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A Time to Reflect on Motor Control in Musculoskeletal Physical Therapy

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Motor control is a popular concept within physical therapy practice and has received a significant amount of attention over the last 25 years. It has been implicitly conceived and understood by clinicians and researchers throughout this time, yet appears to differ considerably with respect to its definition and translation into clinical practice.

The field of motor control research encompasses a number of areas, including physics, engineering, statistics, and behavioral and cognitive science, as well as physiology, neuroscience, and medicine.[26] Within these fields, the concept of motor control appears to be explicitly well understood, but contextually only makes sense from each individual perspective. Under close examination within musculoskeletal physical therapy practice, motor control is a complex, broad, and ambiguous concept. This is likely due to the contributions of the varied fields that draw together to help with the management of patients with musculoskeletal conditions. Complex questions, such as whether pain is a cause or a consequence of altered adaptive or maladaptive motor control strategies, still pervade the musculoskeletal literature and influence motor control treatment approaches.

The purpose of this Viewpoint is to outline the history of motor control and its use in musculoskeletal physical therapy practice and to highlight the consequences of its interpretation and variation in its use. Attention is given to understanding the concept of motor control and its misrepresentation through the use of surrogate terms. A number of comparable definitions are cited in the literature; however, this ambiguity has given rise to surrogate terms, such as *neuromuscular control*, *neuromotor control*, and *core stability*, which may cause confusion in clinical practice, education, and research. How the concept of motor control may be applied in practice to resolve ambiguity and recommendations for the direction of future research are made.

Motor Control in Musculoskeletal Practice

Motor control theories and principles, including motor learning, have emerged to promote health, well-being, physical performance, and development within musculoskeletal practice. Motor control has been broadly described as "an area of science exploring how the nervous system interacts with the rest of the body and the environment in order to produce purposeful, coordinated movement."[15] However, the origins of motor control exercises in physical therapy low back pain literature paint a slightly different picture. The field of clinical biomechanics has dominated the low back pain literature since the late 1970s, when White and Panjabi's[30] work led to a number of assumptions that still appear to exist today. During this time, the focus of understanding low back pain was on the structural integrity of the spine with respect to its stability and function, using in vitro models that suggested that the spine was inherently unstable.[23] As a consequence, therapeutic strategies to enhance the stability of the spine and the ability of the spine to adapt under physiologic load emerged as a focus of motor control strategies. These were subsequently applied to other areas of the body.

Motor Control: A Broad, Complex Concept From a Biomechanical Frame of Reference

Panjabi's[23] model of spinal stability, the most cited antecedent model, is based on the theoretical interactions between

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active (muscular) and passive (articular/ligamentous) stabilizers through a control (nervous) system to meet the demands of spinal stability, with a distinct lack of theoretical linking between them.

This spinal-stability model suggests that causes of symptoms are due to biomechanical instability, tissue damage, or structural change and are not in keeping with a contemporary understanding of musculoskeletal practice that values a multidimensional perspective.[22] Panjabi's model[23] draws from Anders Bergmark's[2] influential biomechanical theory, which delineated the function of the deep and superficial muscles of the body as being distinctively different and potentially relevant in clinical practice. The combination of models contributed to the rise of motor control strategies to theoretically improve painful conditions by isolating movement strategies to target muscles that may contribute to instability. These motor control strategies have been linearly described as the rehabilitation strategy to retrain the deep stability muscles, with the vague notion of progressing to larger and more functional movements. This may, in fact, be simply a graded exposure program with respect to load and movement within safe environments among a myriad of contextually nonspecific factors. Such approaches lack the cognitive, behavioral, emotional, lifestyle, cultural, and contextual understanding that whole-person approaches to health care espouse.[22] This is despite greater theoretical and explanatory models superseding the biomechanical stability model, such as pain adaptation theory,[12] movement variability,[19] and development of first-person neuroscience in the context of pain.[29]

Variation of the Clinical Application of Motor Control in Musculoskeletal Clinical Practice

Many clinical approaches developed from different theoretical models, premises, and measurements have used motor control treatment strategies for musculoskeletal conditions (**TABLE**). This raises the following questions:

1. When describing a patient as having "altered" or "poor" motor control, what does that mean and in what context?
2. When therapists describe motor control exercises, what does that mean and when does a movement exercise become a motor control exercise?
3. If motor control exercises constrain aspects of specific movement strategies (eg, control), do they run the risk of facilitating poorer outcomes such as fear avoidance?[28]

Conceptual Clarification

One way to understand motor control is to examine it at a conceptual level. Concepts have been described as the building blocks of theory[3] and theory development,[18] and are embedded through our use of language and how we clinically practice. Concepts that are vague or not well understood have the potential of creating ambiguity, with unforeseen consequences that may negatively impact knowledge translation, patient-centered care, clinical education, and, ultimately, patient-related outcomes. It is therefore advantageous that both the development and clarification of concepts within the evidence base facilitate a richer understanding and, therefore, application of them. Ironically, despite the implicit importance of conceptual clarity in fields of research and clinical practice,

TABLE Examples of the Use of the Concept of Motor Control Within Musculoskeletal Physical Therapy Practice

Study	Antecedent Theory	Premise	Measurement of Motor Control	Patient Group
Janda[13]	Muscle imbalance theory	Muscle length and tension relationships to posture, muscle activity, and function	Muscle length tests and clinical observations of static postures and dynamic movements	Whole body
Richardson and Jull[24]	Bergmark's[2] biomechanical principles (differentiation between deep and superficial muscles)	Inhibition of deep stabilizing muscles and overactive superficial muscles cause aberrant load and tissue sensitivity	Pressure gauge biofeedback while completing an isometric contraction of the lumbar spine, later applied to the craniocervical neck flexion test	Low back pain and, later, neck pain
Sahrmann[27]	Kinesiopathological model	Abnormal movement variation leading to pathological tissue changes	Movement impairment clinical tests using postural, static muscle length, and dynamic movement tests	Whole body
O'Sullivan[20]	Biopsychosocial model and Panjabi[23] model of spinal stability	Adaptive and maladaptive motor patterns classified into direction-specific control impairment classification	Clinical examination and history taking to determine adaptive versus maladaptive movement behaviors	Low back pain
McGill[16]	Clinical biomechanical movement and loading principles	Load, shear, and movement intolerances	Provocative tests used to evaluate current tolerances to load and capacity	Low back pain
Hides and Stanton[9]	Panjabi[23] model of spinal stability and Bergmark's[2] biomechanical principles (differentiation between deep and superficial muscles)	Repetitive dominance of limb causing asymmetrical trunk muscular hypertrophy, altering force production, active and passive stability, and subsequent injury	Cross-sectional area and symmetry of deep abdominal muscles as visualized with magnetic resonance imaging or ultrasound in the clinic	Low back pain and lower extremity injury[31]

there is still debate among philosophers and researchers regarding the definition and function that underpin the concepts themselves.[25]

Future work with regard to conceptual analysis and Delphi studies on the concept of motor control as used in musculoskeletal practice may provide further insight to address these concerns.

The Language of Motor Control: Core Stability—a Source of Confusion and Potential Deleterious Outcome

The surrogate terms of a concept can cause a lack of clarity and confusion if they depart significantly from the concept's linguistic use and meaning.[5] *Neuromuscular control* and *neuromotor control* contain similar linguistic characteristics in that they refer to the nervous and muscular systems alongside the control of movement. However, the term *core stability* lacks a clear linguistic relationship with movement. The term *core stability* emerged through the use of stabilization exercises of the trunk. The use of stabilization exercises in this context has exclusively been identified from within the musculoskeletal literature in the management of low back pain.[10,11]

McNeill[17] cautioned against using the term *core stability*, as it was "imprecise and open to interpretation," and went on to describe core stability as a subset of motor control, suggesting that it required further clarity and perhaps should be abandoned. O'Sullivan[21] is critical of both the terms *stabilization* and *core stability* with respect to the management of chronic nonspecific low back pain, stating that the biomedical explanation of lack of stability of the spine may cause "fear, abnormal body focus and reinforces pain-related movement and avoidance behaviours, hypervigilance, catastrophising, pain and disability fuelling the vicious cycle of pain." If this were the case with spine-related pain, then it would be reasonable to suggest the same in peripheral joint regions, as discussed eloquently by Jull.[14] Additionally, the relationship between the use of language, a person's understanding, and subsequent meaning in the literature appears to be very clear. Language can indeed have a harmful effect, as studies have identified deleterious consequences in patients experiencing musculoskeletal pain.[1,4,6,7]

Interpretation From Research Into the Clinic: Lessons Learned?

The research literature has a tendency to measure aspects of the concept of motor control and then to conclude that, if any effect is found, then it is due to the concept itself rather than a change in the attribute. Numerous examples identify attributes of motor control, such as muscle force production, muscle timing, and joint position sense, then identify an outcome after an intervention. The observed outcome is then ambiguously reported as being a change in motor control rather than simply a change in the attribute, such as valgus during a single-leg squat motion or reduced movement variability. An example is the seminal paper by Hodges and Richardson,[11] which reported that relative delays in the measurements of transversus abdominis muscle contraction occurred in individuals with low back pain when lifting an arm repeatedly. The conclusion of the paper was that this indicated a "deficit of motor control" and that it was "hypothesised to result in inefficient stabilisation of the spine." The unforeseen consequences are that such descriptions are then observed in clinical practice, both conceptually and literally. Looking back, efforts in clinical practice became more about attempting to feel and retrain the contraction of the deep abdominal muscles, which took precedence over other areas of clinical practice when treating these groups of patients.

The use of the term *motor control* within practice is often used in a specific way (eg, knee valgus or hip internal rotation during a step-down task), but is described broadly as a poor motor control strategy; describing the movement strategy rather than the vague term *motor control* could simply ameliorate this. Perhaps it is of more value to describe the changes in the attribute, or set of attributes, of movement than to suggest that motor control itself changes. This practical approach may improve knowledge translation and resolve ambiguity.

Developing New Theoretical Constructs

With developments in cognitive and pain neuroscience and a greater understanding of the complexities involved between pain and rehabilitation, the physical therapy profession may benefit from its continued vigilance against biomedical oversimplifications. The future applications of motor control require a broad and integrated representation of theoretical constructs that outline multiple mechanisms, consequences, and alterations in movement function in relation to the context of pain and suffering, with a fusion of biological, biographical, psychological, social, and cultural paradigms.

Promising theories from cognitive neuroscience may solve some of the challenges of motor control by stepping away from traditional concepts of input, output, feed forward, optimum, and comparator modeling and toward predictive coding[8] under a unifying theory of biological function.

Key Points

- Motor control has enormous potential for developing our understanding of the assessment, treatment, and management of the patients in our care. However, a significant amount of work is required to develop our understanding at the conceptual level to inform further research and implementation in clinical practice.
- Concepts in musculoskeletal practice that are vague run the risk of unresolved ambiguity in language and our collective understanding. The concept of motor control suffers from ambiguity due to its size and scope, and may benefit from future analysis and completion of a Delphi study within the context of musculoskeletal physical therapy practice.

- In the meantime, being explicit when describing movement strategies through defining their attributes is likely to reduce ambiguity and improve understanding in clinical practice, education, and research.

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