CHAPTER II
LITERATURE REVIEW

2.1 Spinal Stability

Stability is ability to keep position stable while weight bearing and antigravity posture[22]. Stability occurs when activating co-contraction, which is the contraction of antagonist muscle that surrounds proximal joint. Co-contraction is achieved by isometric holding against resistance and antigravity posture[23].

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, static and dynamic load[10].

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[7, 10] as well as to provide a stable base from which the limb can move[7].

Panjabi[10, 11, 24] introduces 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 patients. This model consists of 3 subsystems: (1) passive, (2) active, and (3) neural control[10, 11, 16, 24-26].

2.2.1 The Passive Subsystem

The passive subsystem consists of the vertebral bodies, facet joints and joint capsules, intervertebral discs, spinal ligaments and passive tension from the musculotendinious units[7, 10, 24], and their control of segmental movement, not only at end of range, but particularly around the neutral joint position[11]. 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[10, 11].

The posterior ligaments of the spine including 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[27, 28]. Primarily stabilized at end range extension is the anterior longitudinal ligament, the anterior aspect of the annulus fibrosus, and the zyapophyseal joints[29, 30]. Rotational movements of the lumbar spine, stabilized mostly by intervertebral discs and the zygapophyseal joints[24]. 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[31].

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[10, 31, 32]. 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[32, 33].

Injury to the passive subsystem may have important implications for spinal stability[24]. 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[34, 35].

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[10]. The active and neural control subsystems are primarily responsible for spinal stability in the neutral zone, where passive resistance to movement is minimal[10, 30].

Differing roles have been suggested for the deeper, unisegmental muscles and the more superficial multisegmental muscles such as the abdominal and erector spinae muscles[36]. 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[10].

The multisegmental muscles are responsible for producing and controlling movements of the lumbar spine[24]. Lifting and rotational movements have been studied most extensively because these are tasks frequently performed by the lumbar spine[24]. The lumbar erector spinae muscle group provides most of extensor force required for most lifting tasks[37]. Rotation is produced primarily by the oblique abdominal muscles[24]. The oblique abdominals and the majority of the lumbar erector spinae muscle fibers lack direct attachment to the lumbar spinal motion segments and, there fore, are unable to exert forces directly on individual motion segments[24]. The multifidus muscle is better suited for the purpose of segmental control[38]. 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[24]. The multifidus muscle is proposed to function as a stabilizer during lifting and rotational movements of the lumbar spine[38].

2.2.3 The Neural Control Subsystem

The neural subsystem receives information from the various transducers, determines specific requirements for spinal stability, and causes the active subsystem to achieve the stability goal[10]. That 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[10, 39]. Individual muscle tension is measured and adjusted until the required stability is achieved[10]. 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[10].

The neural control system plays an important role in stabilizing the spine in anticipation of an applied load[24]. Hodges and Richardson[39, 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 system normally anticipates the need for stabilization against the reactive forces from limb movements[24]. In a study of patients with low back pain, the contraction of transverses abdominis muscles was delayed, possibly indicating deficient neural control[39].

2.3 Neutral Zone and 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 results in pain and disability or excessive range of motion without muscular control[11, 35, 41]. The neutral zone represents the range of motion that lack effective restraint, either active or passive. It is the vertebral displacement that occurs before resistance is offered. A large unstable spinal segment has quite a large neutral zone[41].

Nowadays, the muscles that have important role contributing to the local stabilizing system of the spine include transversus abdominis, lumbar multifidus, diaphragm and pelvic floor muscle. Evidence shows these muscles have a role to stabilize spine from two sources that is CNS control muscles and action of the muscles[11, 41].

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 stabilizes. Global stabilizers have a role in eccentrically decelerating momentum. These muscles during movement also provide rotational control[12, 42]. Global muscle system consists of the large, more superficial muscles 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[11]. 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 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[9, 11, 26, 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[12, 42]. 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 spine segmental. The local muscle system includes deep muscles, which have origin or insertion at lumbar vertebrae[11]. The local muscle system includes lumbar multifidus, transversus abdominis, psoas major, medial fibres of quadratus lumborum, diaphragm, lumbar portion of iliocostalis lumborum and longissimus thoracis, and oblique abdominal internus (fibre insertion into thoraco lumbar fascia)[9, 11, 26, 43].

Stability of back is provided by muscular contraction. This muscle system is often affected 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 transversus abdominis muscle (TrA) and multifidus muscle[9, 25, 26, 40, 44-47]. The function of these two muscle groups become poor in low back pain patients[39, 40, 48]. A recent study has showed that in normal subject the transverse abdominis is activated before muscle of the arms or legs while the extremities perform reaching tasks[25, 40]. This has been described by feed-forward mechanism, providing increrased spinal stiffness before loading[9].

Richardson (1990)[49] has reported that the abdominal muscles with a prime stabilizing role are considered to be the internal and external oblique abdominal and transversus abdominis rather than the rectus abdominis.

Moreover, Jull (1993)[50] has said that 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 use primarily on activity in the internal and external abdominal oblique. Obviously, many researchers and clinicians have suggested the importance of this active stability role of the oblique abdominal as well as the transversus abdominis[15, 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 help 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[11].

When the transversus abdominis contracts bilaterally it produces a drawing in 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 transversus abdominis has been suggestion to contributes to both supporting and torque-producing roles[11, 58]. These include control of the abdominal contents, contributes to respiration by increasing expiratory air flow rate[59], decreasing end expiratory lung volume[60] and defending the length of the diaphragm[61]. The production of trunk extension is maintaining the stability of the spine which against external forces causing the spine to flex, and the production of trunk rotation[11].

Recent evidence indicates that the lumbar multifidus (LM)[46] and transversus abdominis muscle (TrA)[62, 63] may be involved in controlling spinal stability. Cresswell and his colleagues[63] chose to use this principle by adding a load to the trunk. A harness, to which a weight could be attached ventrally or dorsally to force the trunk in to flexion or extension, respectively, 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. So, 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 that the transversus abdominis was the first muscle contracted actively. 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 provided important information about the potential for pre-programmed activation of the transversus abdominis to prepare the spine for perturbation.

Activation of feed-forward or pre-programmed strategy used by the CNS to control spinal stability[11]. That is transversus abdominis is active before the prime mover of the limb[40].

Hodge and Richardson[40] have evaluated the sequences of activation of the abdominal muscles and the lumbar multifidus during the performance of hip movement following prior weight shift over the supporting limb. The result of the study confirms the hypothesis that the transversus abdominis is invariably the first muscle that is active during movement of a lower limb following contralateral weight shifting. This finding is consistent with the results of the previously mentioned trunk loading study of Cresswell et al[63]. Because the contraction of this muscle occurs prior to movement of the limb, the transversus abdominis 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[11]. 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. In a very recent study, it has shown that the deep fibres of the multifidus respond in a similar tonic manner[11].

In 1997, Hodge and Richardson[56] 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.

Many studies confirm that the activation of the transversus abdominis is linked with the control of reactive movements produced by limb movement and not due to some other factor. In the study about relationship between limb movement speed and associated contraction of the trunk muscles[64], subjects were requested to move their arm at different speeds including 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 feed-forward manner with fast and natural movements but was not active with slow movements. And in the study of Hodge and Gandivia, subjects performed movement of the shoulder, elbow, wrist and thumb. The transversus abdominis was active only with elbow and shoulder movement. This two finding indicate that the contraction of the transversus abdominis is dependent on the magnitude of the reactive forces, and that this feed-forward activity is linked with the control of spinal stability[11]. 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 so greater forces would be transmitted to the spine with movement of this type[11]. Whereas the transversus abdominis was active approximately 30 millisecond before the prime mover of the shoulder, this period increased to 110 millisecond with leg movement. This finding supports that the transversus abdominis is active in the control of spinal stability[11].

Moreover, Hodge and his colleagues [57] had compared activation of transversus abdominis muscle in four conditions. The conditions are quiet breating; inspiratory loading; voluntary forceful expiration below FRC; 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 received a visual signal to flex their shoulder rapidly, an increase in transversus abdominis EMG occurred before contraction of deltoid. The activity of transversus abdominis occurred 20$\pm$14 millisecond before the increase in deltoid EMG. When subjects breathed with an inspiratory load, the onset of the increase in transversus abdominis EMG forego that on deltoid EMG only when the movement occurred during the mid-expiratory phase of the respiratory cycle. In voluntary expiration below FRC, the onset of increased transversus abdominis EMG occurred before the increase in deltoid EMG when movement occurred during both mid- and end-expiratory phase of respiratory cycle. For static expulsive maneuver, the subjects stopped breathing, and all of the abdominal muscles contracted during a static expulsive maneuver. In contrast to the three earlier conditions, the onset of increased transversus abdominis EMG followed that of deltoid by 22$\pm$8 millisecond when the upper limb was moved[57].

The 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 transversus abdominis and internal abdominal oblique 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[63]. 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 transversus abdominis or internal abdominal oblique was delayed until after the onset of the movement. transversus abdominis and internal abdominal oblique 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 rectus abdominis or external abdominal oblique [62, 63].

2.4.4 Lumbar Multifidus

Lumbar multifidus is the largest and most medial of the lumbar back muscles[7, 11]. 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[38, 43, 65]. 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 zygaphyseal joints[38, 66]. The lumbar zygapophyseal joints are covered by the multifidus on all sides, except ventrally where the joints are indirect contract with the ligamentum flavum[66].

The lumbar multifidus muscle is primarily extensor of the spine when acting bilaterally[11]. In trunk flextion, the multifidus control 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[67]. The lumbar multifidus contribute to support and control of the orientation of the lumbar spine, and support or stabilize the lumbar segments[11]. The importance of their supporting functions 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[68-70]. 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[69, 71]. Multifidus muscle fibres have a large capillary network, with approximately four to five capillaries in contract with each muscle cell. The contraction of oxidative enzymes in all lumbar muscles is large and the endurance capacity is high[68]. 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[68].

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[10, 35]. The result of many studies found that the lumbar multifidus had the strongest influence on lumbar segmental stability[11]. Wilke and his colleagues[46] 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 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[72]. 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[11]. 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[73]. In fact, the multifidus is probably active in all antigravity activity[74, 75]. 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'[75]. 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[74, 75]. Extension of the trunk from the flexed position predictably evokes high levels of multifidus activity[74, 76]. Marked activity of the multifidus also occurs when the trunk is extended or hyperextended in the prone position[75-77]. The multifidus has been shown to be active bilaterally in both ipsilateral and contralateral rotation of the trunk in sitting and standing[74, 76, 77]. For this reason, it has been suggested that, during rotation, the multifidus acts as a stabilizer rather than as a prime mover[75].

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 up wards 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.

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[7]. Hodges and his colleagues 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 intra-abdominal pressure[78]. The previous evidence suggests that diaphragm activity may be associated with voluntary contraction of the transversus abdominis by drawing in the abdominal wall[79].

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 feed-forward 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[11]. In two additional studies, Richardson and his colleagues 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 while abdominal muscles contractions were performed was investigated using fine-wire electrodes inserted through the vaginal wall. Activation of the abdominal muscles resulted in an increased activation of pubococcygeus[11].

2.5 Spinal Stabilization Exercise Programs

Spinal stabilization exercise was based on gaining a co- contraction of the key local muscles which consist of the transversus abdominis and the lumbar mulitfidus. Action of these muscles increase tension in the thoracolumbar fascia and increase the intra-abdominal pressure. Spinal stabilization exercise is an isometric contraction of the transversus abdominis elicited by drawing in the abdominal wall combined with an isometric contraction of segmental levels of lumbar multifidus. This muscle co-contraction can be linked to activating a deep muscle corset to support the spinal segments and lumbopelvic region[11, 41].

2.5.1 Trunk Stabilization Exercises

2.5.1.1 Leg Loading Exercise[11]

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 give 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.

2.5.1.2 Trunk Inclination Exercise[11]

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

2.5.1.3 Formal Exercise Programs

Many researches suggest the spinal stabilization exercise program for increasing spinal stability such as the sit-up, curl-up, 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 knee raise, pelvic rock on wobble board, sitting by using a gym ball[3, 9, 11, 20, 21, 41, 80, 81].

2.5.1.4 Functional Exercise Programs

Functional exercise programs that are used to improve patient's activities daily living, work and sport constitute the final stage of rehabilitation. Training during high impact loading activities includes running and jumping. Training activities includes safe lifting, carrying and handling, or correction of styles in sport[11, 41].

For many years, physical therapists have focused on the muscular system when the patients have low back problem as lumbar instability[9, 11, 41, 82]. Physical therapists have treated lumbar instability with stabilization exercise programs to improve muscular control of the lumbar spine[9, 24, 47]. The concept of exercise program is the ability of muscular system to help maintain a neutral position of spine and to prevent hypermobility of lumbar segment. If muscular system weakness, can lead to high levels of repetitive injury and tissue damage[9].

Many exercise programs are used to improve trunk stability by training muscular control of the lumbar spine[3, 9, 11, 20, 41]. The patient attempts to perform gross isometric contraction of lumbar muscles while gradually increase loads by various extremity motions[9, 15, 20]. Goal of stabilization exercise of the motor system is to improve spinal stability[3, 9, 11, 16, 20, 41, 83].

Kennedy (1980)[15] reporting the term “dynamic abdominal bracing” (DAB) has been used to describe the maneuver which utilizes the intra-abdominal pressure mechanism to stabilize and protect the lumbar spine during movement and position of weight bearing. In 1982, Dr. 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[11].

Saal (1989)[13] 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 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% repeated good or excellent outcome with a 92% return to work. Of the patient returning to work, 90% returned to their previous work.

O’Sullivan (1997)[7] performed a randomized, test-retest study to determine the effectiveness of training specific muscles that provided 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. The study showed a decrease in pain intensity and functional disability levels in specific exercise group and no significant changes in the control group.

Cholewicki (1999)[84] examined the effects of intra-abdominal pressure and wearing an abdominal belt on lumbar spine stability by measuring trunk stiffness with a quick releases 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. And the intra-abdominal pressure was measured with an intra-gastric pressure transducer. The result indicated that both wearing an abdominal belt and raised IAP could each independently, or in combination, increase lumbar spine stability.

Hagins his colleagues (1999)[9] used modified isometric stability test 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 that subjects could improve the ability to perform progressively difficult lumbar stabilization exercises.

Vezina (2000)[85] evaluated activation amplitudes from 3 abdominal and 2 trunk extensor muscle sites in healthy subjects performing the pelvic tilt, abdominal hollowing, and level 1 of the trunk stability test (TST level 1) exercises. He compared 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 exercise 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.

Hobley-Kozey (2002)[86] evaluated the relative activation amplitudes from 3 abdominal and 2 trunk extensor muscle sites of subjects with low back pain (LBP) performing the pelvic tilt, abdominal hollowing, and level 1 of the trunk stability test (TST level 1) exercises. The researcher also compared the activation amplitudes among muscle sites and exercises. The result showed that the TST facilitated 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. The study suggested that 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.

Hides (2001)[19] found that specific localized exercise such as stabilization exercise can decrease recurrent low back pain.

Hammer[47] 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 performed specific localized exercises to restore the stabilizing protective function of the lumbar multifidus (LM) with co-contraction of the transversus abdominis muscle (TrA). All subjects were given a four-week exercise. Both two groups were followed by one and three-year questionnaires. Two to three years after treatment, the rate of recurrence of LBP in the specific exercise group was 35%, but 75% for the control group. The multifidus no longer showed weakness or atrophy in the specific exercise group.

2.5.2 Isometric Stability Test

In 1993, Wohlfahrt and his colleagues[87] designed a specific progressive exercises and this exercise has been called “Isometric Stability Test” (IST). The IST 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 a change in the pressure reading. The IST has measurement level 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[9, 87].

In 1999, Hagins and his colleagues[9] 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 that lumbar stability was improved. Modified IST is used to determine if subject can learn increasingly difficult lumbar stabilization exercises with training. The result indicates that the modified IST is 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[9].

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 also increased. Modified Isometric Stability Test (Modified IST) is thought to create a progressive increase in the magnitude of torque at each level[9].

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[9, 50, 87] and subject handed pressure dial visible to both subject and researcher. Subjects perform exercise level 1 and give manual pressure to air-filled bag until the pressure at 50 mmHg ($\pm$ 4 mmHg) for three cycle of breathing without compensation. If subjects are able to perform abdominal hollowing and maintain pressure at 50 $\pm$ 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[9].

Thongjunjua and her cilleagues (2007) have modified lumbar stabilization exercise which consists of six levels for progression exercise. 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. A series of six progressive exercises test (Level 1: Abdominal hollowing, Level 2: Unilateral abduction, Level 3: Unilateral knee extend, Level 4: Unilateral knee raise, Level 5: Bilateral knee raise and Level 6: Bilateral knee raise together) was designed orderly by increasing levels of muscular control of the lumbar spine for stability. The exercise is ordered according to the progression of the magnitude of torque at each level. The result showed that all subjects who were trained this exercise for four weeks, the spinal stability was significantly increased[20].

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

The specific exercise strategy for segmental stabilization was developed from several sources. It includes 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[11]. 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[11].

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 including 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; and 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[11].

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. On the other hand, a normal cognitive contraction of lumbar multifidus is accompanied by contraction of the transversus abdominis. This muscle co-contraction can be linked to activating a deep muscle corset to support the spinal segments and lumbopelvic region[11]. 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[11].

Two other muscle groups are activated in synergy with 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[78] 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[11].

The essential elements of the specific exercise strategy include: 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[11, 41, 88].

2.7 Diagnostic Assessment

Nowadays, the most direct diagnostic method of measuring motor-control deficits in the transversus abdominis and the final output of segmental levels of the multifidus are 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[11]. The second diagnostic method using a pressure biofeedback unit, 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 simultaneous 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 transversus 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 maneuver is documented using surface EMG[11].

2.7.1 Pressure Biofeedback Unit.

A pressure biofeedback unit consists of an inelastic, three-section air-filled bag, of 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. A pressures dial is used for reading the pressure in the bag for feedback about spinal 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. This device become general use for stabilization exercises for all part of the body. For example, it is used in assessing the action of abdominal drawing-in. A pressure biofeedback unit becomes the most important device to be used in treatment of problems in relation to the local muscle system in low back pain patients[11, 53].