal healthy population, EF ranges from 55 to 70%. At maximum exercise, EF may rise up to about 80%, which is known to be an adaptation to physical workload. A higher EF would represent an increase in ventricular function in healthy individuals, whereas reduction in EF would represent impairment of ventricular function and used as clinical indicator (25). Since EDV is likely limited from size of heart chamber, an increasing in EF, therefore, represents increasing in SV. It is generally known that sympathetic activation during exercise will stimulate cardiac contraction in parallel with faster cardiac rhythm.

However, at sub-maximum exercise intensity, cardiac compensation with greater contraction will bring about higher SV with effective EF (25).

It is generally known that reduction in vascular resistance is due to exercise-induced vasodilation. Even though, we did not explore for metabolic waste products, however, strong evidences showed that these products, in blood circulation and localized in the nearby region known as vasoactive agents, will induce relaxation of vascular smooth muscles (25).

It is normally found in healthy individuals that SBP and DBP showed different characteristics to exercise intervention. Accordingly, SBP increases as a result of higher cardiac contractility, which needs to pump appropriate amount of blood to effectively supply even the periphery. Pulsatile pressure waves derived from cardiac contraction will distend vessels' lumen, this will, therefore, enhance energy stored within vessels' wall. DBP, on the other hands, is the stored pressure sustains within the vessels and will cause recoil of vessels (6). Increasing in SBP while DBP remains or slightly increases will physiologically set human vascular wall in a safety zone. It is because of these characteristics, which keep mean arterial blood pressure (MABP) quite in a low ranges. The present study indicated that MABP of females will be kept in a safety zone with constant speed run.

The result of this study showed that blood perfusion was not limited in both CB and SB conditions which may be explained that bra's shoulder does not induce excessive pressure on the shoulder. The compressive force of 0.6 g/cm^2 was found in the present study shows that pinching or blocking of blood perfusion in under shoulder strap region is likely to be ignored. In contrast to previous study which revealed that more pressure of sports bra will limit extreme breast motion during exercise when compared with fashion bra (9). Blood perfusion of either inside or outside the strap is the result of physical activity. This was found in all groups. Even though the amounts of perfusion are different, but no significances between groups were found. Thus we can, again, conclude that it derives mainly form the result of physical activity. While NB and SB perfusions remain similar throughout the recovery period, lowest blood perfusion inside the strap in CB group during recovery may possibly the result of tight chest straps found in the study. It was one of the benefits of this study to educate subjects how to determine correct bra size.

5.2 The comfortable feeling when put on sports bra

In present study, we expected that sports bra will reduce exercise-induced breast motion together with least of all breast pain. In this experiment, the discomfort or pain rating scale (scale 0: no hurt, 10: hurts worst) was used an indicator of feeling pain in all conditions. This subjective evaluation during wearing sports bra and exercise was slightly more than other conditions. On the other hands, during recovery period found that discomfort scale in sports bra was less than casual and no bra conditions. Previous study of treadmill running showed that the association of reductions in breast pain and discomfort appeared together with diminution in breast motion achieved with highly supportive brassieres. (9, 28, 32, 35)

CHAPTER VI
CONCLUSION

This study indicates that there is no limitation of sports bra on cardiovascular function at rest, during and after exercise. Cardiac functions including rate and contractility exhibit similarly as when subjects were in no bra or casual bra. Peripherally, systolic and diastolic blood pressures and total vascular resistance do not exhibit any changes from casual bra. Even there are fluctuations of some cardiac variables as sports bra is put on, these changes are considered as minor. It is recommended from this study that sports bra can be used safely with no cardiovascular limitations.

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APPENDICES

APPENDIX A

CERTIFICATE OF APPROVAL MAHIDOL UNIVERSITY INSTITUTIONAL REVIEW BOARD (MU-IRB)

COA. No. 2014/166.2312

Certificate of Approval
Central Institutional Review Board, Mahidol University (MU-CIRB)

Protocol No.:	MU-CIRB 2014/164.2910
Title of Project:	Sports Bra Might Possibly Affect on Cardiovascular Function in Active Women (Thesis for Master Degree)
Principal Investigator:	Miss Kanchana Taothong
Co-Investigators:	Associate Professor Dr. Thyon Chentanez Associate Professor Dr. Rungchai Chuanchaiyakul Dr.Metta Pinthong
Affiliation:	College of Sports Science and Technology

Approval includes
1) MU-IRB Submission form version date 23 December 2014
2) Research Protocol version date 23 December 2014
3) Participant Information Sheet version date 23 December 2014
4) Informed Consent form version date 23 December 2014
5) Data Record Form version date 29 October 2014
6) Questionnaire version date 29 October 2014
7) Recruitment Material version date 23 December 2014

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

Date of Approval: 23 December 2014
Date of Expiration: 22 December 2015

Signature of MU-CIRB Chair: .... 23 December 2014
(Professor Shusee Visalyaputra) version date

Signature of Institute Representative: .... 23 December 2014
(Professor Prasit Palittapongarnpim) version date
Vice President for Research

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APPENDIX B

เอกสารชี้แจงผู้เข้าร่วมวิจัย

ในเอกสารนี้อาจมีข้อความที่ท่านอ่านแล้วยังไม่เข้าใจ โปรดสอบถามหัวหน้าโครงการวิจัย หรือผู้แทนให้ช่วยอธิบายจนกว่าจะเข้าใจดี ท่านจะได้รับเอกสารนี้ 1 ฉบับ นำกลับไปอ่านที่บ้านเพื่อปรึกษาหารือกับญาติพี่น้อง เพื่อนสนิท หรือผู้อื่นที่ท่านต้องการปรึกษา เพื่อช่วยในการตัดสินใจเข้าร่วมการวิจัย

ชื่อโครงการการใส่เสื้อชั้นในกีฬาอาจส่งผลต่อการทำงานของระบบไหลเวียนเลือดในผู้หญิงที่ออกกำลังกายสม่ำเสมอ

ชื่อผู้วิจัยนางสาวกาญจนา เต่าทอง

สถานที่วิจัย และสถานที่ทำงาน

ห้องวิจัย ชั้น 1 วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ศาลายา

หมายเลขโทรศัพท์ 02 – 441 – 4297– 8 ต่อ 207 (เวลาราชการ) และ 084-0059112 (ตลอดเวลา)

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โครงการวิจัยนี้ทำขึ้นเพื่อศึกษาผลของการใส่เสื้อชั้นในกีฬาต่อการทำงานของระบบไหลเวียนเลือด เปรียบเทียบกับเสื้อชั้นในปกติซึ่งการสวมใส่เสื้อชั้นในกีฬาอาจทำให้เกิดความรู้สึกไม่สบาย

ซึ่งประโยชน์ที่คาดว่าจะได้รับคือทราบถึงความสามารถในการทำงานของระบบไหลเวียนเลือดทั้งในระยะพักและขณะออกกำลังกายในระหว่างสวมใส่เสื้อชั้นในกีฬาและเสื้อชั้นในปกตินอกจากนี้ผู้เข้าร่วมการวิจัยจะเรียนรู้การวัดขนาดหน้าอกวิธีการดูแลหน้าอกในระหว่างการออกกำลังกายโดยการสวมใสเสื้อชั้นในที่มีการออกแบบมาโดยเฉพาะเพื่อลดผลกระทบจากการเคลื่อนไหวของหน้าอกในระหว่างการออกกำลังกาย และสามารถนำไปใช้ประกอบการตัดสินใจในการเลือกใช้เสื้อชั้นในที่ใช้ในระหว่างการออกกำลังกายได้

ท่านได้รับเชิญให้เข้าร่วมวิจัยนี้เพราะ เป็นเพศหญิง อายุ 18-30 ปี สุขภาพดี ออกกำลังกายเป็นประจำและมีหน้าอกขนาด B ถึงC

การวิจัยนี้จะมีผู้เข้าร่วมการวิจัยนี้ทั้งสิ้นประมาณ 11 คน

หากท่านตัดสินใจเข้าร่วมการวิจัยแล้ว จะมีขั้นตอนการวิจัยดังต่อไปนี้คือ

- ผู้วิจัยจะขอนัด วัน และเวลาที่ท่านสะดวก ให้ผู้วิจัยชี้แจงรายละเอียด วัตถุประสงค์ และขั้นตอนการวิจัย พร้อมตอบข้อคำถามก่อนการเริ่มต้นการวิจัย ที่ห้องวิจัย ชั้น 1 วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล ศาลายา**ซึ่งใช้เวลาประมาณ 5 - 10นาที**

ขั้นตอนการคัดกรอง (ใช้เวลาประมาณ5 - 10นาที)

- ผู้วิจัยจะขอให้ท่านเข้ารับการคัดกรองเพื่อเข้าร่วมการวิจัย ดังนี้

1)ตอบแบบสอบถามข้อมูลสุขภาพและการออกกำลังกายจำนวน16 ข้อ

2)เข้ารับการวัดขนาดเต้านมในขณะที่ไม่สวมเสื้อชั้นใน โดยมีผู้เชี่ยวชาญผู้หญิงจากบริษัทผลิตชุดชั้นในเป็นผู้วัดซึ่งจะทำในห้องที่มิดชิด เพื่อความเป็นส่วนตัวของผู้เข้าร่วมการวิจัย

- หากท่านผ่านเกณฑ์การคัดกรอง ผู้วิจัยจะขอให้ท่านเข้าร่วมการวิจัยในขั้นตอนต่อไป

การเตรียมตัวก่อนการเก็บข้อมูล

-ผู้วิจัยจะขอให้ท่านปฏิบัติดังนี้

1)รับประทานอาหารตามปกติและดื่มน้ำให้เพียงพอ

2)งดกิจกรรมการออกกำลังกายหนักหรือที่จะทำให้เกิดอาการอ่อนเพลียและอ่อนล้า เป็นเวลา 2 วันก่อนวันนัดมาทำการทดสอบ

3)งดดื่มชา, กาแฟ, และเครื่องดื่มแอลกอฮอล์

4)พักผ่อนให้เพียงพออย่างน้อย 8 ชั่วโมง

5)เตรียมรองเท้ากีฬา มาด้วยทุกครั้ง

ขั้นตอนการเก็บข้อมูล

- ผู้วิจัยจะขอให้ท่านมาเข้าร่วมการวิจัย **จำนวน 3 ครั้งใช้เวลาครั้งละประมาณ 1 ชั่วโมง 30 นาที - 2 ชั่วโมง** โดยขั้นตอนการเก็บข้อมูลทั้งหมดจะทำในห้องที่ปิดมิดชิด

- การเก็บข้อมูลแต่ละครั้งจะทำในช่วงบ่าย และในช่วงวันที่ 1-14 ของรอบประจำเดือนของท่านโดยนับวันที่ประจำเดือนมาวันแรกเป็นวันที่ 1 และจะเว้นระยะห่างในแต่ละครั้งของการทดลองอย่างน้อย2 วัน

- ในแต่ละครั้งผู้วิจัยจะขอให้ท่านสวมใส่เสื้อชั้นใน 1 ลักษณะจาก 3 ลักษณะ ตามลำดับที่ได้จากการสุ่มดังนี้

ลักษณะที่ 1 เสื้อชั้นในกีฬา (ผู้วิจัยจัดเตรียมไว้ให้)

ลักษณะที่ 2 เสื้อชั้นในปกติ (ท่านสวมใส่มา)

ลักษณะที่ 3 ไม่สวมใส่เสื้อชั้นใน

- การเข้าร่วมการวิจัยในแต่ละครั้งผู้วิจัยจะขอให้ท่านปฏิบัติดังนี้

1)ผู้วิจัยจะขอให้ท่านสวมเสื้อชั้นในตามลักษณะที่ได้จากการสุ่มแล้วสวมใส่ชุดกีฬาที่ผู้วิจัยจัดเตรียมไว้ให้

2)ผู้วิจัยจะขอให้ท่านวิ่งเหยาะๆ บนลู่กล(Treadmill)ที่ความเร็ว 4 ไมล์ต่อชั่วโมง(6.5 กิโลเมตร/ชั่วโมง) เป็นระยะเวลาประมาณ 15-30 นาที หรือจนกว่าอัตราการเต้นหัวใจของท่านจะเพิ่มขึ้นถึง 80% ของอัตราการเต้นหัวใจสูงสุดทั้งนี้ผู้วิจัยจะขอวัดการทำงานทางสรีรวิทยาอื่นๆ ของร่างกายตลอดการออกกำลังกาย รวมไปถึงในช่วง 5 นาทีแรกของการฟื้นสภาพ โดยใช้เครื่องวัดปริมาตรเลือดที่ออกจากหัวใจและอัตราชีพจรซึ่งเป็นเครื่องที่นิยมใช้ในการวิจัยทางวิทยาศาสตร์สุขภาพอย่างแพร่หลาย โดยจะให้ท่านติดแผ่นอิเล็คโทรดทั้งหมด 6 ตำแหน่ง และมีสายต่อเข้ากับเครื่องที่ใส่กับตัวคาดเอว โดยเครื่องจะไม่เลื่อนหลุดออกจากตัวท่าน นอกจากนี้จะมีเครื่องวัดความดันโลหิต และเครื่องวัดการกำซาบของเลือดที่ผิวหนัง โดยจะวัดทุกๆ 10 นาที ซึ่งจะให้ท่านได้หยุดและเหยียบบนด้านข้างของลู่วิ่งขณะวัด เพื่อความปลอดภัยของท่าน ทั้งนี้เพื่อความสะอาดและความปลอดภัยของท่าน ทางผู้วิจัยได้มีการเตรียมความพร้อมในเรื่องของการทำความสะอาดอุปกรณ์และเครื่องมือทุกชนิดที่จะสัมผัสกับตัวท่านก่อนการใช้งานทุกครั้ง

3)จากนั้นผู้วิจัยจะขอให้ท่านนั่งพักนิ่งๆ เป็นเวลา 10 นาที

4)ผู้วิจัยจะขอวัดการกระจายของเลือดที่ผิวหนัง และวัดค่าความดันโลติดของท่าน ในระยะฟื้นสภาพ (ขณะนั่งพัก)ในนาทีที่ 1,2,3,4 และ 5

5)ผู้วิจัยจะขอสอบถามระดับความรู้สึกเหนื่อยและระดับความสบายในการหายใจของท่านทุกๆ 10 นาที ตลอดระยะเวลาของการออกกำลังกาย และทุกๆ 1 นาที ขณะนั่งพัก จนครบ 5 นาที โดยแสดงแผ่นModified Borg Scale และ Discomfort scale ด้านหน้าในระดับสายตา เพื่อให้ท่านสามารถมองเห็นได้ชัดเจน

ข้อมูลต่างๆ ที่ได้จากการวิจัยจะถูกเก็บรักษาไว้จนกว่าจะเสร็จสิ้นการวิจัย โดยมีเพียงผู้วิจัยเท่านั้นที่สามารถเข้าถึงข้อมูลได้ หลังจากนั้นข้อมูลทั้งหมดจะถูกทำลายทิ้งโดยการลบข้อมูลทั้งหมดออกจากคอมพิวเตอร์ และทำลายเอกสารหรือแบบสอบถามต่างๆทั้งหมด

ระหว่างเข้าร่วมการวิจัย อาจมีผลข้างเคียงที่เกิดขึ้นได้แก่ อาการปวดเมื่อยกล้ามเนื้อ ซึ่งมักเกิดขึ้นภายหลังการออกกำลังกายอย่างหนักเป็นเวลา 1-2 วัน การคลายอุ่นและการเหยียดยืดกล้ามเนื้อภายหลังการออกกำลังกายจะช่วยป้องกันหรือบรรเทาอาการดังกล่าวได้ในระดับหนึ่งหากท่านมีอาการปวดเมื่อยกล้ามเนื้อ และต้องการได้รับยาหรือการรักษาจะทำการนัดหมายเพื่อรับการรักษาที่คลินิกการกีฬา วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล เพื่อรับการรักษาและบรรเทาอาการปวดและไม่สุขสบายที่เกิดขึ้นต่อไปนอกจากนี้ผู้วิจัยมีการเตรียมแพทย์และอุปกรณ์กู้ชีพขั้นพื้นฐานไว้

ตลอดเวลา ณ สถานที่ทำการวิจัย (สถานที่ทำการวิจัยอยู่บริเวณเดียวกับคลินิกการกีฬา) หากเกิดเหตุที่ไม่พึงประสงค์จากการวิจัย เช่น มีอาการหน้ามืด เวียนศีรษะ จุกแน่นหน้าอกท่านจะได้รับการปฐมพยาบาล เพื่อช่วยประเมินและแก้ไขกรณีเกิดเหตุการณ์ไม่พึงประสงค์ และทำการกู้ชีพขั้นพื้นฐานได้ทันที ก่อนส่งต่อศูนย์แพทย์กาญจนาภิเษกต่อไปโดย นางสาวกาญจนา เต่าทอง และวิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬาจะเป็นผู้รับผิดชอบค่าใช้จ่ายในการรักษาพยาบาลที่เกิดขึ้นทั้งหมด

การเข้าร่วมการวิจัยครั้งนี้ ท่านจะได้รับค่าเดินทางมายังสถานที่ดำเนินการวิจัย 3 ครั้ง ครั้งละ 200 บาท รวมเป็นเงิน 600 บาท โดยจะตอบแทนเป็นครั้งๆไป และไม่มีค่าใช้จ่ายที่ท่านจะต้องรับผิดชอบ **หากท่านมีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของท่านเกิดขึ้นระหว่างการวิจัยขอให้ท่านกรุณาแจ้งผู้วิจัยโดยเร็วที่สุด และหากท่านมีข้อข้องใจที่จะสอบถามเกี่ยวข้องกับการวิจัยหรือเมื่อบาดเจ็บ/เจ็บป่วยจากการวิจัยสามารถติดต่อนางสาวกาญจนา เต่าทอง (ผู้วิจัย) ได้ที่หมายเลขโทรศัพท์ 084-0059112 (ตลอดเวลา) หรือ รศ.ดร. ไถ้ออน ชินธเนศกูล (อาจารย์ที่ปรึกษาวิทยานิพนธ์) ได้ที่หมายเลขโทรศัพท์ 089-0709804 ได้ตลอดเวลา**

หากมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ทราบโดยรวดเร็วไม่ปิดบัง

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

ท่านมีสิทธิ์ถอนตัวออกจากโครงการวิจัยเมื่อใดก็ได้ โดยไม่ต้องแจ้งให้ทราบล่วงหน้า และการไม่เข้าร่วมการวิจัยหรือถอนตัวออกจากโครงการวิจัยนี้จะไม่มีผลกระทบใดๆต่อท่าน

โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนของมหาวิทยาลัยมหิดล ซึ่งมีสำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑล สาย 4 ตำบลศาลายาอำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5 โทรสาร 02-849-6223 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อกับประธานคณะกรรมการฯ หรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ข้าพเจ้าได้อ่านรายละเอียดในเอกสารนี้ครบถ้วนแล้ว

ลงชื่อ...ผู้เข้าร่วมวิจัย

(..)

วันที่...

APPENDIX C

หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ

วันที่................ เดือน................... พ.ศ................

ข้าพเจ้า... อายุ............ปี อาศัยอยู่บ้านเลขที่.................................ถนน ....ตำบล................................อำเภอ.....................................จังหวัด............................ รหัสไปรษณีย์........................โทรศัพท์...

ขอแสดงเจตนายินยอมเข้าร่วมโครงการวิจัย เรื่องการใส่เสื้อชั้นในกีฬาอาจส่งผลต่อการทำงานของระบบไหลเวียนเลือดในผู้หญิงที่ออกกำลังกายสม่ำเสมอ

โดยข้าพเจ้าได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัยรายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัยและความเสี่ยงที่อาจจะเกิดขึ้นจากการเข้าร่วมการวิจัย รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าตอบแทนที่จะได้รับค่าใช้จ่ายที่ข้าพเจ้าจะต้องรับผิดชอบจ่ายเอง โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการวิจัยเป็นที่เรียบร้อยแล้ว โดยไม่มีสิ่งใดปิดบังซ่อนเร้น

ข้าพเจ้าจึงสมัครใจเข้าร่วมในโครงการวิจัยนี้ :

ข้าพเจ้าได้ทราบถึงสิทธิ์ที่ข้าพเจ้าจะได้รับข้อมูลเพิ่มเติมทั้งทางด้านประโยชน์และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรืองดเข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบต่อการเรียนการสอนและหน้าที่การงานของข้าพเจ้าต่อไปในอนาคต และยินยอมให้ผู้วิจัยใช้ข้อมูลส่วนตัวของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

หากมีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของข้าพเจ้าเกิดขึ้นระหว่างการวิจัยข้าพเจ้าจะแจ้งผู้วิจัยโดยเร็วที่สุด

หากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับข้าพเจ้าข้าพเจ้า จะสามารถติดต่อกับนางสาวกาญจนา เต่าทอง ได้ตลอดเวลา เบอร์โทร 08-4005-9112 หากข้าพเจ้าได้รับการปฏิบัติไม่ตรงตามที่ได้ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมการวิจัยในคนหรือผู้แทน ได้ที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน กองบริหารงานวิจัย สำนักงานอธิการบดีมหาวิทยาลัยมหิดล โทร. 02-849-6223-5 โทรสาร 02-849-6223

ข้าพเจ้าเข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนายินยอมนี้โดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อ..ผู้เข้าร่วมการวิจัย/ผู้แทนโดยชอบธรรม/ วันที่............................ ..

(...)

ลงชื่อ.......................................ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย/ วันที่............

(...)

ในกรณีผู้เข้าร่วมการวิจัยไม่สามารถอ่านหนังสือได้ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัย คือ............................... จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ.. พยาน/ วันที่........................ ....

(..)

APPENDIX D

แบบสอบถามข้อมูลสุขภาพและการออกกำลังกาย

คำชี้แจง:โปรดกรอกข้อมูลและตอบคำถามต่อไปนี้ตามความเป็นจริง ข้อมูลทั้งหมดในแบบสอบถามนี้จะถูกเก็บเป็นความลับและใช้ในงานวิจัยนี้เท่านั้น

1.น้ำหนัก...............................กิโลกรัม ส่วนสูง.............................เซนติเมตร

2.วัน เดือน ปีเกิด..อายุ.................ปี

3.สถานภาพการสมรส ❑ โสด ❑ สมรส ❑ หย่าร้างจำนวนบุตร.......คน

4.ขนาดเต้านม ❑ A ❑ B ❑ C ❑ D ❑ มากกว่า D

5.ท่านเคยใช้เสื้อชั้นในกีฬามาก่อนหรือไม่ ❑ ไม่เคย ❑ เคย ระบุยี่ห้อ......................

6.กรณีฉุกเฉินติดต่อ..เกี่ยวข้องเป็น..

เบอร์โทรศัพท์ติดต่อ...e-mail..

7.โรคประจำตัว ❑ ไม่มี ❑ มี ระบุ..ยาที่ใช้...

8.ประวัติการเจ็บป่วย

โรคหลอดเลือดและโรคหัวใจ	❑ ไม่มี ❑ มี ระบุ..........................
โรคความดันโลหิต	❑ ไม่มี ❑ มี ระบุ ❑ สูง ❑ ต่ำ
โรคเกี่ยวกับสมองและระบบประสาท	❑ ไม่มี ❑ มี ระบุ..........................
โรคเกี่ยวกับระบบทางเดินหายใจ	❑ ไม่มี ❑ มี ระบุ..........................
โรคลมชัก ลมบ้าหมู	❑ ไม่มี ❑ มี ระบุ..........................
ปัญหาที่เกี่ยวกับกระดูกและข้อ	❑ ไม่มี ❑ มี ระบุ..........................
ต่อมไร้ท่อ	❑ ไม่มี ❑ มี ระบุ..........................
โรคติดเชื้อหรือโรคติดต่อ	❑ ไม่มี ❑ มี ระบุ..........................
ปัญหาสุขภาพอื่นๆ	❑ ไม่มี ❑ มี ระบุ..........................
ประวัติการผ่าตัด	❑ ไม่มี ❑ มี ระบุ...................... .. ..(ตำแหน่ง,วันที่ผ่าตัด)

9.การมีประจำเดือนใน 1 ปีที่ผ่านมา......................ครั้ง/ปีระบุวันที่มาครั้งสุดท้าย................................

10.ประวัติการสูบบุหรี่ ❑ ไม่สูบบุหรี่ ❑ สูบเป็นครั้งคราว

❑ สูบเป็นประจำ ระบุ.....................มวน/วัน

11.การดื่มเครื่องดื่มแอลกอฮอล์ ❑ ไม่ดื่ม ❑ ดื่มเป็นครั้งคราว

❑ ดื่มเป็นประจำ ระบุ...........วัน/สัปดาห์

12.ประวัติการออกกำลังกายในระยะเวลา 3เดือนที่ผ่านมา

13.การออกกำลังกายหรือเล่นกีฬาใน 1 สัปดาห์

❑ ไม่ออกกำลังกายหรือเล่นกีฬาเลย

❑ 1-2 วัน/สัปดาห์

❑ 3-5 วัน/สัปดาห์

❑ 6-7 วัน/สัปดาห์

14.เวลาที่ใช้ในการออกกำลังกายหรือเล่นกีฬาใน 1 วัน

❑ น้อยกว่า30 นาที/วัน

❑ 30-60 นาที/วัน

❑ มากกว่า60 นาที/วัน

15.ประเภทของการออกกำลังกายหรือชนิดกีฬาที่ท่านปฏิบัติ ระบุ.......................................

16.คุณเคยบาดเจ็บจากการออกกำลังกายหรือการเล่นกีฬาหรือไม่

❑ ไม่เคย ❑ เคย ระบุ...

BIOGRAPHY

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