EFFECTS OF LUMBAR STABILIZATION EXERCISES ON EXERCISE LEVEL ATTAINED IN HEALTHY SUBJECTS

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EFFECTS OF LUMBAR STABILIZATION EXERCISES ON EXERCISE LEVEL ATTAINED IN HEALTHY SUBJECTS

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ABSTRACT

The aim of this study was to investigate the effect of lumbar stabilization exercises on exercise level attained in healthy subjects. Thirty subjects with age ranging from eighteen to twenty five years participated in the study. They were divided into two groups: control group and exercise group. Both groups were similar in age, weight, height, and body mass index. Subjects in the exercise group performed a lumbar stabilization exercise program three times per week for four weeks. A series of six exercises were attempted, which required increasing levels of muscular control of lumbar spine for stability.

The testing was performed at pretest, 1^{st}, 2^{nd}, 3^{rd} week, posttest (4^{th} week), 1^{st} and 2^{nd} week after completing the training program. In all tests, each subject was tested using a pressure transducer placed under the lumbar spine to detect the spinal motion. Each test was done twice - once without feedback given from the pressure transducer results and once with feedback. Subjects were assigned an exercise program based on the exercise level attained in the pretest with feedback. They received a pass or fail for each exercise level based on the pressure gauge readings and the absence of compensatory movement.

The results showed the posttest exercise level attained by the exercise group (median values: level 5 with and level 3 without feedback) was significantly higher than the pretest (median values: level 2 with and level 1 without feedback) whereas no significant difference was indicated in the control group. The exercise level attained with and without feedback of posttest in the exercise group (median values: level 5 with and level 3 without feedback) were significantly higher than those of posttest with and without feedback in the control group (median values: level 2 with and level 2 without feedback) while there was no significant difference in the pretest. Additionally, the exercise level attained with feedback was significantly higher than that without feedback in both groups.

In conclusion, the exercise program can enhance ability to perform progressive lumbar stabilization exercises with and without feedback.

KEY WORDS: LUMBAR STABILIZATION / STABILIZATION EXERCISE / PRESSURE TRANSDUCER / FEEDBACK

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ผลของการออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอวต่อระดับความยากของท่าออกกำลังกายในคนสุขภาพดี (EFFECTS OF LUMBAR STABILIZATION EXERCISES ON EXERCISE LEVEL ATTAINED IN HEALTHY SUBJECTS)

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บทคัดย่อ

การศึกษานี้มีจุดมุ่งหมายเพื่อศึกษาผลของการออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอวต่อระดับความยากของท่าออกกำลังกายในคนสุขภาพดี ผู้เข้าร่วมการศึกษาในครั้งนี้จำนวน 30 คน มีอายุระหว่าง 18-25 ปี ผู้เข้าร่วมการศึกษาถูกแบ่งเป็น 2 กลุ่มคือ กลุ่มควบคุมและกลุ่มออกกำลังกาย ทั้ง 2 กลุ่มมีอายุ, น้ำหนัก, ส่วนสูง, และดัชนีมวลกายที่ใกล้เคียงกัน กลุ่มออกกำลังกายจะได้รับโปรแกรมการออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอว 3 วันต่อสัปดาห์เป็นเวลา 4 สัปดาห์ ซึ่งประกอบไปด้วยท่าออกกำลังกายจำนวน 6 ระดับซึ่งเพิ่มระดับการทำงานของกล้ามเนื้อในการควบคุมให้เกิดความมั่นคงแก่ข้อต่อกระดูกสันหลังส่วนเอว

การทดสอบจะทำก่อนการฝึก, สัปดาห์ที่ 1, 2, 3, การทดสอบหลังการฝึก (สัปดาห์ที่ 4), สัปดาห์ที่ 1 และ 2 ภายหลังจากโปรแกรมการฝึกสิ้นสุดลง ในแต่ละการทดสอบทำสองครั้งคือ การทดสอบเมื่อไม่มีการป้อนกลับและการทดสอบเมื่อมีการป้อนกลับ โปรแกรมการออกกำลังกายที่ผู้เข้าร่วมการศึกษาได้รับจะขึ้นกับระดับความยากของท่าออกกำลังกายที่ทำได้ในการทดสอบก่อนการฝึกเมื่อมีการป้อนกลับ

ผลการศึกษาพบว่าในกลุ่มออกกำลังกาย ระดับความยากของท่าออกกำลังกายเมื่อมีและไม่มีการป้อนกลับในการทดสอบหลังการฝึก (ค่ามัธยฐาน: ระดับ 5 เมื่อมีการป้อนกลับและระดับ 3 เมื่อไม่มีการป้อนกลับ) เพิ่มขึ้นจากการทดสอบก่อนการฝึกเมื่อมีและไม่มีการป้อนกลับ (ค่ามัธยฐาน: ระดับ 2 เมื่อมีการป้อนกลับและระดับ 1 เมื่อไม่มีการป้อนกลับ) อย่างมีนัยสำคัญทางสถิติ ในขณะที่ไม่พบความแตกต่างในกลุ่มควบคุม ส่วนระดับความยากของท่าออกกำลังกายเมื่อมีและไม่มีการป้อนกลับในการทดสอบหลังการฝึกของกลุ่มออกกำลังกาย (ค่ามัธยฐาน: ระดับ 5 เมื่อมีการป้อนกลับและระดับ 3 เมื่อไม่มีการป้อนกลับ) เพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับการทดสอบหลังการฝึกเมื่อมีและไม่มีการป้อนกลับของกลุ่มควบคุม (ค่ามัธยฐาน: ระดับ 2 เมื่อมีการป้อนกลับและระดับ 2 เมื่อไม่มีการป้อนกลับ) แต่ไม่พบความแตกต่างในการทดสอบก่อนการฝึก นอกจากนี้ระดับความยากของท่าออกกำลังกายเมื่อมีการป้อนกลับมีค่ามากกว่าเมื่อไม่มีการป้อนกลับอย่างมีนัยสำคัญทางสถิติทั้งสองกลุ่ม จากผลที่ได้สรุปว่า โปรแกรมการฝึกสามารถเพิ่มระดับความยากของท่าออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอวได้ทั้งแบบมีและไม่มีการป้อนกลับ

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LIST OF ABBREVIATIONS

BMI	=	body mass index
IST	=	isometric stability test
TrA	=	transversus abdominis muscle
LM	=	lumbar multifidus muscle
RA	=	rectus abdominis muscle
IO	=	internal abdominal oblique muscle
EO	=	external abdominal oblique muscle
EMG	=	electromyography
LBP	=	low back pain
IAP	=	intra-abdominal pressure
Q_1	=	25th percentiles
Q_3	=	75th percentiles

CHAPTER I
INTRODUCTION

Chronic low back pain is an important problem in a modern society (1, 2). Lumbar instability is a significant factor in patients with recurrent and chronic low back pain (3-5). Exercise for increasing spinal stability is a choice of treatment for chronic low back pain (6-8).

Spinal stability incorporates of three subsystems, those are a passive subsystem, an active subsystem and a neural control subsystem (6, 9). The passive subsystem consisting of the osseous, articular structures, spinal ligament, do not provide any significant stability to the spine in the vicinity of the neutral position. It is toward the ends of the ranges of motion that the ligaments develop reactive forces resisting spinal motion. The active subsystem consists of muscles and tendons regard to the force-generating capacity of the muscles themselves, which provide the mechanical ability to stabilize the spinal segment. The control of muscles and receiving information from the various transducers, determines specific requirements for spinal stability, and causes the active subsystem to achieve the stability goal is described as the neural control subsystem. The functions of three subsystems accomplish the spinal stability. If one subsystem has a problem, it may require compensatory change in the other subsystems (10-12). If any one or more of the subsystems can not work appropriately, it would affect the overall stability of the spinal system and leads to dysfunction or instability (6, 9).

For many years, physical therapists have focused on the muscular system when the patients have lumbar instability (13). Physical therapists have treated lumbar instability with stabilization exercise programs to improve muscular control of the lumbar spine (8, 13). The concept of exercise program is to improve the ability of muscular system to help or to actively maintain a neutral position of spine and to prevent hypermobility of lumbar segment.

The new direction in therapeutic exercise for spinal joint stabilization has been developed over several years. Its development involves clinical problem solving and technique skill (6).

Many exercise programs are used to improve trunk stability, by training the muscular control of the lumbar spine. The patient attempts to maintain isometric contraction of lumbar muscles while gradually increase loads by various extremity motions (13, 14). Goal of stabilization exercise is to improve spinal stability (15).

Previous researches have studied the effect of stabilization exercise programs on the stability of spine in low back pain, herniated nucleus pulposus, spondylolysis or spondylolisthesis and convinced that exercises can reduce recurrent back pain (16), pain intensity (4, 17), and functional disability levels (4, 11, 17).

Nowadays, exercise programs consist of a variety of general trunk and girdle exercises for the most part which seem to have some success (11). Lumbar stabilization exercise can indicate the improvement of stability in subject who can perform difficult exercises without motion in lumbar spine (13). However, how clinicians make a judgment about the effects of stabilization exercise programs is still not clear (13).

In 1993, Wohlfahrt et al (18) designed a specific progression of exercises and this exercise has been called “Isometric Stability Test” (IST). The IST was used to determine the effects of exercise program for improving muscular control of lumbar spinal motion. The IST required the patient to be in supine position while a pressure transducer is placed under low back. The pressure transducer detects motion of the lumbar spine by presenting the change in the pressure reading. The IST has levels from 1 to 5 based on the ability of subject to isometrically contract the abdominal muscles and in order to hold the lower trunk and pelvic stable, while load is progressively increased by movement of the lower limb (13, 18). Recently, Hagins et al had developed a new set of progressive exercise called "Modified Isometric Stability Test" (Modified IST). The modified IST was based on ability to maintain the spine in static position during increasing lower extremity loading. It indicated the lumbar stability have improvement. The modified IST is a reliable tool for evaluating the ability of subjects to perform progressive lumbar stabilization exercises and significantly improved the ability to perform stabilization exercises in healthy subjects (13).

Therefore, trunk muscle exercises are commonly used not only for patient with low back pain as a method of treatment but also for healthy population as a possible prevention for low back pain (19). In 1999, Hagins et al used modified IST to evaluate the effectiveness of practice by a four-week stabilization exercise program, with weekly reinstruction and testing. The result showed that subjects could improve the ability to perform progressively difficult lumbar stabilization exercises.

Many studies have examined effect of practice lumbar stabilization exercises such as Saal et al (1989) (11) who investigated functional outcome of patients with lumbar herniated nucleus pulposus without stenosis. Sixty-four patients who met the inclusion criteria were included in this study. MRI or CT scan was used to indicate a herniated lumbar intervertebral disc without stenosis. All patients assigned an aggressive physical therapy program that included dynamic lumbar stabilization exercises and education of back. For the total group, 90% reported good or excellent outcome with a 92% return to work rate. Of the patient returning to work, 90% returned to their previous work, this proves the success in a non-operative approach. In addition, in 1997 O'Sullivan performed a randomized, test-retest study to determine the effectiveness of training specific muscles that provide stability to the trunk in patients with diagnosis of spondylolysis or spondylolisthesis in comparison to other conservative alternatives (4). Forty-four patients participated in this study. Subjects were randomly assigned to either the specific exercise group or control group. The exercise group followed a ten- week program, training the local muscle system through co-activation and progressing to functional tasks. The control group followed guidelines set forth by their treating clinician. Patients were re-examined post treatment, and showed a decrease in pain intensity and functional disability levels in specific exercise group and no significant changes in the control group. Moreover, in 2002 Hubley-Kozey (20) evaluate the relative activation amplitudes from three abdominal and two trunk extensor muscle sites of subjets with low back pain (LBP) by performing the pelvic-tilt, the abdominal-hollowing, and level 1 of the trunk stability test (TST) exercises. The result showed the TST challenges the coordination of muscle activity while the leg-loading task as evidenced by changes in amplitudes over total exercise time for the external oblique site, but not the other four sites. All three exercises could be used as initial exercises in dynamic stability progression when low-recruitment amplitudes of specific muscles were the objective but not for strengthening.

The exercises that accepted the most effectiveness for increase and improve spinal stability of the spine are lumbar stabilization exercises (6). Many studies reported good or excellent functional outcome of patients with low back pain who received lumbar stabilization exercises.

In Thailand, low back pain patients usually received intervention to control pain such as ultrasound, short wave diathermy, and traction. Exercises were used to improve muscle strength, power, endurance and stability of the spine then the functional demand of the muscle system was improved. However, lumbar stabilization exercise programs used in clinic in Thailand are not popular because it is difficult to learn the controlling position of the spine. It is not clear about level of exercises for progression that is suit for Thai people.

From the literature concerning stabilization exercises, many studies used pressure transducer to give the feedback about position of spine while subjects performed stabilization exercises. All of those studies about stabilization exercises do not appear to have an ability to perform stabilization exercises in exercise level attained without feedback. In daily activities, everyone will not have the feedback device to determine the position of the spine all the times.

Therefore, the aim of the present study was to determine the effects of practice lumbar stabilization exercise program and to investigate the exercise level attained with and without feedback in healthy subjects.

Purpose of the Study

General Objective

To determine the effects of training during four weeks of lumbar stabilization exercise program with feedback in healthy subjects and to investigate the abilities to perform lumbar stabilization exercise with and without feedback.

Specific Objective

1. To compare exercise level attained with feedback in control and exercise groups.
2. To compare exercise level attained without feedback in control and exercise groups.
3. To compare exercise level attained with and without feedback between control and exercise groups.
4. To compare exercise level attained between with and without feedback in control and exercise groups.

Parameter of the Study

Exercise level attained from zero to six levels.

Scope of the Study

This study investigated the effect of practice lumbar stabilization exercise for four weeks with weekly testing. Subjects were healthy males and females, aged from 18 to 25 years.

Hypotheses of the Study

1. The exercise level attained with feedback of posttest was significantly higher than that of pretest in exercise group while non-significant difference in control group.

2. The exercise level attained without feedback of posttest was significantly higher than that of pretest in exercise group while non-significant difference in control group.

3. The exercise level attained with and without feedback of posttest in exercise group were significantly higher than those of posttest in control group while non-significant differences of pretest in with and without feedback between control and exercise groups.

4. The exercise level attained with feedback were significantly higher than those without feedback in control and exercise groups.

Advantages of the Study

1. This study would provide clinical implication of effective therapeutic exercise.

2. The results of this study would indicate the differences in performing the lumbar stabilization exercise with and without feedback.

CHAPTER II
LITERATURE REVIEW

2.1 Definition of stability

Stability is ability to keep position stable while in weight bearing and antigravity posture (21). Stability occurred by activating co-contraction, which is the contraction of antagonist muscle that surrounds proximal joint. Co-contraction achieved by isometric holding agonist resistance and antigravity posture (22).

2.2 Stabilizing System of the Spine

The function of stabilizing system is to provide sufficient stability to the spine to match the instantaneously varying stability demands due to changes in spinal posture during static and dynamic load (9).

The basic biomechanical functions of the spinal column are to allow complex spinal movements, to carry load, and to protect the spinal cord and nerve roots (4, 9) and provide a stable base from which the limb can move (4).

Panjabi (6, 8, 9) introduced an innovative model of the spinal stabilization system which serves as an appropriate model for understanding the entity of spinal stability and instability and fits the clinical paradigm for the assessment and treatment of the muscle dysfunction in the low back pain patient. This model consists of 3 subsystems: (1) passive, (2) active, and (3) neural control (6, 8, 9, 15, 23, 24).

2.2.1 The passive subsystem

The passive subsystem consist of the vertebral bodies, zygapophyseal joints and joint capsules, intervertebral discs, spinal ligaments and passive tension from the musculotendinous units (4, 8, 9, 25), and their control of segmental movement, not only at end of range, but particularly around the neutral joint position (6). While being integral components of the spinal stabilization system, the spinal ligaments offer most resist towards the end of range of movement, but do not provide substantial support in neutral joint postures (6, 9).

The posterior ligaments of the spine include interspinous and supraspinous ligaments along with the zygapophyseal joints and joint capsules and the intervertebral discs are the most important stabilizing structures when the spine moves into flexion (26, 27). Primarily stabilized at end range extension is the anterior longitudinal ligament, the anterior aspect of the annulus fibrosus, and the zyapophyseal joints (28, 29). Rotational movements of the lumbar spine, stabilized mostly by intervertebral discs and the zygapophyseal joints (8). Side bending movements have not been studied extensively, but it appears that the intertransverse ligaments may play an important role in segmental stability for movement occurring in the frontal plane (30).

In the neutral zone of range of motion, the structures of the passive system may function as force transducers, sensing changes in position and providing feedback to the neural control subsystem (9, 30, 31). Evidence for this role is provides by anatomical observations of afferent nerve fibers capable of conveying propioceptive information in most of the structures of the passive subsystem, including the intervertebral discs, the zygapophyseal joint capsules, and the interspinous and supraspinous ligaments (31, 32).

Injury to the passive subsystem may have important implications for spinal stability (8). Intervertebral disc degeneration or disruption of the posterior ligaments of the spine may increase the size of the neutral zone, increasing the demands on the active and neural control subsystems to avoid the development of segmental instability (7, 33).

2.2.2 The active subsystem

The active subsystem of spinal stabilizing system consists of the muscles and tendons. The muscles and tendons of the active subsystem are the means through which the spinal system generates forces and provides the required stability to the spine (9). The active and neural control subsystems are primarily responsible for spinal stability in the neutral zone, where passive resistance to movement is minimal (9, 29).

Different roles have been suggested for the deeper, unisegmental muscles and the more superficial multisegmental muscles such as the abdominal and erector spinae muscles (34). The unisegmental muscles of the lumbar spine, such as the intertransversarii and interspinalis muscles, are proposed to function primarily as forces transducers, providing feedback on spinal position and movements to the neural control subsystem (9).

The multisegmental muscles are responsible for producing and controlling movements of the lumbar spine (8, 35). Lifting and rotational movements have been studied most extensively because these are tasks frequently performed by the lumbar spine (8). The lumbar erector spinae muscle group provides most of extensor force required for most lifting tasks (36). Rotation is produced primarily by the oblique abdominal muscles (8). The oblique abdominals and the majority of the lumbar erector spinae muscle fibers lack direct attachment to the lumbar spinal motion segments and, therefore, are unable to exert forces directly on individual motion segments (8). The multifidus muscle is better suited for the purpose of segmental control (37). This muscle originates from the spinous processes of the lumbar vertebrae and forms a series of repeating fascicles attaching to the inferior lumbar transverse processes, the ilium and the sacrum (8). The multifidus muscle is proposed to function as a stabilizer during lifting and rotational movements of the lumbar spine (37).

2.2.3 The neural control subsystem

The neural subsystem receives information from various transducers, determines specific requirements for spinal stability, and causes the active subsystem to achieve the stability goal (9) is the neutral control subsystem is thought to receive input from structures in the passive and active subsystems in order to determine the specific requirements for maintaining spinal stability, then acting through the spinal musculature to stabilize the spine (5, 9, 38). Individual muscle tension is measured and adjusted until the required stability is achieved (9, 39). The requirements for the spinal stability and, therefore, the individual muscle tensions, are dependent on dynamic posture, that is, variation of lever arms and internal loads of different masses, and external loads (9).

The neural control subsystem plays an important role in stabilizing the spine in anticipation of an applied load (8). Hodges and Richardson (38, 40) suggested that the transverses abdominis and multifidus muscle activity consistently precedes active extremity movement in subjects without low back pain. This finding suggests that the neural control subsystem normally anticipates the need for stabilization against the reactive forces from limb movements (8). In a study of patient with low back pain, the contraction of transverses abdominis muscles was delayed, possible indicating deficient neural control (38).

2.3 Clinical Instability

Clinical instability is defined as a significant decrease in the capacity of the stabilization system of the spine to maintain the intervertebral neutral zones within the physiological limits which result in pain and disability (6, 33).

Nowadays, the muscles that have important role to contribute to the local stabilizing system of the spine included transversus abdominis, lumbar multifidus, diaphragm and pelvic floor muscle. Evidences show that these muscles have roles to stabilize spine from two sources that is CNS control muscles and action of the muscles.

2.4 Muscle Function in Spinal Segmental Stabilization

2.4.1 Global stabilizing system

Muscles are characterized as mobilizer and stabilizer. Stabilizer muscles are further devided into local and global stabilizer. Global stabilizers have a role in eccentrically decelerating momentum. These muscles also provide rotational control (10, 41) during movement. Global muscle system is the large, more superficial of the trunk. These muscles are not only involved in moving the spine, but are also responsible for transferring load directly between the thoracic cage and the pelvis. The main function of the global muscle is to balance external loads applied to the trunk so that the residual forces transferred to the lumbar spine (6, 42). The global muscle system includes rectus abdominis, oblique abdominis externus, oblique abdominis internus, thoracic portion of longissimus thoracis and thoracic portion of lumbar iliocostalis and lateral fibres of quadratus lumborum. These muscles do not attach to the spine directly, thus do not have contribution to segmental spine mobility or stability. The muscles in this system have the capability to produce the torque and improve trunk stability and mobility overall with the assistance of intra-abdominal pressure (6, 13, 24, 43).

2.4.2 Local stabilizing system

Local stabilizer, the functional stability role is to maintain low force continuous activity in all position of joint range and in all directions of joint motion (10, 41). Moreover, the role of local muscle system is to maintain stability and control lumbar segment. Muscles within this system attach to the lumbar vertebrae directly, for this reason their function is to provide stiffness to the spinal segment. The local muscle system includes deep muscles, which have origin or insertion at lumbar vertebrae (6). The local muscle system includes lumbar multifidus, transverse abdominis, psoas major, medial fibres of quadratus lumborum, diaphragm, lumbar portion of iliocostalis lumbarum and longissimus thoracis, and oblique abdominal internus (fibre insertion into thoraco lumbar fascia) (6, 13, 24, 43).

Stability of back is provided by muscular contraction. This muscle system is often involved in people with low back pain (44). Previous research has shown that there is a stability system in the abdomen and low back which involves mainly two muscle groups includes transverse abdominis muscle (TrA) and multifidus muscle (13, 23, 24, 40, 44-47). These two muscle groups have poor function in low back pain patients (38, 40, 48). Recent studies have showed that in normal subjects, the transverse abdominis fires before muscle of the arms or legs while the extremities was assigned in reaching tasks (23, 40). This has been described by feed-forward mechanism, providing increrased spinal stiffness before loading (13).

In 1990, Richardson suggested that the abdominal muscles with a prime stabilizing role are considered to be the internal and external oblique abdominal and transverse abdominis rather than the rectus abdominis (49).

Moreover, in 1993, Jull has said the primary function of the lumbar spine is to move and support loads in the sagittal plane. In this plane, the rectus abdominis and the long erector spinae are anatomically aligned to produce and control the primary movement, while torsional stability is used primarily on activity in the internal and external abdominal oblique (50). Many researchers and clinicians have mentioned about the importance of this active stability role of the oblique abdominal as well as the transverse abdominis (14, 51-55).

Contraction of stability synergists is appearing in four key muscle groups: the transversus abdominis, lumbar multifidus, the pelvic floor and diaphragm. In fact, any one of the four muscles can be used to facilitate another.

2.4.3 Transversus abdominis (TrA)

Transversus abdominis is the deepest of the abdominal muscles. Arises from the thoracolumbar fascia between the iliac crest and the twelfth rib at the lateral raphe, the internal aspects of the lower six costal cartilages. Where it interdigitates with the diaphragm, the lateral third of the inguinal ligament and the anterior two-thirds of the inner lip of the iliac crest. The medial attachment of the muscle is a complex and variable bilaminar aponeurosis. The lower fibers arise from the inguinal ligament and pass down and medially, bending with fibers of the obliquus internus abdominis to the conjoint tendon, which attaches to the pubic crest behind the superficial inguinal ring. The remaining fibers pass transversely and medially to the midline, where they decussate and blend with the linea alba (6).

When the transverses abdominis contracts bilaterally it produces a drawing in action of the abdominal wall, resulting in an increased pressure within in the abdominal cavity (56, 57) and an increase in tension in the thoracolumbar fascia (54, 56, 57). As a result of these actions the transverses abdominis has been suggested to contribute to both supporting and torque-producing roles (6). These include control of the abdominal contents, contributes to respiration by increasing expiratory air glow rate (58), decreasing end expiratory lung volume (59) and by defending the length of the diaphragm (60). The production of trunk extension that is to maintain the stability of the spine against external forces causing the spine to flex, and the production of trunk rotation (6).

Recent evidence indicates that the lumbar multifidus (LM) (46) and transverses abdominis muscle (TrA) (61, 62) may involve in controlling spinal stability. Cresswell et al chose to use this principle by adding a load to the trunk (62). A harness, to which a weight could be attached ventrally or dorsally to force the trunk in to flexion or extension was placed over the shoulder of subjects. When a load was added to the trunk to cause flexion forces, the authors identified a short-latency activation of the erector spinae muscles. However, before the erector spinae was active, the transversus abdominis was already active, with latency less than 30 millisecond. Similarly, with unexpected dorsal loading there was a short-latency activation of the flexing abominal muscles, but once again the transversus abdominis was the first muscle to be active. The authors again proposed the transversus abdominis might be functioning to stabilize the lumbar spine. In a final paradigm, Cresswell et al allowed the subjects to release the weight that would load their trunk themselves. Therefore, subjects had the ability to make prediction. When subjects did this, they chose to prepare themselves by initiating contraction of the trunk muscles prior to loading, the result showed the transversus abdominis was the first muscle active. The latency between the onset of activity of the transversus abdominis and loading was approximately 100 milliseconds, making it difficult to rule out voluntary preparation. Moreover, the results provide important information about the potential for pre-programmed activation of the transversus abdominis to prepare the spine for perturbation (62).

Feed-forward or pre-programmed activation of the strategy used by the CNS to control spinal stability (6). That is transversus abdominis was active before the prime mover of the limb (40).

Hodges and Richardson have evaluates the sequence of activation of the abdominal muscles and the LM during the performance of hip movement following prior weight shift over the supporting limb. The result of the study confirms the hypothesis that the TrA is invariably the first muscle that is active during movement of a lower limb following contralateral weight shifting (40). This finding is consistent with the results of the previously mentioned trunk loading study of Cresswell et al (62). Because the contraction of this muscle occurs prior to movement of the limb, the TrA can be considered to be involved in the preparation of the body for the disturbance produced by the movement (40). The pattern of response of the trunk muscles also provides support for the different roles played by the trunk muscles in spinal control. It has been shown in many studies, that the superficial muscles respond in short phasic bursts that are consistent with the preparatory and resultant spinal motions shown to accompany fast limb movement. In contrast, the transversus abdominis responds in a tonic manner in the majority of subjects. Generally, what is seen is a large initial burst of transversus abdominis activity preceding the prime mover and then a longer duration, continuous, low level tonic contraction. A recent study have shown that the deep fibres of the multifidus respond in a similar tonic manner (6).

In 1997, Hodges and Richardson evaluated the abdominal muscles using fine-wire electromyography (EMG) electrodes inserted under the guidance of real-time ultrasound imaging. Subjects performed unilateral shoulder movement while recordings were taken from the opposite side of the trunk. As predicted a feedforward response of the trunk muscles was identified. Furthermore, the transversus abdominis was the first of trunk muscles active, irrespective of the direction of the movement of the limb or the direction of the forces acting on the spine. This finding provides further evidence that the transversus abdominis contributes to the control of spinal stability (56).

Many studies confirmed the activation of the transversus abdominis that is linked with the control of reactive movements produced by limb movement and not due to some other factors. In the study about relationship between limb movement speed and associated contraction of the trunk muscles (63), subjects were requested to move their arm at different speeds included fast, natural and slow. Since the reactive forces are dependent on the mass and acceleration of the limb, it was expected that with very slow movements the perturbation at the spine would minimal. The result indicated that the transversus abdominis was active in a feedforward manner with fast and natural movements but was not active with slow movements. In the study of Hodges and Gandevia, subjects performed movement of the shoulder, elbow, wrist and thumb. The transversus abdominis was active only with elbow and shoulder movement. These two findings indicate that the contraction of the transversus abdominis is dependent on the magnitude of the reactive forces, and that this feedforward activity is linked with the control of spinal stability (6). In the study about contraction of the abdominal muscles associated with movement of the lower limb (40), the researcher asked subjects to move a leg. The leg is larger mass than the arm and is in close proximity to the lumbar spine therefore greater forces would be transmitted to the spine with movement of this type (6). Whereas the transversus abdominis was active approximately 30 milliseconds before the prime mover of the shoulder, this period increased to 110 milliseconds with leg movement. This finding support that the transversus abdominis is active in the control of spinal stability (6).

Moreover, Hodges et al had compared activation of transversus abdominis muscle in four conditions. The conditions are quiet breating, inspiratory loading, voluntary forceful expiration below FRC and static expulsive maneuvers: subjects were asked to stop breathing and made a submaximal forced expiration. The result of the study showed that when subjects breathing quietly and received a visual signal to flex their shoulder rapidly, TrA EMG occurred before contraction of the deltoid. The activity of TrA occurred 20±14 milliseconds before the increase in deltoid EMG. When subjects breathed with an inspiratory load, the onset of the increase in TrA EMG forego that on deltoid EMG only when the movement occurred during the mid-expiratory phase of the respiratory cycle. In voluntary expiration below FRC, the onset of increased TrA EMG occurred before the increase in deltoid EMG when movement occurred during both mid- and end-expiratory phase of respiratory cycle. For static expulsive maneuver, the subjects stopped breathing, and all of the abdominal muscles contracted during a static expulsive maneuver. In contrast to the three earlier conditions, the onset of increased TrA EMG followed that of deltoid by 22±8 millisecond when the upper limb was moved (57).

The above study confirms that one or more of the abdominal muscles contract before the agonist limb muscles when movement of the arm is performed whole standing (57). This " preparatory" activation of TrA and IO is likely to be programmed as their onsets occur before any relevant afferent activity can initiate them one function ascribed to the preparatory contraction of the abdominal muscles is the production of intra-abdominal pressure to assist in the stabilization of the trunk and to control postural equilibrium disturbed by the movement of the arm (62). The results obtained during the static expulsive maneuvers support the view that the preparatory contractions are implicated in the mechanical stabilization of the trunk. Here there is already an elevation of intra-abdominal pressure due to the co-contraction of the diaphragm and abdominal muscles. When the arm is required to more, there may be less need to provide a more stable platform as this has already been ensured by the contraction of the abdominal muscles. In this situation, the preparatory contraction of TrA or IO was delayed until after the onset of the movement. TrA and IO are likely to be the more important abdominal muscles in any mechanical stabilization produced via an increase in abdominal pressure, as they are more effective in this task than RA or EO (61, 62).

2.4.4 Lumbar multifidus muscle

Lumbar multifidus is the largest and most medial of the lumbar back muscles (4, 6). The muscle has five separate bands, each consisting of a series of fascicles that stem from spinous processes and laminae of the lumbar vertebrae. In each band, the deepest and shortest fascicle arises from the vertebral lamina. The lamina fibres insert into the mamillary processes of the vertebra two levels caudad with the L_5 fibres inserting onto an area of the sacrum above the first dorsal sacral foramen. The other fascicles arise from the spinous process and are longer than the laminar fibres (37, 43, 64). The longest fascicles, from L_1, L_2 and L_3 have some attachment to posterior superior iliac spine. Some of the deepest multifidus fibres attach to the capsules of the zygapophyseal joints (37, 65). The lumbar zygapophyseal joints are covered by the multifidus on all sides, except ventrally where the joints are indirect contract with the ligamentum flavum (65).

The lumbar multifidus muscle is primarily extensor of the spine when acting bilaterally (6). In trunk flexion, the multifidus controls the anterior rotation and anterior translation. On return to upright, the multifidus induces posterior sagittal rotation, assisted by the lumbar erector spinae, which also controls the posterior sagittal translation (19). The lumbar multifidus contribute to support and control of the orientation of the lumbar spine and support or stabilization of the lumbar segments (6). The importance of their supporting function may be reflected in the distribution of muscle fibre type. Several studies have revealed that the lumbar multifidus and the erector spinae muscles have a high proportion of type I fibres (66-68). When comparing the composition of the multifidus with the lumbar erector spinae muscles, a higher percentage of type I fibres, in the proximity of 8-13 % has been reported in the multifidus compared with the lumbar longissimus (67, 69). Multifidus muscle fibres have a large capillary network, with approximately four to five capillaries in contact with each muscle cell. The contraction of oxidative enzymes in all lumbar muscles is large and the endurance capacity is high (66). This histochemical composition of the paravertebral muscles, with a high composition of type I fibres, indicates the tonic holding function and supportive function of these muscles (66).

Several studies have investigated the lumbar muscles capacity to increase the spinal segmental stiffness and, in particular, the control of neutral zone motion in line with Panjabi's hypothesis of clinical instability (9, 33). The result of many studies found that the lumbar multifidus had the strongest influence on lumbar segmental stability (6). Wilke et al investigated the influence of five difference muscle groups on the monosegmental motion of the L_4-L_5 segment. They estimated that of the inter-segmental muscles, lumbar multifidus provides up to two thirds of the stiffness to the spinal segment with reductions in range and neutral zone. It has also been proposed that lumbar multifidus acts as a mechanism not only to relieve the bony and neural arch of potentially damaging bending moments, but it also diminishes the shear forces sustained by the intervertebral joint (46). This is brought about at the expense of increased tensile force on the neural laminae and loading of the zygapophyseal joints (70). The multifidus action was responsible for a significant decrease in the range of motion of all movements except rotation. These results supported those obtained by Steffen et al, who in another in vitro study also found that the influence of lumbar multifidus decreased the neutral zone in flexion and extension (6). There is evidence that the multifidus muscle is continuously active in upright postures, compared with relaxed recumbent position. Along with the lumbar longissimus and iliocostalis, the multifidus provides antigravity support to the spine with almost continuous activity (71). In fact, the multifidus is probably active in all antigravity activity (72, 73). Results of studies performed in the sitting position have varied. It has been reported that the multifidus was inactive in relaxed sitting as well as when subjects were instructed to 'sit upright' (73). Activation of the multifidus has been examined in forward trunk flexion and extension from the flexed position, trunk extension in the prone position and trunk rotation. An argument can be presented that the function of this activity appears to include primarily one of stabilization. As the spine bends forward from the standing position, there is an increase in multifidus activity (72, 73). Extension of the trunk from the flexed position predictably evokes high levels of multifidus activity (72, 74). Marked activity of the multifidus also occurs when the trunk is extended or hyperextended in the prone position (73-75). The multifidus has been shown to be active bilaterally in both ipsilateral and contralateral rotation of the trunk in sitting and standing (72, 74, 75). For this reason, it has been suggested that, during rotation, the multifidus acts as a stabilizer rather than as a prime mover (73).

2.4.5 Diaphragm

The diaphragm is a dome shaped muscle caudal to the lungs, whose costal fibres lie in the same plane as transversus abdominis. From behind it consists of two strong tendons or crura attached to the bodies of the upper three lumbar vertebrae and intervening discs, bridging over the aorta alongside psoas major and passing vertically upwards and forwards into the central tendon. Further laterally muscular slips arise from the inner surfaces of the costal cartilages and lower ribs, interdigitating with those of transversus abdominis and passing to the central tendon (76).

The diaphragm has been shown to have two main functions. On the one hand its major role is that of an inspiratory muscle. The other function of the diaphragm relates to the control of intra-abdominal pressure (IAP) (4). Hodges et al evaluated the contribution of the diaphragm to postural control, using the limb movement model. In this study, the electromyographic activity of the diaphragm was measured using a monopolar needle electrode inserted into the costal diaphragm via the seventh intercostals space. When subjects performed shoulder flexion, they found that both portions of the diaphragm contracted 30 ms prior to the deltoid, at exactly the same time as contraction of the transversus abdominis. Importantly, this occurred during both inspiratory and expiratory phases of respiration. The results provide evidence that the diaphragm does contribute to spinal control and may do so by assisting with pressurization and control of displacement of the abdominal contents, allowing the transversus abdominis to increase tension in the thoracolumbar fascia or to generate IAP (77). The previous evidence suggests that diaphragm activity may be associated with voluntary contraction of the transversus abdominis by drawing in the abdominal wall (78).

2.4.6 Pelvic floor muscles

The muscles of the pelvic floor form the floor of the abdominal capsule and are an integral part of the muscular mechanism of abdominal pressurization.

Preparatory investigations of the contribution of the pelvic floor muscles to the feedforward spinal stability mechanism have been undertaken. Results from EMG recordings of the pubococcygeus indicated similar onsets of activity as for the diaphragm and transversus abdominis (6). In two additional studies, Richardson et al investigated the interaction between the muscles of the pelvic floor and the abdominal muscles. In the first study, subjects were asked to perform maximal contraction of the pelvic floor while the electromyographic activity of the abdominal muscles was monitored using fine-wire electrodes. When subjects performed the pelvic floor contractions, activation of the transversus abdominis increased significantly. In conversely experiment, the electromyographic activity of the pubococcygeus was monitored while abdominal muscles contractions were performed using fine-wire electrodes inserted through the vaginal wall. Activation of the abdominal muscles resulted in an increased activation of pubococcygeus (6).

2.5 Resistance Exercise

Goal of resistance exercise is to improve functional performance and capabilities through the development of increased muscular strength, endurance, or power (22). It included isotonic exercise, isokinetic exercise, isometric exercise.

Isometric exercise is a static from of exercise that occurs when muscle contracts without an appreciable change in length of the muscle or without visible joint motion (22). Forms of isometric exercise include muscle-setting exercises, resisted isometric exercises, and stabilization exercises.

2.5.1 Muscle-setting exercises (22)

Muscle-setting exercises are low intensity isometric exercises performed against little to no resistance. Setting exercises are used to promote muscle relaxation and circulation and to decrease muscle spasm and pain after injury to soft tissues during the acute stage of healing.

2.5.2 Resisted isometric exercises (22)

Resisted isometric exercises are isometric exercises, performed against manual or mechanical resistance, which used to improve muscle strength when joint movement is painful or inadvisable after injury.

2.5.3 Stabilization exercise (22)

Stabilization exercise is isometric exercises, which can be used to develop joint or postural stability.

1. Stabilization exercises are usually performed in weight-bearing position in closed kinematic chain.

2. Emphasis is placed on isometrically controlling trunk muscles and proximal muscles of the extremities. A variety of positions are held against manual resistance or against gravity with body weight as the source of resistance.

3. Rhythmic stabilization exercise

Rhythmic stabilization exercise is form of isometric exercise in which manual resistance is applied to one side of a proximal joint and to the another side as the patient hold a closed-chain position to facilitate a simultaneous isometric contraction of muscles on both side of the joint, which can improve joint stability and postural stability.

4. Dynamic stabilization exercises

Dynamic stabilization exercises are form of isometric exercises designed to improve joint and postural stability, which perform extremity motions within the tolerance of the trunk or neck muscles to control the functional position.

2.6 Trunk Stabilization Exercise Programs

2.6.1 Leg loading exercise (6)

Leg loading exercise has several advantages. Both local and global muscle systems are working synergistically in common in a static-supporting role. Additionally, the magnitude of resistance can be controlled and using pressure biofeedback unit can monitor successful maintenance of control of trunk position, which gives mediate feedback of any change in lumbopelvic position. Most training begins at very low level of load, then progressively by movement of the lower limb.

2.6.2 Trunk inclination exercise (6)

This exercise activates deep muscle co-contraction to train force generating and endurance abilities. This done by requiring patients to control and hold a neutral upright lumbopelvic posture during forward trunk inclination with hip flexion.

2.6.3 Formal exercise programs (6)

- Four-point kneeling position
- Four-point kneeling with arm and leg extension
- Bridging, holding the spine in neutral position
- Bridging exercise with single leg extension
- Sitting by using a gym ball

2.6.4 Functional exercise programs (6)

Functional exercise programs simulating patient's activities daily living, work and sport constitutes the final stage of rehabilitation. Training during high impact loading activities such as running and jumping. Training activities includes safe lifting, carrying and handling, or correction of styles in sport.

For many years, physical therapists have focused on the muscular system when the patient have problem about low back as lumbar instability (13). Physical therapists have treated lumbar instability with stabilization exercise programs to improve muscular control of the lumbar spine (8, 13, 47, 79). The concept of exercise program is the ability of muscular system to maintain a neutral position of spine and to prevent hypermobility of lumbar segment. Weak muscular system, can lead to high levels of repetitive injury and tissue damage (13, 80).

Many exercise programs are used to improve trunk stability by training muscular control of the lumbar spine (81). The patient attempts to maintain isometric contraction of lumbar muscles while gradually increase loads by various extremity motions (13, 14). Goal of stabilization exercise of the motor system is to improve spinal stability (15).

In 1980, Kennedy reporting the term “dynamic abdominal bracing” (DAB) has been used to describe the manoeuvre which utilizes the intra-abdominal pressure mechanism to stabilize and protect the lumbar spine during movement and position of weight bearing (14). In 1982, Basmajian carried out electromyographic studies of the external oblique muscles. This study showed an increase in motor unit activity in the external oblique muscle when DAB was used with exercises and activities such as lifting, pushing and carrying.

In 1989, Saal looked at functional outcome of patients with lumbar herniated nucleus pulposus without stenosis. Sixty-four patients who met the inclusion criteria were included in this study. MRI or CT scan used to indicate a herniated lumbar intervertebral disc without stenosis. All patients were assigned an aggressive physical therapy program that included dynamic lumbar stabilization exercises and education of back. For the total group, 90% repeated good or excellent outcome with a 92% return to work rate. Of the patient returning to work, 90% returned to their previous work (11).

In 1997, O’Sullivan (4) performed a randomized, test-retest study to determine the effectiveness of training specific muscles that provide stability to the trunk in patients with diagnosis of spondylolysis or spondylolisthesis in comparison to other conservative alternatives. Forty-four patients participated in this study. Subjects were randomly assigned to either the specific exercise group or control group. The exercise group followed a ten- week program, training the local muscle system through co-activation and progressing to functional tasks. The control group followed guidelines set forth by their treating clinician. Patients were re-examined post treatment, with showed a decrease in pain intensity and functional disability levels in specific exercise group and no significant changes in the control group.

In 1999, Cholewicki examined the effect of IAP by wearing an abdominal belt on lumbar spine stability and measured trunk stiffness with a quick release method in trunk flexion, extension, and lateral bending. Ten volunteers participated in this study. Electromyography signals (EMG) from 12 major trunk muscles were recorded before and after the release to add to the interpretation of results. The intra-abdominal pressure (IAP) was measured with an intra-gastric pressure transducer. The results indicate that both wearing an abdominal belt and raised IAP can each independently, or in combination, increase lumbar spine stability (82).

In 1999, Hagins et al used modified IST to evaluate the effect of practice follow a four-week stabilization exercise program, with weekly reinstruction and testing. Forty-four asymptomatic subjects were participated in this study. This study used a pressure transducer to detect motion of the lumbar spine. The result showed subjects could improve the ability to perform progressively difficult lumbar stabilization exercises (13).

In 2000, Vezina evaluated activation amplitudes from 3 abdominal and 2 trunk extensor muscle sites in healthy subjects by performing the pelvic tilt, abdominal hollowing, and level 1 of the trunk stability test (TST level 1) exercises and to compare the activation amplitudes among muscle sites and exercises. Twenty-four healthy men without low back pain participated in the study. The result indicated that study were not interchangeable for the pattern of trunk muscle activation amplitudes. The exercises did not recruit the abdominal muscle to adequate levels for strengthening for this healthy sample. All 5 muscle sites were activated, forming the basis of stabilizing exercise approach (83).

In 2002, Hobley-Kozey evaluated the relative activation amplitudes from 3 abdominal and 2 trunk extensor muscle sites of subject with low back pain (LBP) performing the pelvic tilt, abdominal hollowing, and level 1 of the trunk stability test (TST level 1) exercises and compared the activation amplitudes among muscle sites and exercises. The result showed the TST challenges the coordination of muscle activity during the leg-loading task (stabilization phase) as evidenced by changes in amplitudes over the total exercise time for the external oblique site, but not the other 4 sites. They suggested all 3 exercises could be used as initial exercises in a dynamic stability progression when low-recruitment amplitudes of specific muscles were the objective but not for strengthening (20).

In 2001, Hides found that specific localized exercise can decrease recurrent low back pain (84).

Hammer divided 39 acute low back patients into two groups. Control group received medical management and advice to resume normal activity as tolerated, while another group performs specific localized exercises to restore the stabilizing protective function of the lumbar multifidus (LM) with co-contraction of the transverse abdominis muscle (TrA). All subjects were giving four week for exercise. Both two groups were followed by one and three-year questionnaires. Two to three years after treatment, the rate of recurrent of LBP in the specific exercise group recurrent was 35%, but 75% for the control group. The multifidus no longer showed weakness or atrophy in the specific exercise group (47).

2.6.5 Isometric stability test

In 1993, Wohlfahrt et al designed a specific progression of exercises and this exercise has been called "Isometric Stability Test" (IST) (18). The IST used to determine the effects of exercise program for improved muscular control of lumbar spinal motion. The IST required the patient to be in supine position while a pressure transducer is placed under low back. The pressure transducer detects motion of the lumbar spine by present changing in the pressure reading. The IST has level measure from level 1 to 5 based on ability of subject in isometrically contracting the abdominal muscles in order to hold the lower trunk and pelvic stable, while load is progressively increased by movement of the lower limb (13, 18).

In 1999, Hagins et al developed a new set of progressively difficult exercise and called "Modified Isometric Stability Test" (Modified IST). The modified IST based on ability to maintain the spine in static position during increasing lower extremity loading. It indicated lumbar stability was improved. Modified IST is important to determine whether subject can learn increasingly difficult lumbar stabilization exercises with training. The result indicate that the modified IST was a reliable tool for evaluating the ability of subjects to perform increasingly difficult lumbar stabilization exercises and significantly improved the ability of a group of healthy subjects to perform stabilization exercises (13).

Increasing difficulty of the exercise is based on the biomechanical construct that is quantity of torque the lumbar muscles are raising is defined by the mass of the legs and the moment arm from the center of mass of the legs to the axis of rotation. When torque increased, the load on the lumbar spine is increased too. Modified Isometric Stability Test (Modified IST) is thought to create a progressive increase in the magnitude of torque at each level (13).

Testing level of Modified Isometric Stability Test (Modified IST), subject will perform test by assumed a crook lying position (supine with knees flexion approximately 90^{o} and feet flat on the floor). Researcher will place pressure transducer under low back. Then set pelvic into relaxed position and spine into neutral position. After that pumped up pressure to 40 mmHg (13, 18, 50) and subject handed pressure dial visible to both the subject and the researcher. When subjects perform exercise level 1 and give manual pressure to air-filled bag until the pressure at 50 mmHg (± 4 mmHg) for three cycle of breathing without compensation. If subjects are able to perform abdominal hollowing and maintain pressure at 50 ± 4 mmHg mean successful in this level. That subject will attempt to perform exercise level 2 and continue until failure. The highest level that subject can perform successful is subject’s score on modified IST (13).

2.7 Principles of Clinical Management of the Deep Muscle System for Segmental Stabilization

The specific exercise strategy for segmental stabilization was developed from several sources, which included the potential biomechanical effects of a co-contraction of the local muscles, general considerations of motor control and joint stabilization, the responses of the muscle system to training in the clinical situation, and clinical and laboratory evidence of motor control problems in the local muscles in low back pain patients (6). The co-contraction exercise is best described as a specific motor skill. Persons with no history of low back pain can usually perform it quite well, but in low back pain patients usually experience great difficulty in attempting the skill. Such a motor skill is rehabilitated through a motor relearning process rather than through conventional exercise for increasing the strength and endurance of muscles (6).

The features in common with some stabilization programmes are rehabilitation of motor control aspects of muscle function, postures of spine in neutral, low level continuous tonic contractions and co-contraction of trunk muscles with would include the transversus abdominis and lumbar multifidus. The additional features of the specific exercise approach are precise co-contraction of the transversus abdominis and lumbar multifidus independently of the global muscles, utilization of methods of decreasing global muscle activation to allow training of the deep muscle co-contraction, utilization of new facilitation strategies to achieve the deep muscle co-contraction. The selection of a particular treatment strategy is based directly on the assessment of the presenting impairment in the individual low back pain patient and the selection of treatments is continually being refined as the effectiveness is quantified objectively (6).

The concept of the exercise strategy was based on gaining a co-contraction of the key local muscles, the transversus abdominis and the lumbar multifidus. The aim was to effect local spinal segmental support either by the action of these muscles in increasing tension in the thoracolumbar fascia and increasing the intra-abdominal pressure (IAP), or through their direct attachment to the lumbar vertebrae. Drawing in the abdominal wall is the exercise elicited isometric contraction of the transversus abdominis combined with an isometric contraction of the segmental levels of the lumbar multifidus. Biomechanically it would be beneficial for these muscles to co-contract, and there is clinical and preliminary experimental evidence that this occurs. In the clinic, it is observed that the contraction of transversus abdiminis is accompanied by a contraction of the lumbar multifidus in a normal cognitive contraction. Conversely, a normal cognitive contraction of lumbar multifidus is accompanied by contraction of the transversus abdominis. This muscle co-contraction can be likened to activating a deep muscle corset to support the spinal segments and lumbopelvic region (6). Level and type of muscle co-contraction are the other essential features of the exercise. Several factors dictate that the contraction be a low level, tonic, continuous contraction less than 30-40% of maximum voluntary contraction, with no rapid, phasic contraction (6).

Two other muscle groups are activated in synergy between the transversus abdominis and lumbar multifidus during the action of drawing in the abdominal wall. The data from motor control studies of trunk muscle activity in a stabilization model (77) have linked the timing of the activity of the transversus abdominis and the diaphragm. In addition, preliminary studies on the pelvic floor muscles have indicated that these muscles co-activate with the transversus abdominis. This co-activation of the transversus abdominis and the muscles of the pelvic floor and diaphragm is likely to act to maintain the intra-abdominal pressure (IAP) at a critical level, thus allowing contraction of the transversus abdominis to affect spinal support (6).

The essential elements of the specific exercise strategy included: the focus is on the local muscles that are the transversus abdominis and the segmental levels of the lumbar multifidus; low load and tonic isometric contractions; contraction of the pelvic floor muscles forms part of the motor skill test of drawing in the abdominal wall; the patient must be able to breathe normally during the abdominal drawing in action; and maintain specificity of deep muscle action independent of the global muscles.

2.8 Motor Learning Model

In recent time the management of lumbar segmental instability in chronic low back pain patients has been the specific training of muscles whose primary role is considered to be the provision of dynamic stability and segmental control to the spine such as transversus abdominis, lumbar multifidus, based on the identification of specific motor control deficits in these muscles (4, 16, 85). This approach is based on a motor learning model whereby the faulty movement pattern or patterns are identified. The components of the movement are isolated and retrained into functional tasks. The motor learning model of exercise training has been shown to be effective with long-term reduction in pain intensity and functional disability level in subjects with chronic low back pain with diagnosis of lumbar instability (4, 11). The process of motor learning described by Fitts and Posner in a new motor skill (86) and later Anderson (87), who discussed learning in terms of three stages of practice which representative of this model of exercise training (24). These are called the cognitive stage, associative stage and autonomous stage.

2.8.1 Cognitive stage

In cognitive stage the learner is concerned with understanding the nature of the task, developing strategies that can be used to carry out the task, and determining how the task should be evaluated. These effects require a high degree of cognitive activity, such as attention. In this stage the person experiments with a variety of strategies (86). Naturally, considerable cognitive activity is required so that the learner can determine appropriate strategies. Good strategies are retain, and inappropriate one are discarded (87). For management of lumbar segmental instability cognitive stage is the early training period, a high level of awareness is demanded of subjects in order that they isolate the co-contraction of the local muscle system such as transversus abdominis and lumbar multifidus from global muscle substitution. The aim of the first stage is to train the specific isometric co-contraction of transversus abdominis and lumbar multifidus at low level of maximal voluntary contraction and with controlled respiration, in weight bearing within a neutral lordosis of lumbar spine (24).

Progression of first stage

1. Train independence of pelvis and lower lumbar spine and hip to achieve a neutral lordosis without global muscle substitution.
2. Train central and lateral costal diaphragm breathing control.
3. Maintaining neutral lordosis, facilitate the “drawing up and in” contraction of the pelvic floor, lower and middle fibres of transversus abdominis with gentle controlled lateral costal diaphragm breathing and without global muscle substitution. This facilitated is in non-weight bearing postures such as four point kneeling, prone or supine only if accurate co-contraction cannot be facilitated in weight bearing postures such as sitting and standing.

4. Facilitate bilateral activation of segmental lumbar multifidus (at the unstable level) in co-contraction with transversus abdominis and controlled lateral costal diaphragm breathing while maintaining a neutral lordosis.
5. Train co-contraction in sitting and standing with postural correction.

Strategies to inhibit global muscle (such as rectus abdominis and oblique externus abdominis substitution.

1. Oblique externus abdominis and rectus abdominis:
   - Focus on pelvic floor contraction.
   - Facilitate upper lumbar lordosis and lateral costal diaphragm breathing to open sternal angle.
   - Focus on optimal postural alignment in weight bearing.
2. Thoraco-lumbar erector spinae:
   - Avoid thoracic spine extension and excessive lumbar spine lordosis.
   - Ensure independence of pelvis and low lumbar spine movement from thoracic spine and hips.
   - Facilitate lateral costal diaphragm breathing.
   - Focus of palpatory and EMG biofeedback, and muscle relase techniques.

In the early states the instruction is to cease the contraction if global muscle substitution occurs, breathing control is lost, muscle fatigue occurs or there is an increase in resting pain. Training is performed a minimum of once a day about 10-15 minutes, and in quiet environment (24).

2.8.2 Associative stage

The associative stage is the second aspect of motor learning, the person had selected the best strategy for the task and now beings to refine a particular movement pattern. Thus, during this stage there is less variability in performance, and improvement also occurs more slowly. This stage may last days to weeks or months, depending on subject motivation, compliance, nature of pathology (45) and the intensity of practice (86). The subject gradually producing small changes in the motor patterns that will allow more effective performance (87). The subject is taken through these steps whilst isolating the co-contraction of the local muscle system. First this is carried out while maintaining the spine in a neutral lordotic posture, control breathing, co-contraction of the local muscle system (24, 45) and finally with normal spine movement. At all times segmental control and pain control must be ensured. These can be performed for sit to stand, walking, lifting, and carrying objects. The patients carry out the movement components on a daily basis with pain control and gradually increase the speed and complexity of the movement pattern until they can move in a smooth, free and controlled manner. Patients are encouraged to carry out regular aerobic exercise such as walking while maintaining correct postural alignment, low level local muscle system co-contraction and controlled respiration. This helps to increase the tone within the muscles and aids the automaticity of the pattern. This stage can last from between 8 weeks to 4 months depending on the performer, the degree and nature of pathology and the intensity of practice, before the motor pattern is learned and becomes automatic.

2.8.3 Autonomous stage

The autonomous stage is the stage of skill acquisition. Fitts and Posner define this stage by the automaticity of the skill and the low degree of attention required for the correct performance of the motor task. In this stage the person can begin to devote his or her attention to other aspects of the skill in general, like scanning the environment for obstacles that might impede performance, or focusing on a secondary task, or saving his or her energy so as to avoid fatigue (86). This stage is the aim of the specific exercise intervention, whereby subjects can dynamically stabilize their spines appropriately in an automatic manner during the functional demands of daily living. Evidence that changes to automatic patterns of muscle recruitment can be achieved by this intervention is supported by surface EMG data and the long-term positive outcome for subjects who had undergone this treatment intervention (4).

2.9 Diagnostic Assessment of Muscle Activity

Nowadays, the most direct diagnostic method of measurement motor-control deficits in the transverse abdominis and the final output of segmental levels of the multifidus are assessment by EMG using fine-wire electrodes placed within the target muscles. This method measures how the nervous system controls the contractions of the deep muscles, through the use of a reaction task involving arm or leg movements in the standing position (6). The second diagnostic method, which has the advantage of being non-invasive, has been developed from the volitional clinical measures. It involves assessing the level and type of muscle action during the motor skills of drawing in the abdominal wall, isometrically contracting the segmental lumbar multifidus and the leg loading tests. By combining the outputs from various types of measurement apparatus. The measurement employs the simutaneous use of real-time ultrasound imaging, collection of analogue data from a pressure biofeedback unit connect to pressure transducer and surface EMG. For drawing in the abdominal wall in the motor skill, the interaction of the abdominal muscle layers and the control of the action of transverse abdominis to contract in to its shortened range are assessed using ultrasound imaging and pressure changes. Simultaneously, the level of any unwanted in the global muscles during the test manoeuvre is documented using surface EMG (6).

Pressure biofeedback unit (6, 53) consist of an inelastic, three-section air-filled bag, which sections of the cushion communicate with one another. The air-filled bag is inflated to fill the space between target body area and a firm surface. Pressures dial for reading the pressure in the bag for feedback about position. External force performed to air-filled bag is reflected as change in pressure. Movement of the body part onto the back results in an increase in pressure while movement of body part off the bag results in a decrease in pressure. These devices become general use for stabilization exercises for all part of the body. Its use in assessing the action of abdominal drawing-in, however, pressure biofeedback unit become the most important to use in treatment about problems of the local muscle system in low back pain patients (6, 16, 53).

CHAPTER III
MATERIALS AND METHODS

3.1 Subjects

Healthy Thai males and females aged range between 18 and 25 years participated in this study. All of them received subjective examination and were explained about objectives and process of testing and training. Each subject signed an informed consent. This study was approved by the Ethical Committee, Faculty of Medicine Siriraj Hospital, Mahidol University.

Inclusion criteria

Subjects were recruited on the basis that:

1. BMI less than 25 kg/m^2
2. Not having any disability in lower extremities.
3. Having normal range of motion of hip, knee and ankle joints.
4. No musculoskeletal problem.
5. No neurological problem.
6. No activities or exercises involved in stability of lumbar spine.
7. Having right leg dominant.

Exclusion criteria

Subjects were excluded from the study if they have the following criteria:

1. History of low back pain within three months prior to participating in the study.
2. Abdominal or back surgery within the previous year.
3. Scoliosis
4. Previously participated in a specific stabilizing exercise intervention.
5. Could not understand and follow commands.
6. Pregnant or having a baby.

3.2 Instrumentation

3.2.1 Pressure biofeedback unit (Stabilizer, Chattanooga) consists of an inelastic, three-section air-filled bag which sections of the cushion communicate with one another. The air-filled bag is inflated to fill the space between target body area and a firm surface. The pressure gauge is marked in increment of 2 mmHg. It is used to read the pressure in the bag for feedback about position as shown in Figure 3.1.

Figure 3.1 Pressure biofeedback unit (Stabilizer).

3.2.2. Goniometer

3.2.3. Timer

3.2.4. Table

3.2.5. Mat

3.2.6. Pillow

3.2.7. Stand and bar

3.3 Testing Protocol

Subjects received the explanation about the detail in every step of the method. Each subject was asked to sign an informed consent. Subjects were divided into control and exercise groups that matched by sex, age, weight and height. The exercise group performed lumbar stabilization exercises program for 4 weeks. The control group received no training. All subjects in both groups were tested initially, one-week intervals for four weeks and in the first, second week after the training had finished.

The lumbar stabilization exercise program was used for both testing and training. The exercise program was modified from literature review and was tested by the subjects who had similar characteristic to the subjects in the present study. Ordinal level measurement was assigned based on the subject's performance in isometric contracting the abdominal and back muscles in order to hold pelvic and lower trunk stable. The load was progressively increased by lower extremities movement in more advance levels.

Initially, exercise level 1 was tested in all subjects. The subject was required to perform the exercise without changing the pressure gauge dial. While performing the exercise, subjects were not allowed to have any of these compensations, which included flexion or extension of the neck, elevation of the shoulders from the floor, protrusion of the rectus abdominis, extension of lumbar spine and posterior tilting of the pelvis and elevate rib cage (holding the breath) (13).

The researcher monitored the pressure gauge dial for movement and body part of subject from compensation as the previous mentioned and to determine whether the subject completed or uncompleted exercise level. The subject test's score was the highest-level exercise, which the subject could perform successfully. For example, if subject got a score of 3 on lumbar stabilization exercise program that meant the subject could perform lumbar stabilization exercise program at the third level successfully but incomplete in the fourth level. If the subject got score of 0 on lumbar stabilization exercise program, it meant that subject did not pass the exercise level one.

3.3.1 Training before pretest

All subject received 20 minutes for training session before the pretest. Training exercise assisted subjects to learn how to use back muscle as well as abdominal muscle to stabilize the lumbar spine before the pretest. Moreover, this training helped subjects to be accustomed to pressure transducer before the pretest. The training session before pretest consisted of:

A: Abdominal breathing

Subjects were in supine lying with knee bent and feet flat on the floor. The researcher laid the weigh or book approximately 1 kg on the belly and below the navel. Subjects took one hand on the chest and another hand on the abdomen. When subjects inhaled, they kept their chest stable while abdominal expands. When they exhaled, they let abdominal recoil toward the spine and continued this pattern for 5 minutes.

B: Quadruped abdominal hollowing

Subjects were in quadruped on the floor with hips and shoulders flexion approximately 90^o, spine in neutral position. When subjects inhaled, they permited belly to drop. While they exhaled, they tugged belly to the spine and did not allow spine to move. They continued to breathe in this pattern for 5 minutes.

Subject then performed abdominal hollowing in crook lying position. They practiced the exercise testing with pressure transducer for exercise level 1 to 6 in lumbar stabilization exercise program.

3.3.2 Pretest

Each subject performed pretest in a crook lying position (supine with knees flexion approximately 90^o and feet flat on the floor). The researcher put pressure transducer under subject's low back by setting the lower rim at S_2, the upper rim at L_1 (53). The subject was told to relax muscles around pelvis and adjusted the spine into neutral position as shown in Figure 3.2. After that the researcher pumped up the pressure of pressure transducer to 40 mmHg (4).

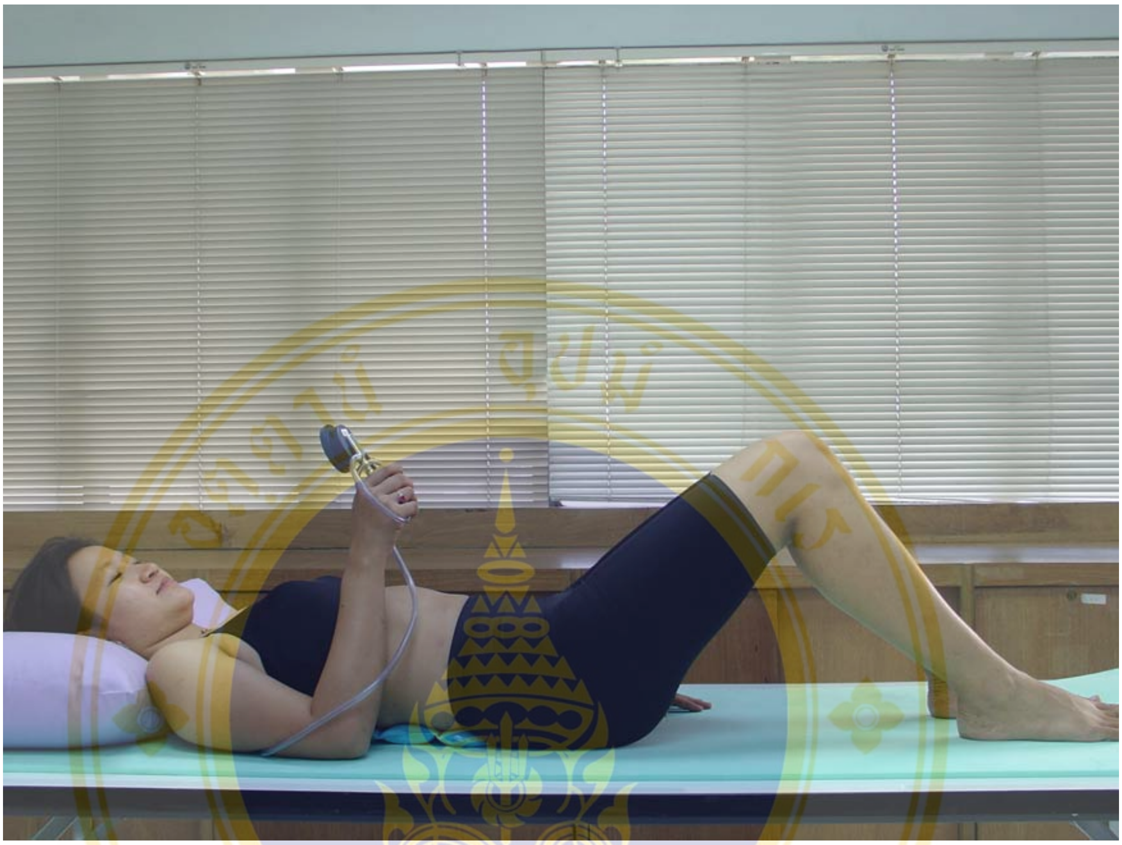

Figure 3.2 Position of subject and placement of stabilizer when performed the test.

Testing without feedback

Subjects were tested without using the feedback in the first time, by invisible scale of pressure (visible only by the researcher). Subjects performed exercise level 1 and maintain pressure at 40 mmHg (± 4 mmHg) for three cycles of breathing without compensation. If subjects were able to perform abdominal hollowing by stabilized back during abdominal breathing and maintained pressure at 40 ± 4 mmHg, it meant that they were successful in this level. The subjects attempted to perform the exercise level 2 and higher until they could not perform the higher level.

Testing with feedback

While the subjects performed level 1, they maintained the pressure at 40 mmHg (± 4 mmHg) (13) which was visible to both subject and the researcher. They sustained that pressure during three cycles of normal breathing without compensation.

The subjects who could perform abdominal hollowing and maintained pressure were able to reach this level. After that, they were allowed to continue with exercise level 2 or higher level until they could not perform or had any compensation.

Exercise level (See figures at Appendix D)

At all levels, subjects were asked to maintain the pressure at 40 mmHg ($\pm$ 4 mmHg) and started to perform the exercises. The degrees of difficulty of the test exercise were as follows:

Level 1: Abdominal hollowing

Subjects were in supine position with knees flexion and feet flat on the floor. They placed their hands on lower abdomen below navel, and felt their muscle contraction. They were asked to imagine the feeling created in abdomen while inhaled. When exhaled, they were asked to imagine to bring belly to the spine. Subjects tried to maintain pressure with breathing normally. They performed this exercise for 5 minutes.

Level 2: Unilateral abduction

Subjects were in supine position with knees flexion and feet flat on the floor. They performed the abdominal hollowing by contracted abdominal muscles. While maintaining these contractions, they were advised to abduct their right leg to approximately 45^{o} in relation to the floor during left knee motionless. After that, they put their right leg to the starting position. Each subject was asked to continue a normal breathing pattern throughout the exercise. Subjects performed this exercise for 5 minutes.

Level 3: Unilateral knee extension

Subjects performed exercise in supine position with knees flexion and feet flat on the floor. They performed the abdominal hollowing by contracted abdominal muscles. While maintaining the contraction of abdominal muscles, they were asked to extend their right knee joint to zero degree and controlled the thigh in the same level both sides. Then they put their right leg to the starting position.

Subjects were advised to keep normal breathing throughout the exercise. They performed this exercise for 5 minutes.

Level 4: Unilateral knee raise

Subjects lay in supine position with knees flexion and feet flat on the floor. They performed the abdominal hollowing by contracted abdominal muscles. While the subjects were maintaining these contraction, they were asked to raise their right leg toward chest until it just passed hip flexion approximately 90^o and allowed the knee to flex naturally. While subjects performed the lift, they did not allow to move the left leg, head, neck and shoulders. After that, they put their right leg to the starting position. Subjects performed this exercise for 5 minutes, with breathing normally.

Level 5: Bilateral knee raise

Subjects were in supine position with knees flexion and feet flat on the floor. They contracted abdominal muscles. While maintaining these contraction, each subject was asked to raise right leg toward chest until it just passed hip flexion approximately 90^o with knee to flexion position. The subjects held their right leg in this position and then raised the left leg in the same manner therefore both legs were elevated. They put their right leg to the starting position followed by left leg. Subjects were instructed to breath normally throughout the exercise. Subjects performed this exercise for 5 minutes.

Level 6: Bilateral knee rise together

Subjects were in supine position with knees flexion and feet flat on the floor. They recreated the abdominal hollowing by contracted abdominal muscles. While maintaining these contractions, they raised their both legs toward chest until just passed hip flexion approximately 90^o with knee flex naturally. Subjects continued to breath normally and did not allow moving head, neck or shoulders. Then, they put their both legs to the starting position together. Subjects performed this exercise for 5 minutes.

After pretest, subjects received exercise program based on exercise level attained in score of testing with feedback in pretest. They performed the exercise program 15 minutes which included 5 minutes of exercise at one level of lower than their pretest, 5 minutes at their pretest level, and 5 minutes at one level of higher than their pretest. For example, if subject attained level 3 of stabilization exercise during pretest, he or she was assigned to train exercise levels 2, 3 and 4 each for 5 minutes consecutively. Subject was allowed to rest for 1 minute between each level. Subject explained the description about three specific exercises. For exercise level 0 and 1, it was necessary to use one or both of the two training session before pretest (3.3.1 A and B) as part of the exercise program. Subjects in exercise group performed exercise program three times per week for four weeks, with weekly testing.

3.3.3 Retest

All subjects returned to retest with and without feedback and to progress in exercise program once a week. If the subject did not success to perform previous assigned exercise level, he or she continued with the three specific exercises that received at pretest. This protocol was followed identically for the following weeks for a total of three interims testing in all subjects.

3.3.4 Posttest

Subjects participated in posttest by using the same protocol as the pretest. They were in a crook lying position (supine with knees flexion approximately 90^o and feet flat on the floor). The researcher put pressure transducer under low back by setting the lower rim at S_2, the upper rim at L_1, then set subject's pelvis into relaxed position and spine into neutral position. After that the researcher pumped up the pressure of pressure transducer to 40 mmHg. Subjects performed testing without feedback and followed with testing with feedback. They were tested the same as posttest for the first and second week after completing the training program as shown in Figure 3.3.

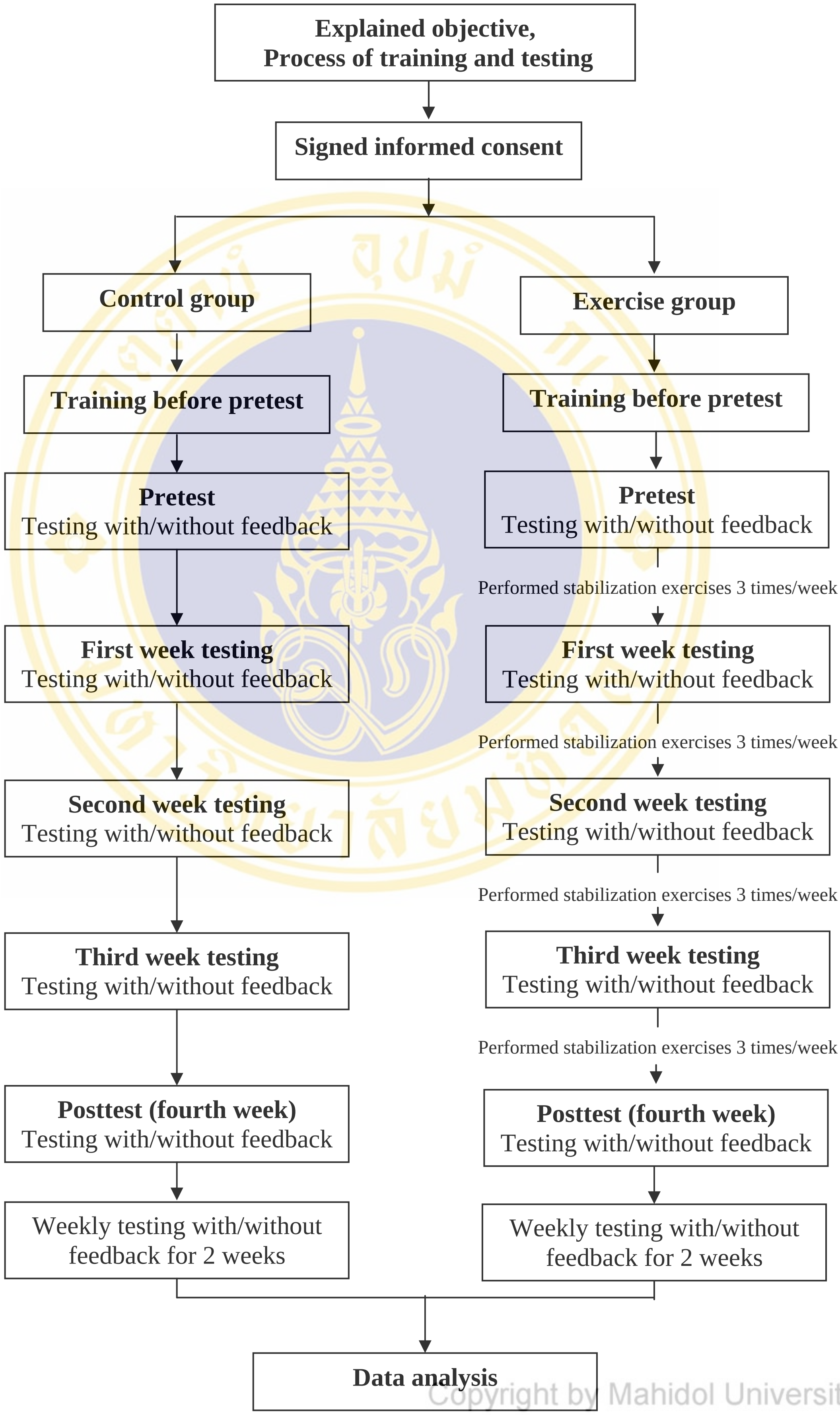

Figure 3.3 The procedure of the study.

3.4 Data Analysis

This study used SPSS for Microsoft Windows release 11.0 program for statistical analysis. The statistical significance was estimated at probability (p-value) level less than 0.05 ($p<0.05$).

1. Kolmogorov-Smirnov Goodness of Fit test was used to determine the distribution of the characteristic data.

For normal distribution data, independent sample t-test was used to compare the differences of age, weight, height, and body mass index (BMI). Mann Whitney U test was used for non normal distribution data.

2. The dependent variable was the score on lumbar stabilization exercise program (exercise level attained), and the independent variable was group (the exercise group and the control group). The dependent measures ranged from zero to six, which represented the highest level of lumbar stabilization exercise program.

Friedman test was used for comparison of exercise level attained among pretest and posttests within group. Then determine which conditions were different by using the following equation (88):

$$\left|R_u - R_v\right| \geq Z_{\alpha / k(k-1)} \sqrt{\frac{Nk(k+1)}{6}}$$

Mann Whitney U Test was used for comparison of exercise level attained between the exercise group and the control group.

Wilcoxon Signed Rank test was used for comparison of exercise level attained in exercise group and control group between with and without feedback.

CHAPTER IV
RESULTS

4.1 Characteristics of Subjects

The subjects in this study were divided into two groups; control and exercise groups. Each group consisted of 5 males and 10 females. Means of age, weight, height, and body mass index between groups were not significantly different.

Table 4.1 Means and standard deviations of age, weight, height, and body mass index of subjects in control and exercise groups

	Control group (n=15)		Exercise group (n=15)		p-value
	mean	SD	mean	SD	
Age (yrs)	22.54	1.12	22.48	1.20	0.886
Weight (kg)	55.90	6.97	55.60	8.24	0.915
Height (cm)	163.93	7.20	162.47	6.22	0.555
BMI (kg/m^2)	20.81	2.16	21.02	2.44	0.802

p-value from independent sample t-test

4.2 Exercise Level Attained with Feedback

Medians and interquartile ranges of exercise level attained in each group at pretest, 1st, 2nd, 3rd week testing, posttest and follow up with feedback are presented in Tables 4.2, 4.3 and Figures 4.1, 4.2.

Table 4.2 Comparison of medians and interquartile ranges of exercise level attained in each group among pretest, 1st, 2nd, 3rd week testing, posttest, 1st and 2nd week followed up with feedback

Test	Group	
	Control	Exercise
	Median (Q_1,Q_3)	Median (Q_1,Q_3)
Pretest	2(1,2)	2(1,2)
1st week	2(1,2)	2(2,3)
2nd week	2(1,2)	4(3,4)
3rd week	2(1,2)	4(4,5)
Posttest	2(2,2)	5(4,5)
1st week follow up	2(2,2)	5(4,6)
2nd week follow up	2(1,2)	5(4,5)
p-value	0.423	0.0001*

p-value from Friedman test

*significant difference at $p < 0.05$

Table 4.3 Multiple comparison between testing sessions of exercise group with feedback

Test	Pretest	1st week	2nd week	3rd week	Posttest	1st week follow up	2nd week follow up
Pretest				*	*	*	*
1st week				*	*	*	*

*significant difference at $p < 0.05$

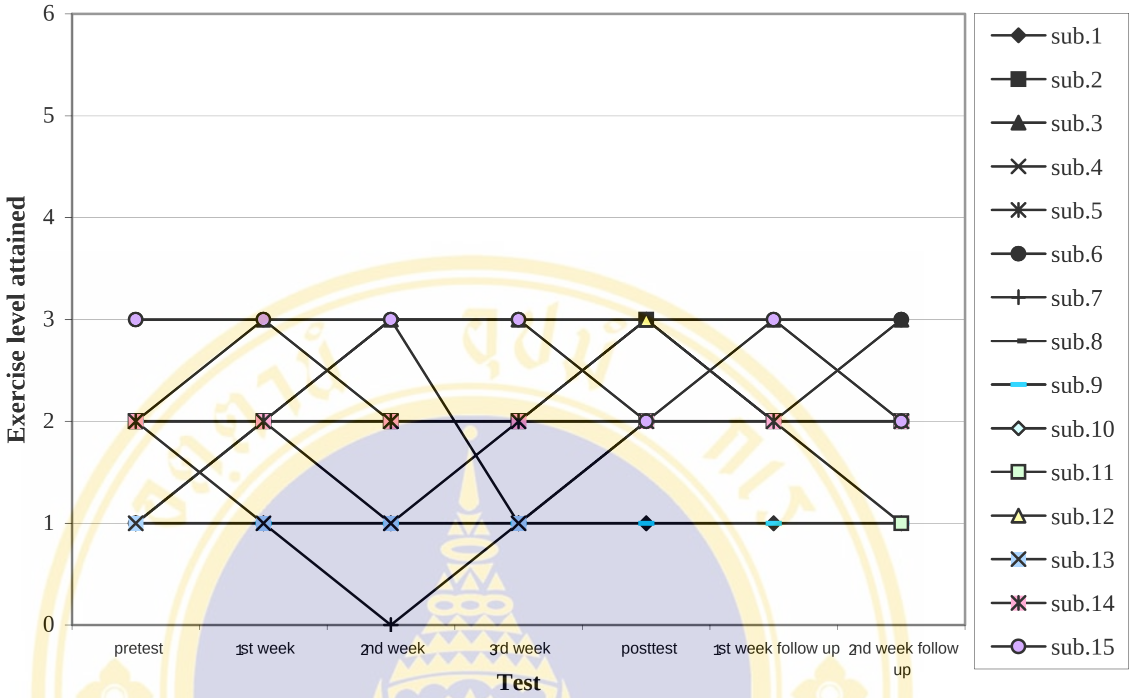

Figure 4.1 Exercise level attained in the control group with feedback.

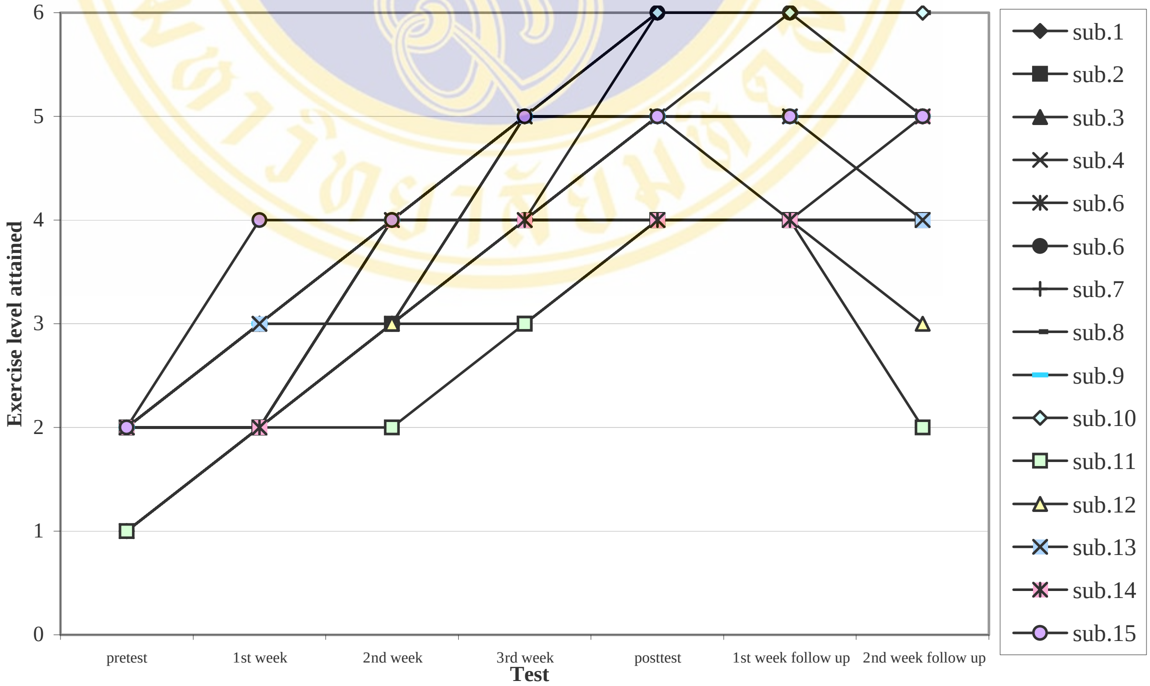

Figure 4.2 Exercise level attained in the exercise group with feedback.

The results of Friedman test demonstrated no significant difference in the control group, whereas there were significant differences in the exercise group. From multiple comparison of exercise group with feedback, the results showed significant differences between pretest and 3rd week testing, pretest and 1st week follow up, pretest and 2nd week follow up, 1st week testing and 3rd week testing, 1st week testing and posttest, 1st week testing and 1st week follow up, 1st week testing and 2nd week follow up, pretest and posttest as shown in Table 4.3.

4.3 Exercise Level Attained without Feedback

Medians and interquartile ranges of exercise level attained in each group at pretest, 1st, 2nd, 3rd week testing, posttest and follow up without feedback are presented in Tables 4.4, 4.5 and Figures 4.3, 4.4.

Table 4.4 Comparison of medians and interquartile ranges of exercise level attained in each group among pretest, 1st, 2nd, 3rd week testing, posttest, 1st and 2nd week followed up without feedback

Test	Group	
	Control	Exercise
	Median (Q_1,Q_3)	Median (Q_1,Q_3)
Pretest	1(1,2)	1(1,2)
1st week	1(0,1)	2(1,2)
2nd week	1(1,2)	2(2,3)
3rd week	1(1,2)	3(2,3)
Posttest	2(1,2)	3(2,4)
1st week follow up	1(1,2)	2(2,3)
2nd week follow up	1(1,2)	2(2,3)
p-value	0.065	0.0001*

p-value from Friedman test

*significant difference at $p < 0.05$

Table 4.5 Multiple comparison between testing sessions of exercise group without feedback

Test	Pretest	1st week	2nd week	3rd week	Posttest	1st week follow up	2nd week follow up
Pretest				*	*	*	*
1st week					*		

*significant difference at $p < 0.05$

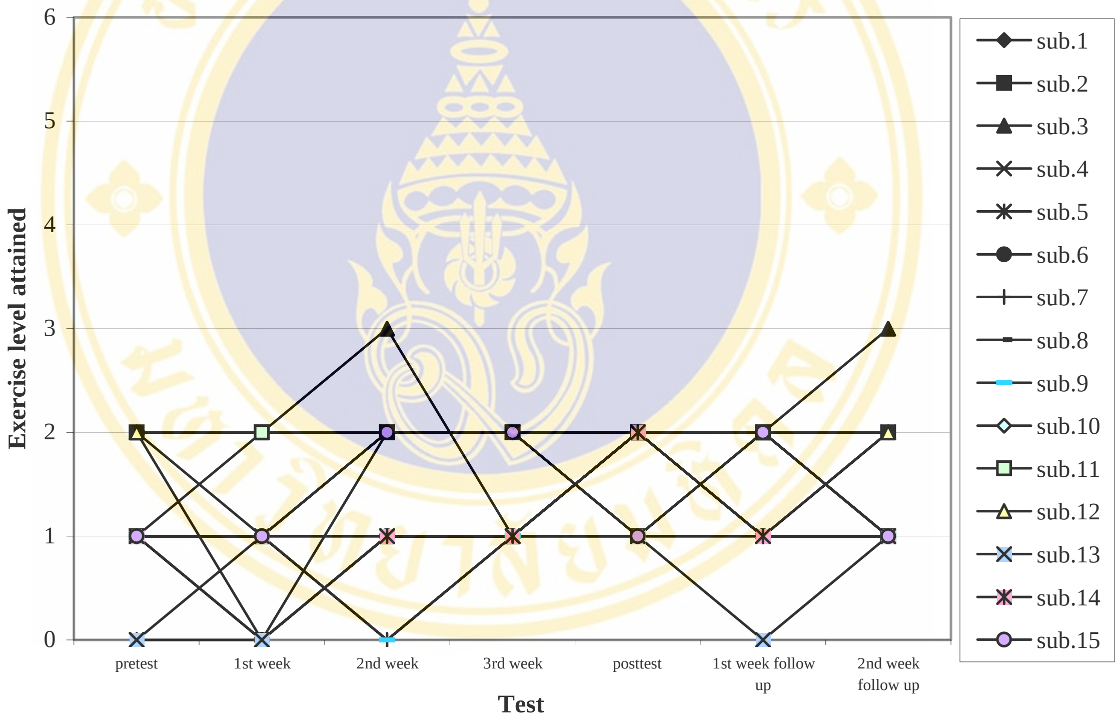

Figure 4.3 Exercise level attained in the control group without feedback.

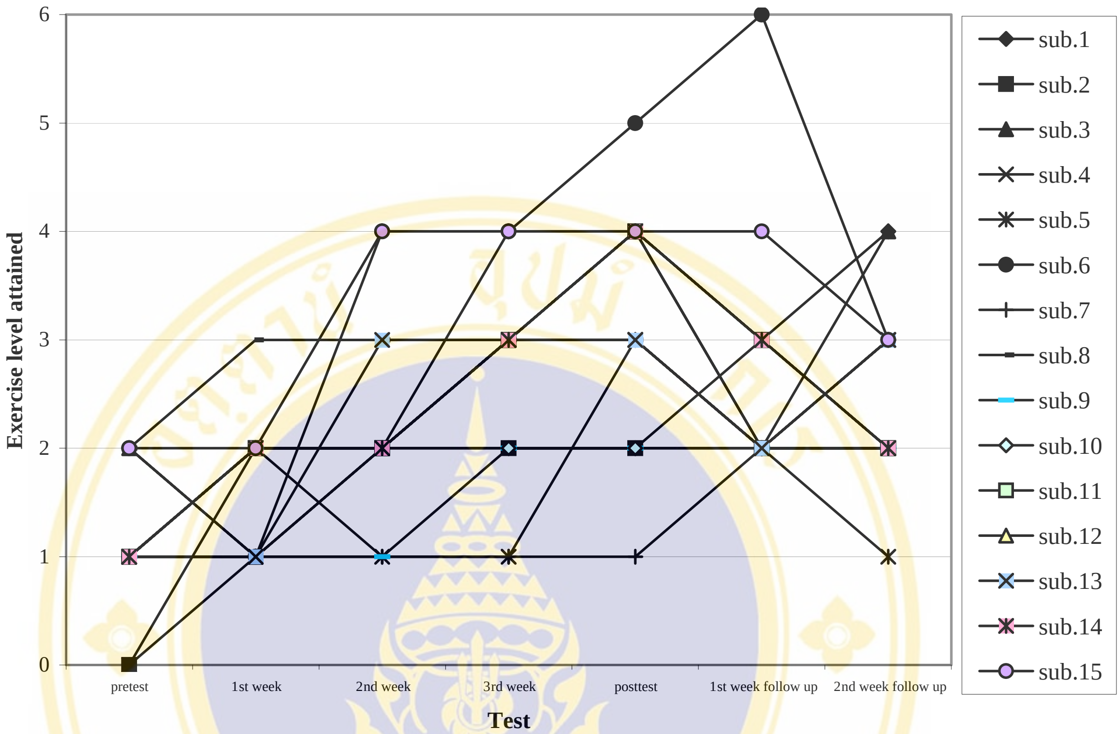

Figure 4.4 Exercise level attained in the exercise group without feedback.

The results of Friedman test demonstrated no significant difference in the control group, whereas there were significant differences in exercise group. From multiple comparison of exercise group without feedback, the results showed significant differences between pretest and 3rd week testing, pretest and 1st week follow up, pretest and 2nd week follow up, 1st week testing and posttest, pretest and posttest as shown in Table 4.5.

4.4 Exercise Level Attained with and without Feedback between Control and Exercise Groups

Medians and interquartile ranges of exercise level attained at pretest and posttest between control and exercise groups with feedback are presented in Table 4.6. Number of subjects in each exercise level with feedback of the control and exercise groups at pretest and posttest were shown in Figures 4.5 and 4.6, respectively.

Table 4.6 Comparison of medians and interquartile ranges of exercise level attained at pretest and posttest between control and exercise groups with feedback

	Control (n=15)	Exercise (n=15)	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	2(1,2)	2(1,2)	0.640
Posttest	2(2,2)	5(4,5)	0.0001*

p-value from Mann-Whitney U test

*significant difference at $p< 0.05$

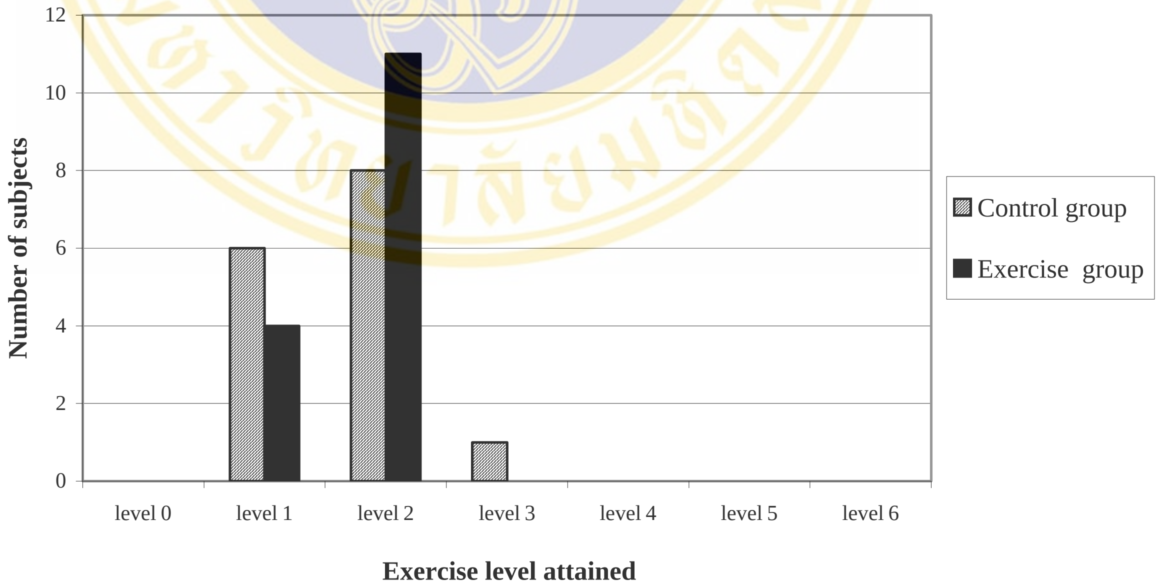

Figure 4.5 Number of subjects and exercise level attained in pretest with feedback of control and exercise groups.

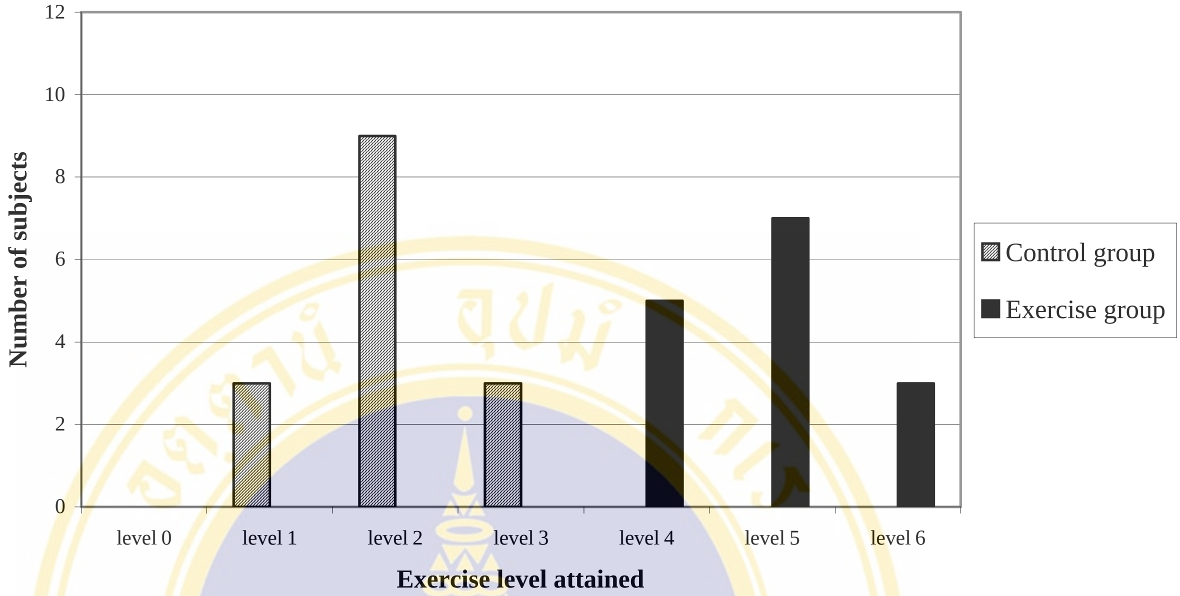

Figure 4.6 Number of subjects and exercise level attained in posttest with feedback of control and exercise groups.

The result of Mann-Whitney U test demonstrated no significant difference in pretest with feedback between control and exercise groups, whereas there were significant difference in posttest with feedback between control and exercise groups.

Medians and interquartile ranges of exercise level attained at pretest and posttest between control and exercise groups without feedback are presented in Table 4.7. Number of subjects in each exercise level without feedback of the control and exercise groups at pretest and posttest were shown in Figures 4.7 and 4.8, respectively.

Table 4.7 Comparison of medians and interquartile ranges of exercise level attained at pretest and posttest between control and exercise groups without feedback

	Control (n=15)	Exercise (n=15)	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	1(1,2)	1(1,2)	1.000
Posttest	2(1,2)	3(2,4)	0.0001*

p-value from Mann-Whitney U test

*significant difference at $p< 0.05$

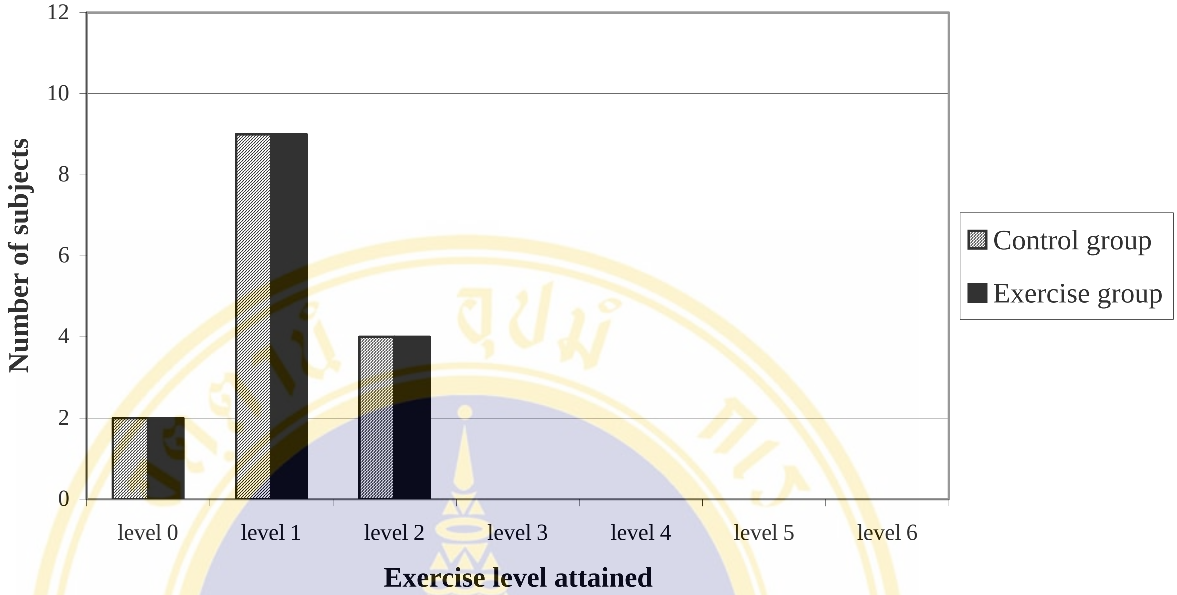

Figure 4.7 Number of subjects and exercise level attained in pretest without feedback of control and exercise groups.

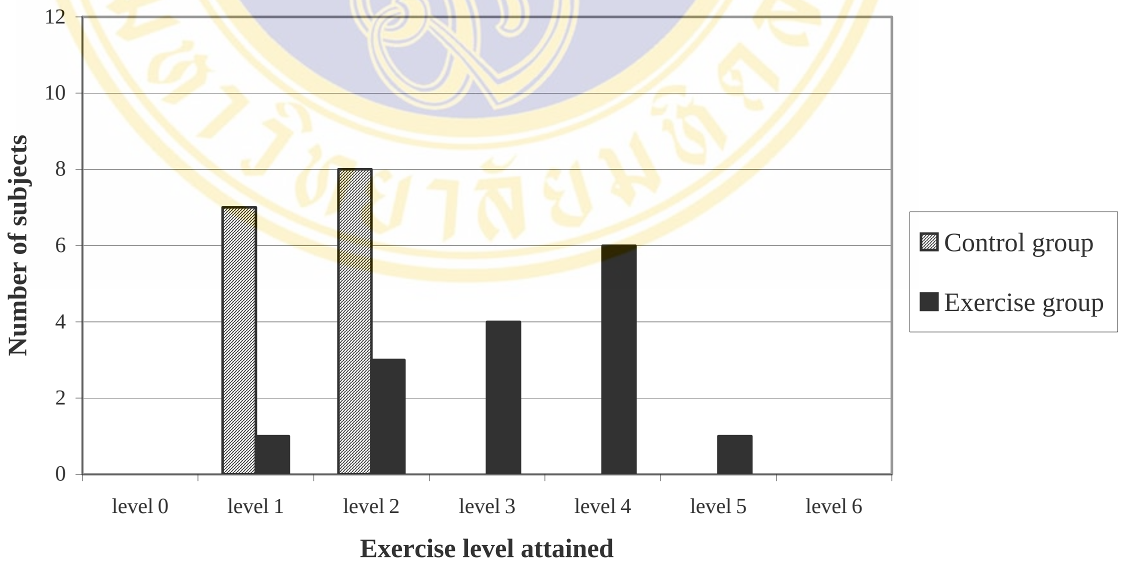

Figure 4.8 Number of subjects and exercise level attained in posttest without feedback of control and exercise groups.

4.5 Exercise Level Attained between with and without Feedback in Control and Exercise Groups

Medians and interquartile ranges of exercise level attained between with and without feedback in control group are presented in Table 4.8. and exercise group are presented in Table 4.9. Number of subjects in each exercise level in pretest and posttest for with and without feedback in the control and exercise groups were shown in Figures 4.9, 4.10, 4.11, and 4.12, respectively.

Table 4.8 Comparison of exercise level attained in control group between with and without feedback

	With feedback	Without feedback	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	2(1,2)	1(1,2)	0.011*
Posttest	2(2,2)	2(1,2)	0.008*

p-value for Wilcoxon Signed Rank test

*significant difference at p<0.05

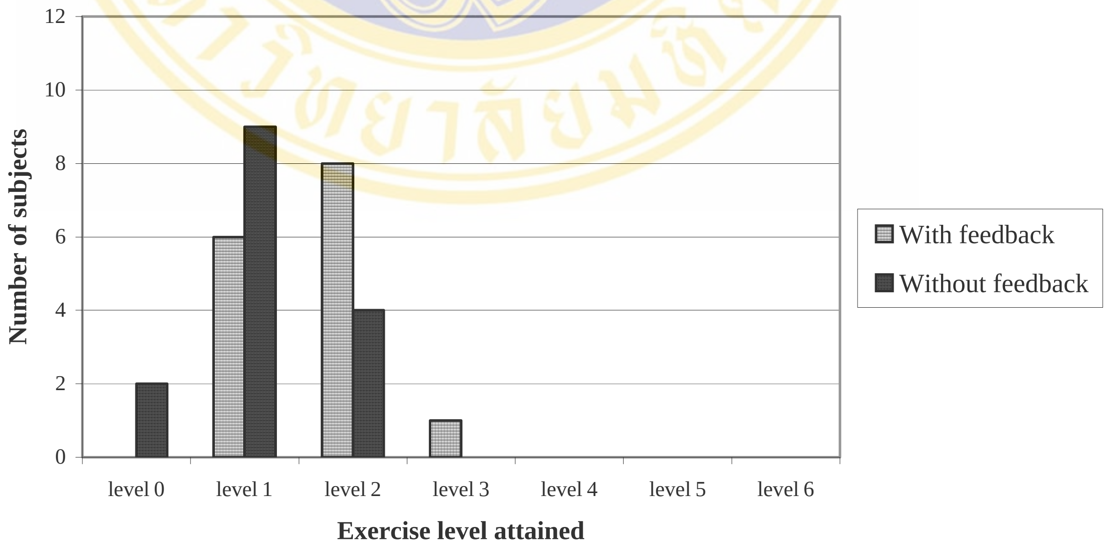

Figure 4.9 Number of subjects and exercise level attained in pretest for with and without feedback of control group.

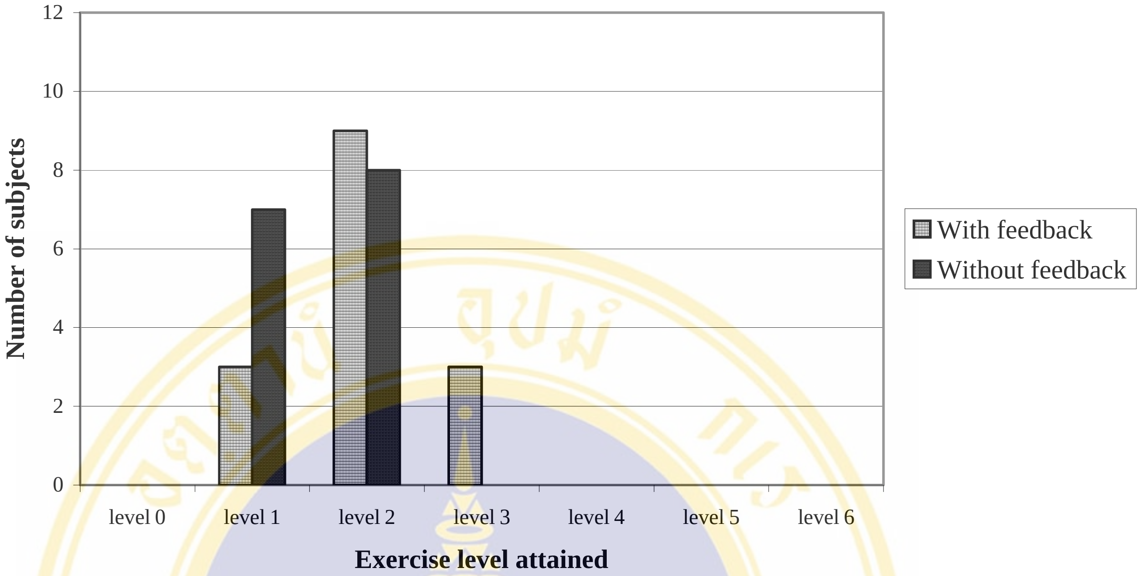

Figure 4.10 Number of subjects and exercise level attained in posttest for with and without feedback of control group.

Table 4.9 Comparison of exercise level attained in exercise group between with and without feedback

	With feedback	Without feedback	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	2(1,2)	1(1,2)	0.014*
Posttest	5(4,5)	3(2,4)	0.003*

p-value for Wilcoxon Signed Rank test

*significant difference at p<0.05

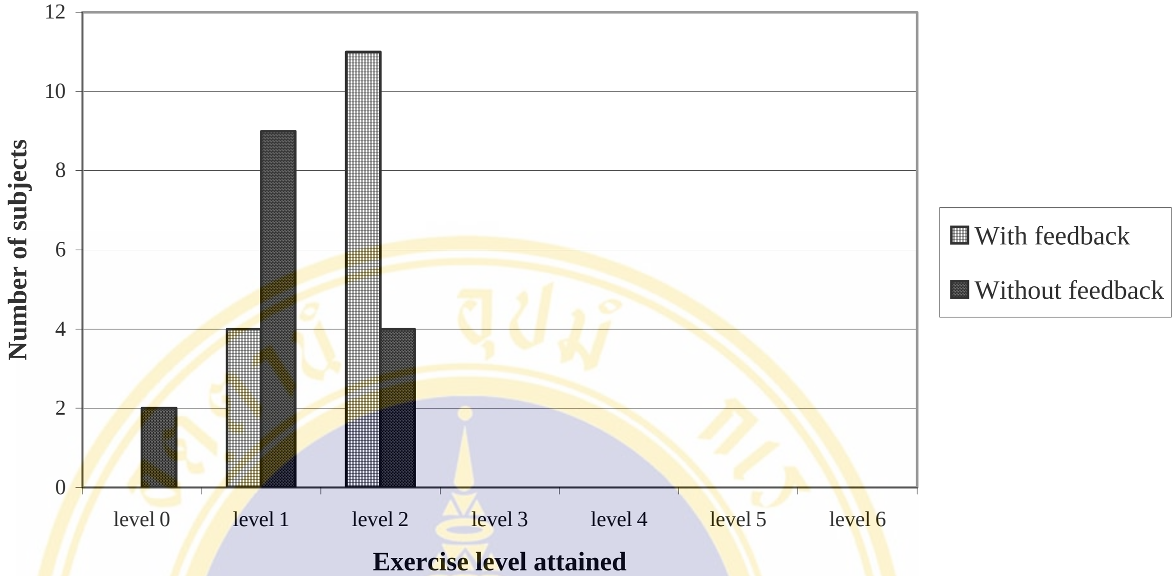

Figure 4.11 Number of subjects and exercise level attained in pretest for with and without feedback of exercise group.

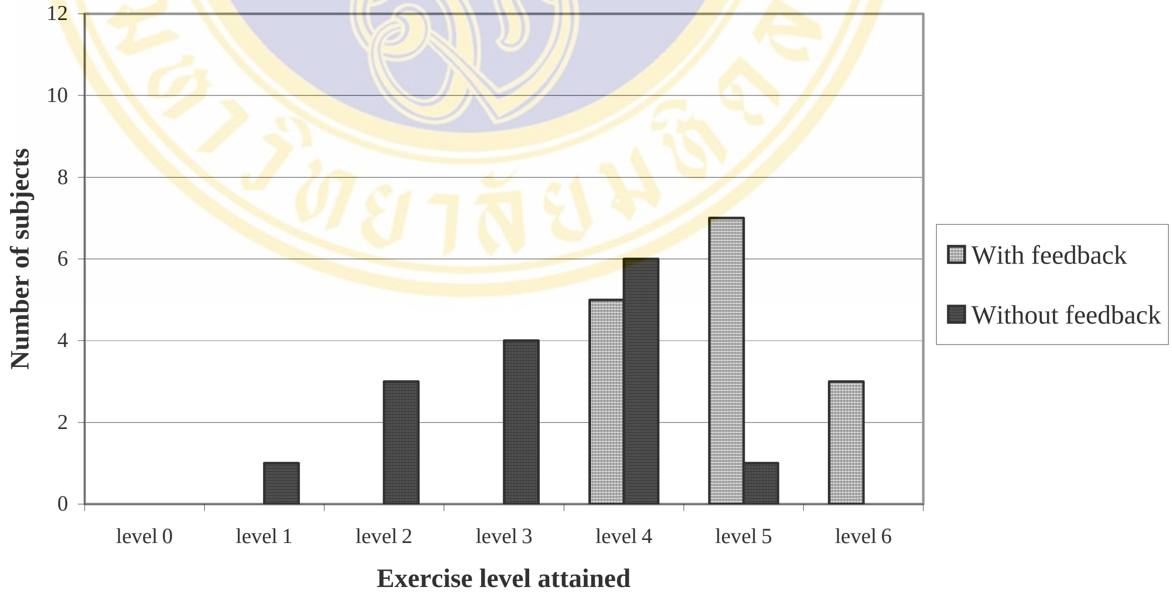

Figure 4.12 Number of subjects and exercise level attained in posttest for with and without feedback of exercise group.

The result of Wilcoxon Signed Rank test demonstrated significant differences in both pretest and posttest between with and without feedback in control and exercise group. The successful level of lumbar stabilization testing with feedback in both control and exercise group are higher than the successful level of lumbar stabilization testing without feedback in pretest and posttest.

CHAPTER V
DISCUSSION

5.1 Characteristics of Subjects and Stabilization Exercise Program

Subjects of control and exercise groups in this study had no significant difference in age, weight, height, and body mass index. The age range between 18 and 25 years was one of the inclusion criteria because it has been reported that at the age of 18 years their strength increases and muscle power is optimum peak at the age of 25 years (89).

All subjects in this study were physical therapy students. It could be assumed that their activities should be similar. During period of this investigation, the researcher told the subjects to do the same routine activities and avoid any other specific training programs. Moreover, the control and exercise groups were matched for sex, age, weight, height and BMI as much as possible. It was possible to conclude that the subjects participated in this study had similar characteristics. Therefore, the difference in exercise level attained after training program would be due to the effect of lumbar stabilization exercise training.

Lumbar stabilization exercises are common programs in the western countries (13). The frequency of exercise program for three times per week was selected to be closed to the realities of clinical practice. Specific frequency and duration of the exercise program are necessary. In 1994, Graves et al indicated that 12 weeks of pelvic stabilization is required to effectively train the lumbar extensor muscles (90). In 1997, O’ Sullivan et al indicated that a ten-week specific exercise treatment program could reduce pain intensity and functional disability levels in patients with chronic symptomatic spondylolysis or spondylolisthesis (4). In 1999, Hagins et al suggested that a four-week lumbar stabilization exercise program could improve the ability to perform progressively difficult lumbar stabilization exercises (13).

In 2003, Sung suggested a four-week spinal stabilization exercise program significantly improved functional status in patients presenting with chronic low back dysfunction (91). In 2003, Yilmaz et al indicated that the training for 8 weeks of dynamic lumbar stabilization exercises is an efficient and useful technique in the patients who have undergone microdisectomy (17). In 2004, Arokoski et al assessed the activities of paraspinal and abdominal muscles during three months of stabilization exercises for the treatment of patients with chronic low back pain. Their result showed no difference of electrical activity between chronic low back pain and healthy subjects after three months training (92). Therefore, this study selected duration for four weeks because the recent studies (13, 91) trained lumbar stabilization exercises for four weeks showed significant improvement in the ability to perform the exercise. In 1999, Hagins et al used modified isometric stability test (IST) to evaluate the effectiveness of practicing follow a four-week stabilization exercise program with weekly reinstruction and testing (13). Their result indicated that subjects could improve the ability to perform progressive lumbar stabilization exercise. Subjects who participated in their study were assigned for a home exercise program that consisted of 15 minutes for 3 levels of the modified IST. Handouts of specific exercise (modified IST) were given, which included written descriptions of 3 levels of exercise and direction how to perform. Their subjects performed the exercise three times per week at home which the exercise program was chosen to simulate the realities of clinical practices (13).

In this study, testing without feedback was performed before testing with feedback in order to prevent learning effect from testing with feedback. Subjects received lumbar stabilization exercise program three times per week and weekly testing but they performed exercise program at the laboratory. This might not be the realities of clinical practice but it could confirm that the exercise group performed the lumbar stabilization exercise accurately. Therefore, the findings of this study were the results from the effects of stabilization exercise.

5.2 Ability to Perform Lumbar Stabilization Exercise with Feedback

In the present study for between group differences, the median of exercise level attained at pretest with feedback that subjects were able to perform successfully. This was the same between control and exercise groups (p>0.05) (Table 4.6). However, at the posttest with feedback the result of the study showed subjects in exercise group could improve the ability to perform progressive lumbar stabilization exercise successfully than the control group (p=0.0001) (Table 4.6). Moreover, within group difference the exercise level attained with feedback of exercise group was highly significant increase (p=0.0001) (Table 4.2). The control group, however, had no significant increase (p>0.05) (Table 4.2), on the ability to perform lumbar stabilization exercise.

The finding of the present study supported the studies of Saal in 1989. They studied 64 patients with herniated lumbar intervertebral disc without stenosis who received dynamic lumbar stabilization exercises and back education. The result showed 90 % reported good or excellent functional outcome such as pain and functional disability level (11). In 1999, Hagins et al reported that at the end of the study, there was a tendency for individuals in the exercise group to perform more complex exercise successfully than those in the nonexercise group (13). In 2003, Yilmaz indicated that pain and functional disability significantly decreased after treatment with lumbar stabilization exercise for eight weeks (17).

As a result of exercise level attained with feedback in exercise group, the ability to perform the exercise increased especially in the second week, and also gradually increased in the third to fourth week. For the control group, exercise level attained with feedback slightly augmented in the fourth week but this increment did not demonstrate significant difference. Therefore, these results supported the effect of lumbar stabilization exercise training.

While performing the lumbar stabilization exercises and during testing sessions, the subject was required to perform the exercise without changing the pressure gauge dial from 40$\pm$4 mmHg and not allowed compensation to occur. The compensation included flexion and extension of the neck, elevation of the shoulders from the floor, elevation of rib cages, holding the breath, protrusion of the rectus abdominis, extension of lumbar spine and posterior tilting of the pelvis (6, 13). Pressure gauge errors or compensation error alone or concurrent between pressure gauge and compensation errors mean the failed test. The most common compensation errors were elevation of the rib cage, holding the breath, posterior tilting of pelvis, protrusion of rectus abdominis and elevation of the shoulders, respectively.

Many subjects were unable to successfully achieve the level because they held their breath or elevated rib cages. The pattern of breathing is important, the breathing with regular pattern should be demonstrated during performing lumbar stabilization exercise. In the testing session, a few subjects bypassed the level of exercise by breathing shallowly or rapidly. This condition should be reported as a failure because regular pattern of breathing should be controlled during lumbar stabilization exercises (13). Richardson et al in 1999 and O'Sullivan in 2000 had suggested including instruction of breathing control when attempting to reduce activities in the global muscles such as rectus abdominis muscles (6, 24, 93). In Pilates, breathing and movement are closely coordinated. Pilates is a fitness program that follow core strengthening principles (93, 94). Breathing control is both guiding principle and goal of Pilates method. Proper breathing guides everything in Pilates training. To breathe properly during Pilates exercise, one needs to fill the lungs completely and expanding them to their greatest capacity and then empty the lung of all air. The more deeply breathe in and the more fully exhale, the better will nourish and cleanse body (93).

The two compensations mostly occurred in this study were posterior pelvic tilt and protrusion of rectus abdominis as same as in the study of Hagins et al. Both compensation errors occur from overactivation of the rectus abdominis (13). Consequently, the rectus abdominis is a global muscle not local muscle, then the aims of stabilization training have to train the local muscle which was capable of controlling the stiffness of the spinal segment (6, 13). Releasing the rectus abdominis and voluntary contraction of the transversus abdominis and lumbar multifidus are the most difficult task in performing lumbar stabilization exercises (13).

The isolated contraction of these local muscles was taught by asking the subject to hollow the abdominal wall especially in the lower abdominal area without moving the vertebral column (6, 16). In this study, the researcher taught the subjects to perform co-contraction of transversus abdominis and lumbar multifidus by “draw your lower abdomen in and pull your navel up” while maintaining the spine in a static neutral position. However, it is not easy to perform this task. If the subject was unable to perform the isolated action of these local muscles, Richardson and Jull in 1995 suggested that the other techniques of facilitation and skill learning would be employed (16). 1) Using instructions, with cueing to correct action such as “draw your lower abdomen up and in” or “pull your navel up towards your spine” which can be used to cue the subject to the muscle action required. 2) The local muscles form a corset like structure which acts to tighten around the waist. The physical therapist should describe and demonstrate the muscle action to the subject. 3) The subject has to concentrate and focus on the accurate muscle action to be achieved. The deep muscle should be co-contraction while the other muscles of the body should be relaxed during this localized exercise. 4) Facilitation technique can help the subject to feel the muscle action required. These can include a deep but gentle manual pressure on the transversus abdominis or manual contact on the lumbar multifidus, or to combine the co-contraction with a contraction of pelvic floor muscles. Moreover, Norris in 2001 suggested that to reduce the recruitment of rectus abdominis and increase the contraction of transversus abdominis, low resistances and slow movements should be used (12).

5.3 Ability to Perform Lumbar Stabilization Exercise without Feedback

The present study found that at the pretest, the median values of successful exercise level attained without feedback of the control and exercise groups were not significantly different ($p>0.05$) (Table 4.7). For the posttest without feedback, the result of the study showed that exercise group could greatly improve the ability to perform progressive lumbar stabilization exercise compared to the control group ($p=0.0001$) (Table 4.7). Furthermore, within group difference, the exercise level attained without feedback in the control group demonstrated no significant difference on the ability to perform lumbar stabilization exercise (p>.05) (Table 4.4).

Although, the increment of exercise level attained without feedback between pretest and posttest in exercise group was increased smaller than with feedback, but the increase was significant difference. As a consequence, subjects should be encouraged to understand the correct position while perform the exercise. For this reason, the subject could perform the exercise without feedback.

Several studies supported about the ability to perform progressively difficult stabilization exercises with feedback by using a pressure transducer or stabilizer to detect motion of the lumbar spine for indicating changes in the pressure reading (6, 13, 16). However, the literature does not describe the ability to perform progressively difficult stabilization exercises when without feedback which invisible the pressure gauge while performing the test. Moreover, this study found that no significant difference between control and exercise groups in ability to perform lumbar stabilization exercise without feedback for the pretest. From the improvement of the ability to perform stabilization exercise without feedback in exercise group, this indicated that subjects could isolate the co-contraction of the local muscle system without global muscle substitution within a neutral lordosis of the lumbar spine. This approach is based on a motor learning model whereby the faulty movement pattern or patterns are identified and corrected. In addition, each component of the specific movement is isolated and should be retrained into functional tasks (24, 45, 85-87).

Ability to perform lumbar stabilization exercise without feedback could be explained base on a motor learning model. In the exercise group, at 1st and 2nd week testing without feedback, the results showed no significant improvement in ability to perform lumbar stabilization exercise. This may be due to, in the early training period, the subjects might be in the cognitive stage of motor learning. A high level of awareness is demanded by subjects in order that they isolate the co-contraction of the local muscle such as lumbar multifidus and transversus abdominis without global muscle substitution such as rectus abdominis. Therefore, in 1st and 2nd week testing, the subjects still depended on feedback. In 3rd week and posttest (4th week) without feedback, the subjects could perform the progressive lumbar stabilization exercise with significant improvement. These indicated the associative stage of motor learning model. The individual subject had determined the most effective way of doing lumbar stabilization exercise and started to make more subtle adjustments how to perform the lumbar stabilization exercise. For 1st and 2nd week follow up after completing the training program, the subjects still maintained progressive lumbar stabilization exercise without feedback. Although the training program had stopped, there were significantly improved the ability to perform progressive lumbar stabilization exercise when compared with pretest without feedback. These findings could be explained by the autonomous stage because the ability to perform progressive lumbar stabilization exercise has become automatic. As a result, these can be supported that the motor learning involved in the practice of this lumbar stabilization exercise (13). In addition, specific exercise intervention based on the motor learning model has been explained in the studies of chronic low back pain patients (4, 24, 45).

5.4 Exercise Level Attained between with and without Feedback in Control and Exercise Groups

The results showed significant difference between with and without feedback in control group both pretest (p=0.011) (Table 4.8) and posttest (p=0.008) (Table 4.8). Furthermore, there were significant differences between with and without feedback in exercise group both pretest (p=0.014) (Table 4.9) and posttest (p=0.003) (Table 4.9). In the pretest, when perform the lumbar stabilization exercise with feedback most subjects could get the higher level than pretest without feedback both control and exercise groups. This finding had also occurred at the posttest. The ability to perform progressive lumbar stabilization exercises without feedback found in this study were decreased when compare with ability to perform the exercise with feedback. This meant that the exercise with feedback assisted to perform the exercise successfully more than without feedback. These findings confirmed that the subject could get a higher level of exercise with feedback. Performing the exercise with feedback could reduce the compensatory movement. These results suggest that the feedback have benefit in stabilization exercise regarding to control compensatory movement and encourage the correct position while performing the exercise. From the present study, the exercise level attained both with and without feedback in the first and second week follow up dropped from the posttest. The exercise level attained without feedback decreased more than with feedback. While subjects performed the test with feedback, the feedback was used to control compensatory movements. Consequently, the reduction of exercise level attained with feedback was less than without feedback.

Exercise level attained without feedback would be a true score representing muscle performance when compare with exercise level attained with feedback since the subjects can not have feedback all the time in daily activity. Therefore, the use of feedback during exercise should gradually be withdraw.

The use of biofeedback unit or stabilizer may make the subject to correctly perform the stabilization exercise easier than not using the biofeedback (95). Biofeedback devices were used to help facilitate the activation of transversus abdominis and lumbar multifidus (6, 16). This may suggest that an increase in using a stabilizer to aid the performance of lumbar stabilization exercise is necessary, particularly without the guidance of physical therapist.

However, in the stabilization training, the subjects must be ensured to understand the correct position while performing the exercise. If subjects can perform the exercise with understanding and control neutral position of the spine while performing the exercise, the feedback is not necessary. In addition, the use of feedback while performing the exercise should be done in the early stage of training for encouraging the subjects to isolate the co-contraction of the local muscles system and control compensatory movements. After that, attempt to perform the exercise independently without feedback by encouraging the subjects to understand the correct position should be done all the time in daily activity. Finally, the subjects can isolate the co-contraction of the local muscle, maintain the spine in a neutral lordotic posture and regular pattern of breathing while perform daily activity such as sit to stand, walking, lifting etc. These can help isolate co-contraction of local muscle to occur automatically (24).

5.5 Clinical Implication and Further Studies

The finding of this study indicated that lumbar stabilization exercise program could improve the ability to perform progressive stabilization exercise in healthy subjects. Moreover, in the early stage of training the subjects might use feedback to help isolate the co-contraction of local muscle and control compensatory movements. Then, encourage the subjects to understand the correct position while perform the exercise and during daily activity. It is possible to use this exercise program in the case of lumbar instability including low back pain patients.

For further study, it is interesting to investigate the electromyographic activity of local muscle system during these lumbar stabilization exercises. The effects of lumbar stabilization exercise program should also be investigated in low back pain patients.

CHAPTER VI
CONCLUSION

The present study determined the effect of training during four weeks of lumbar stabilization exercise program with feedback in healthy subjects and to investigate the ability to perform lumbar stabilization exercise with and without feedback. Thirty healthy subjects with age ranged from 18 to 25 years participated in this study. Subjects were divided into two groups; control and exercise groups. The subjects in exercise group performed lumbar stabilization exercise program 3 times per week for 4 weeks while the control group received no exercise program. The parameter in this study was exercise level attained from 0 to 6 levels. The testings were conducted at pretest, 1^{st}, 2^{nd}, 3^{rd} week, posttest (4^{th} week), 1^{st} and 2^{nd} week after completing the training program.

The findings of this study accepted all hypotheses. In the control group, the results showed no significant differences of exercise level attained in individual with and without feedback whereas the exercise level attained with and without feedback of posttest were significantly higher than those of pretest in the exercise group. The exercise level attained with and without feedback of posttest in the exercise group were also significantly higher than those of posttest in the control group but no significant difference were found during pretest. Additionally, the exercise level attained with feedback was significantly higher than that of without feedback in both groups.

The results of this study indicated that training program of lumbar stabilization exercise three times per week was sufficient to improve the ability to perform progressive lumbar stabilization exercise in healthy subjects regardless of using the feedback. Therefore, performing the exercise with a neutral spine position should be encouraged during lumbar stabilization exercise in order to omit the use of feedback.

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APPENDIX

APPENDIX A
CONSENT FORM

วันที่………..เดือน………………………พ.ศ………..

ข้าพเจ้า……………………………...………..อายุ…..………..ปี อาศัยอยู่บ้านเลขที่……………… ถนน……………แขวง……………..เขต……………..….จังหวัด……………… โทรศัพท์………………… ได้ทราบรายละเอียดของโครงการวิจัยเรื่อง "ผลของการการออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอวต่อระดับความยากของท่าออกกำลังกายในคนสุขภาพดี" โดยข้าพเจ้าจะได้รับการตรวจประเมินสมรรถภาพร่างกายก่อนเข้าร่วมการวิจัย ดำเนินการฝึกโปรแกรมการออกกำลังกายเพื่อเพิ่มความมั่นคงใของข้อต่อกระดูกสันหลังระดับเอวเป็นเวลา 3 วัน/สัปดาห์ นาน 4 สัปดาห์ ทำการประเมินผลทุกสัปดาห์ และจะประเมินผลหลังจากเสร็จสิ้นโปรแกรมการฝึกในสัปดาห์ที่ 1 และ 2

ประโยชน์ที่ได้รับจากการวิจัยในครั้งนี้คือ ผลการศึกษาที่ได้สามารถที่จะเป็นตัวบอกถึงความมั่นคงของข้อต่อกระดูกสันหลังระดับเอวที่เพิ่มขึ้นและนำไปใช้ในทางคลินิกโดยใช้เป็นตัวอย่างโปรแกรมการออกกำลังกายเพื่อเพิ่มความมั่นคงของข้อต่อกระดูกสันหลังส่วนเอวแบบเพิ่มระดับความยาก (Guideline for exercise progression)

ข้าพเจ้ามีสิทธ์ที่จะงดเข้าร่วมโครงการวิจัยโดยมิต้องแจ้งให้ทราบล่วงหน้า โดยการงดเข้าร่วมวิจัยครั้งนี้จะไม่มีผลกระทบต่อข้าพเจ้า

ข้าพเจ้าได้ทราบจากผู้วิจัยว่าจะไม่เปิดเผยข้อมูลหรือผลการวิจัยของผู้เข้าร่วมวิจัยเป็นรายบุคคลต่อสาธารณะชน หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยจะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็วโดยไม่ปิดบัง

ข้าพเจ้าได้ทราบขั้นตอนในการตรวจประเมินสมรรถภาพร่างกาย วิธีการฝึก การประเมินผลและประโยชน์ที่จะได้รับจากการวิจัย และยินยอมเข้าร่วมในการวิจัยครั้งนี้ด้วยความสมัครใจ

ลงชื่อ...

(..)

ผู้เข้าร่วมวิจัย

ลงชื่อ...

(...)

หัวหน้าโครงการวิจัย

ลงชื่อ.......................................….. (พยาน)

ลงชื่อ......................................….. (พยาน)

APPENDIX B
ETHICAL COMMITTEE ON RESEARCH INVOLVING HUMAN SUBJECT

๒ ถนนพรานนก บางกอกน้อย กรุงเทพฯ ๑๐๗๐๐
โทร. (๖๖-๒) ๔๑๑-๑๔๒๙, ๔๑๑-๓๒๕๓
โทรสาร. (๖๖-๒) ๔๑๒-๑๓๗๑

2 PRANNOK Rd., BANGKOKNOI, BANGKOK 10700
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FAX : (66-2) 412-1371

Faculty of Medicine Siriraj Hospital
Mahidol University

The Ethical Committee on Research Involving Human Subject
Faculty of Medicine Siriraj Hospital, Mahidol University

No.39/2004

Protocol Title	Effects of Lumbar Stabilization Exercises on Exercise Level Attained in Healthy Subjects.
Protocol Number	--------
Principal Investigator	Miss. Sathaporn Thongjunjua
Name of Department	Orthopedic Surgery

The aforementioned project and informed consent have been reviewed and approved by the Ethical Committee, Faculty of Medicine Siriraj Hospital, Mahidol University, based on the Declaration of Helsinki on February 6, 2004

Signature of Chairman ....
(Prof. Sumalee Nimmannit)

Signature of Dean ....
(Clin. Prof. Piyasakol Sakolsatayadorn)

APPENDIX C

DATA COLLECTION FORM

☐ Exercise group

☐ Control group

เลขที่………………

1. ข้อมูลส่วนบุคคล

ชื่อ…………………………….. นามสกุล……………..……….. เพศ O ชาย O หญิง

ที่อยู่……………………………………………………………………………………..

โทรศัพท์…………………………………… E-mail address……………………………………….

วันเดือนปีเกิด…………………………………………. อายุ……….……ปี………..……..เดือน

อาชีพ……………………… ลักษณะงาน………………….. สถานภาพการสมรส…….……….

น้ำหนัก………….…….kg. ส่วนสูง………………..cm. BMI………………..Kg/m^2

ขาข้างถนัด…………… ชนิดของกีฬาที่เล่น…………………… เล่นมาเป็นเวลา…………………...

ออกกำลังกายอย่างน้อย 30 นาทีต่อเนื่องกันเป็นเวลา………………………ครั้งต่อสัปดาห์

คุณเคยมีอาการปวดหลังส่วนล่างในระยะเวลา 3 เดือนที่ผ่านมาหรือไม่

O ไม่เคย O เคย

คุณเคยได้รับการผ่าตัดช่องท้องหรือผ่าตัดหลังในระยะเวลา 1 ปีที่ผ่านมาหรือไม่

O ไม่เคย O เคย

คุณเคยได้รับการออกกำลังกายเพื่อเพิ่มความมั่นคงให้แก่ข้อต่อกระดูกสันหลังส่วนเอวมาก่อนหรือไม่

O ไม่เคย O เคย

คุณมีการจำกัดการเคลื่อนไหวของข้อสะโพก, ข้อเข่า หรือข้อเท้า หรือไม่

O ไม่มี O มี โปรดระบุ………………

คุณมีโรคประจำตัวหรือไม่

O ไม่มี O มี โปรดระบุ………………

2. Training before pretest (Date……/……./…….)

3. First week training

Exercises	Level	Time (minute)
1.		
2.		
3.		

Date of training: 1st……/……..…/………
2nd ……/…..…./………
3rd ……/…..…./………

4. Second week training

Exercises	Level	Time (minute)
1.		
2.		
3.		

Date of training: 1st……/……..…/………
2nd ……/…..…./………
3rd ……/……..…/………

5. Third week training

Exercises	Level	Time (minute)
1.		
2.		
3.		

Date of training: 1st ……/…..…./………
2nd ……./……..…/……...
3rd ……../……..…/……...

6. Fourth week training

Exercises	Level	Time (minute)
1.		
2.		
3.		

Date of training: 1st ……./……..…/………

2nd ……./……..…/………

3rd ……./……..…/………

7. Testing

Testing	**Level**	
	With feedback	Without feedback
Pretest (………/………/………)		
First week testing (………/………/………)		
Second week testing (………/………/………)		
Third week testing (………/………/………)		
Posttest (………/………/………)		
After training: First week testing (………/………/………)		
Second week testing (………/………/………)		

APPENDIX D
PICTURES OF LUMBAR STABILIZATION EXERCISE

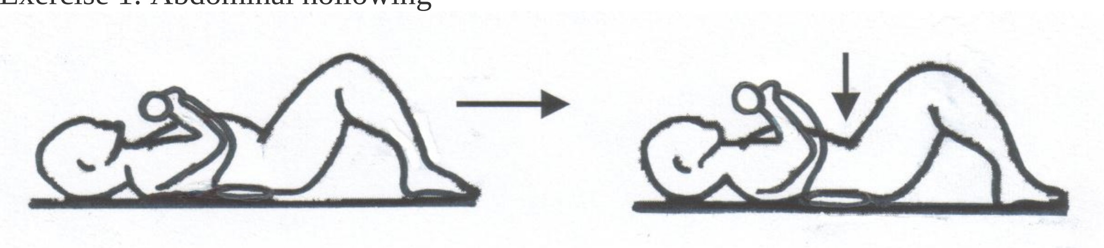
Training Before Pretest

A: Abdominal breathing

B: Quadruped abdominal hollowing

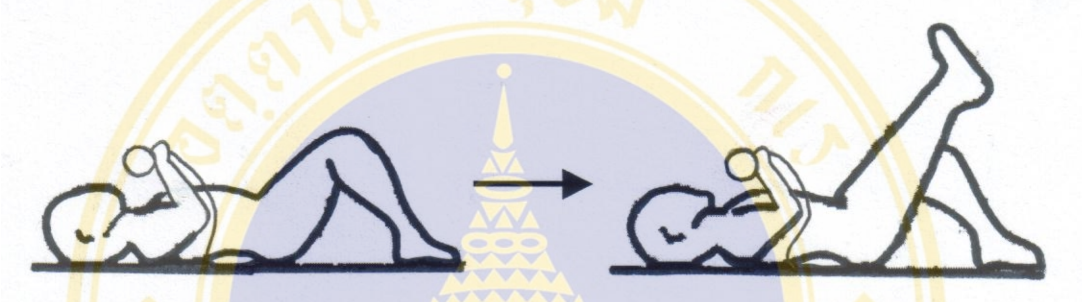
Lumbar Stabilization Exercise

Exercise 1: Abdominal hollowing

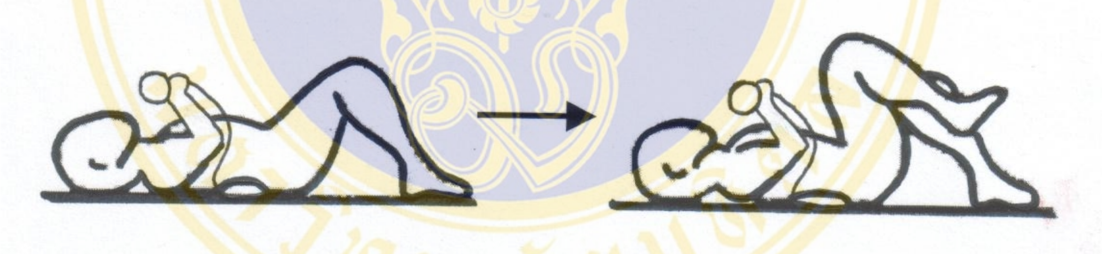


Exercise 2: Unilateral abduction

Exercise 3: Unilateral knee extension

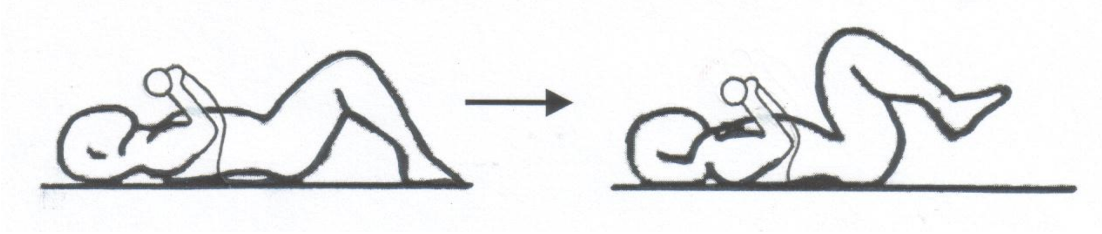


Exercise 4: Unilateral knee raise



Exercise 5: Bilateral knee raise

Exercise 6: Bilateral knee rise together



APPENDIX E

Glossary of Lumbar Stabilization Exercise (Thai)

A: Abdominal breathing	นอนหงายชันเข่า ให้เท้าวางราบกับพื้น จากนั้นให้นำหนังสือ (Textbook) ที่มีน้ำหนักประมาณ 1 กิโลกรัม วางที่ท้องบริเวณต่ำกว่าสะดือลงไป โดยมือข้างหนึ่งวางบนหน้าอก อีกข้างหนึ่งวางบนท้อง ในขณะที่หายใจเข้าพยายามให้หน้าอกอยู่กับที่ในขณะที่ท้องขยายออก และเมื่อหายใจออกให้ท้องยุบลง ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที
B: Quadruped abdominal hollowing	อยู่ในท่าตั้งคลาน ข้อไหล่และข้อสะโพกงอประมาณ 90 องศา กระดูกสันหลังอยู่ในแนวปกติ เมื่อหายใจเข้าพยายามให้หน้าท้องเคลื่อนที่มีทิศทางลงสู่พื้น เมื่อหายใจออกพยายามให้หน้าท้องเคลื่อนเข้าหากระดูกสันหลัง และไม่ให้มีการเคลื่อนไหวของกระดูกสันหลัง ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที
Exercise 1. Abdominal hollowing	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น วางมือข้างหนึ่งบนท้องระดับที่ต่ำกว่าสะดือ จากนั้นให้สังเกตการเกร็งของกล้ามเนื้อท้องขณะที่หายใจออก พยายามให้กล้ามเนื้อท้องเคลื่อนที่เข้าหากระดูกสันหลัง ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติ และควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที

Exercise 2. Unilateral abduction	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น ในขณะที่ทำการเกร็งกล้ามเนื้อท้อง ให้กางขาขวาออก 45 องศา ในขณะที่ขาซ้ายอยู่กับที่ จากนั้นให้เคลื่อนขาขวากลับสู่ท่าเริ่มต้น ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติและควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที
Exercise 3: Unilateral knee extension	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น ในขณะที่ทำการเกร็งกล้ามเนื้อท้อง เหยียดเข่าขวาขึ้นจนกระทั่งข้อเข่าเหยียดตรง โดยพยายามให้ต้นขาขวาอยู่ในระดับเดียวกับต้นขาซ้าย จากนั้นให้เคลื่อนขาขวากลับสู่ท่าเริ่มต้น ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติและควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที
Exercise 4: Unilateral knee raise	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น ในขณะที่ทำการเกร็งกล้ามเนื้อท้อง ให้งอเข่างอสะโพกข้างขวาขึ้นมาจะกระทั่งข้อสะโพกขวา งอประมาณ 90 องศา ในขณะที่ปล่อยข้อเข่าให้งอตามธรรมชาติ จากนั้นให้เคลื่อนขากลับสู่ท่าเริ่มต้น ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติและควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที

Exercise 5: Bilateral knee raise	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น ในขณะที่ทำการเกร็งกล้ามเนื้อท้อง ให้งอเข่างอสะโพกข้างขวาขึ้นมาจะกระทั่งข้อสะโพกขวา งอประมาณ 90 องศา ในขณะที่ปล่อยข้อเข่าให้งอตามธรรมชาติ ยกขาขวาค้างไว้ จากนั้นให้งอสะโพกซ้ายขึ้นมาจนกระทั่งข้อสะโพกงอ ประมาณ 90 องศา ในขณะที่ปล่อยข้อเข่าให้งอตามธรรมชาติ ซึ่งจะทำให้ขาทั้งสองข้างยกขึ้น จากนั้นยกขาขวาลงมายังท่าเริ่มต้น จากนั้นตามด้วยขาซ้าย ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติและควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที
Exercise 6: Bilateral knee rise together	นอนหงายชันเข่า โดยให้ข้อเข่างอประมาณ 90 องศา เท้าวางราบกับพื้น ในขณะที่ทำการเกร็งกล้ามเนื้อท้อง ให้งอข้อสะโพกทั้ง 2 ข้างขึ้นมาพร้อมกันที่ประมาณ 90 องศา โดยปล่อยให้ข้อเข่างอตามธรรมชาติ จากนั้นให้เคลื่อนขากลับสู่ท่าเริ่มต้น ให้พยายามทำท่านี้พร้อมกับควบคุมการหายใจให้เป็นปกติและควบคุมความดันให้อยู่ที่ 40±4 มิลลิเมตรปรอท ทำท่านี้ต่อเนื่องเป็นเวลา 5 นาที

APPENDIX F
INTRATESTER RELIABILITY

The purpose of this study was to determine test-retest reliability method of exercise level attained measurement.

Fourteen subjects consisted of four males and ten females, aged between 20 and 27 years participated in this study. All subjects received 10 minutes for training before by assuming test. Each subject performed the test supine with knees flexion approximately 90^{o} and feet flat on the floor (crook lying). Then subject raised the pelvic, so that researcher could place pressure transducer under low back at central from S_2 to approximately L_1. The pelvic was set into relaxed position and spine into neutral position. After that the researcher pumped up pressure to 40 mmHg. The subject handed pressure dial visible to both the subject and the researcher. Then the subject performed exercise level 1 (see method) and maintain pressure at 40 ($\pm$ 4 mmHg) in three cycle of breathing without compensation. If the subject was able to perform abdominal hollowing and maintain pressure at 40 $\pm$ 4 mmHg mean successful in this level. That subject would attempt to perform exercise level 2,3,4 etc. until the subject cannot perform the level of exercise successfully. The researcher determined the subject complete or incomplete exercise level. The subject test's score is the highest-level exercise, which the subject completed successfully. Each subject was tested for one trial. Fifteen minutes later, retest was performed at the same protocol as the test.

Kappa coefficient was used to determine the intratester reliability.

Table F.1 Exercise level attained in test and retest

Subjects No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Test	2	2	1	1	1	2	3	3	4	3	4	1	4	4
Retest	2	2	3	1	1	2	3	1	4	3	4	1	4	4

Table F.2 Test-retest repeatability of exercise level attained

Test	Retest							
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Row totals
Level 0	0	0	0	0	0	0	0	0
Level 1	0	3	0	1	0	0	0	4
Level 2	0	0	3	0	0	0	0	3
Level 3	0	1	0	2	0	0	0	3
Level 4	0	0	0	0	4	0	0	4
Level 5	0	0	0	0	0	0	0	0
Level 6	0	0	0	0	0	0	0	0
Column totals	0	4	3	3	4	0	0	14

Table F.3 Weighted Kappa coefficient of test-retest repeatability

Test-retest	Weighted Kappa
Trial	0.8082

Kappa coefficient showed almost perfect intratester reliability of test-retest reliability of the researcher in measure of exercise level attained. The Kappa coefficient was 0.8082 as shown in Table F.3.

APPENDIX G
RESULTS OF PILOT STUDY

The purpose of this pilot study was to compare the effects of practice during four weeks stabilization exercise program with weekly testing in with and without feedback between control and exercise groups. Four males and ten females aged between 21 and 23 years voluntarily participated in this pilot study. Subjects were divided into exercise or control group matching by age, weight, height, and BMI. Each group consisted of seven subjects, two males and five females. There were no significant differences in characteristics of subjects ($p>0.05$) as shown in Table G.1. Lumbar stabilization exercise was trained in exercise group 3 times per week for four weeks. Exercise level attained was tested at pretest, 1^{st}, 2^{nd}, 3^{rd} week testing, posttest and follow up testing with in 1^{st} and 2^{nd} week after completing the program in both groups. The lumbar stabilization exercise programs are explained in Appendix E.

The number of subjects and exercise level attained in pretest with and without feedback and posttest with and without feedback are shown in figures G.1-G. 4.

Within-group difference in exercise level attained among pretest, 1^{st}, 2^{nd}, 3^{rd} week testing and posttest were calculated by Friedman test and multiple comparison. Mann-Whitney U test was used to test for the between-group difference. Kolmogorov-Smirnov Goodness of Fit test was used to determine the distribution of the characteristics of subjects that showed normal distribution. The differences in subjects' characteristics between control and exercise groups were tested by independent sample t-test.

Medians and interquartile range of exercise level attained in each group among pretest, 1st, 2nd, 3rd week testing and posttest with and without feedback are presented in Tables G.2 and G.3. Between-group comparisons of exercise level attained at pretest and posttest for control and exercise groups with and without feedback are presented in Tables G.4 and G.5.

The results of pilot study demonstrated significant difference in exercise level attained among pretest, 1st, 2nd, 3rd week testing and posttest in exercise group with and without feedback ($p<0.05$, Tables G.2 and G.4). From multiple comparison of exercise group with feedback, the results showed significant difference between pretest and 3rd week testing, 1st week and posttest, pretest and posttest as shown in table G.3. Although the study demonstrated significant difference in exercise level attained among the testing session in exercise group without feedback, but the testing by multiple comparison did not indicate the significant difference between testing session. For the control group, there was no significant difference in exercise level attained among pretest, 1st, 2nd, 3rd week testing and posttest.

Between-group comparisons, There was no significant difference in exercise level attained between control and exercise groups both with and without feedback in pretest. There was significant difference in exercise level attained in posttest between control and exercise groups both with and without feedback ($p<0.05$, Tables G.5 and G.6).

Comparison between with and without feedback in exercise group, significant difference was found in exercise level attained in posttest ($p<0.05$, Table G.7). For pretest, there was no significant difference in exercise level attained between with and without feedback.

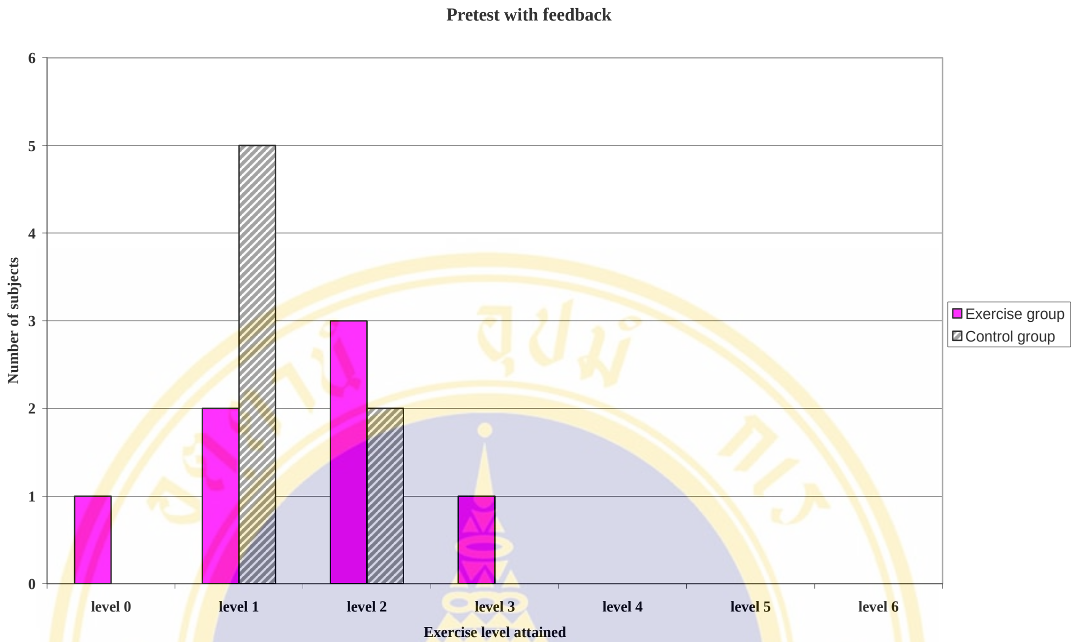


Figure G.1 Number of subjects and exercise level attained in pretest with feedback of control (n=7) and exercise (n=7) groups.

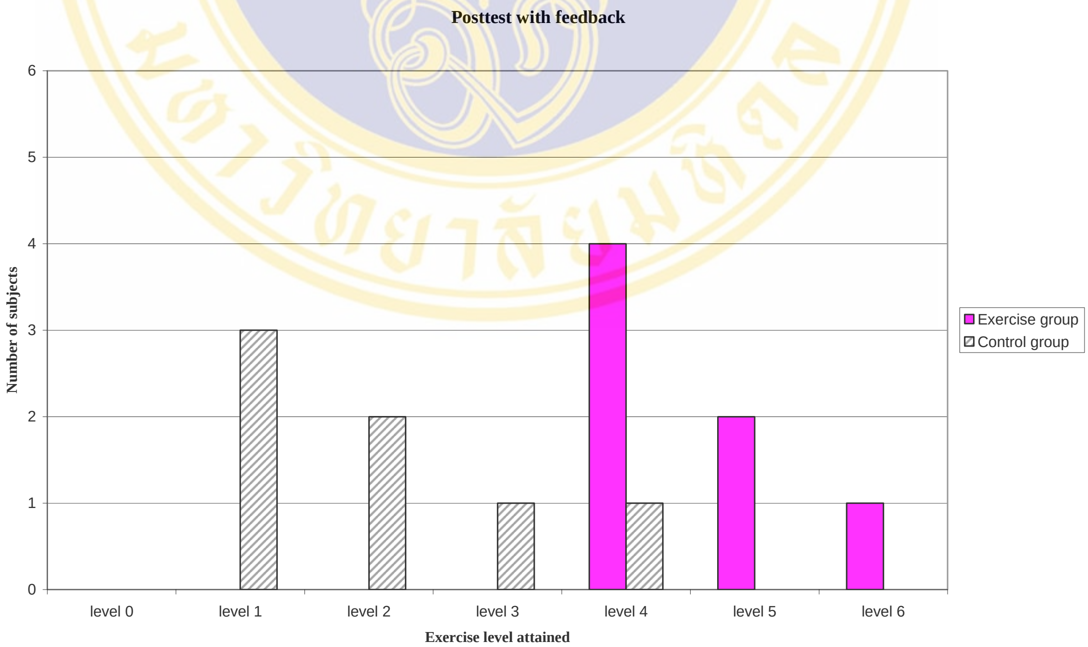


Figure G.2 Number of subjects and exercise level attained in posttest with feedback of control (n=7) and exercise (n=7) groups.

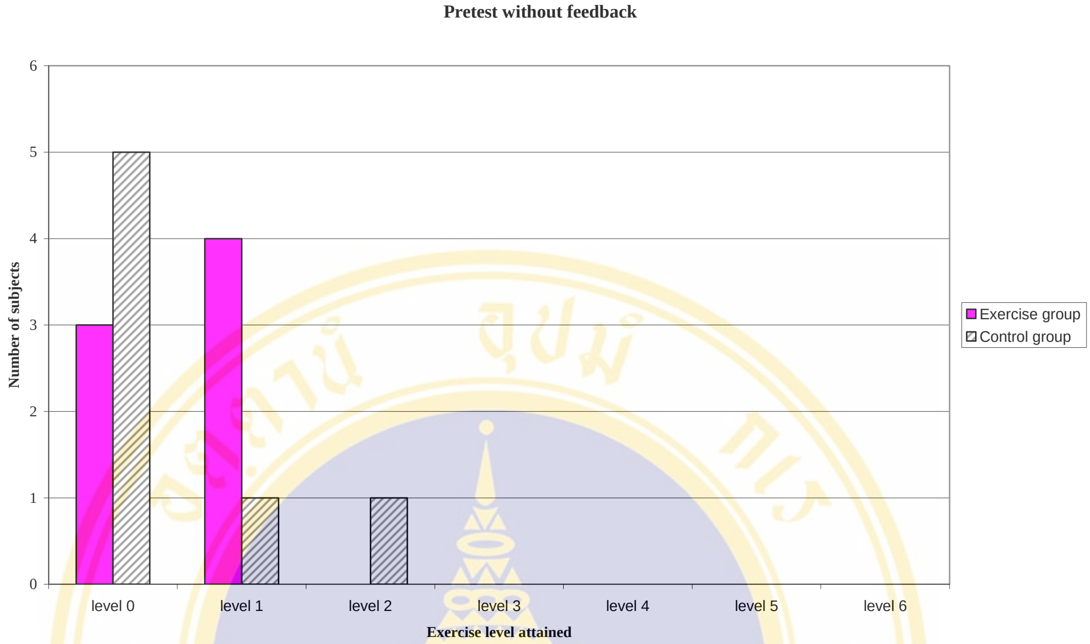


Figure G.3 Number of subjects and exercise level attained in pretest without feedback of control (n=7) and exercise (n=7) groups.

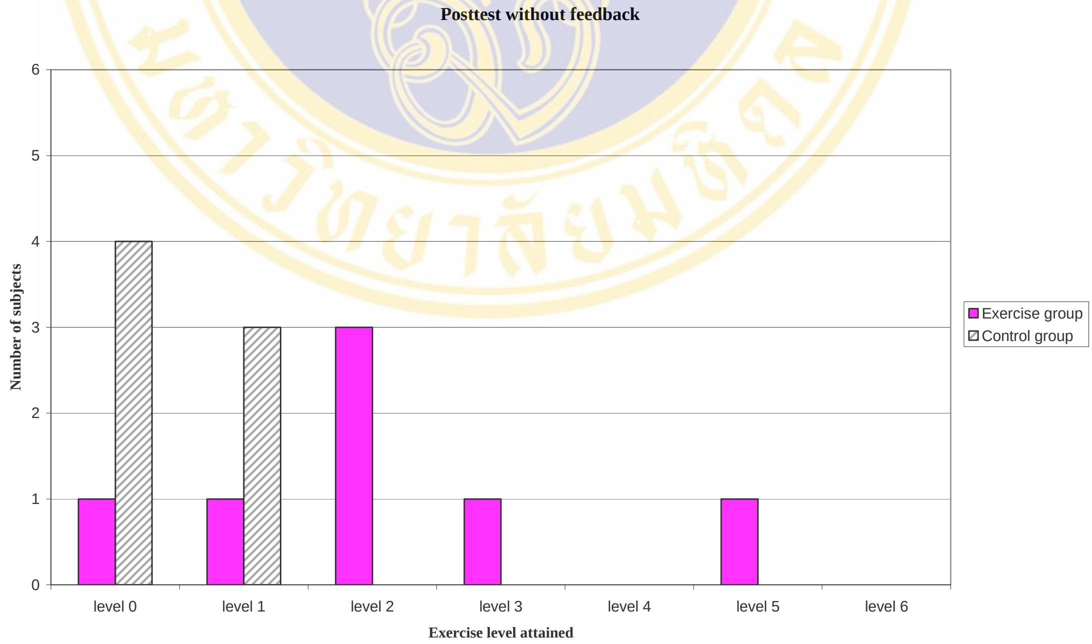


Figure G.4 Number of subjects and exercise level attained in posttest without feedback of control (n=7) and exercise (n=7) groups.

Table G.1 Comparison of means and standard deviations of age, weight, height, and BMI between control and exercise groups

Group	Control group (n=7)		Exercise group (n=7)		p-value*
	mean	SD	mean	SD	
Age (yrs)	22.36	0.93	22.34	0.79	0.977
Weight (kg)	50.43	4.69	51.51	5.56	0.700
Height (cm)	162.29	6.07	165.14	7.84	0.462
BMI (kg/m^2)	19.14	1.46	18.90	1.76	0.780

* p-value from independent sample t-test

Table G.2 Comparison of medians and interquartile range of exercise level attained in each group among pretest, 1st, 2nd, 3rd week testing and posttest with feedback

Test	Group	
	Control	Exercise
	Median (Q_1,Q_3)	Median (Q_1,Q_3)
Pretest	1(1,2)	2(1,2)
1st week	1(1,2)	2(2,2)
2nd week	1(1,2)	3(2,3)
3rd week	2(1,2)	4(3,5)
Posttest	2(1,3)	4(4,5)
p-value	0.104	0.000*

p-value from Friedman test

* significant difference at $p<0.05$

Table G.3 Multiple comparisons between testing session of exercise group with feedback

Test	Pretest	1st week	2nd week	3rd week	Posttest
Pretest				*	*
1st week					*

* significant difference at $p<0.05$

Table G.4 Comparison of medians and interquartile range of exercise level attained in each group among pretest, 1st, 2nd, 3rd week testing and posttest without feedback

Test	Group	
	Control	Exercise
	Median (Q_1,Q_3)	Median (Q_1,Q_3)
Pretest	0(0,1)	1(0,1)
1st week	0(0,0)	1(1,2)
2nd week	0(0,1)	1(0,1)
3rd week	0(0,1)	0(0,2)
Posttest	0(0,1)	2(1,3)
p-value	0.715	0.046*

p-value from Friedman test

* significant difference at $p<0.05$

Table G.5 Comparison of exercise level attained at pretest and posttest between control and exercise groups with feedback

	Control (n=7)	Exercise (n=7)	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	1(1,2)	2(1,2)	0.441
Posttest	2(1,3)	4(4,5)	0.003*

p-value for Mann-Whitney U test

* significant difference at $p<0.05$

Table G.6 Comparison of exercise level attained at pretest and posttest between control and exercise groups without feedback

	Control (n=7)	Exercise (n=7)	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	0(0,1)	1(0,1)	0.467
Posttest	0(0,1)	2(1,3)	0.017*

p-value for Mann-Whitney U test

* significant difference at $p<0.05$

Table G.7 Comparison of exercise level attained in exercise group between with and without feedback

	With feedback	Without feedback	p-value
	Median (Q_1,Q_3)	Median (Q_1,Q_3)	
Pretest	2(1,2)	1(0,1)	.059
Posttest	4(4,5)	2(1,3)	.027*

p-value for Wilcoxon Signed Rank test

* significant difference at $p<0.05$

Sample Size Calculation

The sample size for this study was calculated by the following equation:

$$N = \frac{2S^2p\,[Z_{(1-\alpha/2)} + Z_{(1-\beta)}]^2}{(\mu_1-\mu_2)^2}$$

N = sample size for each subject group

S^2p = pooled variance

$$\frac{S_1^2 + S_2^2}{2} \quad , \text{if } n_1 = n_2$$

n_1 = number of subject of exercise group, who practice lumbar stabilization exercises program in the pilot study

n_2 = number of subject of control group in the pilot study

S_1^2 = variance of subject of exercise group, who practice lumbar stabilization exercises program in the pilot study

S_2^2 = variance of subject of control group in the pilot study

$Z_{(1-\alpha/2)}$ = Z-value when set the confident level equal to 95% or significant level equal to 0.05 (α=0.05) = 1.96

$Z_{(1-\beta)}$ = Z-value when set the power of testing equal to 80% (β=0.2) = 0.84

$\mu_1-\mu_2$ = the difference of means of parameter between exercise group, who practice lumbar stabilization exercises program and control group in the pilot study

A sample size was calculated from the above equation. Ten percentages were added to obtain the sample size of each group.

The data of exercise level attained were used to calculate the sample size. The appropriate sample size for each group in the present study was fifteen subjects.

APPENDIX H

RAW DATA OF THE STUDY

Table H.1 Characteristics of subjects in control and exercise groups

Subjects No.	Control group				Exercise group			
	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m^2)	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m^2)
1	21.17	50.00	156.00	20.55	21.58	53.00	157.00	21.50
2	21.00	50.00	155.00	20.81	21.33	53.00	156.00	21.78
3	23.00	58.00	156.00	23.83	21.25	64.00	160.00	25.00
4	21.75	65.00	180.00	20.06	23.08	55.00	165.00	20.20
5	22.83	47.00	163.00	17.69	21.67	50.00	167.00	17.93
6	21.58	56.00	160.00	21.88	22.75	52.00	155.00	21.64
7	23.42	65.00	172.00	21.97	22.08	67.00	175.00	21.88
8	21.42	62.00	162.00	23.62	23.00	73.00	174.00	24.11
9	23.17	66.00	173.00	22.31	25.17	60.00	167.00	21.51
10	22.25	56.00	165.00	20.57	21.42	50.00	155.00	20.81
11	21.33	54.00	160.00	21.09	20.92	56.00	163.00	21.08
12	23.33	43.00	160.00	16.80	23.92	44.00	160.00	17.19
13	23.33	60.00	160.00	23.44	23.92	63.00	160.00	24.61
14	24.75	50.00	167.00	17.93	22.58	47.00	162.00	17.91
15	23.75	56.50	170.00	19.55	22.50	47.00	161.00	18.13
Mean	22.54	55.90	163.93	20.81	22.48	55.60	162.47	21.02
SD	1.12	6.97	7.20	2.16	1.20	8.24	6.22	2.44

Table H.2 Exercise level attained with feedback in pretest, 1st, 2nd, 3rd week testing, and posttest, 1st and 2nd week follow up of control and exercise groups

Subj. No.	Exercise level attained													
	Control group							Exercise group						
	Week					Follow up		Week					Follow up	
	Pretest	1st	2nd	3rd	Posttest	1st week	2nd week	Pretest	1st	2nd	3rd	Posttest	1st week	2nd week
1	1	1	1	1	1	1	1	1	2	4	4	5	5	5
2	2	2	2	2	3	2	2	2	2	3	3	4	4	4
3	2	2	3	3	3	3	3	2	2	3	4	4	4	4
4	2	2	2	2	2	2	2	1	2	3	5	5	5	5
5	1	2	1	2	2	2	2	2	3	4	4	5	4	4
6	1	2	2	2	2	2	3	2	2	4	4	6	6	5
7	1	1	0	1	1	1	1	2	3	4	5	6	6	6
8	2	2	3	1	2	2	2	2	3	3	4	5	6	6
9	2	1	1	1	1	1	1	2	3	4	5	5	5	5
10	1	2	2	2	2	2	2	1	2	3	5	6	6	6
11	2	2	2	2	2	2	1	1	2	2	3	4	4	2
12	2	3	2	2	3	2	2	2	3	3	4	4	4	3
13	1	1	1	1	2	2	2	2	3	4	5	5	5	4
14	2	2	2	2	2	2	2	2	2	4	4	4	4	5
15	3	3	3	3	2	3	2	2	4	4	5	5	5	5
Median	2	2	2	2	2	2	2	2	2	4	4	5	5	5
Q_1,Q_3	1,2	1,2	1,2	1,2	2,2	2,2	1,2	1,2	2,3	3,4	4,5	4,5	4,6	4,5

Table H.3 Exercise level attained without feedback in pretest, 1st, 2nd, 3rd week testing, and posttest, 1st and 2nd week follow up of control and exercise groups

Subj. No.	Exercise level attained													
	Control group							Exercise group						
	Week					Follow up		Week					Follow up	
	Pretest	1st	2nd	3rd	Posttest	1st week	2nd week	Pretest	1st	2nd	3rd	Posttest	1st week	2nd week
1	1	1	1	1	1	1	1	1	2	2	4	4	2	4
2	2	2	2	2	2	2	2	0	2	2	2	2	3	2
3	2	2	3	1	2	2	3	2	1	2	3	4	3	4
4	1	0	2	2	2	2	1	1	2	2	3	3	2	3
5	0	1	1	1	2	1	2	0	1	1	1	3	2	1
6	1	0	1	1	1	1	1	2	1	4	4	5	6	3
7	1	1	0	1	1	1	1	1	1	1	1	1	2	3
8	2	0	1	1	2	1	1	2	3	3	3	3	2	2
9	1	1	0	1	1	1	1	1	2	1	2	2	2	2
10	1	1	2	2	2	1	2	1	2	2	2	2	2	2
11	1	2	2	2	1	2	1	1	2	2	3	4	2	2
12	2	1	1	1	2	2	2	1	1	2	3	4	3	2
13	0	0	1	1	1	0	1	1	1	3	3	3	2	3
14	1	1	1	1	2	1	1	1	2	2	3	4	3	2
15	1	1	2	2	1	2	1	2	2	4	4	4	4	3
Median	1	1	1	1	2	1	1	1	2	2	3	3	2	2
Q_1,Q_3	1,2	0,1	1,2	1,2	1,2	1,2	1,2	1,2	1,2	2,3	2,3	2,4	2,3	2,3

BIOGRAPHY

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