[CLINICAL COMMENTARY]

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Convergence and Divergence of Exercise-Based Approaches That Incorporate Motor Control for the Management of Low Back Pain

SYNOPSIS: Many approaches for low back pain (LBP) management focus on modifying motor control, which refers to motor, sensory, and central processes for control of posture and movement. A common assumption across approaches is that the way an individual loads the spine by typical postures, movements, and muscle activation strategies contributes to LBP symptom onset, persistence, and recovery. However, there are also divergent features from one approach to another. This commentary presents key principles of 4 clinical physical therapy approaches, including how each incorporates motor control in LBP management, the convergence and divergence of these approaches, and how they interface with medical LBP management. The approaches considered are movement system impairment syndromes of the lumbar spine, Mechanical Diagnosis and Therapy, motor control training, and the integrated systems model. These were selected to represent the diversity of applications, including approaches using motor control as a central or an adjunct feature, and approaches that are evidence based or evidence informed. This identification of areas of convergence and divergence of approaches is designed to clarify the key aspects of each approach and thereby serve as a guide for the clinician and to provide a platform for considering a hybrid approach tailored to the individual patient. *J Orthop Sports Phys Ther 2019;49(6):437-452. Epub 15 May 2019. doi:10.2519/jospt.2019.8451*

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Many physical approaches to managing low back pain (LBP) include exercise that aims to change motor control. In this context, motor control refers to motor, sensory, and central processes involved in control of posture and movement. Although different approaches share the underlying assumption that the manner in which individuals use their body and load their tissues is related to the development and maintenance of their conditions, there are differences in how motor control is assessed and trained, as well as differences in proposed mechanisms for its efficacy. This commentary aims to describe how motor control is used in 4 clinical approaches commonly used in physical therapy, and to consider areas of convergence and divergence between these approaches and how these approaches interface with nonsurgical medical management of patients with LBP.

Clinical Approaches That Focus on Motor Control

The clinical approaches included in this

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commentary are movement system impairment (MSI) syndromes of the lumbar spine, Mechanical Diagnosis and Therapy (MDT), motor control training (MCT), and the integrated systems model (ISM). These were selected with the objective of including approaches with some diversity of underlying concepts, that consider motor control as a central (MSI, MCT, ISM) versus an adjunct feature (MDT), and that are evidence based (MSI, MDT, MCT) versus evidence informed (ISM). Below is an overview of the key features of each approach, including concepts, assessment, treatment, and key research evidence.

MSI Syndromes of the Lumbar Spine

Underlying Concepts The movement system consists of physiological organ systems that interact to produce movement of the body and its parts (**FIGURE 1**). Movement system impairment syndromes are one set of classifications of patients with musculoskeletal pain and comprise the neuromusculoskeletal components of the system. The theoretical construct of MSI syndromes is depicted in the kinesiopathologic model,[67,116,149] which proposes how movement induces pathology (**FIGURE 2**).

In this model, the main inducers of movement impairments are the repeated movements and sustained alignments of everyday activities. The changes in tissues associated with repetition of activities are proposed to induce movement impairments. Studies have demonstrated that rotation-related sports induce movement impairments in individuals with LBP.[13,38,143,146,148,156] Indirect support for a link between daily activities and the problem is provided by evidence that correction of movement impairments during these activities significantly reduces symptoms for 1 year.[146] The characteristics of specific tissue, movement, and alignment changes are proposed to vary because of intrinsic personal characteristics and extrinsic factors, such as the type and intensity of activities. According to the model, the result of these tissue adaptations is a joint that moves more readily in a specific direction (ie, flexion, extension, rotation) than in other directions and more readily than another joint with a similar movement direction,[82] thus becoming the path of least resistance for movement.

The model proposes that the major determinants of the path of least resistance that cause a joint to move too readily are (1) joint relative flexibility (intrajoint and interjoint),[119,125] (2) relative stiffness (passive tension of muscle and connective tissue),[35,67,150] and (3) motor performance and learning.[95,96,147,151] The predisposition for a joint to move more readily in a specific direction, only a few degrees different in patients with LBP than in controls,[119,125] suggests the presence of accessory-motion hypermobility that induces microtrauma that becomes macrotrauma over time.

There are several sources of evidence for the change in joint flexibility contributing to a low threshold for motion. First, patients present with similar types of lumbar motion, for example, rotation, across different clinical tests involving movement of the trunk and lower extremities in a variety of positions.[35,144] Second, the range of lumbar/lumbopelvic motion most often varies with the movement of one lower extremity relative to the other, supporting variation in the flexibility of the joint.[144] Third, motion-capture studies have shown that patients with LBP initiate lumbar/lumbopelvic movement within a few degrees of initiating limb motion and a few seconds earlier than individuals without LBP.[95,119,125] Most studies evaluated knee flexion and hip lateral and medial rotation in the prone position.[68-70] The early onset of motion and occurrence with movements of the trunk and lower extremities in a variety of positions support the concept of intrinsic changes in joint flexibility.

Additional support is derived from studies that demonstrate that patients classified as "extension-rotation" have greater lumbopelvic rotation with hip

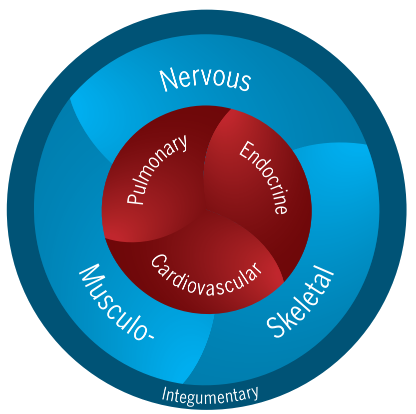

FIGURE 1. Human movement system. Reproduced with permission from Washington University in St Louis Program in Physical Therapy, licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International license. Based on a work at https://pt.wustl.edu/about-us/.

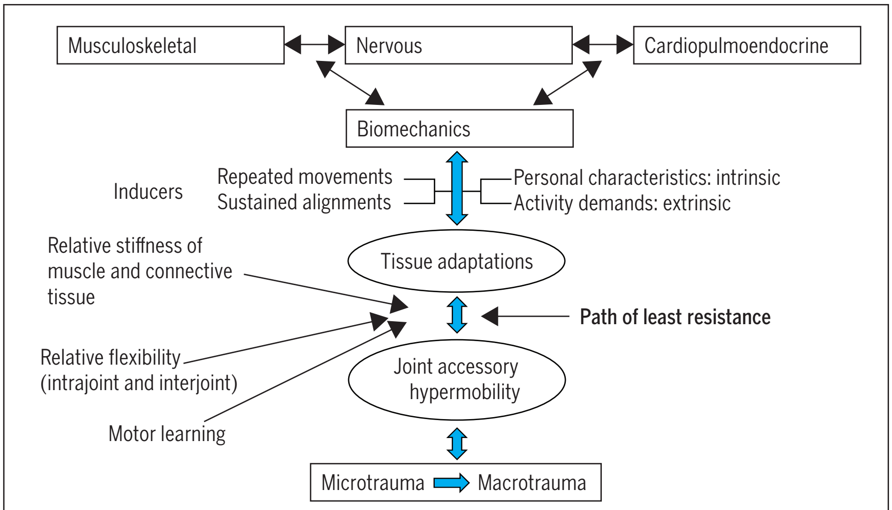

FIGURE 2. The kinesiopathologic model, a theoretical construct of movement system impairment syndromes.

lateral rotation in prone with one extremity than with the other.[144] These patients also demonstrate asymmetrical lateral trunk flexion.[35] This contrasts with patients classified as "rotation," who have symmetrical lumbopelvic rotation with both lower extremities and lateral trunk flexion.[35] Studies of lateral trunk flexion have shown that trunk passive elastic energy asymmetry is predicted by factors of sex and muscle in LBP, whereas in controls only sex is predictive.[34] Thus, muscle factors in LBP likely contribute to the greater imbalance in passive elastic energy. Although muscle and connective tissue can contribute,[34] intrinsic flexibility of the spine is also a factor.

Assessment Procedures Consistent with the model that a specific movement direction is problematic, the primary objective of the clinical examination is to identify the movement directions that elicit symptoms (the path of least resistance) and the contributing factors. The examination also identifies the associated movement impairment, such as excessive early lumbar flexion and limited hip flexion during forward bending. Then, the effect of the patient correcting the movement impairment on the symptoms is noted. Correction of the early lumbar motion has been shown to decrease symptoms.[96,145,151]

The systematic movement exam consists of tests performed in different positions: standing, supine, sidelying, prone, quadruped, and sitting. The tests involve movements of the extremities, primarily the lower extremity, and the trunk. The patient moves in the preferred manner while the symptoms and movement patterns are noted. Then, the movement is corrected, primarily by limiting any associated lumbar motion, and effects on symptoms are noted.[145,150-152,156] An important component of the exam and treatment involves instructing the patient in correct performance of basic mobility activities, as well as those during work and, if relevant, fitness or sports activities. These activities include how to roll, how to come to sitting when recumbent, during sit-to-stand, in a sitting position, when going up and down stairs, during gait, as well as when bending, returning to standing, and sidebending.[95,96,147,151] All these motions are assessed as part of the examination.

The reliability of clinicians performing the examination tests[40,134,150] and the validity of the classifications have been examined and are acceptable.[152] The reliability of examiners to classify patients has also been established (approximately 70% accuracy).[39,40,107,134] Alignment differences between patients with a specific lumbar classification and controls have been documented.[107,126] Other studies have documented that symptoms are elicited with movements of the spine and the extremities and that preventing lumbar motion during limb movements decreased or eliminated the symptoms.[96,145,150] Studies using motion capture have demonstrated that lumbopelvic motion occurs more readily during knee flexion and hip rotation in patients with LBP than in pain-free individuals.[119] A variety of other details related to variations in symptom behavior in men versus women and in the different classifications have also been examined.[33,70]

The validated classifications are based on the motion or alignment that provokes the patient's symptoms. The trunk/lower extremity movements that cause the offending movement are then eliminated or reduced to correct or prevent the offending spinal movement.[151]

The validated classifications are "lumbar extension" (greater lumbar extension in standing; symptom provocation: trunk/lower extremity movements causing lumbar extension; symptom elimination/reduction: alignment correction or prevention of extension), "extension-rotation" (symptom provocation: trunk/lower extremity movements causing extension and rotation; motions are asymmetrical; symptom elimination/reduction: correction of both movement directions), and "rotation" (symptom provocation: rotation or sidebending of the trunk/lumbopelvic rotation with rotation of both hips; symmetrical; symptom elimination/reduction: correction/prevention of lumbar motion).[152]

Intervention Outline During the examination that comprises basic mobility activities, many of which elicit symptoms, the patient is immediately instructed to correct the motion that usually reduces or eliminates the symptoms. The results of the examination identify the movement direction that most consistently elicits symptoms and the associated movement control impairments. The patient is informed of the movement direction and practices the movement correction. The major emphasis is placed on correcting basic daily activities and specifically on other types of activities that elicit symptoms, such as cooking or raking, as well as fitness or sports activities.

The patient is also instructed in specific exercises designed to correct the identified movement impairments. The exercises aim to prevent the offending lumbar motion while moving the trunk and lower extremities. Most often, this involves improved lumbopelvic control by contracting the abdominal muscles and improved extensibility of the hip muscles by elongation of the muscles while preventing lumbopelvic motion.

Evidence of Efficacy A recent randomized controlled trial (RCT) has supported that teaching the patient to keep the spine in neutral during basic mobility and fitness activities reduced symptoms for 6 months after 6 weekly visits consisting primarily of performance training.[146] At 1 year, the symptoms remained significantly lower than at the initiation of treatment. Subsequent RCTs of patients with chronic LBP have shown greater efficacy for symptom reduction by correcting movement and alignment impairments by motor skill training according to the MSI approach than by using strength and flexibility exercises.[147] Research has also demonstrated that patients adhere to training of functional activities significantly more often and for longer than they do to strength/flexibility exercises.[142,146]

Mechanical Diagnosis and Therapy

Underlying Concepts The MDT paradigm is unique in this commentary in that treatment is entirely based on the findings of a mechanical examination of the behavior of the pain source for each patient. Mechanical Diagnosis and Therapy is typically not considered a motor control approach, yet MDT considers posture correction and control to be essential features of recovery and prevention for every patient with a directional preference. The type of correction is determined by establishing the patient's directional preference associated with pain relief during the initial assessment. The performance of matching directional exercises is the key component of treatment, along with similar directional postural modifications. For most, that involves establishing and maintaining a lumbar lordosis and avoiding spinal positions associated with symptom provocation, such as prolonged spinal loading in lumbar flexion.[157] Experiencing the relationship between relief of pain and an erect sitting posture can be sufficiently motivating for most patients to learn to modify their sitting posture to prevent pain from returning.[157] In the MDT approach, patients perform their assigned directional exercise and practice the desired pain-relieving/preventative posture, which then creates a new postural habit that helps prevent the return of their pain.

Assessment Procedures Assessment begins by focusing on mechanical elements in each patient's history and with a dynamic examination (**FIGURE 3**) that mechanically and systematically loads and tests the tissues considered to be the patient's pain source, to determine which familiar patterns of pain response occur as a result.

If the clinical findings/pain response patterns reveal a "directional preference" (a single direction of repeated end-range spinal loading that achieves lasting pain relief) and "pain centralization" (change of pain location toward the spine from the periphery), then this is interpreted to indicate that the patient's pain source is reversible or correctable, as well as reveals the means by which it can be reversed or corrected. This information guides the treatment and is unobtainable by other forms of clinical examination or imaging technology. Research indicates that these 2 clinical findings (**FIGURE 4**) can be elicited in 70% to 91% of patients with acute LBP and in 50% of those with chronic LBP.[17,19,20,29,77,84,89,90,121,131,155]

Numerous studies[31,32,80,81,112,127,155,158] have reported strong interexaminer reliability across clinicians possessing the credentialed level of MDT training provided by the McKenzie Institute International.

Intervention Outline The goals of MDT are to identify mechanical spinal loading strategies that eliminate pain, then implement these strategies to restore each individual's ability to function at home, work, and during recreation. An additional goal is to teach patients successful prophylactic strategies to avoid recurrences and the need for further medical care. Published data support the achievement of those goals for the subgroup that has a directional preference and centralization.

Most patients can achieve these recoveries independently after being taught individualized self-management and preventive strategies.

Evidence of Efficacy Numerous observational cohort studies,[17,19,20,29,77,84,89,90,121,131,155] RCTs,[9,10,30,36,82,89,109,118] and systematic reviews[15,98,132] have reported that patients in whom a directional preference and/or pain centralization is elicited achieved better outcomes when treated with exercises that matched their disorder's directional preference, coupled with appropriate posture modifications, compared with other forms of treatment. The interexaminer reliability of the MDT assessment findings and patient classification—validated by improved patient report of pain reduction and improvement in functional outcomes using self-management strategies—along with the high prevalence rate for directional

FIGURE 3. A "press-up" is a prone end-range lumbar extension test that, when done repeatedly, will often centralize and/or abolish axial low back pain or any variation, such as referred pain or sciatica.

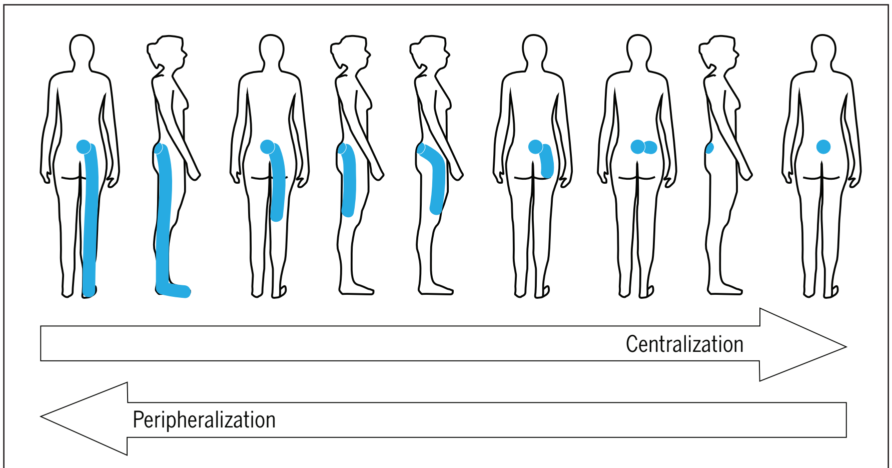

FIGURE 4. Pain "centralizes" when it is intentionally caused to retreat back toward the lumbar midline from its most distal location. It "peripheralizes" when it spreads farther away from the lumbar midline. Reprinted with permission from Donelson R. Is your client's back pain "rapidly reversible"? Improving low back care at its foundation. *Prof Case Manag*. 2008;13:87-96. https://doi.org/10.1097/01.PCAMA.0000314179.09285.5a

preference, supports this examination as a valuable component of evaluation for patients who seek care for LBP. Mechanical Diagnosis and Therapy is typically not considered a motor control approach, yet MDT considers posture correction and control to be essential features of recovery and prevention for every patient with a directional preference. In that context, motor control could be viewed as an adjunct feature of MDT treatment.

Motor Control Training

Underlying Concepts True to the complexity of motor control, MCT encompasses many aspects. It considers sensory and motor aspects of spine function, and each individual's management program is tailored to features considered to be "suboptimal" on assessment. The basic premise of MCT is that, for many individuals, inputs from the spine and/or related tissues (including nociceptive) contribute to maintenance of symptoms secondary to suboptimal loading by person-specific features of alignment, movement, and muscle activation. Motor control training aims to identify and modify the suboptimal features of motor control, with integration into function.

Considerable research has identified motor control features that differ between pain-free individuals and those with a variety of presentations of LBP. Most features are highly variable between individuals. Some examples include compromised muscle structure (eg, atrophy, fatty infiltration) and activation or contraction of muscles (eg, the multifidus[1,55,93,154] or transversus abdominis[26,55]), augmented muscle activation or contraction (eg, the obliquus externus abdominis,[58] obliquus internus abdominis,[44,46,54,72] or erector spinae[2,97]), modified postures,[16] and modified movement features (eg, augmented trunk stiffness,[56] smaller preparatory trunk movements[101]).

Motor control training aims to identify candidate features that might be relevant for the individual's pattern of symptom presentation. It is presumed that not all features will be relevant for the patient and not all individuals with a specific feature will develop symptoms. Motor control training includes therapeutic exercise to modify specific motor control features for a broad, multidimensional view incorporating psychosocial aspects of LBP (**FIGURE 5**). It is important to recognize that MCT considers the potential relevance of both "upregulation" (ie, increased/augmented activation) and "downregulation" (ie, decreased/compromised activation) of muscles. Increased/augmented activation of muscles, particularly those that are more superficial, is common. Laboratory studies reported a universal response of increased muscle activity when exposed to a noxious input, but with a pattern that was unique to each individual.[58]

There are numerous clinical examples. In response to low-load axial loading tasks (25% of body weight), individuals with LBP have greater activation of the obliquus internus abdominis than pain-free controls.[46,53,54] This has been interpreted as a strategy to enhance protection,[65] but could also be related to features such as habitual postures.[16] An MCT program reduced excessive contraction,[46] along with reducing LBP. This can be achieved within a session.[135] The contrasting observation of decreased/compromised muscle activation is also common and may be concurrent with increased activation of other muscles. There is substantial evidence of decreased[26] or delayed[63,93] activation and reduced ability to voluntarily contract muscles.[43,154] There are many mechanisms that could explain compromised activation. These include reflex inhibition[50,60] and other changes at many levels of the nervous system.[65] Activation of deep muscles such as the multifidus is also compromised by changes in structure such as atrophy[55] and fat/connective tissue accumulation,[61,83] which might be secondary to reduced activation or other mechanisms such as a local inflammatory dysregulation.[73] If downregulation of muscles such as the multifidus and transversus abdominis is identified, then the MCT program includes strategies to augment contraction in patients with acute[50] and with chronic[43,154] LBP. Programs that have included this component have decreased the recurrence of episodes of LBP[47] and improved pain/function.[117] It is a common misinterpretation that MCT aims to "upregulate" or increase muscle activity/cocontraction to restrict motion via a unidimensional focus on activation of specific muscles. This is not correct. Instead, the target should be the appropriate balance between movement and stiffness, as required by the task and the individual.[57]

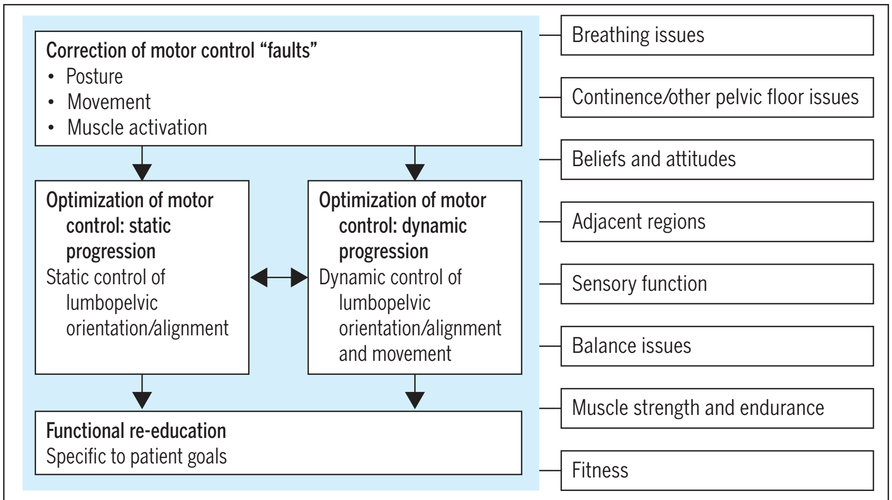

FIGURE 5. Motor control training approach.

Biomechanical/mechanical principles that are considered in program design include the following.

1. A controlled lumbopelvic unit is important for function,[100,139] requiring a balance between movement and stiffness[56,79] achieved through appropriately coordinated activation of the complex array of trunk muscles.[58,140]
2. Maintenance of a "neutral" lumbar spine position (ie, mid-range position with alignment of the trunk relative to gravity, controlled spinal curves, and frontal/transverse plane alignment) is important for sustained static positions.[14,99]
3. For many functions, movement should be initiated from the periphery (not the trunk) but should include the trunk to achieve full range.[119]
4. Adequate mobility and flexibility of adjacent joints and muscles attaching to the pelvis are required to maintain spine control during limb movement.[143]

Assessment Procedures Successful application of MCT principles relies on thorough assessment (including patient interview and physical examination); good communication skills; rapport with and an understanding of the patient, including his or her goals and concerns; and psychosocial context. Although these principles are common to several exercise approaches for LBP, tailoring the MCT treatment to the individual motor control features identified through assessment contrasts with many generalized exercise approaches. Multiple elements of assessment have been shown to have acceptable clinimetric properties.[110,128,133]

1. Assessment of trunk muscle control: assessment identifies features of muscle activation/contraction considered suboptimal (more or less activity/muscle contraction than expected for a task). Clinical muscle tests have been developed for specific trunk muscles that are commonly involved in LBP. These include deep muscles of the abdominal wall[42,43] and the paraspinal muscles, including the multifidus.[42,43] Ultrasound imaging can be used in clinical practice to measure the size and activation/function of trunk muscles.[128,133] Validity and reliability of this measurement method have been established; measures obtained by ultrasound imaging have been validated against measures obtained from magnetic resonance imaging[45,48,49,55] and intramuscular electromyography.[62]
2. Assessment of posture and movement: assessment is based on the identification of features that deviate from those considered ideal for a task and relevant for the patient's presentation. This is based on evidence from a broad base of research that shows person-specific postural attributes related to symptom profile,[16,23] relationships of postures and movements to modified muscle activation,[14] and that posture can be modified with exercise.[25] Tests utilized in MCT are drawn from multiple sources, including related motor control approaches (see Hodges et al[66] for review). Although reliability and validity of some tests have been established,[21,22] further research in this area is required.
3. Assessment of functional tasks: assessment of more complex functional tasks involves careful observation and relies on principles that are common across multiple motor control approaches (see Hodges et al[66] for review).
4. Assessment of broader dimensions of LBP: MCT incorporates, as required, consideration of many features that may determine the relevance of motor control for the patient's symptoms (eg, underlying pain mechanism) and features that may interact with the potential to achieve ideal control. These include a range of features that are related to motor control of the trunk and LBP psychosocial features,[11] breathing,[74,75] continence[124] and pelvic floor function,[111] adjacent joint function,[143] strength and endurance,[115] balance,[71] sensory function,[11] general fitness, etc.[66] Specific assessments used to evaluate these features vary and require further refinement.

Intervention Outline The following is an example of an MCT protocol.[53,66]

1. Optimization of muscle activation: individualized training targets the features identified in the assessment that suggest upregulation and/or downregulation of activity/contraction as required; that is, the training employs strategies to decrease overactive muscles and increase recruitment of muscles found to have demonstrable impairments on clinical muscle testing.[43,154] Training can include voluntary contraction of deeper trunk muscles to teach the skill of activating these muscles[138] for later integration into function, and reducing "overactivity" or increasing "underactivity" of more superficial muscles. The MCT approach to training lumbar paraspinal[135] and abdominal muscles[37] has been shown to induce immediate and sustained[136] changes in coordination of lumbar trunk muscle activation in recurrent LBP. Techniques to assist this phase include position change, feedback (eg, ultrasound imaging of muscle contraction) (**FIGURE 6**), relaxation strategies, imagery, and soft tissue techniques.

FIGURE 6. Ultrasound imaging can be used for detailed assessment and biofeedback of contraction of the deep trunk muscles, including the transversus abdominis and multifidus.

2. Optimization of posture and movement: features of spinal position that are considered suboptimal in the assessment and relevant for symptoms are corrected/trained. Among many options, this can include functional retraining in upright positions, with adjustment of spinal alignment; restoration and maintenance of normal patterns of respiration while exercising; dissociation of movement of the lumbar spine from that of the hip and thorax; practicing functional tasks such as sit-to-stand, with optimal spinal alignment and motion; and control of alignment and motion when challenged by unstable support.[66,76]
3. Functional integration and conditioning: this phase targets the patient's goals and can include exercises to achieve increased endurance of trunk muscles in functional activities and positions. Resistance can be added, with instruction to maintain spinal alignment when using weights. Flexible maintenance of spinal alignment in daily activities is encouraged, without causing rigidity or interfering with normal movement. Application of MCT according to these principles has decreased LBP and the occurrence of new injuries in several groups, including athletes.[51-53]
4. Broader dimensions of management: similar to other management approaches for patients with chronic LBP, MCT can be combined and integrated with other approaches, such as those that manage psychological features (eg, fear, catastrophizing, etc). For MCT, as for many other approaches, understanding pain processes, setting appropriate goals, providing reassurance (minimizing fear avoidance), and restoring pain-free normal movement are paramount.

Evidence for Efficacy Over the last 3 decades, changes to key recommendations in clinical practice guidelines for the management of LBP have placed greater emphasis on self-management and exercise programs targeting functional improvement.[28] A systematic review of 45 exercise trials (all forms of exercise) in patients with chronic LBP showed a modest benefit of exercise for nonspecific LBP, with greater efficacy than other conservative therapies.[120] Although effect sizes were modest, this finding should not be dismissed, because no intervention for LBP has a large effect when delivered in an RCT. Exercises classified as "coordination/stabilization" generally showed a positive effect. Another systematic review of 29 trials of MCT showed a clinically important effect compared with minimal intervention for chronic LBP,[117] but no superiority to other forms of exercise. Of note, early trials with large clinical effects applied MCT to specific patient groups in an individualized manner,[47,108,129] whereas most trials with modest effects have applied nonindividualized treatments to patients with nonspecific LBP. Individualization of treatment, which is now generally recommended, appears to be important. Several trials have shown that specific baseline features of motor control[27,137] and features of symptom presentation[94] are associated with better responses to treatment. These promising findings require further investigation.

Integrated Systems Model

Underlying Concepts The ISM[85,86,88] (**FIGURE 7**) is an evidence-informed (ie, founded on research findings, but not yet tested in RCTs), clinical-reasoning approach to organize knowledge from multiple fields of science and clinical practice for the nonsurgical care of individuals with disability and pain. This approach is compatible with the "regional interdependence model," a term used to describe clinical observations that regions of the body appear to be musculoskeletally

FIGURE 7. The integrated systems model. Reprinted with permission from Diane Lee.

linked, such that dysfunction in one body region could potentially lead to abnormal stresses to other body regions and subsequent development of dysfunction/pain in those regions.[130] Treating people with complex biopsychosocial problems requires an understanding of the relationship between, and the contribution of, various body regions and systems that ultimately manifest as cognitive, emotional, or sensorial dissonance. Collectively, this dissonance can be interpreted by the individual as threatening, and this is thought to have the potential to manifest as pain anywhere in the body, fear of movement, movement impairments, anxiety, breathing disorders, and/or incontinence.[3,5,12,64,103,123,141] Individuals with chronic LBP present with many of these features and have complex histories containing (1) multiple past high loads or accumulative traumas to areas of the body, many only partly resolved, (2) beliefs and cognitions that present barriers to recovery, and (3) poor lifestyle habits.

Ultimately, the ISM considers the impact that each system and body region has on function and performance of the whole body and person.

Assessment Procedures An ISM assessment begins with a patient interview to determine the contributions of the individual's sensations, thoughts, and beliefs to the clinical picture. Negative emotions and beliefs, or thoughts, are common in patients with complex LBP presentations and can be primary barriers to recovery.[113] The patient's goals are also determined through the patient interview, and these goals determine the tasks analyzed in the physical examination.[122] The tasks may not always relate to the location of pain. For example, evaluating the squat task and sitting posture is meaningful for someone who experiences LBP with sitting, but not relevant for an individual with LBP that intensifies with walking. An evaluation of strategies used for stepping forward and thoracic rotation, 2 requisite components of walking, is more meaningful for the latter individual.

The patient is asked to report any sensations evoked as the task is performed, while the clinician observes/palpates each region of the body and notes any areas with alignment, biomechanics, and/or control considered to be suboptimal. This requires an understanding of what is optimal for each body region for that task. Subsequently, manual or verbal cues are given to change the alignment, biomechanics, and/or control used for a body region, and the impact of this correction on the patient's experience, as well as any change in performance of other body regions, is noted. This is called "finding the driver," which refers to the region of the body that, when corrected, results in the best improvement in both the experience and performance of the task. For an individual with LBP, it may be the hip, foot, pelvis, thorax, neck, or a combination of corrections.[102,105,144] The low back is often the "victim" of suboptimal strategies for transferring loads through the trunk, regardless of whether the pain stage is acute or chronic.[92,93] The driver can change both within and between treatment sessions when the whole body is evaluated for each task. The driver informs the clinician where to focus treatment.

Further tests of the driver (the body region found to have the greatest impact on the function/performance of the meaningful task), such as active mobility/control and passive mobility/control, reveal the contribution of various system impairments (articular, neural, myofascial, and/or visceral) to determine individualized treatment, as no 2 patients have identical thoughts, beliefs, and system impairments culminating in their experience. These tests are directed to the driver (thoughts/beliefs, emotions, hip, pelvis, low back, thorax, foot, etc).

In summary, assessment using the ISM approach involves the following.

1. Choosing a relevant assessment task according to the patient's movement goals.
2. Analyzing how the patient performs the task, using observation and manual examination.
3. Correcting alignment, biomechanics, and/or control with manual examination and/or words/cues to assess the impact of changing performance and the impact of changes on other body regions.
4. Choosing to first treat the area of the body that has the greatest impact on performance of the task, regardless of the location of pain.

Intervention Outline Intervention is based on the findings of the clinical examination and a clinical-reasoning approach.[85,87] Intervention using the ISM approach may, therefore, involve a variety of treatment approaches based on different findings from different systems, such as treatments based on altered active control (including motor control[6,42,53-55,59,64,66]), passive mobility or passive control of joint structures[4] (eg, stress tests) or myofascial tissue, or neurodynamics of the nervous system.[106] The assessment findings direct the initial treatment, which is individualized according to the underlying system impairments impacting the body region.

Each treatment may include the following elements.

1. Education: to address negative thoughts/beliefs about pain[12,91] and manual therapy to mobilize any joints thought to be fibrotic or where mobility is reduced secondary to overactive muscles[6,104,114] or fascia.[8]
2. Motor control training[42,53-55,59,64,66,135,136]: to teach better recruitment strategies for neuromuscular support of joints for both static loading and movement, and to restore optimal recruitment of the transversus abdominis, deep multifidus, and pelvic floor muscles.
3. Movement training: to build strength, endurance, and capacity for the individual's movement goals.[24,129]

Evidence for Efficacy This approach is evidence informed, and, although aspects have been tested in trials, no RCT has yet tested the efficacy of the entire approach. The clinician's challenge is to decide which treatment is appropriate for the individual patient. The ISM aims to help clinicians use both the evidence and their experience to clinically reason the best way forward for individuals with disability or pain.

Convergence and Divergence of Consideration of Motor Control in the Management of LBP

Due to its diversity in presentation, LBP has been identified as a condition that may be amenable to subgrouping. Classification of patients to subgroups has been highlighted as a research priority for heterogeneous disorders such as LBP.[7,41] A major aim of subgrouping is to identify groups of individuals who may be more or less responsive to a specific treatment, based on certain presenting characteristics.[18] Evidence to support the potential benefits of identifying different subgroups of patients with LBP who will predictably respond to specific treatments comes from recent trials that show larger effect sizes for MCT in individuals with specific baseline features[27,94,137] and from the large clinical effects identified in early trials that applied MCT to specific groups of patients with LBP.[47,108,129]

While no single approach will solve the entire LBP problem, identifying subgroups of patients whose condition can be resolved by subgroup-specific treatments should be prioritized. Although application of motor control theory to LBP management varies, there is convergence. The **TABLE** summarizes key features considered by each motor control approach. Areas of convergence/similarity between approaches include the following.

1. All approaches incorporate detailed assessment (including patient interview and physical examination) to guide individualized treatment, but the elements addressed differ.
2. All approaches include clinical reasoning. Although some individual elements of the approaches may help some patients when used in isolation, effect sizes appear to be larger when treatment involves integrated use of multiple components in a clinical-reasoning framework, matched to individual patients.[94,153]
3. All approaches assume that tissue loading contributes to symptom maintenance.
4. Some aspects of treatment aim to optimize tissue loading.
5. Correction of posture/alignment is considered in all approaches, particularly with reference to maintenance of a specific alignment during sustained postures.
6. Careful and progressive instruction regarding how to appropriately limit lumbar motions and move appropriately at the hips during function is a common theme in most approaches.
7. Attention is placed on the patient-therapist alliance: the importance of identifying subgroups, understanding the patient's goals and expectations, use of appropriate communication skills, patient education, safety, self-care and patient independence, working together with the patient and the medical/multidisciplinary team, setting realistic goals, reassurance to minimize fear avoidance, understanding pain processes and their relevance, the importance of pain-free movement, and the need to promote LBP prevention.

There are also divergences between approaches.

1. Not all approaches have shown reliability in identifying subgroups that the approach can and cannot treat with predictive effectiveness.
2. Approaches differ somewhat in their primary focus, the most obvious being that MDT emphasizes evaluation of patterns of symptom response to a standardized group of repeated end-range spinal loading tests, whereas the MSI approach, MCT, and the ISM stress correcting alignment and movement patterns, but within different clinical frameworks.
3. Initial management differs. Mechanical Diagnosis and Therapy seeks to identify mechanical subgroups, and patients are taught to perform exercises based on this assessment; the MSI approach involves instructing the patient in alignment and movement correction; the ISM aims to "release and align"; and MCT enhances/reduces muscle activity and modifies alignment and movement as required.
4. Evidence for assessment and treatment differs. Although there are varying levels of evidence for assessment techniques and the efficacy of MDT, the MSI approach, and MCT, the ISM has not been tested, but some assessments and treatments included in the ISM approach have been studied.

The wrong question to ask is which approach is most effective. Rather, by identifying and validating subgroups, some patients can be more effectively treated with one approach than with another.[78] Further, patients often prefer the type of intervention they are willing to undertake and adhere to. Clinicians also have differing skill sets, levels and types of training, levels of expertise, and previous experiences. As LBP can be multifactorial, ideal management must first seek to reliably identify subgroups for which there are predictably effective treatments. Those validated subgroups will then inform the type of intervention needed to bring about improvement: mechanical, medication, motor control, psychosocial, injection, or even surgery. This may require integrating other health professionals who can advise on other forms of treatment (eg, appropriate medication). Ideally, those approaches would be complementary and enhance the response to physical and neuromuscular approaches.

Interface With Nonsurgical Medical Management

Subgrouping patients via movement patterns, posture, and provocative and symptom-relieving mechanical testing, such as the methods described above, is not only relevant for physical therapists, but also an important concept for health care providers of any profession managing patients with LBP. This consideration aids removal of the "non" from "nonspecific" LBP.

TABLE — Features of the Approaches

	Medical Approach	MDT	Movement Systems Approach	Motor Control Training	Integrated Systems Approach
Evidence					
Evidence for effectiveness for patients with acute LBP	?	Yes			
Evidence for effectiveness for patients with chronic LBP	?	Yes	Yes	Yes	
Demonstrated reliability and validity of assessments		Yes	Yes	Yes	
Treatment components related to motor control					
Treatment based on detailed physical examination	Yes	Yes	Yes	Yes	Yes
Spinal posture/alignment is assessed and trained	Yes	Yes	Yes	Yes	Yes
"Neutral spine" is a key feature			Yes	Yes	Yes
Movement is assessed and trained		Yes	Yes	Yes	Yes
Movement quality is a key feature	Yes		Yes	Yes	Yes
Muscle activation is assessed and trained				Yes	Yes
Aim for pain-free movement	Yes	Yes	Yes	Yes	Yes
Focus on importance of mechanical/biomechanical focus		Yes	Yes	Yes	
Body awareness is considered in assessment and treatment			Yes	Yes	Yes
Breathing pattern is assessed and trained			Yes	Yes	Yes
Mobility of adjacent areas is assessed and trained			Yes	Yes	Yes
Includes exercise that aims to integrate into function rehabilitation		Yes	Yes	Yes	Yes
Includes exercise to enhance muscle endurance				Yes	Yes
Includes exercise to enhance muscle strength			?	Yes	?
Biofeedback is used to guide motor control training			Yes	Yes	Yes
Additional aspects considered in design of treatment					
Patient interview provides information to guide treatment application	Yes	Yes	Yes	Yes	Yes
Identifies directional preference in response to mechanical loading		Yes			
Identification of "pain generators" is important		Yes			Yes
Whole-person assessment to identify the "driver" of the patient's presentation		Yes			Yes
Approach considers patient's lifestyle	Yes	Yes		Yes	Yes
Self-management is advocated	Yes	Yes	Yes	Yes	Yes
Aims to enhance prevention of further LBP episodes	Yes	Yes	Yes	Yes	Yes
Approach can be combined with other treatments	Yes	Yes	Yes	Yes	Yes
Approach is staged with guidance for progression of training	Yes	Yes		Yes	Yes
Adjunct treatments					
Considers injection of drugs	Yes	*			
Considers prescription of oral medication	Yes	*			
Psychosocial features are assessed and targeted with management	Yes	†		Yes	Yes
Training					
Approach requires specialized training	Yes	Yes	Yes	Yes	Yes
Credentialed training is available		Yes			Yes

Abbreviations: LBP, low back pain; MDT, Mechanical Diagnosis and Therapy.

**Studies argue that response to MDT assessment may aid this decision (van Helvoirt H, Apeldoorn AT, Knol DL, et al. Transforaminal epidural steroid injections influence Mechanical Diagnosis and Therapy (MDT) pain response classification in candidates for lumbar herniated disc surgery. J Back Musculoskelet Rehabil. 2016;29:351-359. https://doi.org/10.3233/BMR-160662).*

†Studies argue that psychological features may be improved by positive response to treatment (Takasaki H, Saiki T, Iwasada Y. McKenzie therapists adhere more to evidence-based guidelines and have a more biopsychosocial perspective on the management of patients with low back pain than general physical therapists in Japan. Open J Ther Rehabil. 2014;2:173-181. https://doi.org/10.4236/ojtr.2014.24023).

Identification of relevant motor control features or a specific response to a movement test can inform specific movements and corrective exercises, with a rapid response for some patients. Other patients may have a presentation complicated by features such as differences in pain processing, experience of intense pain, fear avoidance, and previous experiences that compromise their full participation in physical treatments. These patients may benefit from coordinating physical and medical treatments to fully accomplish recovery from an episode of LBP and establish a maintenance program and future self-management of LBP episodes. A coordinated interprofessional approach, including medical management, is required to achieve the best outcomes. The **TABLE** presents some of the interfaces between medical and motor control approaches.

At initial presentation, a thorough examination alludes to the potential benefit of combining medical and motor control interventions. The history gives insight regarding medical management that might be necessary as adjunct interventions to physical treatment. Features that may guide medical management include behavioral health (occupational health/psychological interventions), poor sleep (sleep education/medication), quality and distribution of pain recognized as neuropathic (medication), and recurrent soft tissue complaints (interventional procedures).

Some patients benefit from medication to manage symptoms and to enable performance of physical treatments to reach their potential. Decisions about the need for and type of medications[3] are influenced by the time course of LBP, the distribution and quality of pain, the underlying pain mechanism (eg, central, neuropathic, nociceptive), the nature of provocative activities, sleep interference, and the patient's beliefs, experiences, and expectations. A scheduled medication regime may accomplish adequate pain control for the patient to participate in an active physical therapeutic program.

Overall, it is critical for health care providers to understand and consider the relative importance of factors beyond motor control to optimize the treatment approach and achieve successful long-term patient outcomes.[5,139] The importance of standardizing the diagnostic/subgrouping process cannot be overemphasized, as that will inform treatment decision making in a multidisciplinary framework.

CONCLUSION

This commentary reviewed convergence and divergence in approaches to LBP management that include consideration of motor control. The element common to all approaches is the focus on the need to reliably identify membership or nonmembership in validated subgroups of patients who have been shown to respond to treatment that eliminates pain when possible, optimizes alignment, restores and maintains full lumbar motion, and ensures that adjoining body regions demonstrate full and free movement. This focus is applied during exercise as well as in activities of daily living, fitness, and sports. The major differences between approaches relate to the baseline examination methods and the patient-specific treatments used to eliminate pain while restoring optimal alignment and movement.

No evidence supports one treatment approach over another. However, the reliable identification of members of subgroups for which there are predictably effective subgroup-specific treatments begins the process of identifying standardized treatment for members of each subgroup. By identifying areas of convergence/divergence and acknowledging existing literature that validates subgroups, we hope these insights can provide guidance to clinicians regarding which approach will serve their patients best.

This information can also provide a platform for teams to work together to consider hybrid approaches tailored to the individual patient for a focused progression, based on presentation and response. Benefit can be gained by improved communication and increased collaboration between colleagues in multiple disciplines to manage aspects of the multifaceted presentation of LBP (eg, specialist psychological intervention), when needed, and to facilitate treatment approaches that include consideration of motor control (eg, appropriate analgesia). ◉

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