CHAPTER 5

DISCUSSION

5.1 Flexibility

This study provides remarkable insights into the potential benefits of Pilates-based exercise on flexibility. This study aimed to assess and compare whether participating in the Pilates exercise 45 minutes, 2 times per week, for the duration of 8 weeks-training improved flexibility between Pilates training and control groups in 40 healthy individuals.

In the Pilates training group, the flexibility as determined by sit-and-reach test significantly improved by 4.08 cm from baseline when comparison to the data at a completion of 4 week-training session. The trend of improvement also increased continually to 7.2 cm at the end of Pilates training program (8 weeks). The flexibility data were also interpreted relative to the standard norms of fitness categories by age and gender group for trunk forward flexion using a sit-and-reach box (cm) (56). Owning to the standard norms of flexibility (cm) is presented into male/female separately, thereby, this analysis indicated that the flexibility improved from fair level at baseline (o week) to excellent level after 8-week of training in the female Pilates

group. As well as male, the flexibility was changes from fair level at baseline to very good level at 8 weeks of follow-up in the Pilates condition.

In contrast to the control group, there was no statistically significant difference in flexibility from baseline to 4 weeks and 8 weeks of trial follow-up in control group. It seems extremely clear that the flexibility in control group remains unchanged from the baseline throughout 8 weeks of trials.

In comparison between groups, the Pilates-based exercise group significantly demonstrated greater improvement of flexibility than that of the control condition for both 4 and 8 weeks of trial durations.

The Pilates-based exercise prescription in this study was successful to enhance flexibility component in agreement with flexibility exercise prescription by (56). The dosage of exercise which is recommended by ACSM's as following; precede stretching with a warm-up, do a static stretching, perform a minimum of 2 times per week, stretch to the end of the range of motion at a point of tightness without inducing discomfort, hold each stretch at least 15 seconds and perform 2-4 repetitions for each stretch. Pilates-based movements as performed in this study project are a slow, controlled manner with a gradual progression to greater ranges and also compatible with ACSM's guideline, therefore it may be potential to promote flexibility as outcome in this study.

It has been highlighted that flexibility or stretching exercise can provide a systematic elongation of musculotendinous units to create a persistent length of the muscle and also decrease in passive tension (59). The positions of Pilates practice in this thesis study promoting flexibility involved in the “Spine stretch” in finger to floor position, “Roll up” in lying to long sitting position, “Spine stretch” in sitting position, “Spine stretch forward”, and “the Saw” in initial period 4-8 weeks of training. As well as in the advanced period (4^{th}-8^{th} month), the positions of Pilates practice composed of “Back stretch with push-up”, “Spine curls”, “Single leg stretch”, “Double leg stretch”, “Spine stretch forward”, “Spine twists”, and “Spine stretch” in finger-to-floor position. Those modified Pilastes positions may effectively develop flexibility of the trunk and legs muscles in this thesis study. Moreover, the Pilates-based exercise is a combination of dynamic and static stretching method (55, 60). The static stretching involves a slow stretching maneuver of muscle into the end range of motion (point of tightness without discomfort) and then holding that position for an extended period of time with a combination of control breathing pattern. The risk of injury is low due to the gentle way of movement. As a dynamic stretching type, Pilates-based method also uses the gentle momentum created by repetitive slow bouncing movements to produce stretch at the end of resistance without discomfort.

For example, “The Spine Stretch Forward position” in week 1-4 of period training was instructed to the subjects as following step (55).

1. Straight legs in front of you with the straight back (dynamic stretch type)
2. Breath out slowly and dropping the chin down, and then slowly roll the spine forward with slide the hands along the outer thighs (dynamic stretch type).
3. At the depth of the stretch and the out breath, really pull your navel in and try and squeeze your buttock (static stretch type because of still holding leg and back in the same stretch position).
4. Breath in and out, holding the legs stretch, keep navel to spine, feel the upper back stretch with the breath (static stretch type).

All of this practice is step by step and takes approximately 15 seconds in the stretching pattern with 5 repetitions. As recommended by ACSM’s that the greatest change in flexibility has been shown in the first 15 seconds of stretch without significant improvement after 30 seconds (56, 61-62). Nevertheless, little theoretical evidence supporting the proper number of repetition and duration required in order to achieve the flexibility benefits. Several authors and practitioners have experienced with the appropriate length of time that a stretch should be maintained, in order for being effective (63). In accordance with Borms et al., the result demonstrated significant improvements in hip flexibility when subjects performed 10, 20 or 30

seconds static stretches 2 times per week, for a period of 10 weeks (64). A significant increase in flexibility was also presented by the study of Roberts and Wilson, the static stretches were performed 3 repetitions for 15 seconds, or 9 repetitions for 5 seconds during a 5 weeks training (65). Another research found the proper number of stretch exercise in improving flexibility per muscle groups is 2-4 repetitions, and reported of no significant further improvement in muscle elongation presenting in repeated stretching of 5 to 10 repetitions (66). The research by Bandy and Irion (1998) also compared dynamic range of motion and static stretching exercise. The first group performed dynamic stretch of hamstring muscles for 5 seconds duration, 5 days per week, 6 weeks of trial; and the second group practiced 30-second static stretch, 5 days a week, 6 weeks of trial; and the third group served as control condition. The authors found that both static and dynamic stretches are useful to increase flexibility of involving muscle (67).

The present study demonstrates that Pilates-based method can be used as a specific exercise training to promote flexibility and for quality of performance. Increasing in flexibility will promote better performances during various movements. For instance, Wilson et al. who determined the stiffness of the upper limbs after flexibility training which demonstrated the rebound bench press performance causing by a reduction in stiffness of muscle-tendon units, increasing the utilization of elastic

strain energy during the rebound bench press lift (68). The other researches in Pilates relative to flexibility are as following, (9) assessed the effects of Pilates training on flexibility in 32 subjects of community athletic club participating 1-hour session Pilates mat class during 6-month period. It has been shown that Pilates training resulted in improving flexibility. Kish also examined the effects of Pilates conditioning upon functional adductor and hip flexor flexibility in 17 college dances, taking place 3 days per week, 75 minutes duration in Pilates based conditioning and regular dance activities throughout the 4-week trial period (29). In comparison with control group, the Pilates method significantly improved functional flexibility of the adductors and hip flexors.

Notwithstanding available evidences flavouring in benefits of Pilate exercise on flexibility, the study by Wimer demonstrated unclear effects of Pilates training on flexibility. Pilates-based exercise was studied comparing to resistance plus flexibility exercise and control conditions in 24 elderly individuals (65-81 years) for 10 weeks. An important observation after 10 weeks of training found no changes in flexibility in both group conditions (11). The unchanged in flexibility after10 week of training in all conditions may be due to the factor of aging. Aging results in a gradual loss of muscle function, flexibility as well as degeneration of soft tissues properties. Change in flexibility with aging may also be confounded by decreasing activity that

accompanies aging. Therefore, the volume of exercise (i.e., intensity, frequency, duration) in this research may be inadequate to cause change in flexibility**.**

Since previous studies are supported the benefits of Pilates method as specific flexibility training, physiological response to flexibility training requires to be explained. Shrier and Gossal examined the immediate effects of stretching increased range of motion owning to either a decrease in viscoelasticity or an increase in stretch tolerance (69). According to the study by Kubo et al., it was found that the static stretching training affected the viscoelastic of tendon structures but not the elasticity (70). The limitation of composite flexibility is primarily influenced by soft tissues constraints. It has been shown that the soft tissue structures provide the opposition to flexibility with 47% from joint capsule, 41% coming from muscles, 10% from tendons, and 2% from skin. (71). As explained that mechanical characteristics of contractile (e.g., muscles) and noncontractile (e.g., joint capsule, muscle tendons, and skin) tissues as well as the neurophysiologic properties of contractile tissue all affect soft tissue lengthening. Focus on the mechanical response of the contractile unit to stretching exercise when a muscle is stretched initial lengthening occurs in the series elastic component and tension rises sharply. After a point there is a mechanical disruption of cross-bridges as the filaments slide apart resulting in an abrupt lengthening of the sarcomeres (72). Besides, the neurophysiologic change is

responsible by Golgi tendon organ. The Golgi tendon organs, which are encapsulated sensory receptors located in the tendon of muscle (73). These sensory receptors detect differences in the tension generated by either passive stretch or active muscle contraction. (74). When a slow stretch force is applied to muscle, the Golgi tendon organ fires and inhibits the tension in the muscle, permitting the sarcomere of muscle to lengthen (72).

Next, turn to the changes of mechanical characteristics of noncontractile tissues when applied stretching exercise which can be explained with the stress-train curve (72). The material property of each soft tissue is associated with its ability to resist stress or load. When tension stress or a stretching force is applied perpendicular to the cross-sectional area of the tissue in a directional way from the tissue. Initially, the wave collagen fibers are straighten. With additional tension stress, recoverable deformation occurs in the elastic range. Since the elastic limits is reached, resulting in releasing of heat (hysteresis) and new length when the stress is released. Additionally, the principle of creep which occurs with low-magnitude load applied for a long period of time will increase the plastic deformation of noncontractile tissue, usually in the elastic range, allowing a gradual rearrangement of collagen fibers and group substance. Increasing the temperature of the soft tissues will increase the creep. Further the specific of Pilates based exercise as the low load stress tension for a

period of time, the stretching positions was applied after warm-up to raise the muscles temperature improving the creep effect result in lengthen soft tissues (72, 75). Another explain for these changes, both contractile and noncontractile have viscoelastic properties, that is elasticity indicates that length chances are directly proportional to applied force, and viscous properties shows that the rate of muscle deformation. The viscoelasticity property permits a gradual reduction of tension or force within the muscle at a given length (56).

A lack of flexibility on the muscles of the thigh, hamstring muscle and gluteal muscles is primarily related to a high incidence of low back pain also demonstrated relationship between tightness of hamstring muscles and low back pain (76). Additionally, the greater lumbar and hamstring muscles flexibility was presented in men with healthy lower backs than in men with low back pain (77). Therefore, improving flexibility of low back and leg may prevent and alleviate back pain

5.2 Lumbo-pelvic movement control

In current study, we hypothesized the paramount benefits of Pilates on stabilization of the core body “whether Pilates-based conditioning significantly improved the lumbo-pelvic movement control better than the control group”. The

core body or the powerhouse in Pilates concept, has been defined as the enclosure with the abdominals in the front (e.g., transverses abdominis), paraspinals (e.g., mulitifidus) and gluteus muscles in the back, the diaphragm as a roof, and the pelvic floor and hip girdle musculature as a bottom (47). The stability of the core or powerhouse is contributed with active, neural control and passive subsystems (78). The active system plays an important role in movement and control stability of the spine. The local muscles (79) deeply into the trunk serve as the muscular corset. Theoretical evidences demonstrate the incorporation of diaphragm, transversus abdominis, multifidus, and pelvic floor muscles as a unit contributing to lumbo-pelvic inter-segmental stability (80-84). Similar to the concept of Pilates exercise, the combination of breathing pattern increases the respiratory demand and activates the diaphragm muscle, control the powerhouse or core body enhancing the local muscles (transversus abdominis), as well as the pelvic floor muscles to contract in the same time of abdominal muscle activation and diaphragm contraction as mentioned earlier.

Pilates mat exercise was modified in this study, 20 healthy subjects participated in the Pilates class under supervision for 8 weeks of trail. The lumbo-pelvic movement control was determined using PBU to assess passing or failing which indicated the better lumbo-pelvic stability at baseline (0 week), 4, and 8 weeks of training period. Pressure biofeedback unit was used to assess the ability of the

abdominal muscles (e.g., transversus abdominis) to stabilize the lumbar spine during the application of external loads to the lower limbs. Twenty subjects serves as control performing regular daily activities during the period of study. At baseline, there were no subjects passing the lumbo pelvic movement control in both Pilates and control groups. Surprisingly, asymptomatic individuals presented inability of transversus abdominis to control the lumbo-pelvic stability. Lack of trasverses abdominis activation for maintaining L-P stability in normal subjects was also reported similarly in the study of Harringtion (12). In this thesis study at the 4 weeks after training, 65 percent of subjects passed lumbo-pelvic test in Pilates training group but all subjects in control group still failed to control the lumbo-pelvic movement control. The amount of subjects passing the lumbo-pelvic movement control increased into 85 percent after 8 weeks of training. However, the percent change of passing the lumbo-pelvic test after 8 weeks of training was not significantly different from 4 weeks of training. It can be implied that the Pilates training on lumbo-pelvic movement stability significantly occurred since 4 weeks after training and this effect was sustain. Besides, there were no any subjects passing the lumbo-pelvic test in control group at any stages of follow-up. The results significantly indicated that the individual taking place in Pilates exercise program for 45 minutes, twice a week, for 8 weeks duration performed better lumbo-pelvic stability. The study of the influence of

Pilates training on the ability to contract the transversus abdominis in asymptomatic subjects also presented the similar results. Individual performing Pilates exercise appears to have a better stability of lumbo-pelvic movement control when comparing to the control and the regular abdominal exercise groups (12).

The significant improvement of lumbo-pelvic stability in Pilates groups can be explained with the physiological responses, motor relearning and control, and the specific properties of local muscles itself to stabilize the spine. Regarding the physiological response to 45 minutes, 2 times per week, for 8 weeks of Pilates exercise prescription in this study, the program is specific to promote strength, endurance, and neuromuscular control especially for the local muscles (56, 74, 85). The local muscle largely consists of type I skeletal muscle types (47). Type I fibers refers to the slow-twist, fatigue-resistant fibers that derive most of their energy from aerobic source of ATP. The type I fiber also contain plentiful mitochondria, high amount of oxidative enzymes, and a high density of capillaries to achieve a sufficient supply of oxygen and nutrients from blood. These characteristics make them well-adapted for endurance activities over 30 minutes duration such as 45 minutes Pilates-based exercise applying in this trial. The distribution of fiber types can vary in the same muscle among different individuals. In addition, the distribution of muscle fiber type depends on genetics, specific and chronic types of physical activities, thus these

characteristics affect directly of individual exercise performance (73, 74, 86). In women, the mean size of the type I fiber is larger than men, so that a significantly larger area of the muscle is filled with type I fibers (86). It may be related to this study, indicating high percentage of passing lumbo-pelvic movement control in female than male at 4 and 8 weeks of training. Interestingly, the muscle fibers of human skeletal muscles are heterogeneous in their function and structure properties. This heterogeneity covers all possible aspects of muscle contractile function and is directed in optimizing the contractile responses and in performing different motor tasks minimizing fatigue (87). Muscle belly consists of the small unit of muscle fibers and have difference in the proportion of muscle fiber type up to their functions, physical activity, performance, and genetic. The motor units that supply each muscle fiber type will make those muscle fibers have property dependent on motor units. In detail, all of the muscle fibers within a motor unit contains either slow-twist or fast-twist not the mixed of muscle fiber types. There are two categories of alpha motor neurons that innervate skeletal muscle $\propto_1$ and $\propto_2$, motor neurons. The $\propto_2$ motor neuron is a smaller nerve fiber innervating type I fibers motor units. Due to the fact that the $\propto_2$ is a smaller motor neuron, it has a lower excitation threshold than the $\propto_1$ which innervates type IIa and IIa fiber motor units. The difference in nerve size can explain that why slow-twist or type I motor units are preferable activated at low

intensities exercise. As mentioned earlier, it can imply that transversus abdominis as the slow muscle fiber type is sensitive to the Pilates exercise prescription in this study due to low to moderate intensity of the Pilates concept itself. Additionally, slow fibers appear particularly suited for isometric and tonic contraction developing with highest efficiency at low velocity and intensity; and these muscle fibers particularly conform to postural control. For this regard, electromyographic determination of muscle usage in vivo during everyday activity suggests that it is closely related to the percentage of type I fibers of muscle (87). Thus, transverses abdominis as a tonic muscle being activated in feedforward maner to stabilize the lumbar spine during daily activities would be more easily to be activated with low intensity exercise like Pilates maneuver.

Nevertheless, the skeletal muscle adaptation to training should be considered. The increase in size or cross-sectional area, of muscle fibers is termed hypertrophy. In endurance trained individual, the size of the type I fiber can be larger than type IIa and type IIb fibers. These effects results from an increased mitochondrial and membranous mass and muscles filaments within the fibers. Muscle strength is proportional to the cross-sectional area of skeletal muscle. Thereby, training that increase muscle mass will increase muscle strength. Muscle strength also depends on neural components of motor unit recruitment. During initial weeks of

strength training program, muscular strength increases without change of muscle size, thus it results from alternations in number of motor unit recruitment and the stimulation of these motor units in the same time or more synchronous (88)

Apart from physiological response, the specific way of local muscles contributes to lumbar stability is also important. The local or deep intrinsic lumbo-pelvic muscle includes transversus abdominis which is a broad sheet-like muscle with extensive attachments to the lumbar vertebrae via the thoracolumbar fascia, and to the pelvis and rib cage. The muscle fibers have a relatively horizontal orientation contributing to spinal control by involving modulation of intra-abdominal pressure and tensioning the thoracolumbar fascia. Additional data confirm that spinal stability is increased by intra-abdominal pressure (IAP) (80, 89-90). The Pilates based approach focus on the way of transversus abdominis muscle function, consequently, improves the stability of the lumbar and pelvis. Thus, it is supported with that intersegmental muscle forces as low as 1-3% maximal voluntary contraction may be sufficient to ensure segmental stability (91). Importantly, the Pilates exercise focus on powerhouse control providing co-contraction of local system muscles such as transversus abdominis, lumbar multifidus and diaphragm as a result of a stabilizing effect on the motion segments of the lumbar spine within the neutral zone (5, 92-93)

The stability of control the lumbo-pelvic function is dependent not only the muscle but also on the central nervous system which must determine the requirements of stability to plan and implement strategies that meet the demand (94). In the Pilates method, the CNS can predict that the control of the spine will be challenged by an internal and external forces (e.g., as a result of the reactive forces from a moving upper and lower limb in each position of Pilates exercise), it has to plan the strategies of muscle activity (local muscles) in advance of the limbs movement to prepare the lumbo-pelvic stability (feedforward control). Thus, precise control of the lumbar spine and pelvis is rely on the capacity of muscle and sensory system that provides information about the status of stability, recognition of perturbation (limb movement), and the development of the internal model of body dynamics that provides the ability of central nervous system to predict the interaction between body segments and the environment. Moreover, accurate control is also dependent on the capacity of the motor system to plan the proper strategy to meet the demand of stability. Many theoretical evidences support this feedforeward concept of these local muscles.

The specific Pilates exercise as in this thesis study can be explained in the simplest form and fit well with the process of motor learning described by Fitts and

Posner who reported three stage of motor learning a new motor skill as following (95);

1. The cognitive stage of learning, the beginner plays attention on cognitively oriented problem. Subjects need high level of awareness in order to isolate the contraction of transversus abdominis from superficial abdominal muscles at low level or simple level of Pilates training. This position focuses on hollowing action with breathing pattern control to make subjects could contract the muscle in the simple movement of the limb during exhalation or breathing pattern control to enhance the co-contraction of transversus abdominis, diaphragm, multifidus, and pelvic floor muscles. The verbal cues were given to correct the core control and limbs movement in every stage of movement in all positions of Pilates practice throughout 45 minutes of training. The palpation for checking the isolated contraction of transversus abdominis was also a one of feedback to make sure that subjects learned to correctly control the core. Performance in this stage is marked by a large number of errors and the errors are also highly variable showing a lack of consistency from one attempt to next. Thereby, subjects still needed to practice follow the instructor step by step for the control of the core. When a desired movement was challenged by a reduction in base of support (decrease proprioception) and increased load by change the lever arm movement, for example, change from basic one hundred (both knee flexion) to

advanced one hundred (both legs raise) and the trunk lift from the floor. This challenged resulted in difficulty of core control as well as the degree of efficiency and range of motion often suffered. The subjects also over recruited superficial abdominal muscle to stabilize the core. Cognitive learning must take place first with the internal and external feedback.

2. The associative of learning stage

The subject learned to associate some environmental cues with the movements, subjects made fewer errors and could control the core by isolating the transversus abdominis consistency when the movement challenge was given. Subjects could detect their own errors on poor control of the core body when changed from the position of Pilates to the difficult one. Subjects also kept their good alignment with less verbal feedback. One association take place the new movement sequence may become automatic.

3. Autonomous of stage of learning; regarding the duration of training, 8 weeks of training might not provide enough automatic learning. If the practice keeps going until one year, the new movement sequence may become automatic. It is this automatic execution of new movement that reduces the risk of re-injury and increases efficiency.

Pilates can be identified as stabilizing exercise technique to improve the core stability. Similar in developing of active and control subsystems to encourage inter-segmental and core control of the lumbo-pelvic region, the Pilates has different strategies from stabilizing exercise to enhance core control and stability as following:

1. Pilates enhances both local and global muscles of the core body (i.e., transversus abdominis, multifidus, abdominal internal oblique, abdominal external oblique) up to the progression of positions. Whereas stabilizing exercise focuses on specific local muscles (i.e., transversus abdominis, multifidus).
2. The Pilates approach is similar to daily activities and has different level of progression including base of support modification and specific sport-related training.
3. There are many and various positions of Pilates practice which can be modified to suit for individual ability, and also the pattern of limb movement is flowing from one position to other position harmoniously.

5.3 Psychological stress

The current study also evaluated the effect of Pilates-based method on psychological stress. The level of psychological stress was determined by the Stress Inventory questionnaire. It demonstrated that the stress level significantly decreased

after 8-week of training when compared to baseline (0-week) of trail within the Pilates group. In contrast, the stress level was not significantly different through duration of the study in control group. However, when comparison between groups, the changes in stress level in Pilates training group at 8-week follow-up was not significantly different from control group. It may be due to the fact that the effect size in psychological stress level is quite low. Nevertheless, the result appears to demonstrate that Pilates-based approach gradually showed the trend of improvement in psychological outcome

The inclination of decrease in stress level in this study supports the benefits of Pilates-based method on psychological benefit. This finding seems to be in agreement with several previous studies. Relevant articles linking physical exercise and fitness to influence psychological stress, mood, anxiety, and depression. Most available data are accounted for the generalization that physical exercise is a positive experience when performed at the mild to moderate intensity such as relaxation and flexibility training. In accordance with these suggestions, Pilates-based exercise as a low to moderate dosage showed the positive effect on psychological stress improvement. The study by Sunsern et al. also supported this finding (16). The author examined the effects of 45 minutes, 12-week biweekly aerobic exercise program on psychological stress in Thai postmenopausal women. The result was dramatic reduction in stress after participating in 12-week of exercise program. In this thesis study, a significant reduction in stress level was reached earlier (i.e., 8 weeks) after participation in Pilates exercise. It may be the fact that the Pilates approach is a combination of mind, body, and spiritual which focuses on meditation with concentration on core control during flowing movement of the whole body parts

contributing to decrease mental stress. So it made the individuals in Pilates group reached the chances in stress level quickly as only 8-weeks of practice.

Others researches also focus on the effects of aerobic exercise on psychological stress response. Gillis and Perry found that participating in 12-week exercise program reduced stress significantly. The results of this cross-sectional study suggests that individuals who exercised at least 2-3 times per week experienced significantly less stress than those exercising less frequently or not al all (96). Additionally, Hassmen et al. found that regular exercise at least 2 times a week perceived their physical fitness and sense of coherence and a strong feeling of social integration than their less exercise frequency (97). Similar in frequency of exercise per week in the present study, the Pilates enhanced the reduction of stress level. However, the stress level change was not reached the significant level when compared to the control group. It may result from the difference in training duration, this thesis study is only 8 weeks but the training duration of exercise in Hassmen's study was longer (i.e., more than 1 year) or defined as regular exercise. Therefore, effects of 8-week duration exercise may not clearly show the difference between exercise and control groups. In addition, longitudinal studies on physical exercise demonstrated a both physical and mental health as a result of physiological adaptations. Generalization from this explanation, the psychological stress response is not only affected from exercise but may also depend intimately on social and other environmental cues and on participation's expectations (98). In these issues, the confounding factors could not be controlled in the present study.

According to the result of this current study, more theoretical evidences presented the similar results even though the exercise program was different in

frequency and duration of training. Norris et al. postulated the effects of 45 minutes, 3 times per week, for 10-week aerobic exercise training on psychological stress and well-being. Subjects undergoing aerobic training showed the larger changes on self-report measures of stress and well-being (99). Again, Norris determined the effects of physical activity on psychological well-being in an adolescent population. Adolescents who experienced a higher incidence of life events also demonstrated a strong association between stress and anxiety/depression. The higher moderate intensity of exercise was assigned twice a week for 20-30 minutes in 10 weeks compared with low intensity and control groups. Data analysis revealed that individuals who performed high intensity of aerobic exercise significantly reported less stress than subjects undergoing low intensity exercise or control groups (100). Interestingly, the relationship between stress and anxiety/depression/hostility for the high intensity group was extremely weakened at the end of training. Comparing to the Pilates exercise, the psychological stress tended to positively response to low to moderate intensity of exercise whereas the study by Norris significantly improved stress from high aerobic intensity. The different sample groups may influence on the response of psychological stress to vary exercise intensities.

The decline of stress level related to physical fitness improvement, there is available data demonstrated about these issues. In a meta-analysis by Crews and Landers, it was indicated that aerobically fit subjects frequently showed a decrease in psychological stress level compared to less fit subjects (101). In consistent with the study of aerobic fitness and the response to psychological stress and aerobic fitness level, an aerobic program exercise consisted with 3-4 times per week in 1 hour session for a 10-week period indicated fitness improvement. So that the improvement

of aerobic fitness tended to correlate with psychological stress. DiLorenzo et al. also conducted the long-term effects of aerobic exercise on psychological outcome. A sample of 111 healthy adults participated in 20 minutes, 3 times per week, for 12-week of study. Exercised-induced increasing in aerobic fitness have beneficial short-term and long term effects on psychological outcomes (i.e., stress level, depression, anxiety, mood, and positive self-concept) after 12 weeks of training (102). These results are in agreement with previous studies as mentioned. Most studies were aerobic exercise training with moderate to high intensity and the duration of training longer than 8-week comparing to this current thesis study. Therefore, the low to moderate intensity of Pilates approach itself including the shorter duration of training may influence on the response of stress in Pilates group that it was not significantly showed the different changes from the stress level of control group. Another explanation for this is that the mean stress scores in both Pilates and control groups were in the normal range. Within normal stress level, people are satisfied with live, properly modify themselves to environments, and cope with stress in the right way naturally. They are also stay in social and successful in works. Thus, the stress level might change not much from normal range. It is interesting to study in the subjects with high level of stress as well that may show the dramatic result.

It has been highlighted that an important in physical fitness has a close relationship with and improvement in psychological outcome. The data revealed that Pilates-based method significantly demonstrated improvement of physical fitness (i.e., lumbo-pelvic stability and flexibility components). Therefore, psychological stress may improved as a consequence of physical fitness gain. Improvement in lumbo-pelvic stability and flexibility components may make the individuals feel confident to

do activities effectively in daily life. With individual's expectation to have more quality of life after Pilates training may indirectly decrease stress level. The studies of Byrne et al. postulated obtaining fitness after exercise reported concurrent improvement in psychological outcomes. The psychological advantages attributed to physical activity include enhanced mental performance and concentration, improved self image and feelings of confidence and the perception of mastery, greater sleep quality and a reduction in perceived of anger, time urgency, and time pressure (15). Brown also reported the quality of life or life satisfaction, self-esteem, cognitive functioning, personality, and mood including positive affects such as happiness, vigor and morale as results of exercise training (103). The sense of coherence also can be a possible effect of exercise that improves mental stress. Individuals with sense of coherence consider life in general to be comprehensible, manageable, and meaningful. People with a strong sense of coherence are thought to be able to manage the stresses of life better and maintain their health. On the other hand, persons with a weak sense of coherence tend to be more vulnerable to damage their mental health (104).

In the Pilates exercise in this study was performed in group (3-6 persons per class). Grouping exercise provides social interaction; some had agreed to keep doing exercises together. Participating in exercise also generates distraction from the hassles and worries of daily life reducing the available time for dysfunction of ideation.

Increased fitness may directly affect on neurochemicals in the brain such as serotonie function to elevate mood. Stress-adaptation as a result of exercise affects adaptation of adrenal gland. The physiological adaptations that underline behavioral adaptation to psychological stress are to be found in the central nervous system (105).

Turn to more details of neuroendocrine changes, changes in catecholamines epinephrine and norepinephrine are involved in the maintainace of blood pressure. Epinephrine and norepinephrine also responds to emotional stimuli, and they form the basis for Cannon's "fight or fight" hypothesis of how the body responds to challenges environments (106). Cannon's concept explains the activation of sympatatic nervous system prepare you to confront a dangerous situation or escape from it. Epinephrine and norepinephrine bind to ∝ and beta-endrenergic receptors and cause changes in cellular activities such as increased heart rate. The low blood pressure and too much emotional stress bring about changes of epinephrine and norepinephrine level as well as exercise activity stimulate epinephrine and norepinephrine secretion. Linking to endorphins, endogenous morephine-like substances interacts with opiate receptors in the brain involving pain area. Beta-endorphin is formed in the anterior pituitary, and would respond to exercise stress. High intensity endurance exercise influences elevated plasma beta-endorphin level may be related to change in mood and pain threshold (85, 107).

Other possible factor is that a lower resting plasma beta-endorphin may be an adaptation to exercise training and was related to greater emotional stability and lower depression. The lower resting beta-endorphin in the jogging group may be related to lower perceived stress as effect of exercise, relative to sedentary group (108).

The last possible explanation of effects of exercise on psychological stress is about noradrenergic system that serves as antidepressant effects and opioid activation involving mood improvement. In general, stressors activate brain norepinephrine system and acutely deplete brain level of norepinephrine. When performing exercise,

the long-term exercise training will increase brain norepinephrine levels to serve as antidepressant (109). The opioid mechanisms in effects of exercise, stress also stimulates either central or peripheral opioid systems. Spontaneous exercise involves increasing endogeneous opioid activity in the peripheral and central nervous systems. The release of opioid is indirectly important to psychological chances. Opioid mechanisms have also been implicated in mood. In animal study, the repeated activation of endogenous opioid system by exercise training leads to tolerance and withdrawal phenomina. The important function of opioid responses arises from their inhibitory control of stress responses. Opioid antagonists increase cardiovascular stress responses to both physical and psychological challenges (110), increase the intrinsically smaller stress reactivity in certain individuals, and revere the effect of relaxation training to reduce blood pressure response to psychological stress (111, 112).

In the central nervous system, catecholaminergic stress responses are under opioid inhibition. Importantly, opioid mechanisms affects from exercise, so that the plasma beta-endorphin response to exercise increase with training. And also, the possible opioid inhabitation accounts for the reduction in cardiovascular stress after exercise training contributing to decreased in psychological stress. In the simple view, the regular exercise recruits opioid activation and attributes effects of exercise to a release of endorphin. The interaction of increased opioid activation by exercise training with the opioid tolerance that develops through training. Scientific evidences are in agreement with adaptive changes in opioid systems link regular exercise to reduced stress responses, especially controlling by noradrenergic systems (38).

Attention on intensity of exercise and opioid mechanisms, the moderately high intensity exercise activate the release of the opioid peptide beta-endorphin to the circulation, moreover, endorphin levels probably remain elevated for 15-60 minutes following exercise. However, low or moderate (less than 75%VO_2max) intensity may not stimulate this response. This regard can explain why psychological stress changes insignificantly in the Pilates groups comparing to control group.

Additional interpretation for the insignificant differences of psychological stress between groups, the Stress Inventory questionnaire with 70.4 sensitivity and 64.6 specificity may not be sensitive enough to detect the changes of stress level in asymptomatic individuals. Another issue is the ambiguous of the questions, for instance, the question about “decrease in sexual enjoyment”. Most participants were not sure to answer this question but they have to make it completed without clarify truly. Many single participants also complained without experience or concerning in this question. To detect accuracy stress level, the assessment should apply stress questionnaire with laboratory test including urine sample for catecholamine, blood pressure and heart rate (113).

5.4 Conclusion

The results of this thesis study indicate the specific of Pilates-based exercise as a low to moderate intensity, 45 minutes per session, with frequency of twice per week, and 8 weeks of duration contributing to physiological and psychological benefits. The major findings of this thesis study are summarized as followings:

1) The Pilates exercise significantly improves flexibility after 4-week training and continues increasing after 8-week of training.

2) The specific volume of Pilates exercise in this thesis study significantly enhance lumbo-pelvic movement control and stability that occurs following 4 weeks of training and continues to 8 weeks of training.
3) The Pilates exercise also significantly decreased the psychological stress level in Pilates training group following 8-week of training.

5.5 Study limitations

1) The lumbo-pelvic movement control was assessed with PBU after one day following 4 and 8 weeks of training. The passing of lumbo-pelvic movement control may indicate the physiological adaptation but motor learning effects must be considered. To assess the motor learning effects or the persistence characteristic of improved performance (lumbo-pelvic stability), the test should be measured again after 2-3 week of training (95) to confirm the learning effects.
2) The evaluation of psychological stress level with Inventory Stress questionnaire in this thesis study significantly showed improvement of psychological outcome following 8 weeks of training in Pilates group but the change was not significantly different from control condition. This may be due to both inadequate sensitivity and specificity of questionnaire for the healthy subjects as in this study project and unable to control the social environment that also affects mental situation. Thereby, the accuracy psychological outcomes should be determined with both subjective (i.e., questionnaire) and objective (i.e.,

urine sample test for catecholamine and cortisol level, heart rate variability, and blood pressure) assessments.

5.6 Suggestions

1. The Pilates program in this thesis study focused on enhancement of transversus abdominis, pelivic floor, and diaphragm muscles. As mentioned previously, the co-contraction of transversus abdominis, diaphragm, pelvic floor, and lumbar multifidus muscles plays an important role to stabilize lumbo-pelvic region. Thereby, the Pilates program should be modified to enhance both agonist (abdominal muscles) and antagonist (back muscles) to work corporately to improve stability. It is interesting to add more Pilates positions into this thesis program to promote the back extensor activity such as “the Swan dive”, “Prone press up”, “Triceps push up”, and “Quadruped” positions.

2. The Pilates practice in this study program has some positions of exercise similar to the lumbo-pelvic movement control test for example “Single leg fold”, as well as “Back bending forward” which are similar to the sit-and-reach test. To clearly evaluate the benefit of Pilates on physiological outcomes, therefore the Pilates programs which are similar to the outcome measure should be removed.

3. Regarding to lumbo-pelvic stability test, in this thesis study follows the method of Harrington et al. (2005) which used the starting position of hip flexion 70 degrees to set the neutral position of position of lumbar lordosis for all participants however this method may be not directly measure the actual neutral position for individual person. The possible measurement of individual’s lumbar neutral position would be considered in the future study.