



Core Stabilization Exercise and Movement System Impairment Approaches for Patients with Movement Control Impairment: A Review Article

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Abstract

Treatment-based and movement system impairment-based classifications have been widely used to identify movement control impairment (MCI) in patients with non-specific low back pain. Clinical observation of aberrant movement patterns is an essential aspect of the examination to identify patients with MCI. The treatment of these patients is a therapeutic exercise that involves static and dynamic stability of core stabilizing muscles. Although exercise prescriptions for these patients are similar, intervention may vary based upon its concept. Interventions include the core stabilization exercise (CSE) approach based upon stabilizing system model, and movement system impairment (MSI) approach based upon kinesiopathologic model. CSE focuses on neuromuscular function to compensate for impairment of intervertebral disc and joints, whereas MSI emphasizes movement correction and enhances movement efficiency to prevent injury and impairment. Both approaches seem equally effective in reducing pain and disability for the MCI group. Therefore, clinicians can utilize either approach for rehabilitating patients with MCI. However, if differences in effectiveness are found when utilizing these different approaches we should explore if the MCI classification needs further definition. In addition, further study needs to investigate the underlying mechanisms in patients with MCI, and the ability of each approach to change those mechanisms.

Keywords: *Movement control impairment, Core stabilization, Movement system impairment approach*

1. Introduction

Low back pain (LBP) is a common health problem worldwide. Authors have reported a lifetime prevalence of LBP between 70-85%, and a lifetime recurrence rate at 85% (1). Accordingly, LBP is one of

the important causes for health care services, especially physical therapy and rehabilitation. Moreover, a high recurrence rate can lead to high cumulative treatment costs which could be a financial burden for patients themselves, their employer, or social services (1).

Cause of LBP includes chemical and/or mechanical changes that stimulate nociceptors in the tissues in the lumbopelvic region resulting in localized discomfort below the costal margin and above the inferior gluteal folds, with or without referred pain (2). LBP can be classified into 3 categories: 1) serious pathological low back pain, 2) low back pain with radiculopathy, and 3) non-specific low back pain (NSLBP) (2). Serious pathological low back pain is diagnosed when known pathology, such as compression fracture, can be specified. Low back pain in which specific pathology cannot be identified is referred to as NSLBP. NSLBP is approximately 85% of LBP population (3).

Several researchers have investigated different physical therapy treatments (i.e. core stabilization exercise, back school, spinal manipulation, etc.) in patients with NSLBP in order to determine the effectiveness of physical therapy treatment on clinical outcomes in those patients (4-6). The results have inconclusive evidence to support about the effectiveness of physical therapy interventions. However, researchers suggest that different signs and symptoms in the patients with NSLBP are caused by different mechanisms (7-11). They also agreed that sub-classification of patients with NSLBP is necessary to apply the appropriate physical therapy intervention.

Treatment-based and movement system impairment-based classification systems has been widely used to match patients with NSLBP with preferred intervention (11, 12). Clinical observation of aberrant patterns of movement during functional activities is one physical examination component in those classification systems, and has construct validity and moderate to excellent

inter-rater reliability to identify patients with MCI (11, 13). Identified by both classification systems are patients with movement control impairment (MCI) as a subgroup of patients within NSLBP. MCI is clinically defined as poorly coordinated and controlled spine and pelvis position and movements during functional tasks (10, 11, 14).

Physical therapy interventions commonly used in patients with MCI include: 1) core stabilization exercise approach, and 2) movement system impairment approach. These approaches typically focus on isolated muscle contraction, co-contraction, and dynamic stability during functional activities. Another emphasis is to bring co-contraction of core stabilizing muscles into a subconscious level. Interestingly, both approaches seem “to improve dynamic stability and trunk movement control during functional activities”. Despite these similarities, both approaches can be explained by different treatment concepts. The purposes of this review article are to differentiate treatment concepts for each of these physical therapy interventions, as well as to provide research evidence that support each treatment concept. Better understanding of these treatment concepts will facilitate the application of those concepts to effective treatment in patients with MCI, and help in developing a theoretical framework to investigate underlying mechanisms in patients with LBP.

2. Treatment concepts of physical therapy intervention in patients with movement control impairment

2.1 Core stabilization exercise approach

Core stabilization exercise approach (Figure 1) is an intervention

widely used in patients with MCI. Patients are examined with the treatment-based classification to identify those patients with MCI who would benefit from core stabilization exercise approach (9, 15). This exercise approach, designed and developed by Richardson and Hodges, aims to restore function of transversus abdominis muscle (TrA) and lumbar multifidus muscle (LM)

in order to regain static and dynamic spinal stability while performing various activities of daily living (16). The core stabilization exercise program emphasizes the TrA and LM by facilitating isometric co-contraction. Stages of training program (see appendix A) are based primarily upon motor learning concept which is out of scope of this review article.

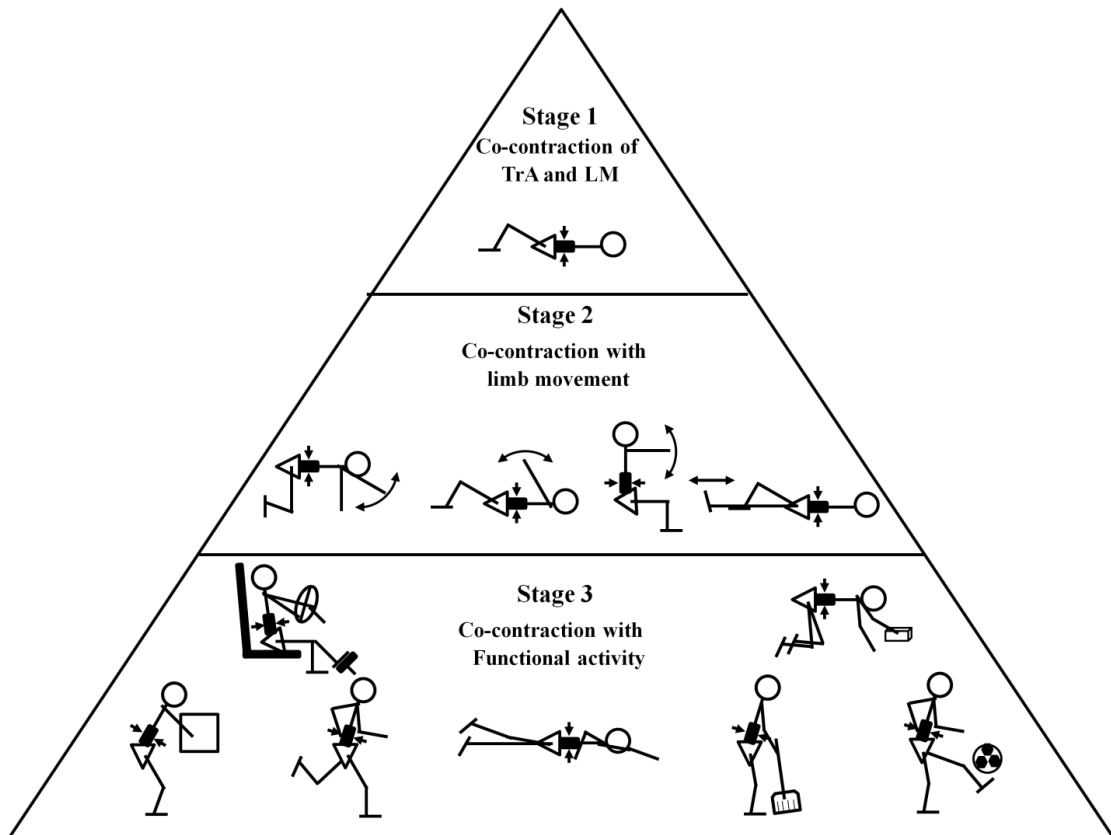


Figure 1. 3 stages of core stabilization approach to improve spinal stability designed and developed by Carolyn A. Richardson and Paul W. Hodges. TrA = Transversus abdominis muscle. LM = Lumbar multifidus muscle.

The core stabilization exercise approach is based upon Panjabi's concept of the stabilizing system (14). The stabilizing system (Figure 2) is an interaction among 3 anatomical systems including 1) passive subsystem consisting of the bones and joints of the vertebral column, 2) active subsystem

the stabilizing muscles, and 3) control subsystem the neural control of movement. Under usual conditions the interaction of these subsystems provides adequate spinal stability and movement so that the spine can carry loads, protect the spinal cord and nerve roots, and enable the movement

between body segments. Dysfunction in one or more of these subsystems will compromise the stability of the spine. Consequently, this will put soft tissues

around the spinal column at high risk of injury eventually resulting in low back pain episode.

Stabilizing System

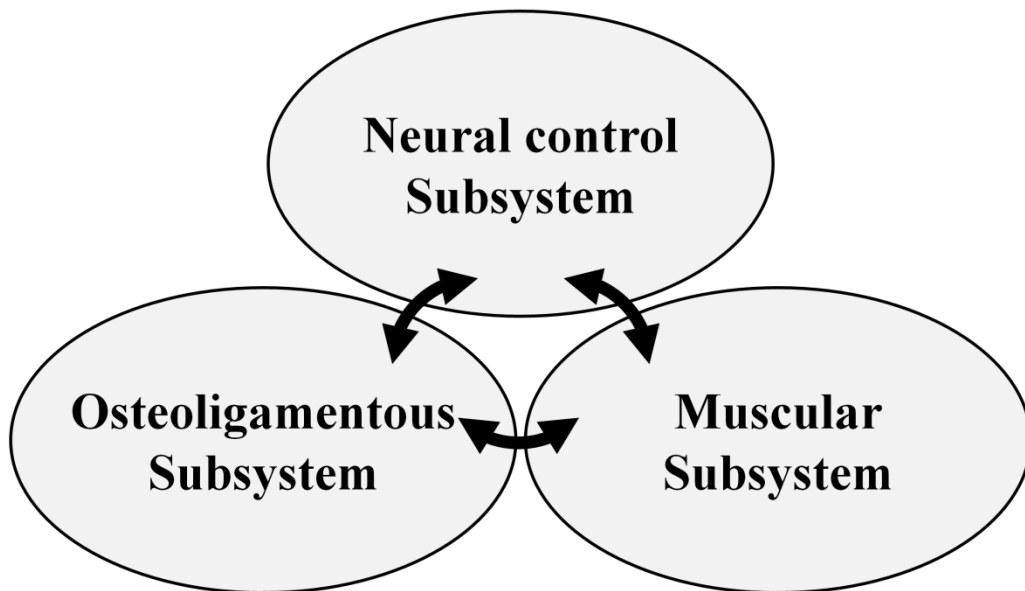


Figure 2. Stabilizing system of the spine introduced by Manohar M. Panjabi and widely used to explain low back pain mechanism and treat patients with low back pain.

Passive subsystem: Spinal column

The passive subsystem includes vertebrae, intervertebral disc, intervertebral joints, and spinal ligaments. These structures enclose and protect the spinal cord and nerve roots. The stability contribution is largely at end range of spinal motion where tissues build up tension to resist further spinal motion. In addition to passively providing stability, this subsystem provides the control subsystem with sensory feedback of spinal position and motion from the joint receptors located in joint capsule or ligament. Low back pain can result from injury, deterioration, or dysfunction of structures within the passive

subsystem, such as spondylolithesis or intervertebral disc degeneration. These compromise the integrity of the spinal stability, and alter the essential sensory feedback.

Active subsystem: Spinal muscles

The active subsystem is composed of muscles and tendons surrounding the spine. Contraction of the deep spinal muscles generates tension between spinal segments increasing static and/or dynamic spinal stability. The magnitude of muscle contraction responds to spinal stability requirements through interaction between mechanoreceptors in muscle (muscle spindle) and tendon (Golgi tendon organ),

and the control subsystem (14). Without this active subsystem, the spine is unstable even when we apply a slight external force to the spine (17). Accordingly, dysfunction of the active subsystem, such as reduced core muscle contraction or muscle fatigue, can cause significant decrease in spinal stability leading to low back pain.

Control subsystem: Neural control

The control subsystem consists of the peripheral and central nervous systems. The control subsystem receives feedback from the sensory receptors in the passive and active subsystems, computes spinal stability demand, and sends signals to active muscular subsystem to achieve spinal stability. This is a continuing process that each muscle sends and receives signals to modify tension to achieve the spinal stability requirements. Control systems also provide the anticipatory activity of muscles to adjust spinal control. When the control subsystem is impaired spinal stability will be compromised. These impairments include delayed muscle onset timing or altered pattern of muscle activation.

If one of subsystems has been compromised, the person might not experience low back pain because of the compensation from other subsystems (14). For instance, intervertebral disc degeneration is the major cause of dysfunction in the

passive subsystem. The person may have no pain if the control and active subsystems compensate and provide adequate stability to protect the disc and surrounding tissues from injury. Therefore, passive subsystem dysfunction can occur without low back pain. While the control and active subsystems can compensate for pathology of the passive subsystem, inadequate compensation can result in further injury and low back pain.

In addition to stabilizing system, Panjabi proposed the concept of zones of movement. He defined the neutral zone (Figure 3A) as the initial portion of the physiological range of motion under neuromuscular control where spinal motion occurs with minimal resistance from the passive subsystem (i.e. joint capsules and spinal ligaments) (14). The elastic zone is measured from the end of neutral zone to the physiological limit. In this elastic zone there may be considerable internal resistance from tissues surrounding the spine (14). Dysfunction such as spondylosis or trunk muscle weakness can cause an increase in neutral zone size (Figure 3B), thereby increasing shear force on intervertebral disc which will increase the risk of injury followed by an occurrence of low back pain (14).

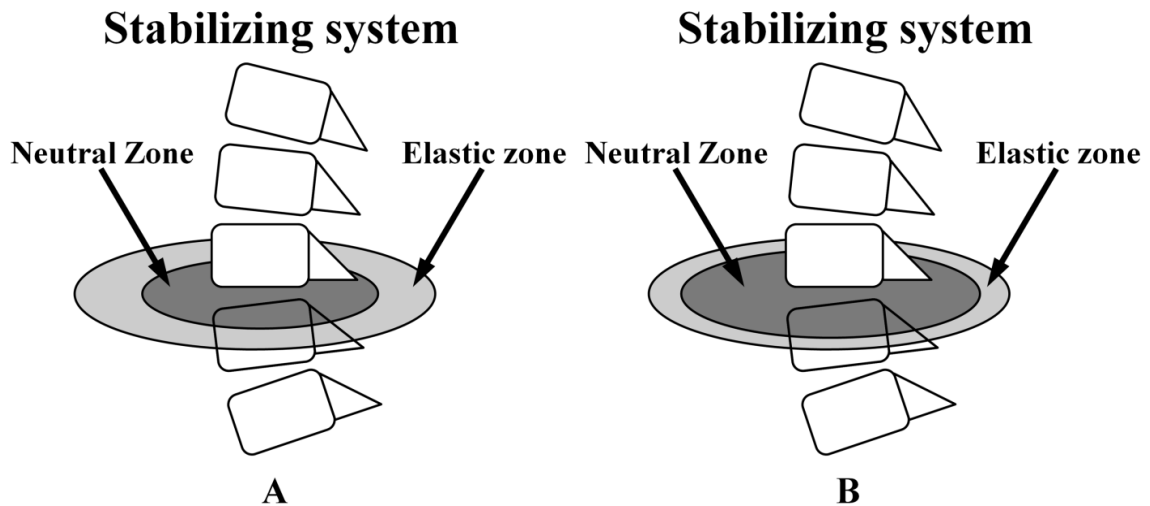


Figure 3. Neutral zone and elastic zone proposed by Manohar M. Panjabi in person (A) with normal spine, and (B) with impairment of stabilizing system increasing size of neutral zone.

Dysfunction in the passive subsystem is one reason for diminish spinal stability. Intervention to improve spinal stability aimed directly at this passive subsystem is spinal stabilizing surgery. Research related to physical therapy focuses on the active and control subsystems. Many studies have identified the transversus abdominis muscle (TrA) and lumbar multifidus muscle (LM) as two key trunk stabilizing muscles (18-22). In patients with NSLBP changes in these 2 muscles occur such as altered co-contraction or delayed muscle onset timing. These impairments may be due to physiological change such as fatty infiltration in the LM which alters its contraction ability (18-22). This change is persistent up to one year after the first episode of LBP even when the back pain has subsided (23). This indicates that the active system to stabilize the spine is impaired and may contribute to the high incidence of recurrent LBP.

2.2 Movement system impairment approach

The movement system impairment approach is another physical therapy intervention widely used for treatment the patients with MCI. This approach is based upon Kinesiopathologic model (Figure 4) proposed by Sahrman (24). Similar to the core stabilization approach, Sahrman proposes that MCI results from underlying pathology. However, Sahrman has proposed that daily activities that deviate from an ideal mode of movement can cause pathology and tissue dysfunction. Sahrman proposed a Kinesiopathologic model that focuses on interaction of 4 contributing elements: Base (musculoskeletal and connective tissue), Modulator (nervous system), Biomechanical (kinetics and kinematics), and Support (cardiopulmonary systems). Optimal function of these elements results in precise and efficient osteokinematic and arthrokinematic movement (24).

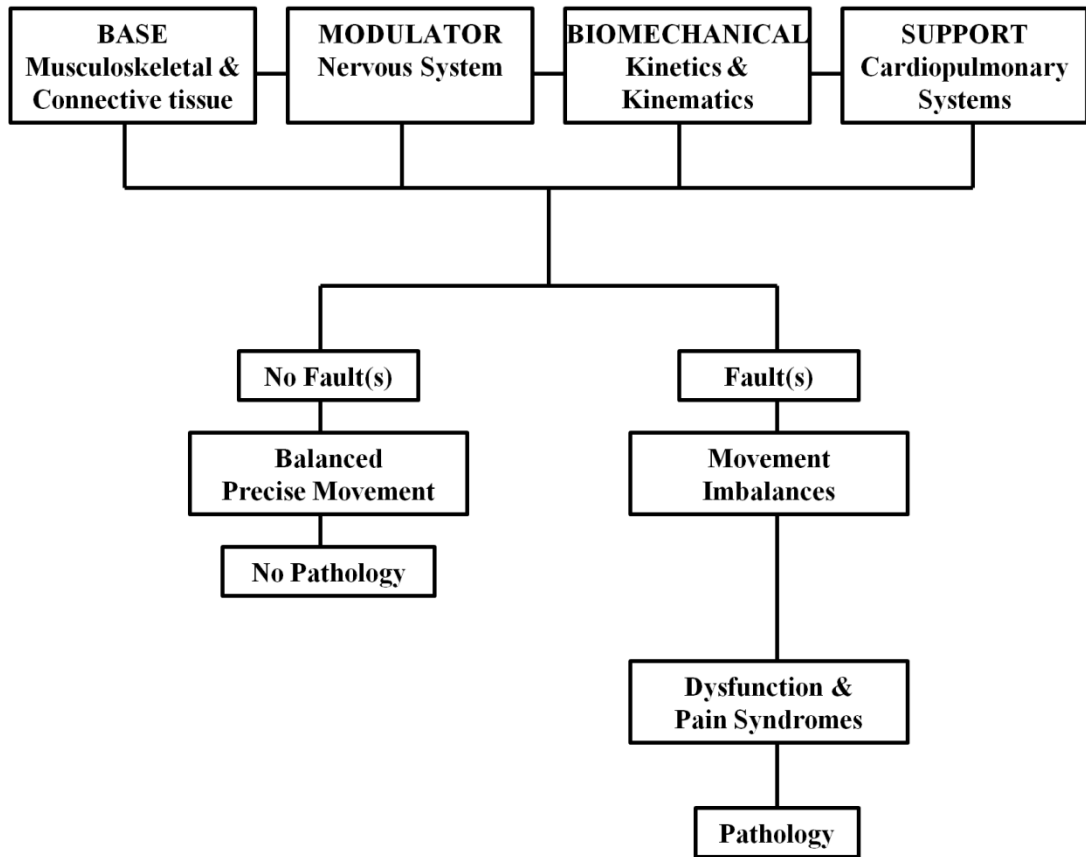


Figure 4. Kinesiopathologic model introduced by Shirley A. Sahrman, and widely used to treat movement system impairment.

The assumption is that repeated trunk and pelvic movements that deviate from the ideal mode of movement, and prolonged postures in daily activities result in excessive tissue stress and microtrauma (24). If repeated abnormal movements and prolonged postures persist, they will contribute to further tissue stress (cumulative microtrauma and predisposition to new injury), and lead to episodes of LBP (24).

MCI can be caused by variations in forces acting at spinal segments. These variations alter the path of the instantaneous

center of rotation (PICR) during active movement (24). PICR during active movement should be consistent with the kinesiological standard for the joint to maintain the state of movement system balance. Normal trunk movement demonstrates small PICR movement area (Figure 5A). However, repeated movement can cause intervertebral disc degeneration leading to movement system imbalance and less effective function. Eventually, PICR movement area will be increased (Figure 5B) (25-27). This increases risk of spinal injury (24).

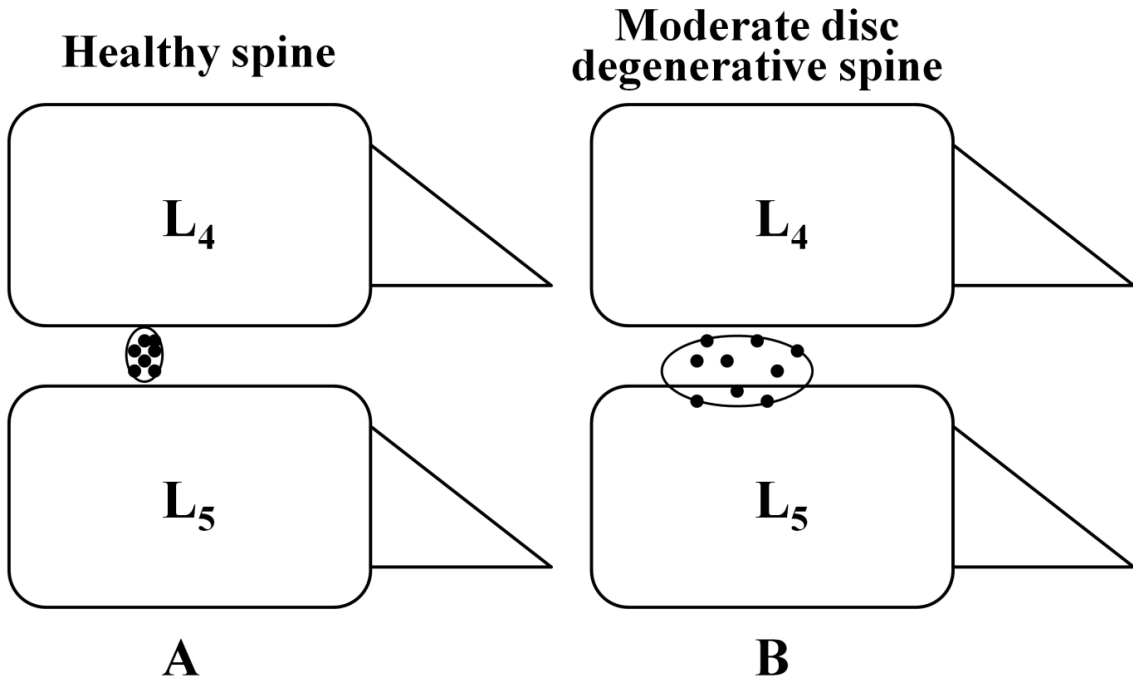


Figure 5. Path of instantaneous center of rotation (PICR) in person (A) with healthy spine, and (B) with moderate disc degenerative spine proposed by Shirley A. Sahrman.

Altered PICR caused by repetitive movements or prolonged postures can be explained by the “path of least resistance” concept (24). If trunk muscle tightness or intervertebral joint stiffness significantly intensifies resistance to the movement, the movement system will find adjacent muscles or joints that have less resistance to the movement resulting in an aberrant movement pattern (11, 24). For example, the patient has hamstring muscle tightness that resists a forward flexion movement. When performing this movement the decreased hip motion transfers the motion to the lumbar spine which has less resistance during active trunk forward bending. This compensation will lead to “directional susceptibility to movement” (the direction that the patient is more likely to have an injury), and may result in injury of tissues surrounding the lumbar spine (11, 24).

Non-specific low back pain results from cumulative microtrauma from impairments in spinal alignment, intervertebral joint stability, and trunk movement patterns (24). Therefore, the movement system impairment approach (see appendix B) emphasizes correcting movement patterns and postures to restore movement system balance, and preventing detrimental movement (24). In the movement system impairment-based classification each patient with MCI will be classified based upon their directional susceptibility to movement (11, 24).

3. Research evidence related to core stabilization exercise and movement system impairment approaches

Several studies have analyzed these approaches (9, 11, 15, 28). Each treatment approach is effective when patients are

evaluated based on its classification system. If patient's characteristics meet the classification's criteria, patient are likely to benefit from that approach (9, 11, 15, 28). One study compared the clinical outcomes in patients with MCI after 6 weeks of core stabilization or movement system impairment approach (29). The results revealed both approaches are equally effective. It is not surprising because both approaches have the same ultimate goal to improve spinal stability and trunk control during functional activities.

Although researchers found that no statistically significant difference in clinical outcomes in patients with MCI between these 2 approaches, the treatment concepts used to explain improvement in clinical outcomes are different. Moreover, evidences to support those approaches are still limited. Therefore, this would be an opportunity for researchers to further investigate underlying mechanisms of patients with MCI based upon each treatment concept. For example, muscle activity associated with path of instantaneous center of rotation could be investigated to verify the MSI concept. O'Sullivan has already shown that when the active muscle subsystem is enhanced by stabilizing exercises LBP decreases in patients with passive system dysfunction such as spondylolithesis (30). Additional research is needed to more fully investigate the clinical outcomes of these concepts. . In addition, researchers can design a comprehensive study to determine biomechanical and clinical changes in patients with MCI after receiving each intervention. These studies will lead to better understanding of underlying mechanisms associated with MCI, and the ability of core stabilization exercise and movement system impairment approaches to change the impairments

related to each approach. These will provide evidence for clinicians, and help them refine intervention that addresses specific impairment in patients with MCI which should in turn optimize patient clinical outcomes and minimize the recurrence of LBP.

4. Summary

Both core stabilization and movement system impairment approaches are physical therapy interventions widely used in patients with MCI. Although both approaches aim at activation and control of abdominal and back muscles to correctly provide dynamic stability during various functional activities, the treatment theory behind each approach is dissimilar. Core stabilization exercise approach focuses on active and control subsystems to compensate for function of passive subsystem to improve spinal stability during functional activities, while movement system impairment approach concentrates on control of trunk muscles to have an appropriate and efficient function.

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7. Appendices

Appendix A: Core stabilization exercise approach can be divided into 3 stages as follows (30):

Stage 1: This stage of exercise focuses on isolated activation of TrA and LM in the neutral spine position. Activation of TrA is accomplished by teaching the patient the abdominal drawing in maneuver. Next, the clinician teaches the patient to perform an isolated contraction of LM. After the patient can perform these isolated muscle contractions, the clinician teaches the patient to perform co-contraction of both of these core stabilizing muscles. When the patient is able to hold co-contraction up to 30 seconds without compensation from other muscles, the patient will progress to the next stage.

Stage 2: This stage emphasizes exercise intensity and co-contraction of TrA and LM with limb movement. For instance, clinician teaches the patient to perform co-contraction of those core stabilizing muscles, while slowly performing upper and/or lower limb movement in the supine position. In addition, the clinician can progress the exercise by changing the patient position side-lying, sitting, or quadruped. The patient will progress to stage 3 when he/she is able to perform co-contraction with limb movements in different positions without any substitution of other muscles, such as observed pelvic tilt or transverse rotation.

Stage 3: This stage of exercise concentrates on co-contraction with perturbation and functional activities, particularly activities similar to his/her daily activities. The goal of this stage is to sub-consciously perform the dynamic co-contraction of the stabilizing muscles. For example, clinician teaches the patient to maintain co-contraction while driving a car.

Appendix B: Movement system impairment approach can be divided into 3 stages as follows (11, 24):

Stage 1: This stage is to use "positioning for control of symptoms". After identifying directional susceptibility to movement, the clinician teaches the patient to position himself/herself in normal alignment reducing muscle tightness by increasing muscle length, and muscle weakness by increasing muscle strength to restore movement system balance. Patient should avoid moving into the direction that exacerbates the symptoms. For example, the clinician teaches the patient in rotation with extension group (pain when extending and rotating) in sitting position to contract deep

abdominal muscles, flatten lower back against a chair, and avoid contraction of lower back and hip muscles.

Stage 2: This stage emphasizes “modification of functional activities”. The clinician teaches the patient to correctly use and control specific muscles during various functional activities. For example, the patient attempts to activate abdominal muscle contraction during walking, and use both hands to monitor pelvic rotation and hip hiking because body will find these substitutions as a path of least resistance. In addition to use correct muscles for each functional activity, the patient should be taught to contract the muscle at the right time. For example of active trunk forward bend, the patient should be trained to contract abdominal muscles throughout the

movement with more lumbar spine contribution in the first half, and more hip/pelvis contribution in second half of the movement.

Stage 3: This stage focuses on “exercise for precision of trunk movement”. After the patient is able to perform various functional activities using correct muscles and timing, the clinician teaches the patient to perform exercise that specifically matches their directional susceptibility to movement by accurately recruiting involved muscles. For instance, the patient contracts abdominal muscles, and flexes their upper limb while maintaining neutral position during performing quadruped with upper limb flexion. The patient should also control trunk and pelvis to avoid trunk and pelvis rotation.