CHAPTER 2

LITERATURE REVIEW

This chapter provides background information related to four outcome measures investigated in current study. It includes the lumbopelvic stability control, flexibility, pain and stress. Each topic discussed the principle, changes in low back pain patients, assessment method, and treatment technique.

2.1 Lumbopelvic stability control

Control of lumbopelvic stability has received much attention recently as it is suspected to be a cause of spinal injury and pain. This section reviews the principle of lumbopelvic stability control in both normal and low back pain. Assessment and treatment of lumbopelvic stability control were also presented.

2.1.1 Principle of lumbopelvic stability control

An innovative model of the control of lumbopelvic stability has been proposed by Panjabi (19). The model incorporates a passive subsystem, an active subsystem and a neural control subsystem. The passive subsystem incorporates the osseous, articular and spinal ligaments, all of which contribute to the control of spinal movement and stability towards the end of range of movement. Active subsystem refers to the forces-generating capacity of the muscle which provides the mechanical stability to the spine. However, the function of muscle is depended on the control subsystem. The neural control subsystem must sense the requirements of stability and plan strategies to meet those demands.

Injury and degenerative disease can affect any structures of the motion segment and can result in both abnormal segmental movement and muscle dysfunction. Panjabi (19) considers the segment's neutral zone as a sensitive region. It is a small range of displacement around the segment's neutral position where little resistance is offered by passive spinal restraints. The subtle movement in this region may increase with injury, disc degeneration, and weakness of the muscles (19).

Bergmark (20) in his dissertation on lumbar spine stability proposed a difference between local and global muscles. Global describes the large torque producing muscles linking the pelvis to the thoracic cage and provides general trunk stabilization. Such muscles balance external loads and in that way helps minimize the resulting forces on the spine. Local muscles refer to those attaching directly to the lumbar vertebrae. These muscles are considered to be responsible for segmental stability as well as controlling the positions of the lumbar segments.

Two local intrinsic lumbopelvic muscles have received attention specifically in the literature: the transverse abdominis (TrA) and the lumbar multifidus. TrA is a broad sheet-like muscle with extensive attachments to the lumbar vertebrae via the thoracolumbar fascia, and to the pelvis and rib cage. The muscle fibers have a relatively horizontal orientation and, therefore, have minimal ability to move the spine, although they may contribute to rotation. Contribution to spinal control is likely to involve modulation of intra-abdominal pressure (IAP) and tensioning the thoracolumbar fascia. TrA has been shown to be associated closely with control of IAP (21), and recent data confirm that spinal stiffness is increased by IAP. Fascial tension may restrict intervertebral motion directly or provide gentle segmental compression via the posterior layer of the thoracolumbar fascia. Recent porcine studies confirm that the combined effect of IAP and fascial tension is required for TrA to increase intervertebral stiffness, and the mechanical effect of its contraction is reduced if the fascial attachments are cut (22-24).

The lumbar multifidus has five fascicles that arise from the spinous process and lamina of each lumbar vertebra and descend in a caudo-lateral direction. The most superficial fibers cross up to five segments and attach caudally to the iliac and sacrum, whereas the deep fibers attach from the inferior border of a lamina and cross a minimum of two segments to attach on the mamillary process and facet joint capsule. The superficial fibers are distant from the centers of rotation of the lumbar vertebrae, have an extension moment arm, and can control the lumbar lordosis. By contrast, the deep fibers have a limited moment arm and a minor ability to extend the spine (8, 25, 26).

Lumbar multifidus muscles control intervertebral motion by generation of intervertebral compression. The proximity of deep multifidus to the center of rotation results in compression with minimal extension moment. In addition, multifidus may contribute to the control of intervertebral motion by control of anterior rotation and translation of the vertebrae, or by tensioning the thoracolumbar fascia as it expands on contraction. Several studies have provided in vitro and in vivo evidence of the ability of multifidus to control intervertebral motion (27-29).

Although all muscles of the trunk have the potential to contribute to stabilization of the spine, recent evidence has indicated that transverses abdominis (TrA) may be crucially important (23, 24). The result of TrA contraction is primarily an increase in tension in the thoracolumbar fascia (30) and the production of intra-abdominal pressure (23). Cresswell and colleagues (23) have shown that under a variety of conditions changes in intra-abdominal pressure are most closely governed by TrA. Both these actions have been suggested to contribute to increased stability of the lumbar spine (23, 31).

TrA actives in a feedforward manner, the contraction of muscle prior to the movement of a limb may contribute to the control of stability of the adjacent joints in addition to controlling the position of the centre of gravity within the base of support. When the stability of the lumbar spine is challenged by rapid motion of the upper limb, TrA is the first trunk muscle active and the onset of its activity is not significantly affected by the direction of the reactive forces due to changes in the direction of movement of the limb. It is suggested that this muscle may contribute to the control of trunk stability (32).

Activation of TrA which remote from movement of the limbs and trunk occurs under a variety of circumstances, often before the movement is initiated. This muscle activity prior to limb movement is considered to prepare the body for the impending disturbance to the position of the centre of gravity relative to the base of support (33) and the reactive forces imposed on adjacent segments (34-36).

2.1.2 Change of lumbopelvic stability control in chronic low back pain

The control of lumbopelvic stability in chronic low back pain was observed in many studies (37, 38). Factors affecting lumbopelvic stability control included feedforward control, feedback-mediated control, dysfunction of diaphragm, pelvic floor and multifidus, fatiguability, muscle composition, size and consistency.

Changes in feedforward control

Feedforward strategies are preplanned by the nervous system and represent the pattern of muscle activity initiated by the central nervous system in advance of predictable challenges to lumbopelvic stability to prepare for the perturbation (39). However, this control strategy have changed and relevance with incidence of low back pain. Hodges and Richardson (37) have shown that activation of TrA has significantly delayed in low back pain patients and failed to occur in the preparatory period prior to movement of the arm and leg in all directions. Principally, the response of TrA contribute to lumbopelvic stability is independent on the direction of force acting on the spine. Nonetheless, the finding in low back pain has shown that the response of TrA is earlier with shoulder extension rather than other movement. This response is similar to the response of the superficial trunk muscles (37, 40).

The motor planning provides the preparation of movement. The delayed reaction time of arm movement was found when the preparation movement is reduced. However response of TrA is always earlier than other muscle (41). The motor planning for movement has been determined and supported with the study of transcranial magnetic stimulation of the motor cortex. The study confirmed that cortical inputs do contribute to the ongoing postural activity of TrA (42). The TrA activity in low back pain was studied when subjects performed the same task with difference in preparation movement. The result of this study displayed delayed response of TrA in all preparation movement such as shoulder flexion and abduction (38). This finding supported that motor planning of stabilizing control in low back pain have changed.

Changes in feedback-mediated control

Feedback-mediated strategies are the neural control system that initiates a response of the trunk muscles to afferent input from an unpredicted perturbation (43). The study of TrA response to unexpected perturbation has indicated changes in tasks that comprised of feedback contribution. Tonic activity, which isometric function of the TrA was observed during the study of feedback contribution that perform with hallowing the abdomen (44). The electromyographic activity in low back pain was changed during performing this task. Similar finding of reduction of tonic activity of TrA was found in experimental induced pain (45).

Identification of TrA changes can be done with ultrasound imaging. Changes in muscle thickness, fascicle pennation angle and fascicle length are related to muscle activity (46). Ferreira (47) demonstrated that there were autonomic recruitment of abdominal muscle including TrA when performed the gentle isometric leg efforts.

Normal abdominal muscles responded by increase thickness, conversely muscles of low back pain patients showed decrease in thickness including TrA.

Dysfunction of diaphragm and pelvic floor muscles

Although there is no direct study of the diaphragm and pelvic floor muscles in low back pain, the relationships of these two muscles were concerned with challenge in postural control. The changes in trunk control during increased respiratory demand are similar to low back pain patients. When the respiratory demand increased and the movement was initiated. Postural activity of TrA, diaphragm and pelvic floor muscles is reduced in association with rapid limb movement and support surface translation while global muscle activity is increased (38, 48). In addition pelvic floor muscle dysfunction has been observed in correlation with low back pain. The results report that individuals with incontinence have almost double the incidence of low back pain (49).

Dysfunction of the multifidus

A link has been established between dysfunction in the local muscles and back pain. Several researchers have demonstrated dysfunctions in the multifidus muscle of back pain patients. During functional tasks, reduction in amplitude of the multifidus activity was found in chronic low back pain patients (50), and altered responses have been observed during loading of the trunk. Sihvonen (51) found a reduction of activity of multifidus at L4 and L5 levels in low back pain when monitored with electromyography. Moreover the demonstration of four millimeter sliding between lumbar vertebrae during flexion was found in segmental instability patients.

Fatiguability

Fatiguability is an inability of muscular support over extended periods of time. There is evidence to support the relationship of fatiguability and low back pain. Electromyography can be used to evaluate fatigue rates of multifudus. Greater fatigue rates were reported in subjects with a history of low back pain (52). Higher fatigue rates of multifudus rather than iliocostalis lumborum was observed in low back pain individuals (53).

Composition

Changes in muscle size and internal structure of both type I and type II muscle fibers were observed in paraspinal muscles of low back pain patients. Type I muscle fibers in low back pain have changed in the internal structure while the size of these fibers remain generally unaffected (54-56). The abnormality of internal structural are considered with the appearance of core-targetoid and moth-eaten which reflected mitochondria dysfunction (56). The changes of internal structure in type I have been observed in symptomatic low back pain range from three weeks to one year (54). Moreover, the study of multifidus biopsies in patients with lumbar disc herniation reported the decrease in mean size of the type I and type II muscle fibers on affected side and vertebral level (57).

Changes in muscle fibers were studied in five years postoperative low back pain patients by comparing the muscle biopsy (55). Patients were divided into two groups according to positive or negative outcome of their functional handicap. No significant change in muscle atrophy between the groups was found. In contrast, changes in the internal structure of type I muscle fiber were dramatically different between the groups. Moth-eaten and core-targetoid were seen in the multifidus biopsy samples of all patients. In addition moth-eaten were seen in the negative functional handicap group, which increase from 2.7 to 16.7 percent.

Size and consistency

Cross-sectional area of multifidus and lumbar erector spinae muscles have been evaluated in low back pain individuals. Imaging modalities, such as computerized tomography (CT) scanning, MRI and ultrasound imaging were used in assessment of paraspinal muscles atrophy. Muscle consistency is an evaluation of fatty infiltration (increased fat/muscle fiber ratio) or actual fatter replacement of fiber (58, 59).

Evidences of paraspinal muscle atrophy in chronic low back pain or postoperative patient were exhibited in term of difference between sides and vertebral levels (58, 60). Postoperative studies demonstrated that the size of paraspinal muscles reduced 10-30 percent on the affected side compared with unaffected side, and fatty degeneration of the paraspinal muscles was also evident (58). Furthermore, paraspinal muscles in low back pain highlighted atrophy at the lumbosacral junction, which presented with changes of fat content of these muscles (60).

Multifidus atrophy appears to be a common finding in patients with chronic low back pain. MRI study in 78 low back pain populations defined the changes of multifidus consistency, which fatty or fibrous tissue replacement as mild (replacement less than 10%), average (replacement less than 50%), and severe (replacement greater than 50%) (61). MRI investigation reported 80% of the subjects presented with degeneration of multifidus and 85% had degenerated lumbar discs most commonly at L4-L5 and L5-S1. In addition multifidus significantly correlated with intensity of leg pain (radicular and nonradicular).

Comparison study of cross-sectional area of the multifidus, lumbar erector spinae and psoas in chronic low back pain were obtained using CT scanning (62). Cross-section area of multifidus is selectively decreased, which significantly smaller than other muscles. The evidence also supported the concept of level-specific changes in the multifidus. Moreover, distinct reduction of multifidus activation was found in low back pain compared with the controls in ultrasound imaging study (63).

2.1.3 Assessment of lumbopelvic stability control

To assess the lumbopelvic stability control in the local muscle system, a three-tier model of assessment is proposed. The model is tiered in degrees of sophistication of the assessment, depth, type and detail of information that could be derived. The measures used from first to third tier are: screening test, clinical assessment, and diagnostic assessment.

The screening test is a non-invasive technique and based on the clinical assessment of the abdominal hollowing while controlling lumbopelvic posture during progressive leg loading. The pressure biofeedback unit is used to provide quantitative evaluation. However this test only assessed whether or not the deep muscles are working with the contraction of the superficial trunk muscle but does not measure specific details of the motor control deficits. Therefore, it is useful as a screening measure for physiotherapy. As the test is simple and non invasive, it can be applied for general used by healthcare workers, exercise trainers in workplace or for individual home use.

The clinical assessment is also a non-invasive technique but required the clinical knowledge and skill of physiotherapy. This method used a combination of pressure biofeedback unit, electromyography biofeedback and also observed the compensation on body and breathing pattern to detect the deficits in deep muscle activation.

The diagnostic assessment consisted of non-invasive and invasive techniques to measure deep muscle activation. The non-invasive technique combined the use of ultrasound imaging, pressure biofeedback, and surface electromyography. This technique was developed for diagnose the motor control deficits in the deep muscles, and more precisely evaluate the re-education strategies. For the invasive technique, electromyography with fine-wire electrode was inserts into the deep muscles to directly measure the motor control deficits in a reaction time task.

2.1.4 Principle of lumbopelvic stability training in chronic low back pain

Alteration of lumbopelvic stability control is evident in chronic low back pain as a result of pain, injury to joint structures and the lack of weight bearing from lifestyle factor. Lumbopelvic stability control is necessary for joint protection and need to be addressed in therapeutic exercise. The principle of exercise strategies are based on training muscle performance and re-education of control by central nervous system. Since the control of muscular system is the major factor in low back pain, it is logical to address motor learning to these patients.

Motor learning is important in improving the movement and coordination and results in permanent change in movement performance. Two key theories of motor learning have been developed by Fitts and Posner (64), and Gentile (65).

Fitts and Posner (64) categorized motor learning into three main stages, which were cognitive, associative, and autonomous phase. First, cognitive phase, which focused on cognitively oriented problems. This stage needed high conscious attention for organizing all element of movement. Feedback, movement sequence, performance and instruction during practice were all important. The characteristic of this stage presented with frequent large error and variability. Second, associative phase, characterised by decreased in cognitive demand and the fundamentals of the movement have been obtained. This stage focused on consistency of performance, success and refinement and exhibited in reduction of number of error. Third, autonomous phase was achieved after considerable practice and experience, the task became habitual or automatic. Therefore, the demand of conscious was reduced.

Gentile (65) categorized learning into two phases based on the goal of the learner. For the first phase, the goal of the learner was to get the idea of the task. In the second phase, fixation or diversification of the skill were involved to improve consistency in stable environment and improved transfer to new contexts.

The management of motor control deficit in low back pain implicit with motor learning theories. When the deficit in movement has been identified, the strategies carry out on re-education of control of this component. The idea of correct performance must give to the patient. During practice, patients must pay cognitive attention to the task. Feedback or guided experience of the correct performance via sensory inputs must be addressed. Therefore, ranges of exercise options are available to meet the demand of re-education of movement performance that fall within the spectrum of motor learning.

2.2 Flexibility

Flexibility is another outcome measure investigated in current study. Effect of Pilates training on flexibility was claimed in normal but few were tested in chronic back pain.

2.2.1 Definition of flexibility

Flexibility is the ability to move a joint through its complete range of motion. Flexibility depends on a number of specific variables including distensibility of the joint capsule, adequate warm-up, and muscle viscosity. Additionally, compliance (“tightness”) of various other tissues such as ligaments and tendons also affects the range of motion.

2.2.2 Change of flexibility in chronic low back pain

The lumbar spine requires adequate level of trunk and pelvis flexibility for providing effective spinal mechanisms. Shortening of muscles due to poor range of motion may adversely affect spinal mechanisms, thus resulting in possibly increased loads on the spine (66).

Pelvic mobility, which is essential in lifting and bending activities may effect by inadequate hip range of motion. Tightness of hip flexor muscles could limit pelvic movements resulted in excessive strain on the lumbar spine (67). Moreover, the tightness of hip extensor may decrease lumbar lordotic curve, making the spine less resilient to axial loadings (67).

Generally, low back pain associated with tight hamstrings showed a significant limitation in range of motion during movements of the trunk and pelvis (68). Many studies confirmed that in low back pain patients, the range of motion of the trunk and hips decreased especially in flexion and extension (69, 70). Therefore, it is necessary to consider flexibility of the trunk and pelvis in management of low back pain.

2.2.3 Assessment of flexibility

Laboratory tests usually quantify flexibility in terms of range of motion, expressed in degrees. Common devices for this purpose include various goniometers, electrogoniometers, the Leighton flexometer, inclinometers, and tape measures (71). The sit-and-reach test is another method commonly used to assess low back and hamstrings flexibility. From the study of Jones and colleagues (72), sit-and-reach test exhibited good reliability in both symptomatic (r=0.80-0.95) and asymptomatic (r=0.88-0.99) low back pain.

2.2.4 Principle of stretching

Stretching techniques are used to increase the extensibility of the muscle tendon unit and the periarticular connective tissue. Stretching can be performed in four ways: static stretching, ballistic stretching, proprioceptive neuromuscular facilitation (PNF) stretching, and active isolated stretching (73, 74).

Static stretching is a method of stretching the muscles and connective tissue in a stationary position at their greatest possible length for some period. In clinical, a minimum of 15 to 30 seconds hold time is used. No additional advantage is gained if holding time is longer (75, 76). Static stretching requires less overall force and energy. It also decreases the risk of exceeding the tissue extensibility limits and muscle soreness (77). Static stretching has less effect on the Ia and II spindle afferent fibers induce to decrease the contractile elements' resistance to deformation (73). The position to perform static stretching requires comfortable supportive surface. The limb is taken to the point at which a gentle stretching sensation is felt, and the stretch is held for 15 to 30 seconds. The stretch is relaxed and then repeated.

Ballistic stretching uses quick movements to change the length of muscle or connective tissue. This method activates active contraction of the antagonistic muscle to the muscle and connective tissue being stretched. Movements of ballistic stretching appear to be jerky in nature and tend to increase a muscles' resistance to stretch and facilitate the Golgi tendon organ. Ballistic stretching may induce to injury due to excessive uncontrolled forces during stretch and proposed neurologic inhibitory influences associated with rapid-type stretching (78, 79). Ballistic stretching performance should be well stabilized and comfortable. The limbs is moved to the point of gentle stretch is felt, and then gentle bouncing the end range if performed.

Proprioceptive neuromuscular facilitation stretching (PNF) utilizes the neurophysiologic concept of stretch activation. PNF stretching use a contract-relax (CR) sequence, and agonist contraction (AC), or a contract-relax-agonist contraction (CRAC) sequence (80). The objective of PNF is to purposefully stimulate the neural mechanisms of contraction and relaxation.

Active isolated stretching is another method designed for improving flexibility (74). This technique can be performed actively with rope or band or assisted by the practitioner. Active isolated stretching focus on respiration during utilized this method, which asks the individual to exhale during the work phase of stretching that held for two seconds, and to inhale when return to starting position. One or two sets of 10 stretches are performed.

2.2.5 Effect of Pilates training on flexibility

Flexibility is one factor that commonly addressed in fitness components. Whether Pilates training is performed with mat or reformer, improvement in flexibility were found in trained subjects. Several evidences demonstrated that Pilates training improve flexibility in healthy subjects, and also chronic low back pain (18, 81).

Pilates training for one hour session weekly for two months in healthy subjects improve the ability to perform fingertip-to-floor test. The improvement of flexibility was maintained for six months after intervention period (18).

Moreover, Pilates training was used in chronic low back pain management. Pilates based mat exercise for 12 weeks, twice a week were assigned to low back pain subjects. Comparison was made between baseline and the end of intervention period. Significant difference in flexibility measured by sit and reach test was observed (81).

2.3 Pain

Pain is the main presenting symptom of most chronic low back pain patients. In this section, possible pain mechanism associated with motor control was reviewed and pain assessment using visual analogue scale was discussed.

2.3.1 Possible pain mechanism that associate with motor control of trunk muscle

Two models were proposed to explain the alteration of trunk muscle recruitment activities in low back pain: the pain-spasm-pain model and the pain-adaptation model. Pain-spasm-pain model has been used to explain the changes in muscle activity causing spinal pain. Travell proposed that pain occurred after injury lead to contraction of the muscles surrounding the injured structures and this in turn induced pain (82).

Pain-spasm-pain cycle has been proposed with two distinct neural pathways. First, due to nociceptive stimuli projected onto higher centers giving rise to the perception of pain. These fibers also projected onto alpha motorneurons at the segmental level which resulted in hyperactivity of back muscles in response to pain (82, 83). Second, the nociceptors affected the output of muscle spindles via direct excitatory projections on the gamma motorneurons. An increased output of muscle spindle induced hyperexcitability of the alpha motoneuron (84).

Pain-adaptation model has been used to explain clinical findings on muscle activity in pain syndrome. The model states that pain decrease the activation of muscle when active as agonist and increase when the muscle is active as antagonist. The effect of this control resulted in limiting the velocity, force, and range of motion (85).

A neural pathway of pain-adaptation model consisted of the nociceptors that project on the alpha motorneuron via both inhibitory and excitatory interneurons. The excitability of these interneurons is controlled by the central nervous system (CNS), in such a way that depending on the instantaneous motor command inhibition or excitation of the alpha motorneuron dominates. The nociceptive afferents are sent via excitatory interneurons projecting on the agonists and inhibitory interneurons projecting on the antagonist resulted in a reduce activation of agonists and increased activation of antagonists.

Hyperactivity of erector spinae muscles at the end of spinal flexion was observed in low back pain (86). This change was also found during gait at heel contact period (87). In addition, removing load from the trunk increased function of superficial trunk muscles (88). Hypoactivity of deep intrinsic trunk muscle and hyperactivity of superficial trunk muscle altered spinal stabilizing mechanisms in low back pain and these changes affect the control of trunk stability.

The mechanisms that explained the effect of pain on motor control have been investigated (89). The three possible mechanisms included changes in excitability at the spinal or cortical level, changes in proprioception or afferent mediated control, and specific cortical effects imparted by aspects of pain, such as its demand on CNS resources, stress or fear (89).

The changes in excitability have been considered in many levels of motor system during pain. Acute experimental pain has been shown to cause changes in spinal motor neuron activity. The amplitude of stretch reflex of the soleus muscle was increased after intra muscular injection of hypertonic saline (90). Reduction of amplitude of motor potential evoked by transcranial magnetic stimulation over the motor cortex was also found in response to experimental pain. Changes in motor drive may occur 'upstream' of the motor cortex, for instance, involving areas associated with motor planning (89). Reflex inhibition of motor neuron excitability has been suggested to occur in association with swelling (91) and injury to joint structures (92), which has been argued to indicate polysynaptic inhibition at a spinal level (93).

Many studies argued that changes in trunk muscle activity in low back pain may not be medicated by a simple change in excitability. Several changes in coordination of the trunk muscles and pain were shown and these were inconsistent with a change in excitability or delayed transmission of the motor command (89). If the delay in response observed during pain was due to a change in excitability, it may be predicted that the response would remain consistent although delayed. However, this is not the case. For example, the response of TrA is independent of the direction of arm movement (32). In low back pain, TrA responses earlier with shoulder extension than the other movements, which is similar to the response of superficial trunk muscle, normally under differential control (37). These findings indicated motor planning alteration.

The evidences of changes in motor planning have shown that pain has strong effects at the supraspinal level (94, 95). One area of the brain that has been found to be affected in experimental pain is the anterior cingulated cortex (ACC) (96, 97). The ACC has also been reported to be chronically active in chronic low back pain (97). The ACC is important in motor response and directly projects to motor and supplementary motor areas (98). Activation of this cortical area during pain may influence movement control. The use of noxious cutaneous stimulation of the finger and back in low back pain subjects resulted in increased activity in somatosensory cortex (99). These changes may contribute to the long lasting of pain in the absence of peripheral nociception, but may also contribute to the motor changes.

Another mechanism used to explain the hypothesis of pain lead to changes in motor control is related to increasing of attention demand, stress or fear, which respect of pain may have influenced on motor output. Several studies reported increased latencies and/or error rates in the presence of pain (100, 101). Hence, pain may lead to changes in movement coordination as a result of the increased demand place on information processing resource (89).

Further, association of stress with pain produced the change in control of the trunk muscles. There were numerous evidences to support that stress (i.e. perception of threat) affect motor control (102, 103). The study in chronic pain patients has been shown that the changes in paraspinal muscle activity was associated to subjective examination of distress and anxiety, rather than intensity of pain (104, 105).

The association between fear and pain also induced to change in motor control. Fear avoidance model was used to determine the behavioral response to pain and injury, and argued that fear of pain and injury or re-injury prevented normal return to activity, which lead to deconditional and disability (106). Several studies reported that fearful low back pain patients had greater reduction of paraspinal muscle endurance (107) and less relaxation at the end of trunk flexion (108) when compare to non-fearful patients.

Focusing on spinal control in low back pain, there was an increasing of general stiffness which created from superficial trunk muscle activity. This may result in CNS perceived the demand for fine-tuning to be diminished and lead to decrease in activity of the deep intrinsic spinal muscle (89). Essentially the sensory element of the motor system is important in accuracy control of the movement. Inaccurate afferent input would affect all aspect of motor control whether simple reflex those arising from stimulation of mechanoreceptors in the muscle (109) or complex movement that depend on an accurate internal model of body dynamic (110), which allows the CNS to predict the interaction between internal and external forces. This impairment results in ability to accurately reposition of spinal motion in low back pain (111).

In addition, the sensitivity of muscle spindle is altered by pain, and muscle activity (112, 113). Changing in activation also influences perception of movement. Several evidences supported that fatigue reduced sensory acuity (114). Therefore, decreased muscle endurance with injury or pain may lead to impaired sensory acuity via increase fatigability. After resolution of the pain, this adapted strategy may also resolve.

2.3.2 Pain assessment

Pain can be assessed using various methods such as pain ratings, pain drawing, and overt pain behavior. However, the simplest, most useful clinical method of measuring the severity of pain is visual analogue scale.

Visual analogue scale (VAS) is used to evaluate pain intensity. The scale consisted of a horizontally orientated 10 centimetre line anchored at opposite ends by the descriptors “No pain” and. “Worst pain” (115). VAS is simple to administer and most patients find it easy to understand. The major difficulty is to interpret exactly what the pain scale measures. It is in no sense an absolute or objective measure of pain, and it bears very little relationship to any physiologic or pathologic change. The patient's report of pain is influenced by nociceptive stimuli, physiologic phenomena, cognition, psychologic distress, pain behavior, and communication (116).

Because patients are likely to remember the previous pain scores, reliability of VAS can be improved by eliminate division marks and only marking both ends of the scale. The patient then places a mark along the scale corresponding to her pain level (115).

2.4 Stress

Stress is theorised as a particular relationship between the person and environment that is appraised as exceeding individuals resources and endangering their well-being (117). Stress is typical found in chronic low back pain patients. This section explains simple method for assessing stress and effect of exercise on stress.

2.4.1 Stress in chronic low back pain

Low back pain is a multifactorial process which depends on constitutional, somatic, psychological and environment factors regarded to psychological and sociological factors. Many works demonstrated that they are of minor importance as far as acute low back pain is concerned, but play a major role in chronic low back pain (118).

Chronic low back pain provides not only physical suffering but also creates psychological stress. Quint et al (119) demonstrated that patients with chronic low back pain had higher level of psychological stress. This is in agreement with Truchon (120) who stated that the significant contribution of psychosocial factors is increasingly recognized in chronic low back pain patients. Therefore, psychological factors and transactional processes do play a role when low back pain is likely to become a chronic problem.

2.4.2 Stress assessment

Stress Inventory questionnaire can be used to evaluate psychological status in chronic low back pain patients. This questionnaire was developed by Department of Mental Health, Thailand. This questionnaire contained 20 questions with four choice answers. The questionnaire can be completed in 5-10 minutes. Good reliability was reported with this questionnaire (sensitivity 70.4, specificity 64.6, and Cronbach's Alpha coefficient 0.86) (121).

2.4.3 Effect of exercise on stress

The association between improved psychological status and exercise is extraordinary important for the treatment of chronic pain patients. Psychological effects of exercises were explained according to six mechanisms: acting on the central nervous system, improving of self-esteem , feeling of mastery, increasing of work capacity, distraction and addiction to exercise (122).

Effect of exercise on the central nervous system

During stress, muscles contracted and loose their normal resting muscle tone. Exercise allow muscles to work, and releasing stored energy and allowing muscle groups to return to their normal resting potential. Muscle tension has changed after habitual rhythmic exercise such as walking, running, and cycling at 30-60% of maximum intensity. In addition, duration of exercise may affect the reduction of muscle tension. The changes in the left hemisphere of the brain have been measured and decreased arousal activity levels and reflex responses were found. The pleasurable levels of CNS arousal can achieve with exercise without side effects.

Central nervous system may be affected with biochemical activity change during and after exercise. Post-exercise increased in plasma levels of most powerful endorphin, beta-endorphin that have chemical properties which were similar to those of morphine. Morphine had well-known analgesic and euphoric properties. The increasing of beta-endorphin produced mood elevation, or anti-depressant effects.

Sufficient duration and intensity of exercises caused an increase in body temperature (123). This increasing temperature enhanced indirect affect to CNS, which affected central and peripheral neuron activities and the action of brain monoamines. Moreover, exercises promoted an increasing of rectal temperature and slow wave sleep. In addition, the cognitive function may be improved after exercise by an increasing of oxygen and glucose transport to the brain.

The effects of exercise on self-esteem

Exercise had a positive effect on self-esteem. Exercise increased physical fitness and resulted in improvement of self-esteem. Improvements of self-concept may cause a reduction of depression. The measurement of self-esteem scores could account for improvement of physical activity, feeling of well-being, and a sense of mastery.

The effects of exercise as a mastery experience

Providing of situations in which participant can master the task may result in improvement of self-esteem by exercise. The anti-depressant exercises provide the specific goals, which participant can control. People who are able to control all things that will happen to them seem to improve an ability to manage depression. If individualized goals of exercise are set for each patient, a sense of achievement and mastery should be gained. The improvement of fitness provided an increasing of the sense of mastery experience.

The effects of exercise as a distraction

Different kinds of exercises can produce positive psychological effects. Exercises provide a distraction for the participants. During exercise the participants concentrate on the exercise program instead of their problems and stress.

The effects of exercise on work capacity

Participating in exercise program leads to improve physical fitness. Participants should experience in an increased capacity for physical work. The increasing of capacity might be felt by having more energy available for daily tasks, thus diminishing feelings of fatigue and exhaustion. This increased sense of vigor could explain some psychological effects which have been report. Previous studies in this area suggested that there was a link between physiological and psychological improvements. Therefore, the improvements in fitness may affect on psychological as well.

The effects of addiction to exercise

Positive addiction to exercises depends on an activity which provides pleasure and satisfaction. The positive feeling of exercise allows the participants to gain sense of self-confidence or psychological strength. Furthermore, the activity affords the individual an opportunity to experience euphoric mental state.

In summary, six possible mechanisms for the psychological effect of exercise have been reviewed. Exercise has been associated with changes in the CNS, with improve self-esteem and feeling of mastery, and with increase work capacity. In addition it has been suggest that exercise may be beneficial because it distracts people from other aspect of life, or that becoming addicted to exercise may provide psychological strength.