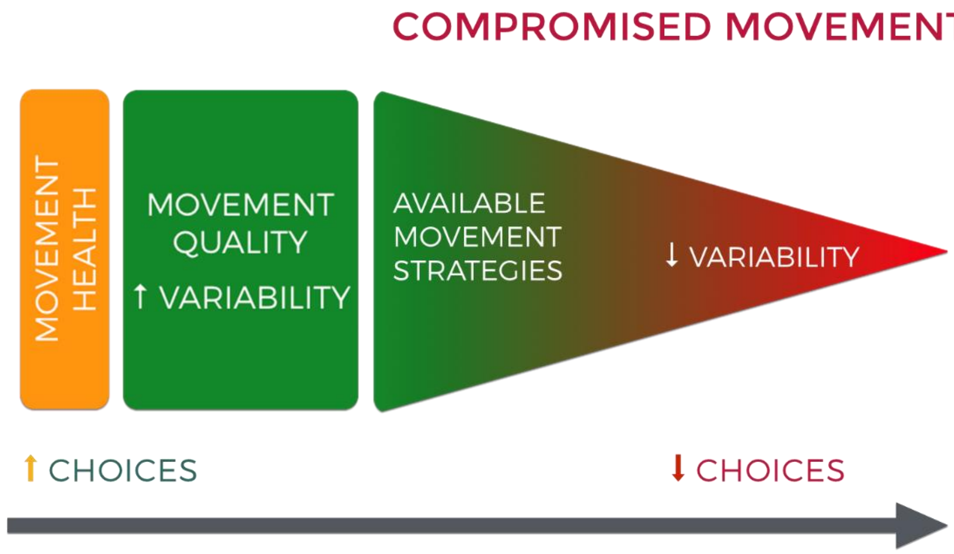
Movement Control & Muscle Functional Roles

What supports Movement Health?

Many muscles can perform the same task due to the presence of motor abundance/redundancy (Latash, 2012). For example, many muscles may flex the hip or rotate the head. This characteristic allows for the formation of muscle synergies, a collection of muscles united to contribute in varying amounts to a movement. For any given movement task, at any given intensity, the muscles within a synergy may vary in their contribution, allowing the individual to perform the task at hand in a number of different ways. As the task, intensity or other factors change muscles within the synergy can adapt to meet the changing demands.

Muscle synergies can then be seen to supply the individual with a robust, problem solving capacity, managing intrinsic and extrinsic demands in both the short and long term. A robust movement system may then be one possessing multiple movement options to the demands of life, able to employ the wealth of options that exist within motor abundance.



Losing choices and back-up strategies

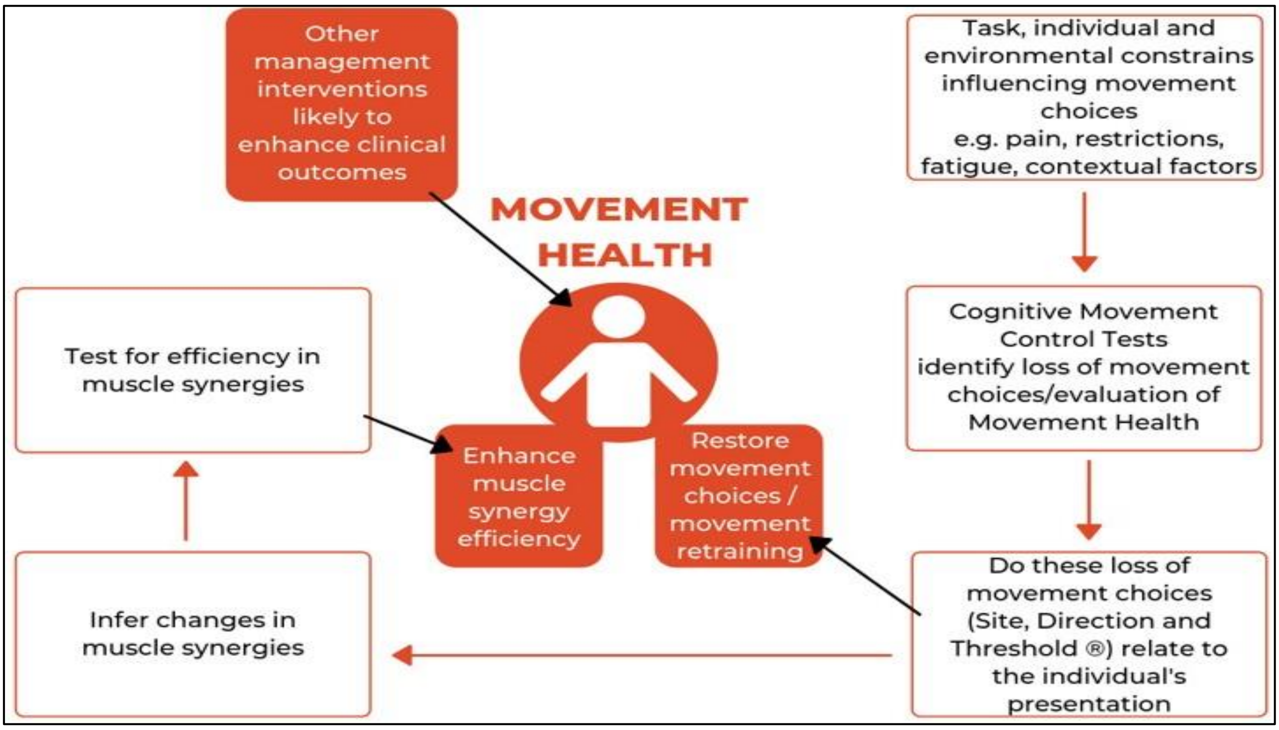
In the presence of factors such as pain, history of pain and fatigue, movement options are lost and there is change in the synergistic mix. In the schematic below, an individual is seen to possess many movement options that are then lost in the presence of pain.

In the presence of pain or a history of injury (initial state), the many movement strategies available to the individual are no longer present. The individual may employ 'back-up' strategies as their primary option. There is less choice in movement, and a reduced state of Movement Health. A narrower band of movement options are employed which may then further stress already sensitised tissues on a more regular basis, or place volumes of work on currently non-painful structures.

Mottram & Blandford (2020)

MOVEMENT HEALTH

Assessing movement strategies:
Testing patterns of movement co-ordination strategies



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Movement efficiency is assessed based on a number of movement related tests.

The process incudes consideration of:

- co-ordination strategies (co-ordination module) – *Control of direction (site & direction)*
- synergistic contributions within a synergy (muscle synergy module - *Control of range, control of extensibility and control of translation*

Comerford & Mottram's (2012) muscle role classification system has considered each individual synergist within a synergy against multiple criteria in order to establish how it may be most efficiently employed within a movement task. When employed clinically, the model allows the synergies to be evaluated in terms of efficiency.

Fundamental to the Kinetic Control process is the use of movement as the intervention to the manage patients' current pain state, functional status and future Movement Health.

This process uses cognitive movement control test to identify 'Lost Movement choices' (LMCs). These Lost Movement Choices (LMCs) provide a diagnosis of the Site & Direction of movement co-ordination impairments / uncontrolled movements (UCMs).

MOVEMENT CONTROL IMPAIRMENTS (Lost Movement Choices)

The altered patterns of movement that result from these compensatory strategies are observed as altered trajectories of motion. If the brain and CNS are unable to provide the best strategy to control the trajectory of motion, then abnormal stress is placed on a variety of neuro-musculo-skeletal structures and pathology may develop.

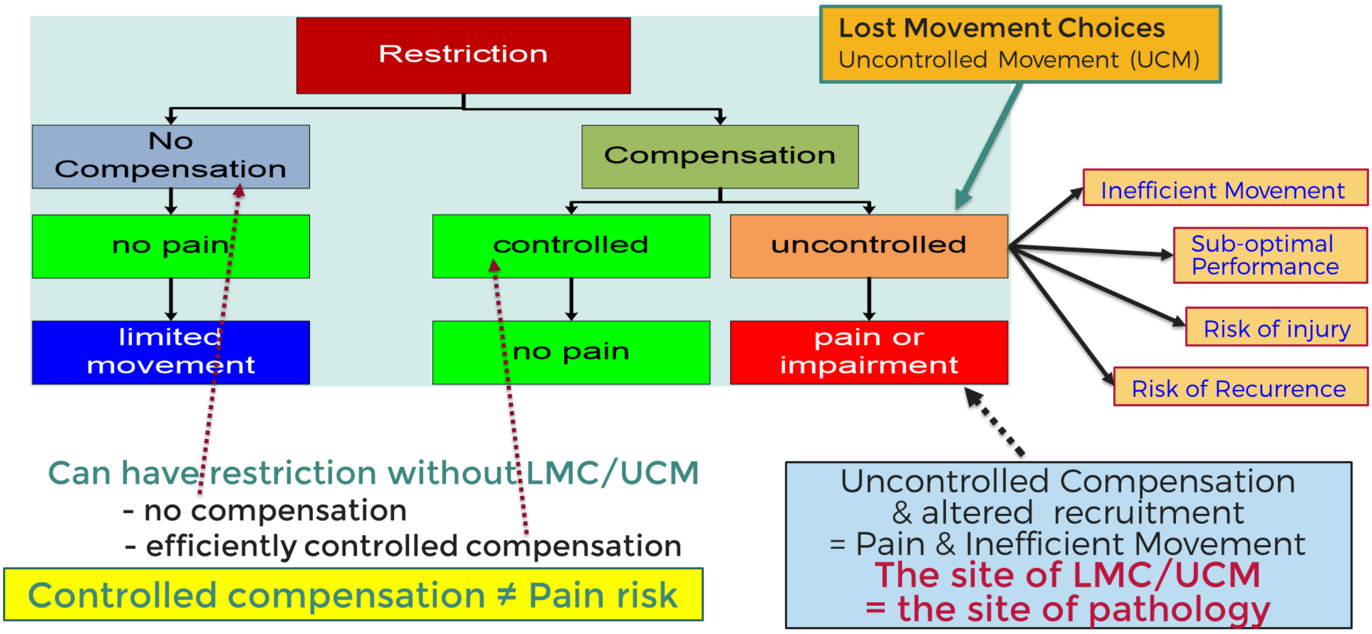
While compensation for acquired restriction is a normal adaptive process, compensation that is well controlled is not impairment and is usually non-symptomatic. However, compensation that is poorly controlled is maladaptive and contributes to dysfunction (uncontrolled movement). **This movement control impairment presents as poor low threshold muscle control within the functional range of movement or the translational glide of a joint and may involve either local or global muscle dysfunction**. This demonstrates a 'weak link' in the efficiency of control of the trajectory or path of motion.

- Movement control impairments can present as dysfunction of **articular** motion associated with abnormal **translation** at a single motion segment.

- Movement control impairments can occur in the **myofascial** system in the physiological and functional movements associated with **range and direction** of movement across **one or more motion segments**, e.g. abnormal myo-fascial length and recruitment (or patho-neuro-dynamics).

These movement impairments increase micro-trauma in the tissues around the joint which if accumulative lead to dysfunction and pain. This imbalance can be the result of extrinsic or intrinsic factors. Extrinsic load changes such as running on cambered side of a road or intrinsic load changes due to shortening of the ilio-tibial band (adolescent growth spurt) will contribute to valgus loading of the knee and external tibial torsion.

When range of motion is habitually increased or decreased at a joint in any specific direction, then myofascial tissue must proportionally adapt and increase or decrease its extensibility to match the altered joint range. There is frequently (but not always) a relationship between the loss of range of movement at one or more motion segments, and the development of compensatory excessive movement at adjacent segments. This imposes abnormal compression or impingement on some aspects of the joint system or abnormal tension or strain on other aspects of the joint. These adaptive movements increase micro-trauma in the tissues around the joint and eventually exceed tissue tolerance resulting in dysfunction and pain.



Movement Control Impairments – 'UCM' or 'LMC

Although it is accepted that it is normal to compensate for acquired restrictions in order to maintain function, several questions are often asked: "How much compensation is normal?" "When does compensation become abnormal?" "What defines dysfunction?"

Increased range of joint motion or compensation is frequently observed due to a variety of reasons. This hypermobile range does not necessarily constitute a stability dysfunction. Stability dysfunction requires a demonstrable lack of muscle control of joint motion.

The terms **'lost movement choice** can also be used to describe this uncontrolled movement. This can present as lack of control of normal functional motion or hypermobile range and may be associated with dysfunction in the myofascial, articular, neural or connective tissues. It may be identified in the physiological or functional movements of joint range, or it may be identified in the accessory translational gliding movements of a joint. The 'UCM' or 'LMC' can be compensation for restricted tissues in series or in parallel and is usually related to:

a) **RELATIVE FLEXIBILITY** - movement will take the path of least resistance so in the presence of a restriction (increased resistance) the joint may adaptively move in the direction of least resistance

Restriction → Compensation → 'UCM/LMC' → aberrant functional movement

b) **GLOBAL MUSCLE IMBALANCE** - The path of movement will be pulled towards the strongest force vector i.e. the dominant mobiliser synergist

Overpull vs. underpull → 'UCM/LMC' → aberrant functional movement

The Site of the Uncontrolled Movement = Site of Pathology

During functional movement, the site of uncontrolled motion is the **'site of the movement control impairment'**. The uncontrolled segment or region is the most likely site of the source of pathology and symptoms of mechanical origin. The uncontrolled movement abnormally loads myofascial, articular, neural or connective tissue structures. Some tissues around the site of 'UCM' are excessively compressed or impinged while others are excessively tensioned or strained by direction specific translational or physiological motion. The direction of 'UCM' relates to the direction of tissue stress or strain and pain producing movements and it is important not only to find the site of 'UCM' but also relate the direction of 'UCM' to provocative movement (Sahrmann, 1993 2002).

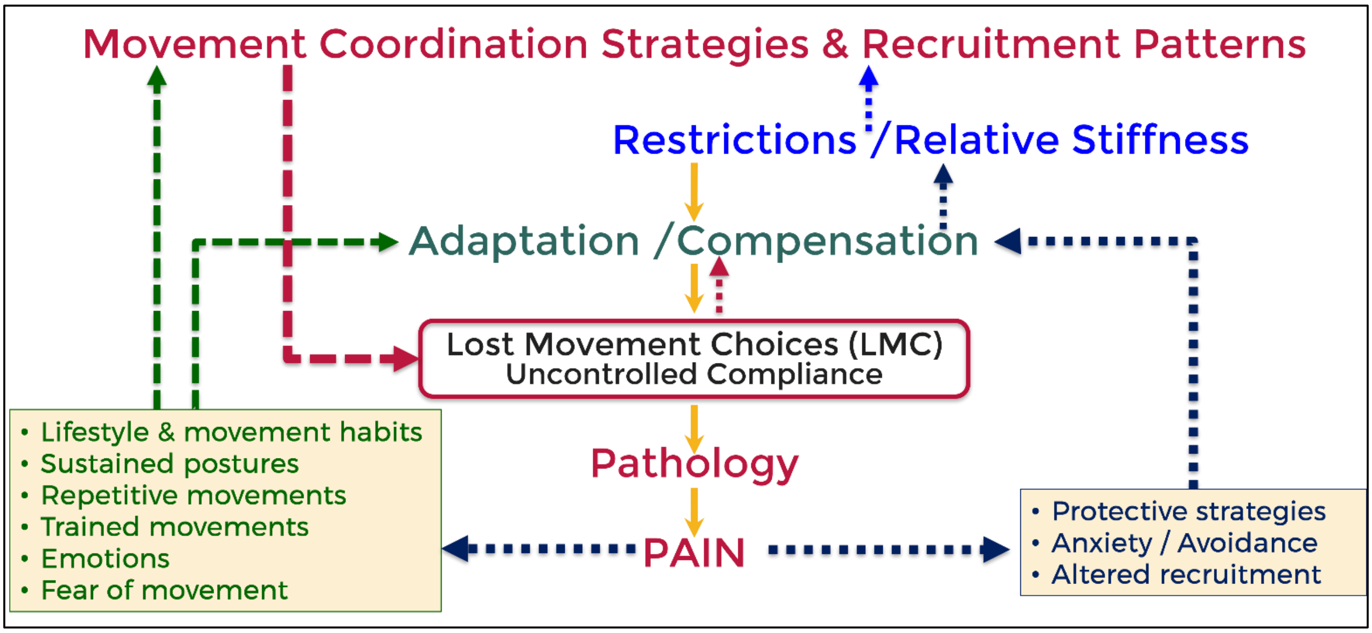
Stiff or restricted segments are **not** usually the *source* of pain during normal functional movement or loading. However, pain may be elicited from restricted segments under abnormal movement or load (e.g. grade IV manual segmental mobilisation or forceful stretch). Generally, the stiff or restricted segment may be a *cause* of compensatory 'UCM' at an adjacent joint (or in the same joint but in a different direction)

Occasionally, restrictions may be the source of symptoms. Though, this is usually due to some process of sensitisation. In musculo-skeletal pain syndromes there are two situations to consider that may give rise to abnormal pain sensitisation:

1. **acute inflammation** and the associated primary hyperalgesia due to chemical sensitisation from various chemical mediators of inflammation (e.g. histamine, bradykinen, substance P etc.)

2. **neural sensitisation and neurogenic pain** associated with secondary hyperalgesia and allodynia. This develops in situations of peripheral neural irritation and with 'central pain' phenomena.

Each of these processes needs specific management.



MUSCLE FUNCTIONAL ROLES

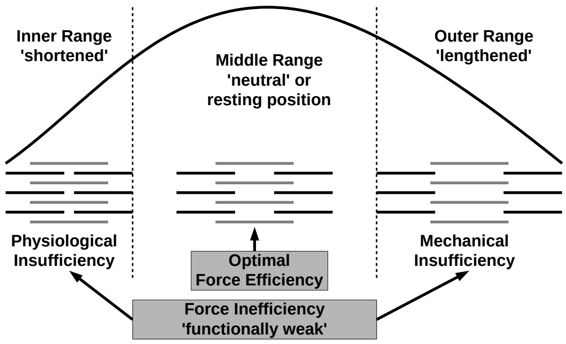
Muscle: Basic Functional Ability

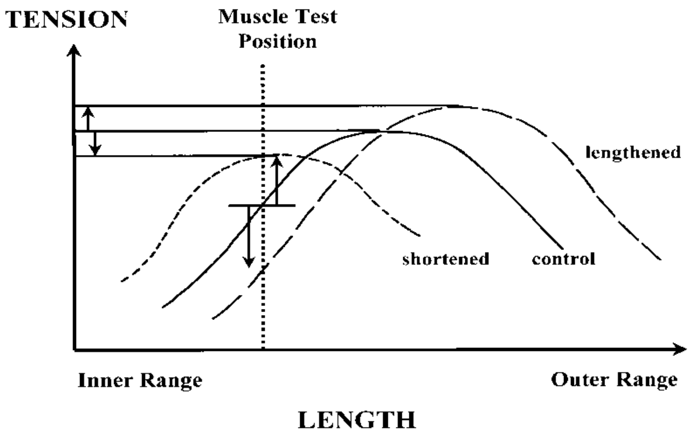
All muscles have the ability to:

a) Concentrically shorten to produce joint range of motion and accelerate body motion segments, which will be termed 'mobility function'
b) Isometrically hold position, which will be termed 'postural control function'
c) Eccentrically lengthen under tension to decelerate motion and control excessive range of motion, which will be termed 'stability function'
d) Provide afferent proprioceptive feedback to the CNS for co-ordination and regulation of muscle stiffness and tension.

Some muscles are more efficient at one of these roles and less efficient at other roles. Even within a group of synergistic muscles, some muscles are better suited to certain roles while other muscles are more suited to different roles. All muscles are not equally force efficient and for some muscles, generating high force is detrimental to good function.

Muscles are most efficient and generate optimal force when they operate in their mid-range. They are inefficient and appear functionally weak when they are required to function in a shortened or lengthened range relative to their normal or habitual length.





However, when a muscle habitually functions at an altered length (either lengthened or shortened), then its length - tension relationships adapt accordingly, so that the position in range where it generates optimal force efficiency changes to follow the relative lengthening or shortening.

A muscle's structure also affects its ability to generate force. Muscles with long levers (multi-joint) are biomechanically very efficient to produce range of movement during concentric shortening. They are not particularly efficient though, at preventing excessive movement during eccentric lengthening. These muscles primarily have a mobility role. Muscles with short levers (one-joint) are not biomechanically efficient to produce movement during concentric shortening. However, they are very efficient during eccentric lengthening to limit excessive movement and therefore for protection against overstrain. These muscles primarily have a stability role. When a muscle has such a short lever that it produces minimal length change, it has greater potential to control intersegmental translation.

CLASSIFICATION OF MUSCLE ROLES

Stabiliser & Mobiliser Muscle Roles

Rood, in Goff (1972), Janda (1996) and Sahrmann (2002) have described and developed functional muscle testing based on stabiliser and mobiliser muscle roles.

Stabiliser Role Characteristics	Mobiliser Role Characteristics
• One joint (mono-articular) • Deep (short lever and short moment arm) • Broad aponeurotic insertions (to distribute and absorb force and load) • Leverage for load maintenance, static holding and joint compression • Postural holding role associated with eccentrically decelerating or resisting momentum (especially in the axial plane - rotation)	• Two joint (bi-articular or multi-segmental) • Superficial (longer lever, larger moment arm and greatest bulk) • Unidirectional fibres or tendinous insertions (to direct force to produce movement) • Leverage for range and speed and joint distraction • Repetitive or rapid movement role and high strain / force loading

Functional Implications of Stabiliser - Mobiliser Roles:

- Muscles with predominantly stability role characteristics (1 joint) *optimally* assist postural holding / anti-gravity / stability function. Muscles that have a stability function (one joint stabiliser) demonstrate a tendency to inhibition, excessive flexibility, laxity & weakness in the presence of dysfunction (Janda term: ‘phasic’ muscle).

- Muscles with predominantly mobility role characteristics (multi-joint) *optimally* assist rapid / accelerated movement and produce high force or power. Muscles that have a mobility function (2-joint or multi-joint mobiliser) demonstrate a tendency to overactivity, loss of extensibility, excessive stiffness in the presence of dysfunction (Janda term: ‘postural’ muscle).

Local & Global Muscle roles

Bergmark (1989) developed a model to describe the muscle control of load transfer across the lumbar spine. He introduces the concept of local and global systems of muscle control.

Local Muscle System Characteristics	Global Muscle System Characteristics
• Deepest layer of muscles that originate and insert segmentally on lumbar vertebrae. • Controls the spinal curvature. • Maintains the mechanical stiffness of the spine controlling inter-segmental motion. • Responds to changes in posture and to changes in low extrinsic load.	• Superficial or outer layer of muscles lacking segmental insertions. • Large torque producing muscles for range of movement. • Global muscles and intra-abdominal pressure transfer load between the thoracic cage and the pelvis. • Responds to changes in the line of action and the magnitude of high extrinsic load.
General features	**General features**
• Deepest, 1 joint • Minimal force, stiffness • No/min length change • Does not produce or limit range of motion • Controls translation • Maintains control in all ranges, all directions, all functional activities • Tonic recruitment with low load and high load activities • No antagonists	• Deep 1-joint or superficial multi-joint • Force efficient • Concentric shortening to produce range • Eccentric lengthening or isometric holding to control range • No translation control • Direction specific \ antagonist influenced

Functional Implications of Local - Global roles:

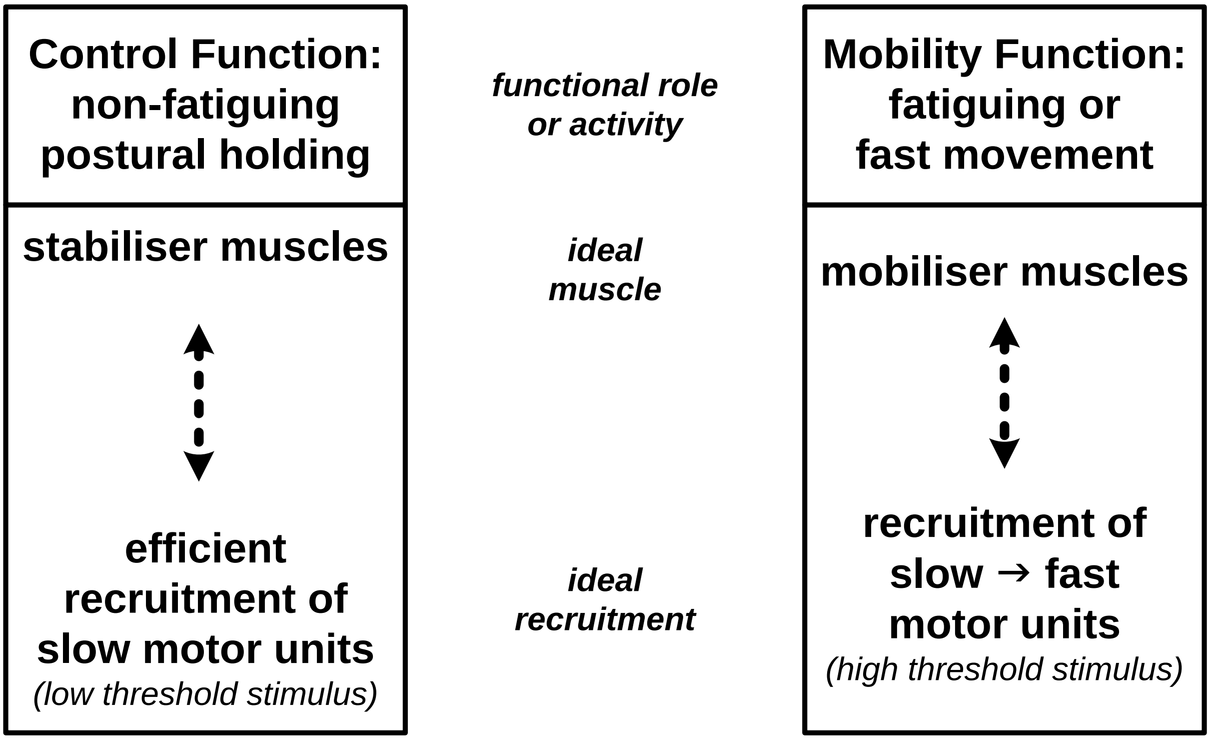
- **Local Muscle 'System':** The local muscle system is responsible for increasing the segmental stiffness of the spine and decreasing excessive inter-segmental motion and maintaining muscle control during low load tasks and activities. It is independent of the direction of loading or movement and is biased for low load function. The local muscles do not significantly change length during normal activation and therefore do not primarily contribute to range of motion. They maintain activity in the background of all ranges of motion.

- **Global Muscle 'System':** The global muscle system is responsible for the production of movement and the control of high physiological load. It is direction and load dependant. The global muscles change length significantly and therefore are the muscles of range of motion. These global muscles may have a primary stability or mobility role.

Both the local and global muscle systems must integrate together for efficient normal function. Neither system in isolation can control the functional stability of body motion segments.

The Relationship Between the Biomechanical & Physiological Characteristics of Muscles

In an ***ideal or normal*** situation:

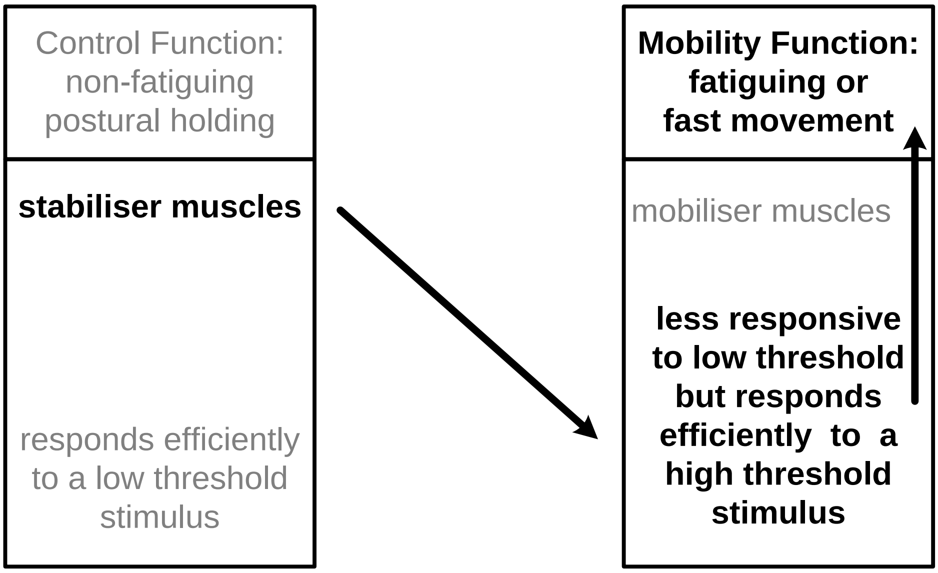


For an anti-gravity or postural holding function, muscles with stabilising characteristics would demonstrate greater recruitment of their slow motor units. They are sensitive to low threshold stimuli and should react efficiently to low force loading situations such as postural sway, maintenance of postural positions and normal functional movements of the unloaded limbs or trunk.

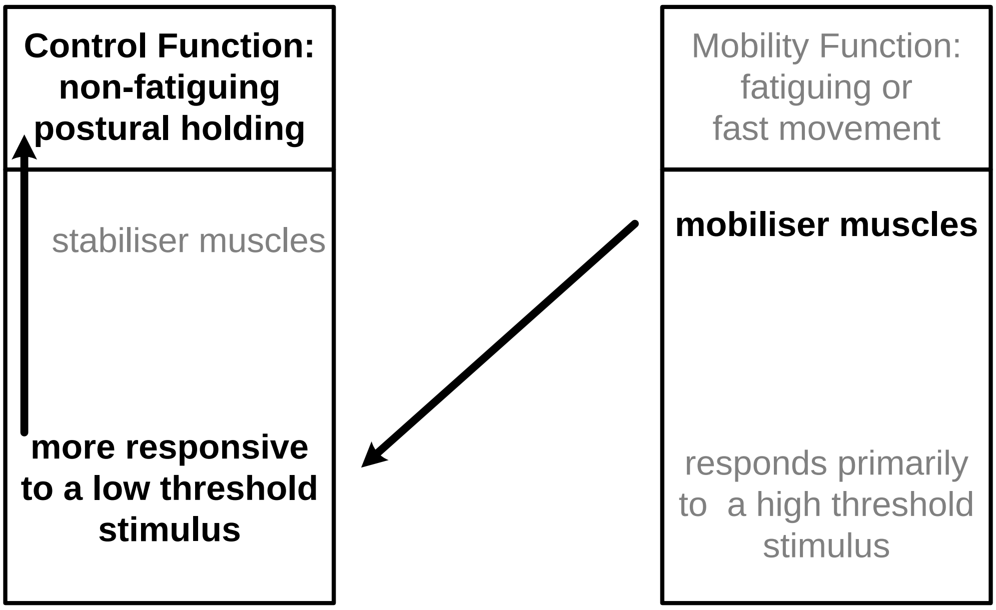
... while

For a fast, repetitive movement or power function, muscles with mobilising characteristics would demonstrate greater recruitment of their fast motor units (although the slow motor units are still recruited first). They are less sensitive, have higher recruitment thresholds and react more efficiently to high force loading such as accelerated movement, rapid movement, a large or sudden shift of the centre of gravity, high force or heavy loads and conscious maximal contraction.

Altered Recruitment Strategies associated with Pain or Impairment



Clinically, the one joint stabiliser muscles demonstrate a recruitment problem. They appear to increase their threshold, become less responsive to low load stimulus and react best when the load becomes greater. Therefore, the stability muscles appear to respond mainly to higher load activities such as accelerated movement, rapid movement, high force and a large shift of the centre of gravity.

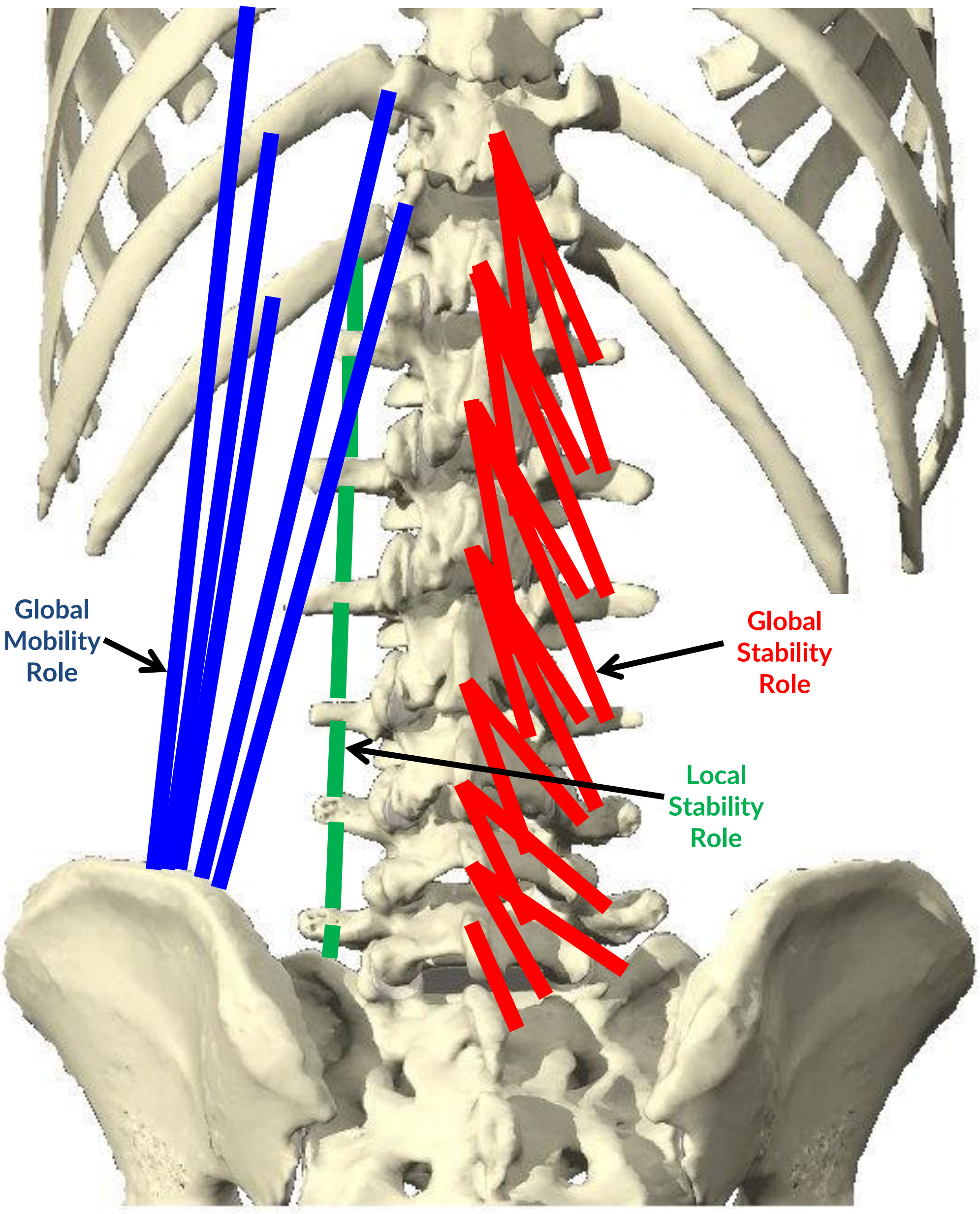


Clinically, the two joint mobilisers take over the stability role. They appear to decrease their threshold and become more reactive to low load stimulus. Therefore, the mobilising muscles appear to respond to low load activities such as postural sway, maintained postural position and slow movement of the unloaded limb. The decrease in threshold and increased tonic activity of SMU recruitment in the mobiliser muscles contributes to their observed dominance in postural control (Sahrmann 2002, O'Sullivan et al 1998, Jull 2000).

FUNCTIONAL CLASSIFICATION OF MUSCLE ROLES

The concepts of local and global muscle systems and stabiliser and mobiliser muscles provide useful frameworks to classify muscle function. However, alone, they have some clinical deficiencies. By inter-linking these two concepts though, a clinically useful model of classification of muscle functional roles can be developed.

LOCAL STABILISER Muscle Role / Strategy	GLOBAL STABILISER Muscle Role / Strategy	GLOBAL MOBILISER Muscle Role / Strategy
Function & Characteristics: • ↑ muscle stiffness to control segmental motion / translation • Controls the neutral joint position • Contraction = no / min. length change ∴ does not produce R.O.M. • Activity is often anticipatory (or at the same instant) to expected displacement or movement to provide protective muscle stiffness prior to motion stress • Recruitment is not anticipatory if the muscle is already active or loaded • +/- Muscle activity is independent of direction of movement • +/- Continuous activity throughout movement • Proprioceptive input re: joint position, range and rate of movement	***Function & Characteristics:*** • Generates force to control range of motion • Contraction = eccentric length change ∴ control throughout range • Functional ability to: (i) shorten through the full inner range of joint motion (ii) isometrically hold position (iii) eccentrically control the return against gravity • and control hyper-mobile outer range of joint motion if present • Deceleration of low load/force momentum (especially axial plane: rotation) • Non-continuous activity • Muscle activity is direction dependent ∴ powerfully influenced by muscles with antagonistic actions	***Function & Characteristics:*** • Generates torque to produce range of joint movement • Contraction = concentric length change ∴ concentric production of movement (rather than eccentric control) • Concentric acceleration of movement (especially sagittal plane: flexion / extension) • Shock absorption of high load • Muscle activity is very direction dependent • Intermittent muscle activity • (very on : off phasic patterns of activity – often brief bursts of activity to accelerate the motion segment then momentum maintains movement)
Impairment: • Motor control deficit associated with delayed timing or recruitment deficiency • Reacts to pain and pathology with inhibition • ↓ muscle stiffness and poor segmental control • Loss of control of joint neutral position	***Impairment:*** • Muscle lacks the ability to (i) shorten through the full inner range of joint motion (ii) isometrically hold position (iii) eccentrically control the return • If hypermobile - poor control of excessive range • Poor low threshold tonic recruitment • Poor rotation dissociation • Inhibition by dominant antagonists	***Impairment:*** • Loss of myo-fascial extensibility – limits physiological and/or accessory motion (which must be compensated for elsewhere) • Overactive low threshold, low load recruitment • Reacts to pain and pathology with spasm



- All 3 functional muscle roles within the lumbar paraspinal muscles

Muscle Characterisation

Although all muscles can perform all basic abilities, some muscles are ideally suited to some roles better than others. Our understanding of a muscle's ideal role should consider the co-relation of 4 significant features:

Function	Dysfunction
1. Anatomical location & structure 2. Biomechanical potential 3. Neurophysiology	4. Consistent & characteristic changes in the presence of pain or pathology

- If an analysis of all four of these features supports each other's conclusions, then we can be reasonably confident that we understand a particular muscle's primary function or role. This 4-point support is available only for a limited number of the muscles that physiotherapists work with on a regular basis. E.g. Transversus Abdominis, External Obliquus Abdominis, Rectus Abdominis, Hamstrings,

- If analysis of these four features provides conflicting conclusions then we can be confident that there is confusion, misunderstanding or misinterpretation of this muscle's function. Several possibilities exist to explain this apparent conflict.

    a. Discrepancies between measured features. E.g. Quadratus Lumborum, Latissimus Dorsi, Piriformis (e.g. high load versus low load function, neurophysiology does not match biomechanical modelling)

    b. Misinterpretation of measured features. E.g. Psoas Major, Upper trapezius, Lower Trapezius, Vastus Medialis Obliquus (e.g. assumptions based on EMG, assume fusiform but structure is pennate)

    c. The muscle is designed to participate in more than one primary functional role. E.g. Hodges (2003) suggests that a muscle may have 3 functional roles:
        i) control of inter-segmental motion
        ii) control posture and alignment
        iii) produce and control movement

    Some muscles can effectively perform all three of these roles. E.g. Gluteus Maximus, Infraspinatus

This conflict seems to be present with many muscles that physiotherapists work with on a regular basis.

For the greater percentage of muscles that physiotherapists work with on a regular basis we do not have enough information on all four of these features to claim to adequately understand the primary function or role of these muscles. E.g. Serratus Anterior, Adductor Magnus, Subscapularis

Muscle Function: Primary Roles

LOCAL STABILITY Muscle Role / Strategy	GLOBAL STABILITY Muscle Role / Strategy	GLOBAL MOBILITY Muscle Role / Strategy

Understanding a muscle's primary role or is not always simple!

Single Task Muscles

- **Some muscles do appear to have a single, very specific primary role.**

They have a specific task orientated role associated with being characterised as having only a local stabiliser role (e.g. Transversus Abdominis, Vastus Medialis Obliquus) or a global stabiliser role (e.g. External Obliquus Abdominis) or a global mobiliser role (e.g. Rectus Abdominis, Hamstrings, Iliocostalis Lumborum,).

In the presence of pathology and / or pain very specific impairments develop. These impairments are highly predictable, but are dependent on (and are specific to) the primary functional muscle role

Very specific retraining, or correction has been advocated in treatment (Hodges & Richardson 1996 1997, Hodges et al 1999, Hides et al 1996 2001, O'Sullivan 2000, Jull 2000). This very specific training or corrective intervention is usually non-functional and as such is designed to correct very specific elements of the impairment. This specific retraining or correction may or may not integrate into normal functional activity. There is no way at the moment to predict or clinically measure automatic integration into normal function. In many subjects this integration has to be facilitated.

Multi-Task Muscles

- **Some muscles appear less specific and seem to participate in a variety of roles without demonstrating dysfunction.**

They appear to have a multi-tasking function associated with being characterised as having the potential to perform more than one role. That is, there is good evidence to support both a local role and a global role, or the evidence may support the muscle having a contribution to both stability and mobility roles (e.g. Gluteus Maximus, Infraspinatus and Pelvic Floor). They appear to be able to contribute to combinations of local stabiliser, global stabiliser and global mobiliser roles when required in normal function.

In the presence of pathology and / or pain a variety of different impairments may develop. These impairments can be identified as being associated with either or all of the multi-tasking roles and are related to the 'weak links' in an individual's integrated movement control system.

Correction & retraining has to address the particular impairment that presents, usually needs to be multi-factorial and it should emphasise integration into 'normal' function

PAIN, RECRUITMENT & MOVEMENT IMPAIRMENT

Evidence of Altered Recruitment Strategies & Recruitment Impairment

Local Muscle Impairment	Global Muscle Impairment
• Uncontrolled segmental translation • Segmental change within cross-sectional area • Altered pattern of low threshold recruitment • Motor recruitment timing deficit	• Length associated change affecting muscle efficiency • Imbalance in low threshold recruitment between synergists and antagonists • Direction dependant - relative stiffness : relative flexibility

(review: Comerford & Mottram 2001)

Implications of Recruitment Impairments

There is consistent evidence of altered recruitment in the presence of pain. Pain affects slow motor unit recruitment more significantly than fast motor unit recruitment. Pain does not appear to significantly limit an athlete's ability to generate power and speed …so long as they can mentally "put the pain aside". It has been suggested anecdotally that up to 90% of sporting world records are broken by athletes with a chronic or recurrent musculo-skeletal pain problem.

Local impairment	Global impairment

• **High incidence of recurrence**
• **Uncontrolled translation (glide)**
• **Related to pain but there is no clear evidence that retraining these muscles treats pain better than anything else**
	• **Motor control & strength deficits**
	• **Muscle imbalance affecting range**
	  ○ **short mobilisers → compensation**
	  ○ **inefficient stabilisers → uncontrolled range**
	• **Diminished performance**
	• **Related to direction specific pain & is useful to treat direction specific pain**

Pain & Recruitment

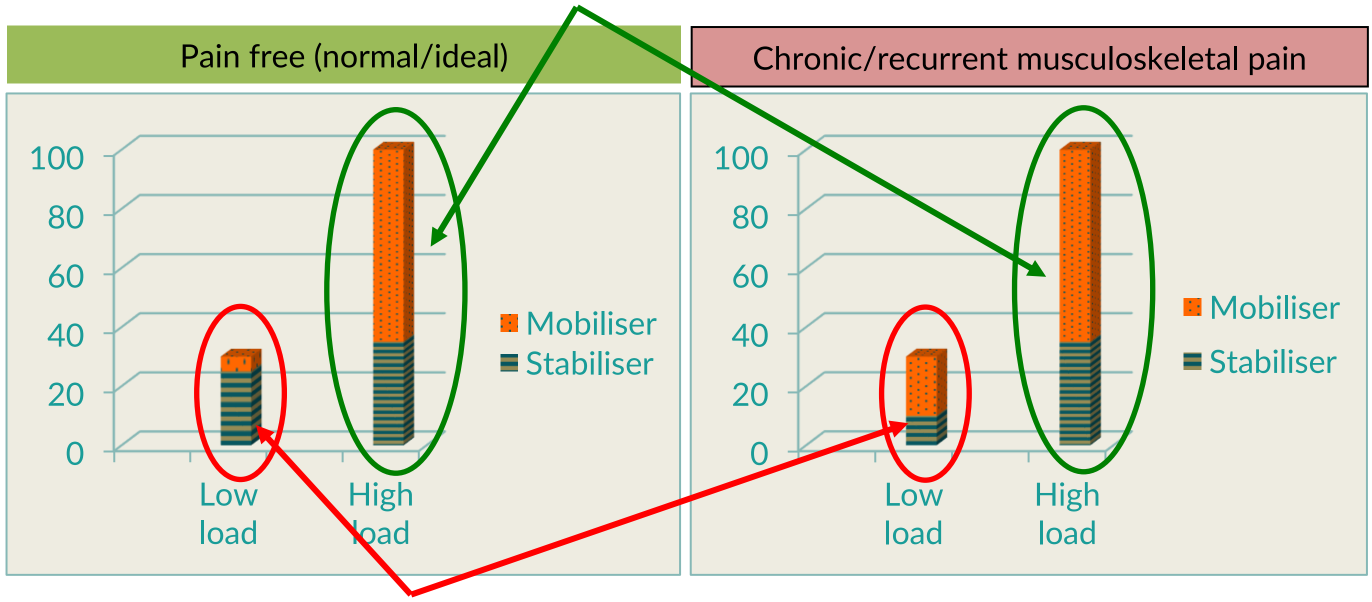
Research (Hodges & Moseley 2003, Hodges 2005) indicates that in the pain-free state, the brain and the central nervous system (CNS) are able to utilise a variety of motor control strategies to perform functional tasks and maintain control of movement, equilibrium and joint stability. However, in the pain state, the options available to the CNS appear to become limited. These altered (or limited) motor control strategies present as consistent co-contraction patterns usually with exaggerated recruitment of the multi-joint muscles over the deeper segmental muscles.

Recent research on musculo-skeletal pain has focused on motor control changes associated with the pain state. This research has provided important new information regarding chronic or recurrent musculo-skeletal pain. A large number of independent research groups are all reporting a common finding in their studies. They have consistently observed and measured that in the presence of chronic or recurrent pain subjects change the patterns or strategies of synergistic recruitment that are normally used to perform low load functional movements or postures. They demonstrate that these subjects employ strategies or patterns of muscle recruitment that are normally reserved for high load function (e.g. lifting, pushing, pulling, throwing, jumping, running etc.) for normal postural control and low threshold functional activities.

Stabiliser - Mobiliser recruitment patterns

No pain related change to recruitment patterns with high load

? benefit of strengthening programmes to treat chronic and recurrent pain

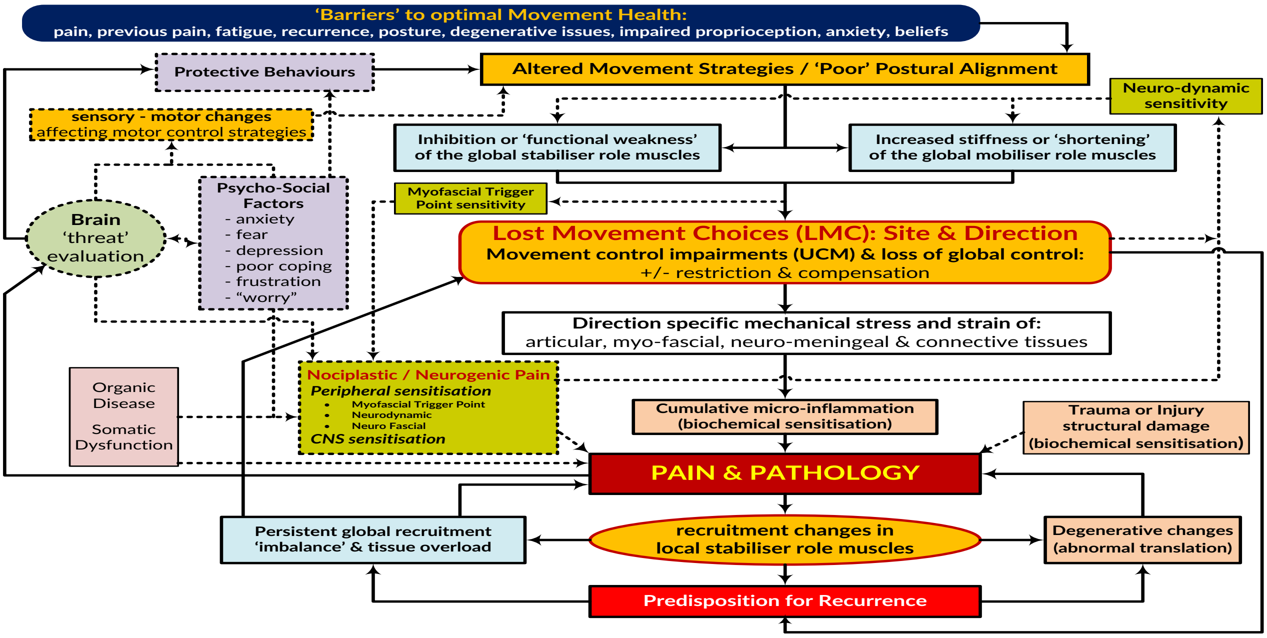


However, there are significant pain related changes in recruitment patterns between stabiliser & mobiliser synergists under situations of low threshold loading

There is a need to emphasise low threshold re-training

These altered strategies or patterns have been described in the research and clinical literature as 'substitution strategies', 'compensatory movements', 'muscle imbalance' between inhibited / lengthened stabilisers and shortened / overactive mobilisers, 'faulty movements', 'abnormal dominance of the mobiliser synergists', 'co-contraction rigidity' and 'control impairments'.

Understanding the Clinical Implications of Different Pain Mechanisms



Clinical Implications of Multiple Pain Mechanisms

Pain is multi-factorial experience and presents with different pain mechanisms. The presenting mechanisms determine the appropriateness & priority of the types of treatments utilised. It is not uncommon to have multiple (or even all) pain mechanisms present in the same clinical presentation, thus requiring a multimodal management approach

The predominant pain processes experienced by people with chronic musculoskeletal pain are:

1. Nociceptive pain which has a mechanical mechanism of provocation and inflammatory physiology

- Excitatory stimulation (beyond discharge threshold) of peripheral receptors (nociceptors, mechano-receptors, thermo-receptors +/- chemo-receptors)
- Inflammatory chemical sensitisation of receptors (especially mechano-receptors & nociceptors) in peripheral tissues associated with musculo-skeletal pain

2. Nociplastic / Neurogenic pain which involves both peripheral and central neural sensitisation

- Peripheral nociplastic / neurogenic +/- autonomic involvement
- Central nociplastic / neurogenic +/- autonomic involvement
- Neuropathic (Peripheral or CNS pathology or injury)

3. Psychological, Social, Behavioural, Environmental and Contextual factors that contribute to (or amplify) the pain experience and result in adaptive moments & postures

Pain Neuroscience – Chronic Pain (Nijs et al 2014)

1. Targeted Therapeutic Pain Neuroscience Education

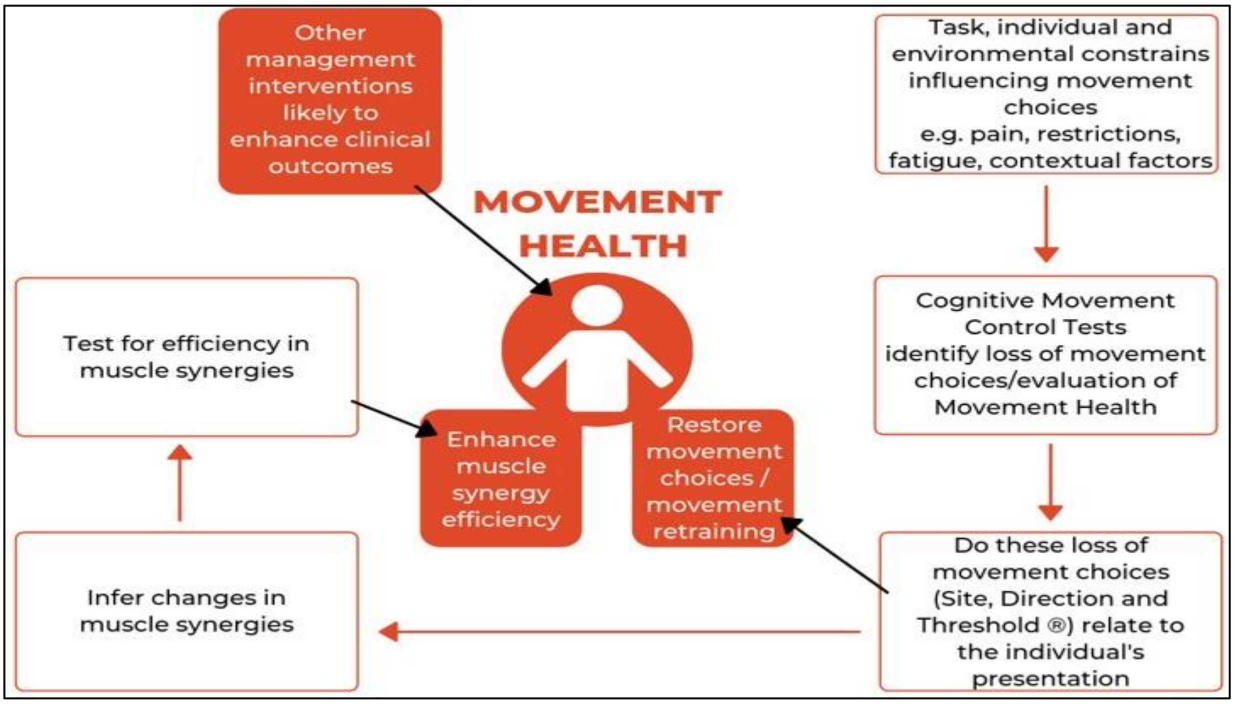
- Time-contingent approach vs symptom-contingent approach
- Reduced central nervous system hyperexcitability and increase in prefrontal volume in response to time-contingent therapy
- -Explain pain
- Prepare for a time-contingent cognition-targeted approach to daily physical activity and exercise therapy

2. Cognition Neuromuscular Training

- Time-contingent vs symptom-contingent
- Progression preceded by motor imagery
- Address pts cognitions about their problems / outcomes / to have positive perceptions about outcome
- Discuss patients' perception of exercise

3. Cognition-targeted Dynamic and Functional Exercises

- **Co-ordination & Control of Direction**
  - control site & direction of Lost Movement Choices (LMCs)
  - retrain lost movement coordination strategies
- **Global Recruitment Synergies throughout Range**
  - retrain global stabiliser efficiency through range of motion
  - recover active control of global mobiliser extensibility
- **Translation Recruitment Efficiency**
  - Retrain local muscle control of intersegmental articular translation



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PRINCIPLES OF MOVEMENT CONTROL RETRAINING

Restoring Lost Movement Choices

Control of Direction Co-ordination

- **Retrain Dynamic Control of the Direction of Stability Dysfunction**

Control the 'UCM' and move the restriction. Retrain control of the movement control impairment in the direction of symptom producing movements. Use low load integration of stabiliser muscle recruitment to control and limit motion at the segment or region of 'UCM' and then actively move the adjacent restriction. Only move through as much range as the restriction allows or as far as the 'UCM' is dynamically controlled. Control of direction directly unloads mechanical provocation of pathology and therefore is the key strategy to symptom management.

Motor control and co-ordination of direction specific stress and strain

Control of Global Recruitment Synergies

- **Rehabilitate Global Stabiliser Control throughout Range**

Rehabilitate the global stability muscle system to actively control the full available range of joint motion. These muscles are required to be able to actively shorten and control limb load through to the full passive inner range of joint motion. They must also be able to control any hyper mobile outer range. The ability to control rotational forces is an especially important role of global stabiliser muscles. Eccentric control of range is more important for stability function than concentric work. This is optimised by low effort, sustained holds in the muscle's shortened position with controlled eccentric lowering.

- **Regain Global Mobiliser Extensibility through Range**

When the 2 joint global mobility muscles demonstrate a lack of extensibility due to overuse or adaptive shortening, compensatory overstrain or 'UCM' occurs elsewhere in the kinetic chain in an attempt to maintain function. It becomes necessary to lengthen or inhibit dominance or over-activity in the global mobilisers to eliminate the need for compensation to keep function.

Balancing functional length and recruitment dominance between global synergists

Local Stability System - Control of Translation

- **Control of Translation within the Neutral Training Region**

Retrain tonic, low threshold activation of the local stability muscle system to increase muscle stiffness and train functional low load integration of the local and global stability muscle systems to control abnormal translation in and around the neutral joint position.

Low threshold recruitment of the local muscle system to control articular translation

GRADED MOVEMENT CONTROL TRAINING FLOWCHART

Principles & Strategies of Graded Movement Control Training (for UCI/CCI)

All cognitive recruitment and active movements are initially performed with low / minimal contraction force (non-fatiguing) and with isometric recruitment or slowly through very small ranges of motion. Progression into larger ranges of motion is only considered after careful evaluation of tolerance.

If there are non-provocative directions of neck movement and provocative directions of neck movement: - move away from provocation in the direction of relieving or non-provocative movement

↓ ↑

Cognitively, isometrically control / prevent / limit / minimise movement in the upper cervical spine (palpation or visual feedback to maintain a neutral mid-range position), then move at an adjacent sites / region (e.g. lumbo-pelvic – thoracic spine – scapula – low cervical spine)

↓

Facilitate recruitment / activation of the Global Stabiliser (GS) muscles in the neck (lower Cx spine & upper cervical spine). Priority is given to GS muscles that can isometrically or eccentrically control the provocative / 'unstable' movements

A. Isometric activation in neutral positions
B. Small range concentric-eccentric movement towards shortened range (i.e. inner range hold & eccentric return)
C. Concentric activation through the full available inner range of motion and eccentric control through the non-provocative outer (often hypermobile) range of motion

↓ ↑

- Inhibit recruitment substitution & increase flexibility / extensibility of the over-active Global Mobiliser (GM) synergists

↓

- Add fatiguing resistance with a 'rotation challenge' (prioritise GS synergist) to increase strength & endurance efficiency
- Add a perturbation / unpredictable displacement challenge

If there are **NO** non-provocative directions of neck movement (i.e. all directions of neck movement are provocative) - consider whether this is due to:

a) nociplastic central sensitisation (clinical tip: symptoms do not respond to peripheral analgesics or NSAID medication) – Often requires central acting neuromodulator medication)

and / or

b) multidirectional uncontrolled translational movement (clinical tip: symptoms do respond well to peripheral analgesics or NSAID medication) – Requires prioritisation of Local Stabiliser (LS) muscle recruitment and retraining

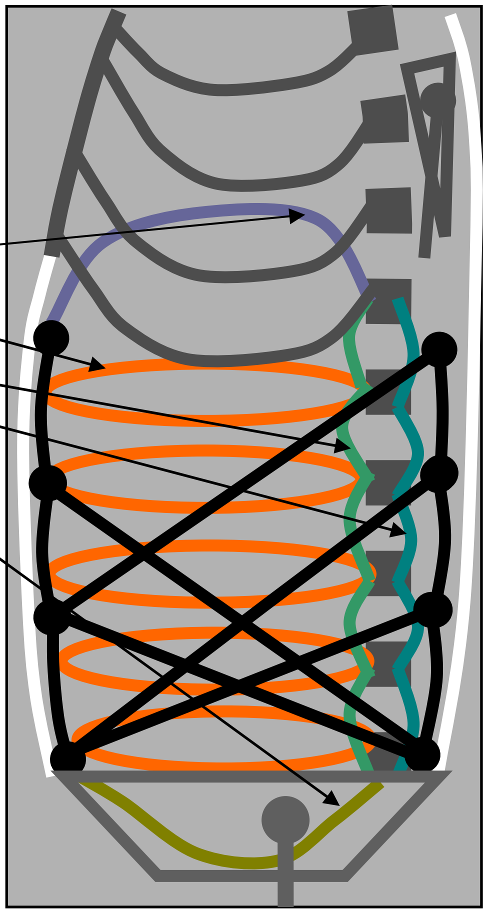
↓

Facilitate recruitment / activation of the Local Stabiliser muscles in the neck (upper Cx spine +/- lower cervical spine) to control excessive / hypermobile intersegmental displacement / translation

- Cognitive isometric recruitment of LS synergists: Initially in a supported mid-range neutral position – with progression into recruitment in ,multiple different mid-range positions and then into unsupported postures

THE ‘CORE’ - REDEFINED

The concept of the ‘core’ has been expanded to include a more functional framework. The core is best represented as a double walled cylinder consisting of the lower back and abdomen and the upper back and chest (the Trunk), which links to the limbs via the shoulder girdle (scapula) and the pelvic girdle (pelvis).



Local Lumbar Cylinder

The **inner wall** of the core cylinder is made up of the deep local muscle system **(inner core).** The muscles with a **lumbar local stability role** include:

- the diaphragm
- transversus abdominis
- posterior psoas
- segmental multifidus
- the pelvic floor

Local muscle control of the sacro-iliac joint:

- the lumbar local stabilisers (above)
  +
- deep sacral gluteus maximus

Local muscle control of the neck:

- **sub occipital cuff**
- **longus colli (medial fibres)**
- **cervical multifidus (segmental fibres)**
- **upper trapezius & fascia nuchae**

Local muscle control of the shoulder girdle:

- lower trapezius
- subscapularis (capsular fibres)
- supraspinatus
- (? infraspinatus / teres minor) (*)

Local muscle control of the hip:

- posterior psoas major
- quadratus femoris
- gemelli

Global Shell

The **outer wall** of the core is made up of the outer global muscle system **(outer shell)**. This consists of the muscles which have a global stability role along with the muscles having a global mobility role.

These global trunk muscles work within the trunk and connect the pelvis and scapula to the trunk. They influence postural alignment and contribute to the production and control of range of motion.

Global Muscles Linking the Pelvis to the Trunk:

Trunk Global Stabilisers	Trunk Global Mobilisers
• the oblique abdominals • superficial multifidus and spinalis • anterior psoas • oblique fibres of quadratus lumborum (*)	• rectus abdominis • longissimus • iliocostalis • lateral fibres of quadratus lumborum (*)

Global Muscles Linking the Scapula to the Trunk:

Trunk Global Stabilisers	Trunk Global Mobilisers
• serratus anterior • lower trapezius • middle trapezius • upper trapezius • subclavius	• pectoralis minor • rhomboids • levator scapula • latissimus dorsi

The Girdles

The expanded concept of the ‘core’ also consists of the head and neck, and the pelvic and shoulder girdles. The neck provides the link between the head and trunk. The scapula provides a mechanical linkage between the arms and the trunk, while the pelvis provides the link between the legs and the trunk.

	Global Stabilisers	**Global Mobilisers**
Neck **Linkage: head to the trunk**	• upper cervical cuff • longus colli & capitis • semispinalis • superficial multifidus • trapezius (upper)	• sterno-cleido-mastoid • scalenes • hyoids • splenius • longissimus • levator scapula
Shoulder Girdle Linkage: arm to the scapula	• subscapularis (humeral fibres) • teres major • deltoid (ant, mid, post) • coraco-brachialis • infraspinatus (*) • teres minor (*)	• pectoralis major • latissimus dorsi • infraspinatus (*) • teres minor (*) • biceps brachii • triceps brachii
Pelvic Girdle Linkage: leg to the pelvis	• gluteus max • gluteus med • gluteus min • obturators (externus, internus) • iliacus • pectineus • adductor brevis • proximal adductor magnus (*) • adductor longus (*)	• rectus femoris • sartorius • tensor fascia latae + ilio-tibial band • piriformis • hamstrings • sup glut max + ilio-tibial band • gracilis • distal adductor magnus (*) • adductor longus (*)

In functional activities forces are transmitted across the neck and girdles. In normal function the pelvis and trunk (also the head and trunk) often counter rotate relative to each other and these rotation forces are co-ordinated and controlled at the neck and the two girdles by the global muscle system. During throwing, force is transferred from the lower limbs across the pelvic girdle, through the trunk, then across the shoulder girdle to accelerate the upper limb. In attempting to tackle a running opponent in various codes of football, the arms are used to hold onto the runner. High deceleration forces are transmitted from the arms across the shoulder girdle, through the trunk then across the pelvic girdle to the legs. Co-ordinated recruitment within synergists of the global muscle system provides this force and control at the shoulder and pelvic girdles.

The global 'outer shell' can develop patterns or strategies of aberrant recruitment between 1-joint stabiliser and 2-joint mobiliser synergists. These impaired movement strategies are sometimes referred to as 'muscle imbalance'. These aberrant recruitment patterns may result from poor postural habits, inefficient repetitive movements, chronic overloading (overuse) or chronic unloading of muscle synergies, movement compensations or protective (guarding) strategies associated with chronic or recurrent pain and also psycho-social influences or behavioural adaptations associated with anxiety or fear of potential or anticipated pain.

Various 1-joint muscles that demonstrate a global stabiliser role become 'down-regulated and become inefficient at producing and controlling non-fatiguing functional movement. The multi-joint muscles that demonstrate global mobiliser roles become 'up-regulated' and dominant and 'take over' from the stabiliser muscles, or they create restrictions resulting in compensatory movement patterns.

These compensatory patterns can present as low threshold motor control deficiencies in non-fatiguing normal functional movements and postural control tasks; or as high threshold deficiencies in fatiguing speed or strength of global stability muscle roles.

This expanded cylinder concept, when modified to represent a double walled sleeve can be applied to many joints.

CORE CONTROL IS MULTI-FACTORIAL

Movement Control Function:

Assessment of the musculo-skeletal system under low load testing

- **Low threshold - non-fatiguing low load & slow/static**
  - **influences alignment and coordination**

Muscle motor control assessment of stability function is based on the extensive research on muscles like transversus abdominis. Motor control elements of stability function (or dysfunction) are reliably tested under low load situations (e.g. fine wire EMG, imaging ultrasonography). Testing is based on the ability to pass or fail a low threshold test of motor recruitment. The benefit of having good stability function of both the local and global stabiliser muscles is in improved low threshold motor control and in decreasing mechanical musculo-skeletal pain.

- **Pass** – no movement induced pathology and pain free function
- **Fail** – increased risk of development of pathology and pain.

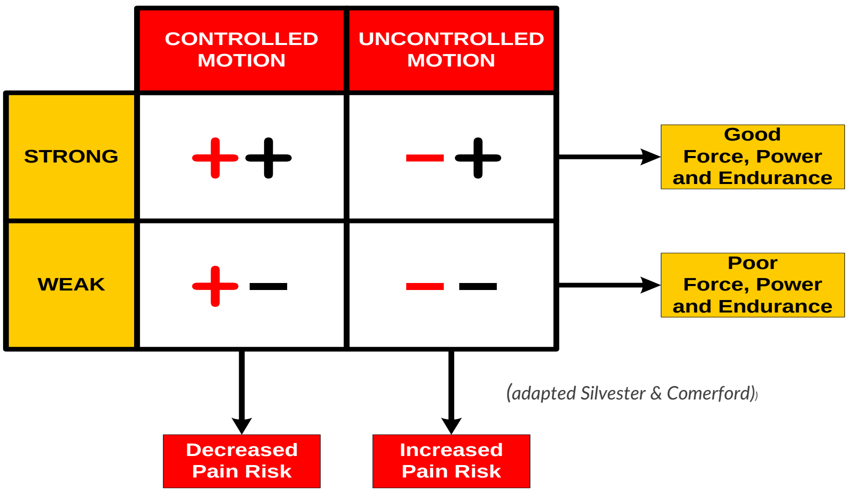
Muscle Strength Function:

Assessment of the musculo-skeletal system under high load testing

- **High threshold - fatiguing high force or sustained endurance**
  - **influences high load or high speed**

Muscle strength is measured as the ability to pass or fail a test of resisting or supporting a high load. The grading of muscle strength as 1 to 5 with manual muscle testing is an example of muscle strength testing that physiotherapists are trained to perform. This testing is often performed using force dynamometers to provide more objective measurements. The benefit of having good strength is that performance is improved or maintained. Strength training does not demonstrate consistent improvement in pain and pathology or low threshold motor control function.

- **Pass** – good power, endurance and high load performance
- **Fail** – weakness and the loss of performance.



(adapted Silvester & Comerford)

Points to consider:

- Different individuals learn in different ways and respond to different facilitation strategies and options
- Motivation & compliance: Structured vs. non-structured; Specific vs. non-specific
- Mechanical vs. non-mechanical issues
- Start rehab programmes with local & global exercise but it is OK to start with just global exercises or just local exercises
- A couple of exercises done well often achieves more than many exercises done poorly
- Maintenance programme

A total of 3-5 minutes (2-4 exercises) daily is an appropriate maintenance regime. There is considerable argument as to the necessity of maintenance exercise. Poor proprioceptive awareness of motion segment position is probably a good indication for an ongoing maintenance programme.

Identification of Risk and Potential for Prevention

Prevention is of primary importance. Signs of postural alignment faults, poor movement control, aberrant movement patterns, aberrant recruitment strategies and length-associated changes in muscle are all guides to the identification of uncontrolled movement and movement control impairments. The presence of uncontrolled movement in the movement system identifies risk factors, which may aid in the prevention of musculo-skeletal pain syndromes of mechanical origin. Movement dysfunction results in microtrauma, which if repetitively performed, accumulates and eventually exceeds tissue tolerance, finally, resulting in tissue pathology and painful function.

In the same way that excessively high blood pressure predisposes an individual to having a stroke, and excessively high cholesterol levels predispose to heart disease; uncontrolled movement (UCM) the predispose an individual to the development of musculoskeletal pain. For example, excessive or uncontrolled segmental lumbar flexion may predispose an individual to low back pain. The general population pays minimal attention to maintenance of their musculo-skeletal system. This is reflected in the very high incidence of postural, overuse and occupational pain that evident in the community at large.

With our extensive training in movement and palpation, physiotherapists hold the key to early identification of signs of mal-alignment, movement control impairments and muscle imbalance and to the design of preventative programmes.... But we have to not only develop these skills; we have to use them in such a way that the community associates musculo-skeletal maintenance with Physiotherapy.