

**Dedicated, as always, to Tsafi, Mattan, Guy and Pinuki**

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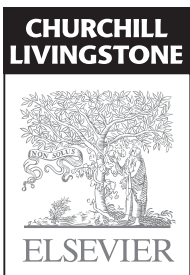


# THERAPEUTIC STRETCHING

Towards a functional approach

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# Preface

Stretching has many uses and forms and is one of the principal tools used in physical therapies. However, in the last decade and a half the therapeutic value of stretching has been eroded by research. These findings leave us with a difficult choice: to ignore them and become clinically irrelevant, or to progress by accepting and incorporating them into our practice. Incorporating these findings means that we have to transform our thinking and the way we apply stretching clinically. This is not a simple task; in particular, as stretching techniques have remained virtually unchanged for decades, or even centuries.

This book is all about the direction and changes that we may need to consider, and how to apply them clinically. In particular, it explores the use of stretching in conditions in which individuals experience a loss in range of movement (ROM).

The book starts by looking at the difference between therapeutic and recreational stretching; whether stretching is a physiological necessity; and the classification of stretching approaches (Ch. 1). This is followed by exploring what constitutes ROM and defining normal and dysfunctional ROM (Ch. 2). From there the book explores the processes associated with ROM loss and recovery, focusing on adaptive processes. Chapters 5–7 explore what makes stretching effective, identifying behaviour as one of the main driving forces for adaptive changes. The motor control component of ROM, and how it is influenced by different stretching methods, is discussed in Chapter 8. The experience of pain, sensitization and pain tolerance in relation to stretching and ROM recovery are discussed in Chapters 9 and 10. In Chapter 11 the psychological considerations in ROM management are addressed, and Chapter 12 integrates all the information from previous chapters and presents a functional approach in therapeutic stretching. This approach uses the individual's unique movement repertoire to help them regain functionality. A demonstration of this approach is found in Chapter 13 and on the accompanying website. A grand summary of the book is found in Chapter 14.

Interestingly, the message from the sciences is that we should be moving towards a bio-psycho-behavioural-social approach for ROM rehabilitation; away from traditional stretching models that focus on biomechanics and structure. The premise here is that ROM recovery is a multidimensional process intrinsic to the individual but also highly influenced by their environment. The locus of recovery is intrinsic to the patient, not external in the “therapist’s hands”. As such, the role of the therapist needs to be reconsidered: from a provider of cure to a facilitator of recovery; providing support, direction, management and assistance. It is an approach that promotes self-care.

To write this book I have used several sources: studies in the areas of biomechanics, biomedicine and health studies, motor control, psychology, cognition and behaviour, and my own research. Yet, I still found that, despite this vast volume of published research, many theoretical and practical questions about stretching remain unanswered. A pure science-based book about stretching was therefore not the solution. As a consequence, I have committed the sin of adding my experiences from physical therapy teaching and supervising clinicians, yoga instruction, clinical work that spans 26 years and a dose of what seems (to me) like common sense.

This book is suitable for all manual and physical therapists, sports and personal trainers, athletes who require special movement ranges and individuals who would like to recover or improve their range and ease of movement. I hope that this book will present an insight into the fascinating world of stretching and provide you and your patients with an effective therapeutic approach.

Dr. Eyal Lederman

London 2013

Information on courses: [www.cpdo.net](http://www.cpdo.net)

## THE WEBSITE

Besides the wealth of information found within *Therapeutic Stretching: Towards a Functional Approach*, the Publishers have created a unique website – [www.therapeuticstretch.com](http://www.therapeuticstretch.com) – to accompany the volume. This site contains a selection of video clips which have been specially prepared to allow the reader to practice the techniques described in the volume.

To access the site, go to [www.therapeuticstretch.com](http://www.therapeuticstretch.com) and follow the simple log-on instructions shown.

# Introduction to Therapeutic and Functional Stretching

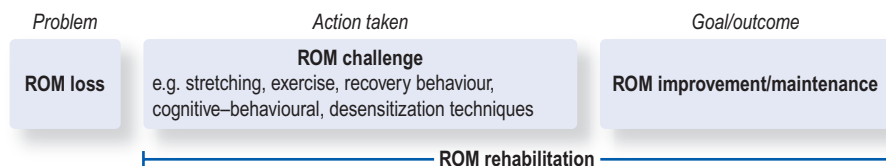
Stiffness and restricted range of movement (ROM) are the most common clinical presentations second to pain. This book is for all therapists and individuals who would like to help others or themselves to recover or improve their ease and ROM. The book aims to provide the know-how to achieve this therapeutic goal with maximum effect.

## WHAT IS STRETCHING?

For the purpose of this book stretching is defined as *the behaviour a person adopts to recover, increase or maintain their range of movement*. This behaviour includes passive and active stretching, which can be in the form of exercise or with the assistance of another person (therapist/trainer). Stretching therefore is the means by which the ROM can be increased, but it is not the only one. There are several ways to achieve ROM improvements depending on the processes associated with the loss of ROM. *ROM rehabilitation* is perhaps a more suitable term to describe the therapeutic method used to recover/improve movement range. *ROM challenge* is the term given to all the different methods and techniques that are used to achieve this movement goal (Fig. 1.1).

## THERAPEUTIC, SPORTS AND RECREATIONAL STRETCHING

Stretching behaviour can be observed in many spheres of human activity. It is often used in sports training as a warm-up, for prevention of injury and to improve sports performance. It is widely used by specialist groups such as athletes and yoga practitioners to develop the high level of flexibility required for performance/practice. Stretching is also used recreationally for general flexibility, enjoyment and self-awareness, as part of spiritual development, and for supporting health and well-being (e.g. yoga, Pilates and t'ai chi). Therapeutic



**FIGURE 1.1** Terminology used in therapeutic stretching. ROM, range of movement.

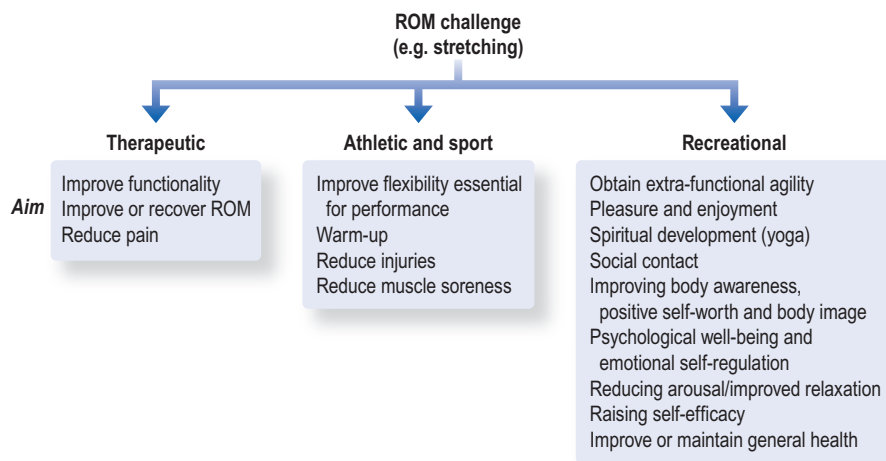
stretching is used predominantly to help individuals to regain functionality that has been affected by ROM losses, and occasionally to alleviate pain (Fig. 1.2).

Therapeutic stretching, recreational stretching and sports stretching depend on the same biological-physiological processes to promote ROM changes. The differences are in their overall goals (recover ROM or feel great) and the context in which the ROM challenges are applied (in clinic or in a yoga class). The definition of stretching given above can also be used to define ROM rehabilitation or therapeutic stretching.

This book will focus on the therapeutic use of stretching and ROM rehabilitation. However, many of the principles discussed here can be applied to recreational and athletic stretching.

### Is stretching essential for normalization of ROM?

It seems that only humans do it; that is, regular, systematic stretching. There is a shared animal and human behaviour of “having a stretch” and yawning



**FIGURE 1.2** Categories of stretching and their aims. Whether these aims are realistic or achievable will be discussed in the book. ROM, range of movement.

called *pandiculation*. It is often a combination of elongating, shortening and stiffening of muscles throughout the body. Pandiculation tends to occur more frequently in the morning and evening and is associated with waking, fatigue and drowsiness.<sup>1</sup> Erroneously, it is assumed that animals use pandiculation as a form of stretch. This behaviour is too short in duration, too infrequent and too specific to a particular pattern to account for general agility. It has been proposed that pandiculation may provide psychological and physiological benefits other than flexibility.<sup>1,2</sup>

Among humans, only relatively few individuals stretch regularly. Those who stretch tend to focus on particular parts of the body. For example, rarely is the little finger stretched into extension or the forearm into full pronation-supination. So what happens to the majority who do not stretch? Do they gradually stiffen into a solid unyielding dysfunctional mass? And what happens to the parts that we never stretch? Do they stand out as being stiff/range-restricted?

It seems that going about our daily activities provides sufficient challenges to maintain functional ranges; otherwise, we would all suffer from some catastrophic stiffening fate. This suggests that stretching is not a biological-physiological necessity but perhaps a socio-cultural construct. We stretch because it provides special flexibility, it is fashionable and enjoyable (for some), and some believe that it is essential for maintenance of healthy posture and movement. There may be other benefits to recreational stretching such as improving body awareness, positive self-worth and body image, psychological well-being, reduced arousal/improved relaxation, emotional self-regulation and raising self-efficacy.

However, the most important message from the discussion so far is that *functional movement, the natural movement repertoire of the individual*, is sufficient to maintain the normal ROM. It suggests that ROM rehabilitation, in its most basic form, should put an emphasis on return to pre-injury activities, whenever possible.

### Is stretching useful therapeutically?

Recovering ROM becomes important when a person is unable to perform normal daily activities, often as a result of some pathological process that results in range limitation. So there is an obvious need for ROM rehabilitation, but the question is which ROM challenges are most effective?

It has been assumed for a long time that traditional stretching approaches can provide effective ROM challenges. This assumption was supported by numerous studies demonstrating that in healthy young individuals regular stretching results in ROM improvements. Since the biological processes for



ROM improvements are similar to those for recovery, the logical conclusion was that stretching is clinically useful. However, only in the last decade has the use of stretching been explored clinically, as a treatment for contractures after joint surgery, neurological conditions and immobilization. The outcome of these studies was summarized in 2010 in a systematic review (35 studies with a total of 1391 subjects).<sup>3</sup> It was found that in the short term stretching provides a 3° improvement, a 1° improvement in the medium term and no influence in the long term (up to 7 months). These findings were similar to all stretching approaches, active or passive. Let us assume for the sake of discussion that these reviewers underestimated the effects of stretching. Stretching will still be clinically irrelevant even if these results are doubled (6° and 2°) or tripled (9° and 3°).<sup>4</sup> Such modest changes would be meaningless as far as functional activities are concerned;<sup>5</sup> most patients (in my experience) would consider this outcome a treatment failure.

The erosion of belief in the usefulness of stretching is also seen in other areas. Stretching as a warm-up before and after exercising has failed to show any benefit for alleviating muscle soreness. It provides no protection against sports injuries and vigorous stretching before an event may even reduce sports performance.<sup>6–16</sup> It was demonstrated that strength performance can be reduced by 4.5–28%, irrespective of the stretching technique used.<sup>17,18</sup>

One reason that stretching was not shown to be useful in all these areas may go back to biological necessity. If it was beneficial we would expect Nature to have “factored-in” stretching as part of animal behaviour, in particular if it improved performance. Yet, with the exception of humans, no animal performs any pre-exertion activities that resemble a stretch warm-up. Lions do not limber up with a stretch before they chase their prey, and reciprocally the prey does not halt the chase for the lack of a stretch. The stretch warm-up in humans seems to be largely ceremonial. A person would stretch in the park before a jog but would not consider stretching to be important for sprinting after a bus. A person may stretch before lifting weights in the gym but a builder is unlikely to stretch, although they may be lifting and carrying throughout the day. The point made here is that we have evolved to perform maximally, instantly and without the need to limber up with stretching. There seems to be no biological advantage in stretching nor is it physiologically essential.

The ineffectiveness of stretching leaves us with the clinical conundrum of how to recover ROM losses. We do know that most of the time people do recover their ROM losses after conditions such as immobilization, surgery, disuse and even frozen shoulder. If they do not do this by stretching, some other phenomenon must account for the recovery; but what is it and can it guide us to a more effective ROM rehabilitation?

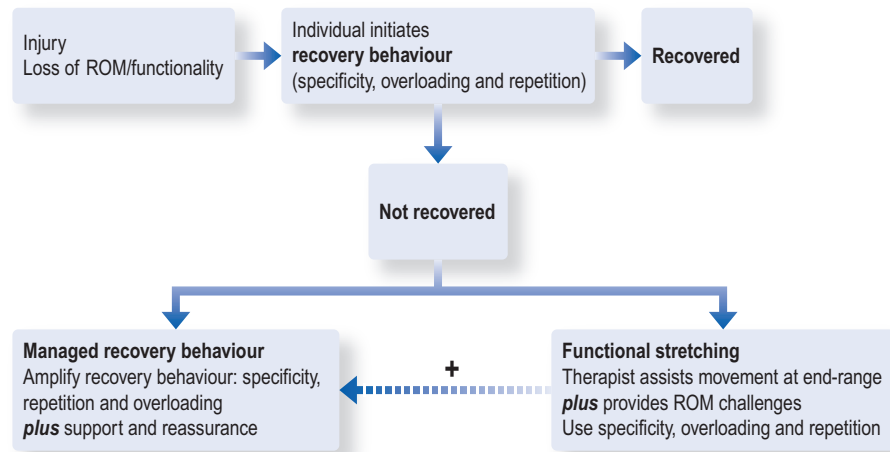
## TOWARDS A FUNCTIONAL–BEHAVIOURAL APPROACH

The place to start exploring the solution to ROM rehabilitation is the natural *recovery behaviour* seen after an injury or immobility. There seems to be a universal behaviour in which the individual will attempt to perform the affected movement in a guarded progressive manner. A person who has limited reaching ROM will attempt that same movement, gradually increasing the range of reaching, forces used to lift or speed of that particular movement. Through such behavioural experiences the individual learns that taking certain actions will eventually help them to achieve their movement goals. So the recovery of ROM is driven by the individual's actions or behaviour.

Imagine if somehow “the essence” of the recovery behaviour could be extracted and provided to patients who are not improving naturally. The recovery behaviour contains three identifiable traits that are beneficial for improving ROM. The movement closely resembles the affected daily functional tasks and it is repeated many times throughout the day. The recovery behaviour also contains movements that are progressively amplified to provide increasing physical demands on the body. These components of the recovery behaviour are similar to the *specificity*, *overloading* and *repetition* principles used to optimize sports performance. Thus, a ROM rehabilitation programme can be constructed by simply amplifying these three traits. The management for a person with a shoulder problem who cannot reach overhead is to attempt this particular movement (specificity; Ch. 5), trying to reach further overhead (overloading; Ch. 6), many times during the day (repetition; Ch. 7). It is basically about performing functional activities with an emphasis on end-ranges. This form of ROM rehabilitation is termed *managed recovery behaviour*.

Managed recovery behaviour assumes that the patient is able to self-care and can maintain a rehabilitation programme. However, some patients may need assistance, a “helping hand” from others. In the assisted programme the essence of the recovery behaviour is still the guiding model. The therapist helps the patient to reach the end-ranges. In these positions the patient attempts to perform a variety of daily movements. For example, in shoulder contractures, the therapist helps the patient to attain a comfortable flexion position. At this angle, the patient is instructed to imagine and perform a functional activity, such as painting the ceiling or waving a flag.

The therapist-assisted form of ROM rehabilitation is termed, here, *functional stretching* (Fig. 1.3). The term functional stretching is used solely for its simplicity. Most practitioners, and more importantly patients, can understand its meaning and aims. This approach is discussed in greater detail in Chapter 12, and presented in Chapter 13 and the accompanying video.



**FIGURE 1.3** Using elements from the recovery behaviour as a basis for a functional range of movement (ROM) rehabilitation (see expansion of this chart in Ch. 12).

ROM challenges and management that are modelled on the recovery behaviour are termed, here, *functional challenges* or *functional ROM rehabilitation*. The reason for choosing one form of management over another depends on patient-related factors (Fig. 1.3). A managed approach could be beneficial for patients who may need psychological/emotional support in their journey of recovery, or simply need help in identifying suitable daily challenges and organizing/scheduling their rehabilitation programme. An assisted approach is often used when the patient is unable to self-provide/fulfil the recovery behaviour because of physical incapacity or pain (see Ch. 12).

### Advantages of functional challenges

There are several advantages to functional ROM rehabilitation. Functional challenges are essentially “exaggeration” of the individual’s normal daily movements. Hence, the patient uses movement patterns they are familiar with; they do not have to learn anything new. Functional challenges can be practised anywhere and anytime, thereby reducing the need for special equipment or set-aside time for training. There is also a strong motivational factor in functional challenges. There is a clear resemblance between the movement used in the clinical session and the patient’s functionality goals and hopes; imagine rehabilitating a person who is unable to play tennis by using tennis as a ROM challenge.

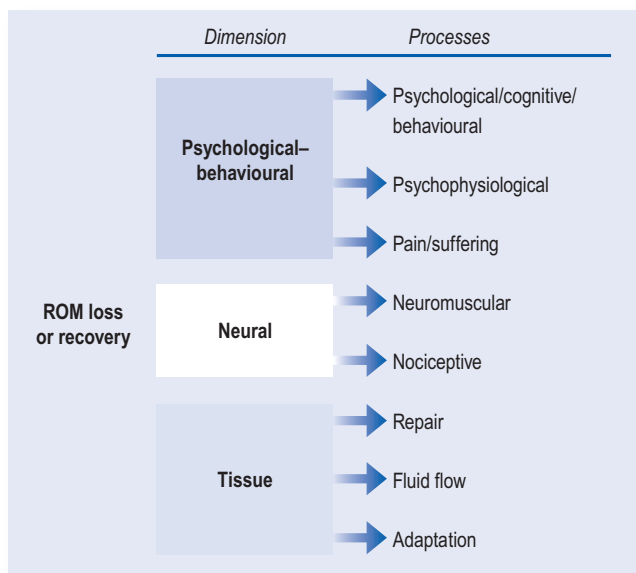
A functional approach promotes individualization of the management. It is tailored to the patient’s movement repertoire, needs and therapeutic

goals. These factors could help to increase compliance and adherence to the rehabilitation programme, which is particularly important as most ROM losses are chronic conditions in which self-care is essential for success. There is a strong indication from the sciences that such inclusive management could provide clinical solutions where traditional stretching methods may have failed (see Chapters 2–14).

## TOWARDS A PROCESS APPROACH

ROM loss and recovery is a multidimensional process intrinsic to the individual but also highly influenced by their environment. It is often a complex mixture of processes that occur within biological, neurological and psychological dimensions (Fig. 1.4).

The tissue dimension is mostly associated with processes such as repair and biomechanical/morphological adaptation of local tissues and local fluid dynamics (lymph, blood). The neurological dimension is mostly associated with motor control and nociceptive processes such as sensitization. The psychological dimension is associated with psychological, cognitive, behavioural, pain experience and psychophysiological processes. These dimensions and related processes are open systems: processes often span several dimensions,



**FIGURE 1.4** The dimensional model. Range of movement (ROM) loss but also recovery is associated with dimension specific processes.

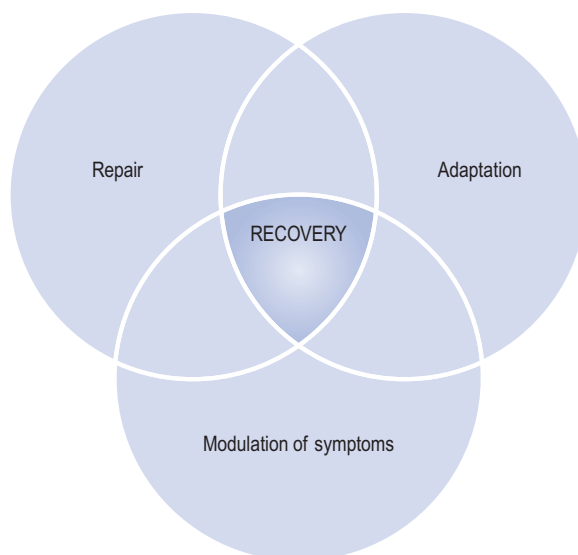
but tend to be prominent in particular ones depending on the presenting condition. (For full discussion of the dimensional model, see Lederman.<sup>19</sup>)

The complex interaction of processes and dimensions can be illustrated by contractures after immobilization. ROM losses are due to tissue shortening and adhesions, processes that occur within the *tissue dimension* (Ch. 4). Immobilization is also associated with an adaptive dysfunctional motor control that limits the ability to perform the *active* ROM, a process that occurs in the *neurological dimension* (Chs 4 and 8). The patient's will and level of commitment, psychological distress and pain/movement-related fears may affect their recovery behaviour and consequently their ROM improvements. These processes and their management are occurring within the *psychological-behavioural dimension* (Ch. 11).

### Processes underpinning ROM recovery

The recovery from any condition is associated with three basic recuperative processes: repair, adaptation and/or modulation of symptoms (Fig. 1.5). The success of ROM rehabilitation depends on engaging these intrinsic processes.

Repair is a process in which the body restores the functional and structural integrity of damaged tissues. During the period of repair ROM can be affected by various processes that include pain, swelling, protective motor responses



**FIGURE 1.5** Recovery from any condition is dependent on repair, adaptation and modulation of symptoms (symptomatic relief). The success of ROM rehabilitation is dependent on these intrinsic recuperative processes.

and movement-related anxieties (Chs 9 and 11). In acute injuries, these ROM losses tend to recover along with the resolution of repair. However, long-term loss and recovery of ROM after an injury is more often associated with adaptation processes.

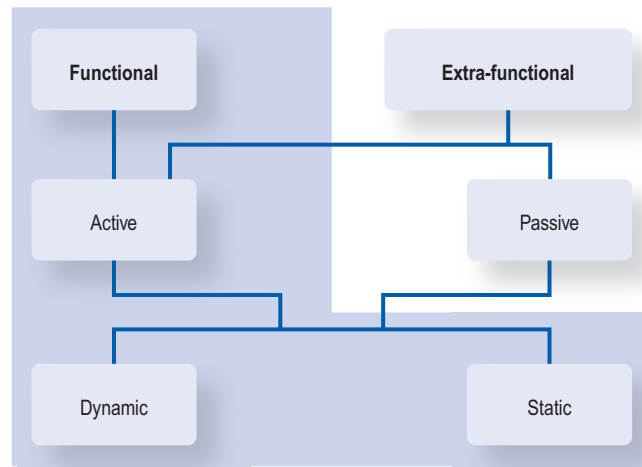
Adaptation is an alteration in the physiological, biomechanical, morphological and psychological-behavioural characteristics of the body/individual in response to a change in their physical and social environment. ROM recovery is often the consequence of adaptation in several of these processes and dimensions (Ch. 4).

Often ROM losses are associated with the experience of pain, discomfort and stiffness. Hence, some ROM improvement can be down to symptomatic relief. This can come about by various processes: resolution of repair, adaption within the nociceptive system, such as sensitization and de-sensitization (Ch. 9), and “psychological adaptation”, such as pain tolerance (Chs 9 and 10). Symptomatic relief can also be homeostatic in nature; a brief response to stimulation and a return to the symptomatic default. This transient response can explain some of the immediate ROM changes observed following some forms of physical therapy (Ch. 9).

A process approach acknowledges the multidimensional processes that underlie ROM loss and recovery and aims to co-create, with the patient, environments that support the recovery processes. It steers away from the traditional orthopaedic-structural models prevalent in physical therapies; models that promote the belief that recovery can be achieved by correcting, balancing and adjusting the body according to a mechanical-structural ideal.<sup>20,21</sup> The functional model of ROM rehabilitation promoted in this book is derived from a process approach.

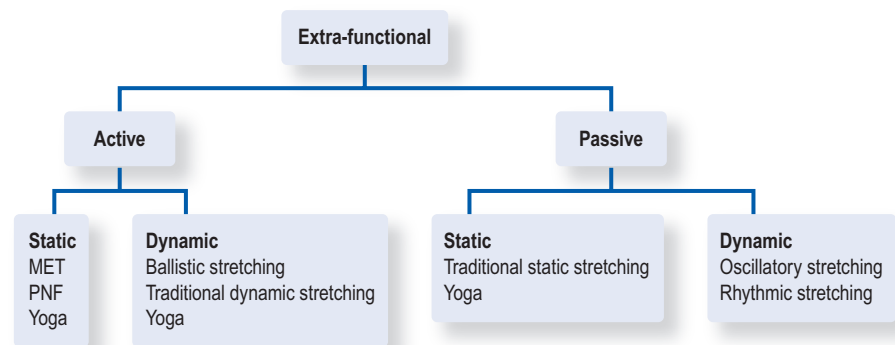
## CLASSIFICATION OF STRETCHING

A functional approach is also the point from which we can classify stretching techniques. As discussed above, recovery behaviour usually consists of functional movement patterns. So the ROM challenges can either resemble or be unlike functional movement (Fig. 1.6). Techniques or movement patterns that resemble the normal daily activities of the individual are called *functional challenges*. ROM challenges that use movement patterns that are outside the individual’s repertoire or experience are called *extra-functional challenges*. Lying on the floor and performing straight leg raises to stretch the hamstring is an example of an extra-functional challenge. Most traditional stretching techniques fall within the extra-functional category. They include techniques such as static and dynamic stretching, proprioceptive neuromuscular facilitation (PNF), muscle energy techniques (METs) and ballistic stretching.



**FIGURE 1.6** The classification of range of movement challenges.

Generally, all functional challenges are active. This is because there is no passive movement in the functional repertoire of humans (except short phases during some active movements; see Ch. 2). Extra-functional ROM challenges can be either passive or active, and sometimes they are a mixture of both. Sitting on the floor and forcefully pulling on the foot to stretch the calf muscle is an example of an extra-functional passive approach. A standing calf muscle stretch is an example of an extra-functional active approach. METs and PNF are extra-functional approaches that mix passive and active challenges (Fig. 1.7).



**FIGURE 1.7** Classification of extra-functional stretching approaches into active or passive and static or dynamic. Disciplines such as yoga can be both active and passive. MET, muscle energy technique; PNF, proprioceptive neuromuscular facilitation.

Finally, the last subdivision is whether a challenge is dynamic (with movement) or static (no movement). Functional challenges can be either dynamic or static, depending on the task. For example, reaching with the arm to a demanding overhead position is a dynamic functional challenge, whereas maintaining that position is a static functional challenge. Ballistic stretching is an example of a dynamic extra-functional challenge. All techniques in which the therapist stretches and holds the patient at the end-range position can be considered to be static extra-functional challenges.

Throughout the book this classification will be used to discuss stretching and ROM rehabilitation. The term *traditional stretching* refers to all extra-functional challenges.

### What about traditional forms of stretching?

All forms of stretching activate some of the intrinsic processes associated with ROM recovery. However, functional challenges optimally engage all traits associated with the recovery behaviour. So there are important therapeutic advantages in using a functional ROM rehabilitation over traditional stretching approaches (see further discussion throughout the book, and in particular Ch. 12). This does not mean that traditional forms of stretching should be given up; we just need to do a lot more of the one (functional) than the other (traditional). This is what this book is all about.

## SUMMARY

- ROM rehabilitation is the therapeutic process used to recover or improve movement range
- ROM challenges are the different techniques and methods used to achieve ROM change
- The natural recovery behaviour of an individual after an injury or immobilization is the most widely used ROM challenge
- Recovery behaviour contains three traits that are important for ROM recovery: specificity, repetition and overloading
- Specificity is how closely the ROM challenge resembles the affected functional movement. Repetition is the overall exposure to the challenge, and overloading is the progressive increase in physical demands on the affected movement
- Repair, adaptation and mechanisms associated with symptomatic relief are the processes that underpin ROM recovery
- Recovery processes occur in the tissue, neurological and psychological-behavioural dimensions



- Understanding the processes and dimensions associated with the ROM loss is important for developing and individualizing the rehabilitation programme
- ROM challenges can be either functional or extra-functional. Functional challenges are active approaches that resemble normal movement patterns
- Movements that are dissimilar to daily patterns are termed extra-functional challenges
- Managed recovery behaviour is a functional approach. It is where the therapist helps the patient to develop a self-care daily programme using the specificity, repetition and overloading principles
- Functional stretching is a therapist-assisted functional challenge. It is used when the patient is unable to execute the recovery behaviour
- Many of the traditional stretching methods are extra-functional challenges
- This book focuses on functional approaches in ROM rehabilitation. They include managed recovery behaviour, a self-help approach and functional stretching – a therapist-assisted functional rehabilitation

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# Functional and Dysfunctional ROM

In setting out to rehabilitate range of movement (ROM) the first task is to establish what is normal ROM and what is abnormal ROM; and this task is not as simple as it seems. Take two asymptomatic individuals and ask them to bend forwards to touch their toes. One will just about reach their knees while the other will place their hands flat on the floor. Which of these individuals has a normal ROM and which a pathological ROM, the stiffer individual or the hyperflexible individual? Does it matter if the stiffer person cannot reach their toes?

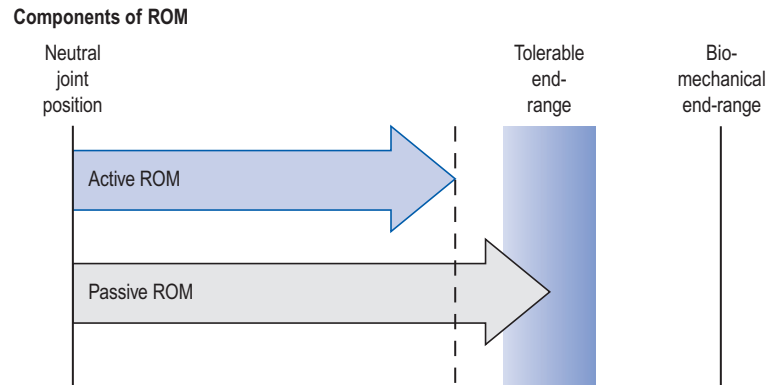
This chapter explores what constitutes ROM, in particular:

- Where is the end-range?
- What are active and passive ranges?
- What is normal ROM?
- When is ROM dysfunctional?
- When is ROM considered to be normalized?

## ROM INGREDIENTS

ROM is composed of active and passive movement components. The active ROM is generated by voluntary muscle activation. The passive ROM is the extent to which a joint or a limb can be moved in the absence of voluntary contraction (Fig. 2.1).

Daily activities are mostly voluntary and are therefore performed within the active ROM.<sup>1-5</sup> This, as will be discussed later, has important implications for ROM rehabilitation (Ch. 8). Passive ROMs often constitute a smaller proportion of functional activities. For example, during the terminal phase of walking the ankle is “passively” dorsiflexed by the forward shift of the body over the extended leg. However, such movements are not fully passive. They are often controlled by eccentric activity in the antagonistic muscles. Passive ranges are also observed in particular postures or at rest: passive ankle dorsiflexion during

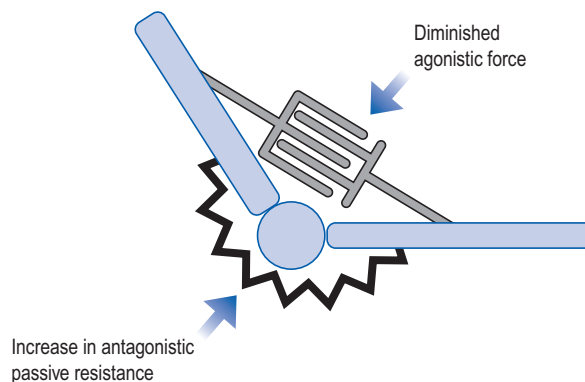


**FIGURE 2.1** Normal active–passive range of movement (ROM). The active ROM is the extent to which a person can voluntarily move a joint or limb. The passive ROM is the extent to which a joint or limb can be moved in the absence of voluntary contraction.

a full squat, spinal side bending while side-lying, or hyper-extension of the wrist when kneeling on all fours. In many of these postures, body weight provides the forces necessary to attain the passive ranges.

### Active end-range

The active end-range is predominantly determined by the contraction forces generated by the muscles and the resistance from the antagonistic tissues. As movement approaches the end-range the agonist muscle's contraction force tends to diminish progressively while, conversely, the passive resistance from antagonistic tissues tends to rise (Fig. 2.2).



**FIGURE 2.2** Active range of movement is limited by a fall in the forces generated by the agonistic muscles owing to excessive filament overlap, and an increase in passive resistance in the antagonistic tissues.

Several factors can influence the active end-range. If you actively extend your index finger the range will be different depending on whether the wrist is held in flexion or extension; so positioning of adjacent joints/limb plays an important part in this range. Also, if you repeat the movement several times, fatigue will set in and you may find that the full range is progressively more difficult to attain. There are many other factors that can affect the active end-range: abnormal shortening of connective tissues, local sensitivity, pain, muscle atrophy, loss of motor control, excessive activity in the antagonistic pair, fear of movement, and many more. So the active end-range is highly variable. But what about the passive end-range? Is it absolute?

### Passive end-range

In most joints, the passive ROM is a measure of the individual's tolerance to discomfort or pain and not a true measure of range (Fig. 2.1). If you pull your index finger into extension the end-range will be determined by how much you can tolerate discomfort or pain (see stretch tolerance, Ch. 10). If a goniometer was at hand this position would be measured as the full extension range. However, the extension range would increase further if we were to anaesthetize the area and apply a greater force. So the painful range does not necessarily represent the full biomechanical range. This would apply to joints in which end-ranges are limited by soft-tissue resistance such as the spine, shoulder, hip and ankle, but not where there is bony apposition, such as in elbow extension.

So passive end-range is determined by stretch tolerance, which, by itself, can be highly variable and influenced by numerous factors. For example, sensitivity has natural variations during the day; a stretch performed with discomfort in the morning may be easier in the evening. An individual who stretches regularly will often complain of "good" and "bad" agility days. Sensitivity can change transiently simply as a result of repeating the same movement several times. Stretch the index finger into extension and then repeat it. On the second stretch you will find that it extends further with less discomfort (see creep deformation, Ch. 4). This means that the passive end-range is a vague clinical construct, highly variable and not an absolute measurement as we are often led to believe.<sup>6</sup>

### ROM and sensitivity

End-ranges become even more blurred in conditions in which ROM losses are accompanied by pain and sensitization. In these conditions there is reduced tolerance to stretching and the experience of pain and stiffness determines the end-ranges. As a consequence, passive and active ROM losses can be due to elevated stretch sensitivity, but without physical changes in the length or

stiffness of the tissues. For example, patients with low back pain often complain of increased spinal and hamstring stiffness in forward bending. However, they have the same flexion ROM as asymptomatic individuals.<sup>7–10</sup> Hence, stretching the back and the legs, a common exercise given to patients with chronic back pain, is unlikely to have any therapeutic value (since nothing is short, it just feels like it).

The variability of tolerance can complicate and add uncertainty to ROM assessment and treatment. We can never be sure how much of the ROM loss is due to “real” biomechanical limitations or is simply because the patient cannot tolerate the discomfort. Furthermore, because the end-range is experiential and not a mechanical phenomenon it provides inaccurate feedback during stretching; it can be difficult to determine how much force to use during stretching. If the area is highly sensitized the patient may terminate the stretching long before it reaches effective levels. Pain and sensitivity can also confuse the treatment progression. Unpredictable adverse reactions and fluctuating sensitivity can overshadow positive biological–adaptive ROM changes. A further discussion of this topic can be found in Chapters 9 and 10.

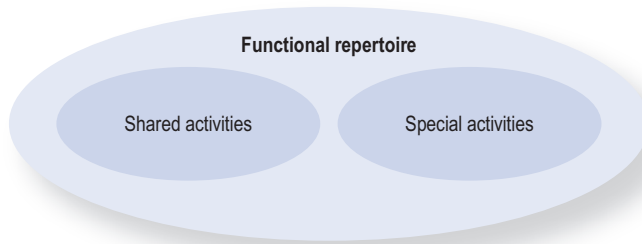
## DEFINING FUNCTIONAL AND DYSFUNCTIONAL ROM

A patient who presented to my clinic complained of several months of moderate shoulder discomfort during the night. On examination, there was total loss of external rotation on the affected side, but all other ROMs were normal. Interestingly, the patient was unaware that she had such profound ROM losses, in particular as she was still able to carry out all her daily activities to the full. She was only concerned about the pain that kept her awake at night.

This case suggests that ROM can be evaluated by using a clinical-anatomical and functional reference points. A clinical-anatomical model often uses the unaffected side or published ROM values as a reference for comparison.<sup>11–16</sup> A functional assessment explores how ROM changes impact the patient’s ability to perform a range of daily activities. These two forms of evaluation are not necessarily linked and the functional one is often more important in defining recovery. But what do we mean by functional ROM?

### Functional ROM

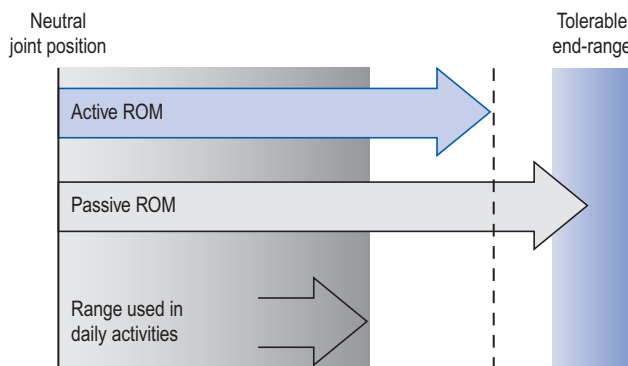
Functional movement is *the unique movement repertoire of an individual* (Fig. 2.3).<sup>17</sup> This repertoire contains some shared movement patterns associated with daily needs and demands such as feeding, grooming and travelling. Some of the functional repertoire is particular to the individual, containing specialized occupational and recreational activities or sport pursuits.



**FIGURE 2.3** Functional movements contain the movement repertoire of the individual. This includes universal shared activities and special occupational and recreational activities, which are unique to the individual.

Within functional movement is the person's *functional ROM*. It is the ROM required to perform functional activities effectively, efficiently and comfortably;<sup>18</sup> to have sufficient ROM to reach for a shelf, bend to lift or hip flexibility to walk (shared activities), or the extra flexibility needed for a dancer to perform full splits (special activities).

Most individuals use a relatively small percentage of their full active ROM when performing shared activities (Fig. 2.4).<sup>1-5,19</sup> Hence, these are often performed within a comfort zone, with relative ease and without any stretch discomfort or pain. Infrequently, some shared activities may challenge the margins of this comfort zone, such as the full lumbar flexion required to pick an object off the floor or the full cervical rotation needed for reversing the car.<sup>1,2,19</sup> Special activities, such as yoga or dance, require greater functional



**FIGURE 2.4** In many areas of the body daily activities are performed within a small proportion of the active range. Occasionally the full active range is engaged. Passive end-ranges are less often engaged during daily activities. This is why recovery of active range of movement (ROM) should be the focus of rehabilitation.

ROM and are often expected to be performed with some level of discomfort and effort. How far a person chooses to move into ranges that are uncomfortable and even painful depends on their movement goals and pain tolerance. These individuals may consider movement in this extended zone to be normal and even desirable.

### Dysfunctional ROM

Often a person will become aware of ROM losses when they are no longer able to perform functional activities to the full. Hence, the use of functionality as a reference point can also help to define dysfunctional ROM: *ROM limitation that impedes the ability to perform functional movement.*

The value an individual gives to any ROM loss is closely related to how adversely it affects their functionality. ROM losses that affect shared activities are obvious, noticeable and likely to be considered dysfunctional by the person concerned. An example would be loss of hip extension affecting walking ability. However, a small loss of full shoulder flexion may go undetected unless the person is attempting to perform a special activity, such as painting a ceiling or doing a handstand. Furthermore, a minor ROM loss for one individual may be experienced as a serious impediment for another. The loss of full shoulder flexion would be more limiting and distressing for a dancer than, say, a footballer. So whether ROM is functional or dysfunctional is determined by the individual's expectations and the requirement of their functional repertoire.

This brings us back to the original question in the introduction; is the lack of flexion ROM in forward bending functional or dysfunctional? That depends on what the person is trying to achieve. There is no ROM "pathology" as long as the stiffer individual is comfortable and able to perform daily activities that require some degree of forward flexion, such as putting on their socks. They are still likely to be within their functional ROM even if they take up a new sport that does not require any special forward bending flexibility, such as running. If they took up yoga their limited flexion ROM would become an impediment, but only in relation to this new activity. Their other shared daily activities would remain unaffected and therefore functional.

## FUNCTIONAL AND CLINICAL ROM IDEALS

The use of functionality as a reference point can also help to define treatment success and to some extent determine the treatment ending.

Most patients commence their therapeutic journey in the hope of regaining their health; ideally, as they were before the onset of their condition. Functionality is often their reference point for evaluating improvements and



treatment success. This may even be in the absence of full ROM recovery. For example, a patient with frozen shoulder may recover full functionality, but on examination the therapist observes a residual 15–20° loss of flexion. The patient considers the treatment a success but the therapist with the medical knowledge does not. It could be argued that, since this residual loss does not impede functionality, recovering it remains a clinical ideal but an irrelevance to the patient. For example, it was found that after knee replacement the majority of patients obtained a flexion greater than 115° while some obtained flexion greater than 125°. <sup>20</sup> However, there was no difference between the two groups on functionality scores.

So what do we do, terminate the treatment once functionality is attained or continue until ROM is fully recovered? Ultimately, the decision depends on the patient's expectations and how the loss limits their functional repertoire. But it also depends on their knowledge of their condition and their beliefs about flexibility. Many patients (and therapists) believe that residual losses will result in some joint pathology and disability later in life. Because of this fear some will pursue the clinical ROM ideal and choose to continue the treatment. These fears can be alleviated by reassuring the patient that such long-term consequences are unlikely and that, in time, normal daily use will promote recovery. So, often a *well-informed* patient would choose to end the treatment when the ROM has *sufficiently* recovered to perform functional tasks. However, some patients' expectations are set within the clinical ideals. They would like to have full ROM.

All this does not exclude the possibility that in some situations the clinical ROM ideals are essential treatment goals, i.e. full ROM recovery beyond what is needed for full functionality. However, as I write this text I am struggling to recall any clinical example where this was the case.

## SUMMARY

- In healthy individuals active ROM is often determined by the inability of an agonist muscle to overcome antagonistic tissue tension. Passive ROM is limited by experience of discomfort and pain (in joints where there is no bony apposition)
- ROM contains active and passive components set within variable and (often) ill-defined end-ranges
- Functional movement is the unique movement repertoire of an individual
- Functional movement contains shared activities, which are universal to all, and special activities, which are specific to each individual
- Functional ROM is defined as the ROM required to perform functional activities effectively, efficiently and comfortably

- Dysfunctional ROM is defined as the ROM limitation that impedes the ability to perform functional movement
- Most daily activities are performed within the active ROM. This suggests that the ROM challenges should also be active and in ranges that support the individual's functional needs
- There are therapists' clinical ROM ideals and patients' functional ROM expectations
- Clinical ROM ideals are based on striving for perfection in physiological ROM and may not reflect the patient's expectations and needs
- Functional ROM expectations are patient-centred movement goals and therefore form the basis for ROM rehabilitation

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# Causes of ROM Loss and Therapeutic Potential of Rehabilitation

A patient with a stiff frozen shoulder, an elderly patient with severe cervical spine degeneration and rotation loss, a stroke patient with hand–wrist contractures, a person with Dupuytren’s contractures and a patient with post-immobilization range of movement (ROM) limitation: who is likely to benefit from ROM rehabilitation and to what extent?

ROM loss is often the outcome of a condition but rarely its cause. Therapeutic outcome is determined largely by the potential for recovery of the causal condition. It also depends on the capacity of treatment to influence the resolution of the causal condition and its capacity to stimulate the adaptive mechanisms underlying ROM recovery. A patient with central nervous system (CNS) damage (cause) may develop contractures (outcome). Stretching the contracture (outcome) does not normalize the abnormal motor control which maintains the condition (cause). In this case stretching alone without motor rehabilitation is likely to be ineffective. On the other hand, frozen shoulder (cause) is associated with capsular contractures (outcome). Since frozen shoulder is a self-limiting condition it is expected that treating the outcome (shortening) will facilitate ROM recovery.<sup>1</sup>

Hence, identifying the cause and outcome and whether the underlying condition is self-limiting or persistent will have an impact on the treatment priorities, choice of management and the prognosis as well as managing the therapist’s and patient’s expectations. It is also essential for delimiting the clinical use of ROM rehabilitation.

This chapter will explore the following topics:

- What are the common causes of ROM losses?
- What physiological processes are associated with ROM losses?
- When is ROM loss recoverable?
- When is ROM rehabilitation useful?
- Is stretching always necessary to recover ROM?

DEFINING THE BOUNDARY OF ROM REHABILITATION

There are two key factors that determine whether ROM rehabilitation will be therapeutically useful (Fig. 3.1). The first consideration is the prognostic path of the causative condition: whether it is self-limiting, persistent or progressive. Another consideration is the condition’s potential for repair and adaptation as well as symptomatic relief: the three processes that underlie ROM recovery (Ch. 1). When these processes are preserved, ROM rehabilitation is likely to be more successful than in those conditions in which they are disrupted by the disease process.

Self-limiting conditions

Acute tissue damage is one of the most common self-limiting causes of ROM loss. In many forms of injury, tissue damage is not associated with *tissue shortening or stiffening*. The limitation in movement is often due to internal swelling within the affected tissues combined with a complex protective strategy that includes pain, increased sensitivity and motor reorganization of movement.<sup>2,3</sup> Such acute ROM loss can be seen in delayed onset muscle soreness (DOMS)

		Potential for adaptation/repair	
		Preserved	Lost
Condition	Self-limiting	Post-immobilization Post-surgery Frozen shoulder Tendinopathies?	
	Persistent	Postural Post-stroke Scoliosis	Burns Autoimmune
	Progressive	CNS disease	Dupuytren's contractures Autoimmune

**FIGURE 3.1** Classification of the prognosis path of the condition in relation to potential for adaptation and repair. CNS, central nervous system.

after exercise, a mild form of muscle damage.<sup>4</sup> Stiffness and ROM losses develop very rapidly within days after exercising, last for a few days and recover fully in line with muscle repair. The patient's subjective experience of stiffness/ROM loss is due to swelling and sensitivity and a loss in force production. Since in acute injuries there is no "true" shortening of tissues the therapeutic aim is to support the tissue repair processes. This can be facilitated by passive or active movement *within pain-free ranges* (see Ch. 9).<sup>5</sup> Although stretching is widely used by therapists and athletes to treat ROM losses following acute injuries or DOMS, it is unnecessary and may even be detrimental.<sup>6,7</sup>

Inactivity or restricted movement range is another common cause of ROM losses. This outcome is often seen after prolonged disabling injuries, post-surgery and following immobilization. In this spectrum of conditions the ROM losses are an adaptive response, secondary to the underlying condition. The shortened, inextensible tissues often preserve their capacity for adaptation and therefore have a good potential to recover to a pre-injury state, depending on various factors such as the magnitude of damage (Ch. 4). In this group of conditions, ROM challenges are likely to be useful.

Between the self-limiting and persistent conditions are several conditions in which pain and sensitization give rise to the experience of stiffness and ROM loss; yet, there is no true shortening of the affected area (Ch. 9).<sup>8,9</sup> This phenomenon is observed in many long-term conditions such as chronic back and neck pain,<sup>10,11</sup> trapezius myalgia<sup>12,13</sup> and many of the tendinopathies such as tennis elbow, plantar fasciitis and Achilles tendinosis.<sup>14–18</sup> In this spectrum of conditions, pain alleviation and desensitization may also be associated with adaptation within the nociceptive system. Stretching may have little or no effect on these processes and other forms of management should be considered, such as the use of relaxation or working with fear-related cognitions. This group of conditions and their management are discussed in more detail in Chapters 9 and 11.

## Persistent conditions

Within the persistent group are ROM changes which are associated with behavioural, non-pathological conditions. There is a widely held belief that prolonged restrictive postural sets/behavioural patterns will result in tissue shortening. For example, some people believe that prolonged sitting with hunched shoulders will result in protracted scapula and shortened pectoral muscles. However, there is very little support for this from the sciences. It seems that even small breaks from the causal activity will offset or "normalize" these imbalances (Ch. 7).<sup>19</sup> There are occasional exceptions, such as the association between regular wearing of high-heel shoes with shortening of the calf muscle and modest ROM restriction in the ankle.<sup>20</sup>

In this group of conditions the adaptive capacity is fully preserved. Hence, if such shortening is evident it can be easily resolved by modifying the causal activity, for example by wearing flat shoes or changing sitting posture. Traditional stretching methods are likely to be ineffective and short-lasting unless there is a concomitant change in movement behaviour. So some ROM recovery can just be about a change in behaviour.

Certain occupational and sports activities may also result in low-level ROM changes in specific joints and movement planes.<sup>21–24</sup> These changes often represent positive, sport-specific ROM adaptations that are beneficial for optimum performance. For example, runners tend to have stiffer lower limbs, which is believed to be a positive adaptation related to movement economy.<sup>25</sup> Similarly, baseball players may develop minor changes in scapular position and motion.<sup>26</sup> In these forms of adaptation, tissue changes are often minor and unlikely to have a negative impact on daily activities. Importantly, there is no pathology here and it might be imprudent to interfere with such beneficial sport-specific adaptation. There is no clinical or physiological value in stretching and it may even reduce sports performance.<sup>27–32</sup>

Scoliosis also falls within the persistent category. Correction of this benign postural state has been the target of many failed manual and physical stretching approaches (it might be the time to give up).<sup>33</sup> Post-surgical complications, severe adhesions and surgical shortening of tissue can result in permanent, non-progressive ROM losses. In such non-progressive conditions some ROM recovery may be possible, particularly if it is adaptive and secondary to the condition (such as from disuse). However, this recovery, too, depends on the extent of damage/repair and the tissues' capacity for adaptation.

Non-progressive CNS damage, such as stroke and head trauma, can result in persistent dysfunctional movement control that may lead to joint contractures.<sup>34–40</sup> It has been estimated that up to 6 hours of daily stretching is required to compete with the chronic neuromuscular drive that maintains the shortening (see competition in adaptation, Ch. 7).<sup>35</sup> In these conditions the therapeutic focus should be on recovering motor control (cause). ROM rehabilitation is unlikely to be effective without such improvement.<sup>34</sup> This can be exemplified in a case of a stroke patient who presented with severe hand and wrist contractures. Initially, his carer could only open the clenched fist by using full force and throwing her body weight behind it. This strategy was used for 5 years without any obvious improvement. Over a period of a few months he was taught to relax the arm and was eventually able to open the clenched hand fully without any stretching (but with some assistance). Interestingly, once this control was achieved he was able to permanently maintain the relaxed hand position throughout the day and night. So some ROM rehabilitation is about motor control rather than stretching.

### Progressive conditions

The most prevalent progressive ROM loss is seen in ageing.<sup>41–43</sup> ROM tends to decline irregularly, affecting particular movement planes and specific joints.<sup>43–45</sup> For example, in the lumbar spine flexion and extension ROMs tend to decline but not rotation ROM.<sup>43,44</sup> Some range loss may be partly adaptive owing to disuse and loss of force production necessary to achieve full active end-ranges. Some of these losses can be recovered by stretching as well as resistance training.<sup>46–49</sup> However, these force–flexibility gains are notoriously difficult to adhere to and rapidly vanish when the training is terminated (competition in adaptation),<sup>48</sup> in particular for an elderly individual who is adopting a progressively sedentary lifestyle and may have other health problems.

There are numerous persistent and progressive conditions that lead to ROM losses. They include degenerative musculoskeletal disease (e.g. osteoarthritis), progressive CNS pathologies (e.g. muscular dystrophies, Parkinson’s disease),<sup>50</sup> Dupuytren’s contractures and autoimmune conditions, such as rheumatoid arthritis and scleroderma.<sup>51</sup> In this group of conditions rehabilitation may improve ROM marginally and temporarily,<sup>51</sup> but is unlikely to prevent ROM losses in the long term. The therapist should consider a multidisciplinary approach in which ROM rehabilitation is combined with other forms of therapy to help resolve the underlying condition.

In summary, ROM rehabilitation is likely to be effective in self-limiting conditions in which the affected tissues have maintained their adaptive or reparative capacity (Fig. 3.2). In these situations the aim is to help the patient recover

		<i>Potential for adaptation/repair</i>	
		Preserved	Lost
<i>Condition</i>	Self-limiting	High	
	Persistent	Low Unlikely	Unlikely
	Progressive	Unlikely	Unlikely

**FIGURE 3.2** Potential for range of movement recovery.



functionality within the shortest time possible. This therapeutic potential diminishes in persistent and progressive conditions, particularly when the recovery mechanisms have been affected by disease processes.

## SUMMARY

- ROM loss is often the outcome/symptom of a condition
- The conditions that cause ROM loss can be classified as self-limiting, persistent or progressive
- ROM recovery is dependent on repair and adaptation (and symptomatic relief)
- ROM rehabilitation is likely to be more effective in conditions where the adaptive and reparative capacity of the affected tissues is saved
- ROM rehabilitation will have a diminishing effect in persistent and progressive conditions, in particular if the adaptive or reparative capacity of the affected tissue is reduced

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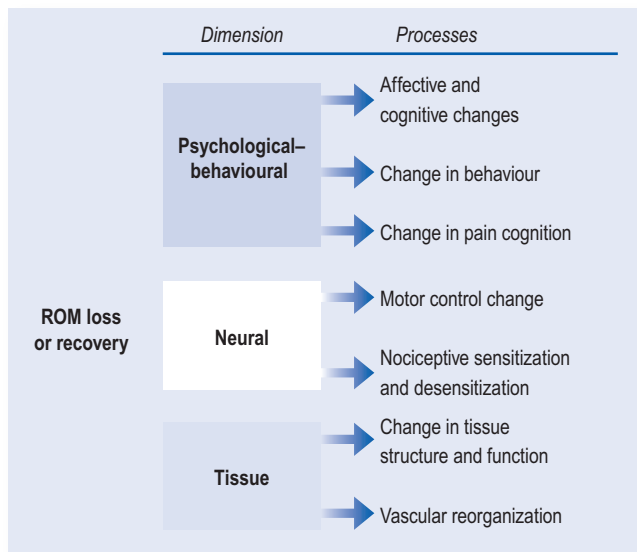
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# Adaptation in ROM Loss and Recovery

The capacity of the musculoskeletal system to undergo range of movement (ROM) adaptation can be seen in a number of human experiences, from the dramatic elongation of the anterior abdominal wall in pregnancy and the gains of flexibility in yoga and dance to ROM losses during immobilization and ROM recovery during rehabilitation. These adaptive processes are whole-person changes that can be observed in the tissue, neurological and psychological dimensions (Fig. 4.1).



**FIGURE 4.1** Adaptation in range of movement (ROM) loss and recovery is multidimensional. Adaptation in the neurological and psychological dimensions is discussed in Chapters 8, 9 and 11.

This chapter will explore the following topics:

- What is the physiology of adaptation?
- What happens to tissues during ROM loss?
- How do tissues adapt in ROM recovery?
- What drives adaptation?

The focus in this chapter will be primarily on adaptation in the tissue dimension, using immobilization and post-injury and post-surgery conditions as a model to explore ROM loss and recovery.

## THE WONDERS OF MECHANOTRANSDUCTION

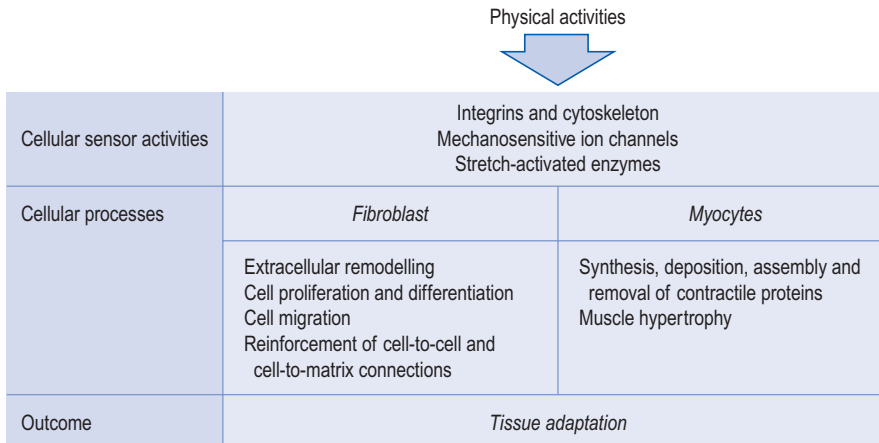
Underlying the body's adaptive capacity is a physiological mechanism called *mechanotransduction*. It is a mechanism whereby the body converts mechanical signals into biological processes.<sup>1–18</sup> A notable example of mechanotransduction is the musculoskeletal adaptation seen in response to sports training. Mechanotransduction is also the process underlying the tissue changes observed during ROM loss and recovery.

Within the musculoskeletal system the masters of mechanotransduction are the myocytes and fibroblasts (often called mechanocytes). They produce the various biological materials that compose the tissues in which they are found.<sup>19,20</sup> These physiological functions are modulated by the physical stress that is imposed on the tissues. Recurrent, habitual physical loading results in higher synthesis and turnover of these biological materials and lowered turnover during inactivity.<sup>21</sup> Generally, mechanotransduction is more readily stimulated when connective tissue and muscle are preloaded in tension – the essence of many ROM challenges.<sup>22,23</sup>

More recently the interface at which mechanotransduction occurs has been identified as the attachment points between the fibroblasts' and myocytes' cell surfaces to the extra-cellular matrix.<sup>20,24,25</sup> At these sites there are specialized proteins that act as mechanical sensors. When a stretch is applied, the deformation of the tissue activates membrane channels that convert the mechanical signals into chemical signals within the cells (Fig. 4.2).<sup>20,25</sup>

Mechanotransduction can be activated by mechanical signal alone in the absence of blood or nerve supply. This phenomenon can be demonstrated in denervated muscle and laboratory samples of muscle or isolated fibroblast/connective tissue.<sup>26,27</sup> This highlights the significance of physical stress in shaping adaptation; a salient message for ROM rehabilitation.

The mechanical signals that stimulate mechanotransduction activate a cascade of cellular events that continue long after the cessation of stimulation.



**FIGURE 4.2** Processes associated with mechanotransduction.

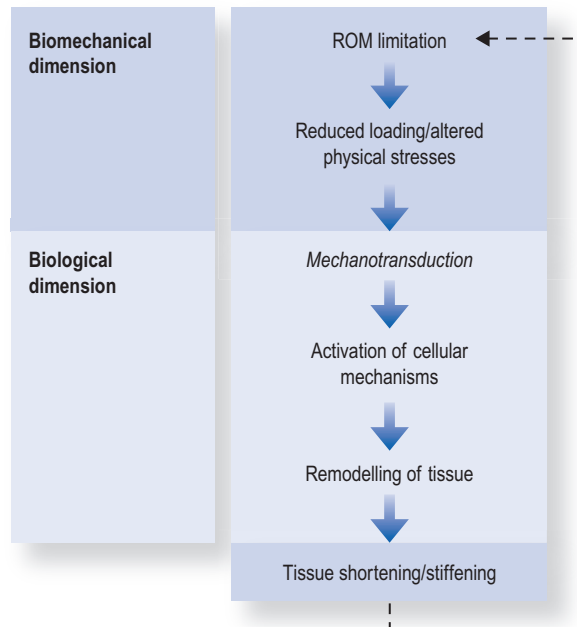
This phenomenon can be observed following resistance training.<sup>18</sup> Muscle hypertrophy (biological dimension) does not occur during the training session (biomechanical dimension), but later, long after the cessation of exercise and including times when the person is resting. For example, a peak release of mechanogrowth factor can be observed in the human forearm muscles 2 hours after eccentric exercise.<sup>15</sup> A similar phenomenon can be observed in connective tissue after the cessation of stretching or exercise. Fibroblast activity and re-orientation of collagen fibres can be observed after several hours; it peaks at 24 hours and can remain elevated for up to 3 days.<sup>21,28</sup>

## DYSFUNCTIONAL ADAPTATION AND ROM LOSSES

ROM loss is a form of dysfunctional adaptive reorganization that takes place when loading forces change or drop below a functional threshold (Fig. 4.3). The deleterious influences of underloading/immobilization are pervasive, affecting all musculoskeletal tissues, including the muscle–tendon unit, fascia, ligaments, joint capsule and intracapsular structures such as articular surfaces and synovium (Fig. 4.4).<sup>29–34</sup>

### Connective tissue and intracapsular structures

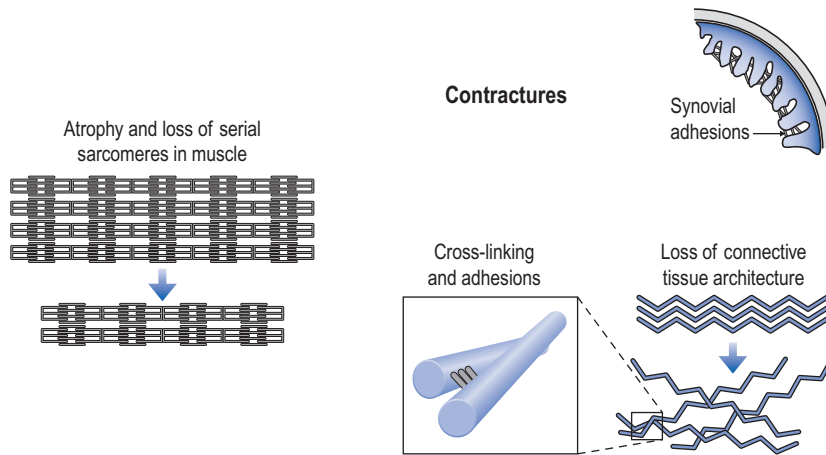
There are several mechanisms associated with the loss of ROM during immobilization. The loss of extensibility is partly due to collagen fibres adhering to each other by chemical bonds called *cross-linking*.<sup>35</sup> Under normal circumstances, the collagen fibres are intermingled with a gel, containing



**FIGURE 4.3** The transition from biomechanical to biological processes as a model for dysfunctional range of movement (ROM) adaptation.

glycosaminoglycans, that has a high water content.<sup>36</sup> This gel provides volume to the collagen matrix, helping to keep the collagen fibres apart, similar to dipping a cotton-bud in water – it tends to swell as the fibres separate. The gel also acts as a lubricant that allows the fibres to glide over each other. During immobilization the gel content tends to decline, resulting in approximation of the fibres and loss of lubrication.<sup>37</sup> As a consequence, the fibres tend to “stick” to each other, and, like glue, will “set” and become progressively strong over several days.<sup>38</sup> This process is more marked during the first 2 weeks after an injury or immobilization, when there is a high turnover of collagen in the tissues.

A similar process underlies adhesion formation. Here, the abnormal deposition of collagen and cross-linking is between gliding surfaces, such as tendons within their sheaths or synovial villi. In animal studies, adhesion of the synovial villi was found to be a major cause of ROM loss during immobilization (Fig. 4.4).<sup>39–43</sup> Longer durations of immobilization result in stronger and more numerous cross-links. The consequence is formation of adhesions that



**FIGURE 4.4** Some of the adaptive changes associated with immobilization and contracture.

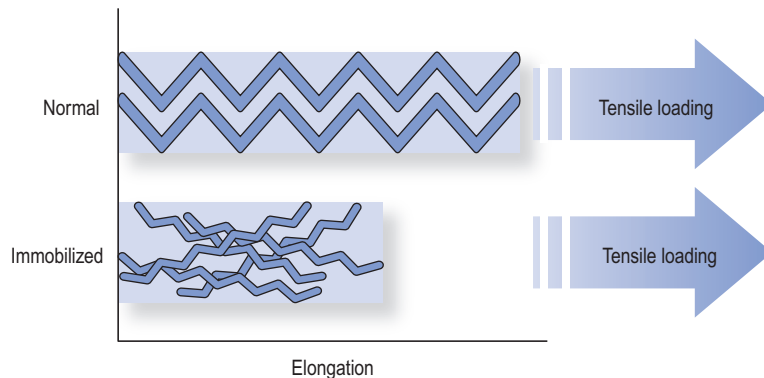
have greater tensile strength than the tissues to which they are attached. When this occurs, vigorous stretching may fail to break up the adhesions but may damage the tissues to which they are attached.

In addition to cross-linking and adhesion tissue extensibility may be reduced by shortening and reorientation of the collagen fibres (Fig. 4.5).<sup>44,45</sup> Normally, collagen fibres have a crimp-like structure organized along the lines of tension in the tissue. During tension loading, some elongation occurs by flattening of this crimp structure. In immobilization, this crimp architecture is lost. The normal longitudinal arrangement of the fibres becomes disorganized, forming a random criss-cross pattern. The outcome is stiffening and weakening of the tissue (Fig. 4.5).

Not all tissues respond equally to immobilization. Ligaments demonstrate reduced cross-section, weakening and an increase in compliance (less stiff), whereas tendons increase in stiffness.<sup>38,46–50</sup> In animals, 8 weeks of immobilization resulted in a 40% decrease in tensile strength and a 55% increase in ligament compliance.<sup>51</sup> However, this may vary between conditions; for example, in osteoarthritis of the knee there is an increase in stiffness of the medial, lateral and collateral ligaments.<sup>52,53</sup>

Clinically, it is difficult to assess tissue strength. There is always an uncertainty as to how much force we should use during stretching. This uncertainty can





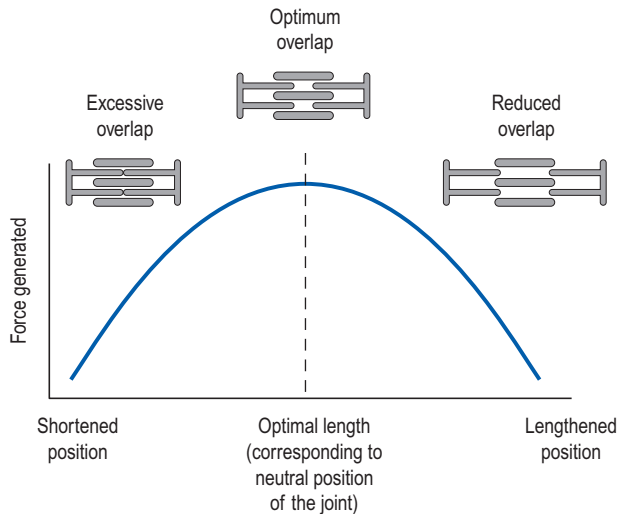
**FIGURE 4.5** Loss of connective tissue extensibility can be due to reorientation, loss of crimp structure and shorter fibres.

be overcome by introducing tissue loading in a graded manner over several sessions (see graded challenge, Ch. 6).

### Muscle changes

Muscle–tendon adaptation is largely related to the efficiency and effectiveness of force production. Optimal force production is observed when the muscle length corresponds to the resting position of the muscle or neutral position of the joint. Force production is diminished if the muscle has to contract while overstretched or in a shortened position (plotted as the *active force–angle curve*; Fig. 4.6). This change in force (and velocity) generation is related to the overlap of the myofilaments. In the neutral position the cross-bridges are optimally overlapped for force generation, whereas they are excessively overlapped in the shortened position and insufficiently overlapped in the lengthened position.

During immobilization, the neutral position of the joint is displaced and, as a consequence, the muscle has to adapt around this new position.<sup>54</sup> However, the sarcomeres have only a limited capacity to change their length. This is overcome by the muscle’s capacity to add or remove sarcomeres to preserve the optimal overlap (Fig. 4.7). This is akin to making a chain longer or shorter by adding or removing links rather than changing the size of the individual links. In a similar manner, sarcomeres are removed when the muscle is immobilized or forced to function in a shortened position, and added in the lengthened positions.<sup>54–64</sup> The loss of sarcomeres in series can be as high as 40% in the shortened muscle, and there may be a 20% gain in the lengthened muscle.<sup>56</sup> This adaptive process was shown to start within hours of immobilization or when the muscle is stimulated to contract in a shortened position/



**FIGURE 4.6** The active force–angle curve. Force generation is optimal close to neutral joint angles and tends to diminish in the shortened or lengthened positions.

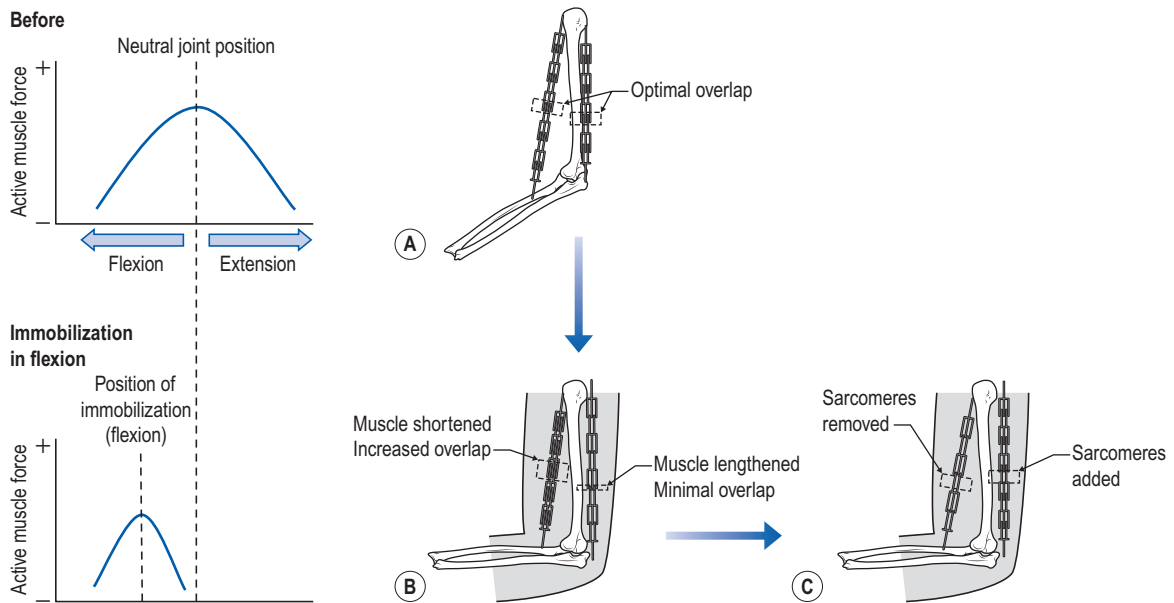
range.<sup>57</sup> The deposition of new sarcomeres can be observed within 4 days of stimulating the muscle.<sup>65</sup>

During the first 2 weeks of immobilization muscle shortening/stiffening plays a larger role in loss of ROM than other joint structures. In animal studies, 2 weeks of joint immobilization resulted in a 20° loss as a result of muscle adaptation compared with a 6.5° loss attributed to joint structures. After that adjustment period, the muscle seems to complete the process of adaptation and “settle” around the angle of immobilization. At that stage it contributes marginally to the contracture. For example, at 32 weeks only a 1.0° loss is attributed to muscle tissue versus a 51.5° loss attributed to connective tissue structures.<sup>39–41</sup>

The reorganization of the muscle length around the position of immobilization is also associated with loss of parallel sarcomeres. The outcome is muscle atrophy and force loss, the essential components of the active ROM. This highlights the importance of introducing active challenges early in the ROM rehabilitation programme.

### Connective tissue change in muscle

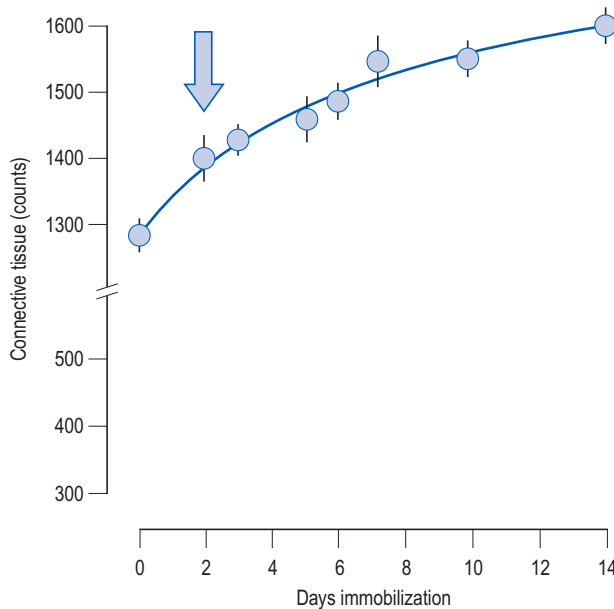
Normal mechanical links between the muscle cells and their final insertions are essential for optimal transmission of contraction forces.<sup>16,66</sup> This link originates from the attachment of the myofilaments to the connective tissue in the



**FIGURE 4.7** Muscle contraction is optimized during immobilization or change in use by adding or removing sarcomeres in series. A. Normal. B. Immediately following immobilization there is excessive overlap in the lengthened muscle. C. After a few weeks sarcomeres are removed in the shortened and added in the lengthened muscle.

extra-cellular matrix, to the perimysium and subsequently to the tendon, aponeuroses and bone. Transmission of the contraction force can be impeded by damage or dysfunctional adaptive changes in any part of this connective tissue link (Fig. 4.8).<sup>16,66,67</sup>

Changes in the muscle's connective tissue can be observed during immobilization or partial mobility.<sup>16,66–68</sup> Within the first 2 days after immobilization the ratio of collagen in muscle increases as a result of a rapid loss of muscle fibre (in the shortened but not in the lengthened muscle).<sup>66</sup> Within 4 weeks of immobilization the muscle's fascia can shorten by as much as 25%.<sup>59,60</sup> Interestingly, in this particular study changes in the fascia were also observed in the non-immobilized, control side (15% decrease in the connective tissue length and reorientation of the fibres). This adaptation was associated with the abnormal movement patterns imposed on the animal by the one-sided immobilization. Furthermore, in immobilized muscle, collagen fibres were found to be arranged at a more acute angle to the axis of the muscle fibres than in controls.<sup>66</sup>



**FIGURE 4.8** Connective tissue content of immobilized muscle (endomysium and perimysium). Arrow. Threshold at which there is a significant difference between the experimental and control measurements. Reprinted from Williams PE, Goldspink G. *Connective tissue changes in immobilised muscle*. *J Anat* 1984;138(2):343–50 with permission from John Wiley & Sons.

## ADAPTATION IN ROM RECOVERY

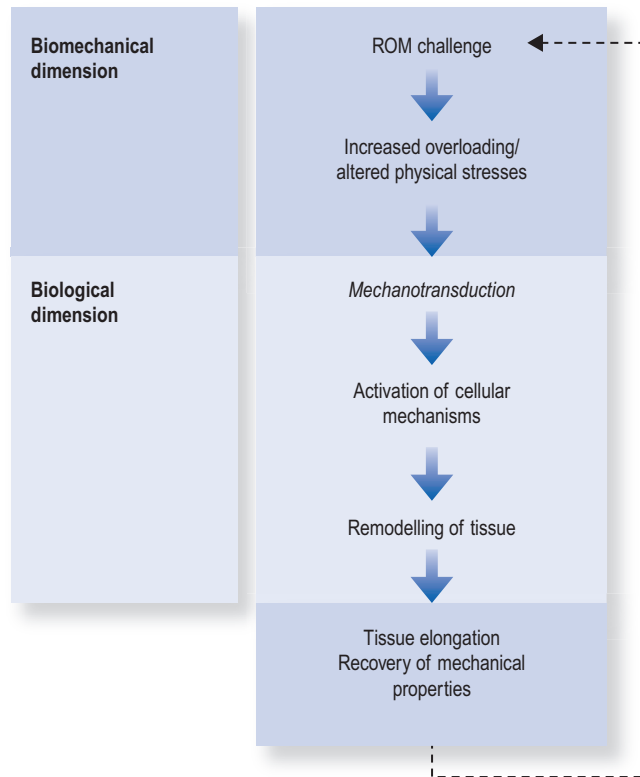
The adaptive recovery of ROM is the story of ROM loss but in reverse (Fig. 4.9).

### Recovery in connective tissue

There are two potential mechanisms that could account for ROM recovery: normalization of the tissue's stiffness/compliance or gradual adaptive elongation of the fibres.

During remobilization there are several factors which account for recovery the tissues' extensibility: normalization of the gel content,<sup>37</sup> reduction of abnormal collagen cross-bridges, recovery of the crimp structure, normalizing of fibre reorientation,<sup>28,35,69</sup> and reduced intra-articular adhesions.<sup>70</sup> In ligaments, reorganization of collagen fibres can take place in as little as 6 weeks of remobilization.

How length changes occur in connective tissue is not entirely clear. One potential mechanism is by assembly of collagen fibres in series, similar to the



**FIGURE 4.9** Adaptive range of movement (ROM) recovery. The transition from biomechanical to biological dimension as a model for tissue-related ROM recovery.

deposition and removal of sarcomeres in muscle. The fibroblasts lead a double life: they construct the tissue's matrix but at the same time produce the enzymes that degrade it. This turnover of collagen is elevated during tensional loading and may account for a length adaptation. A similar length remodelling process is seen in connective tissue during the repair process.<sup>71-76</sup>

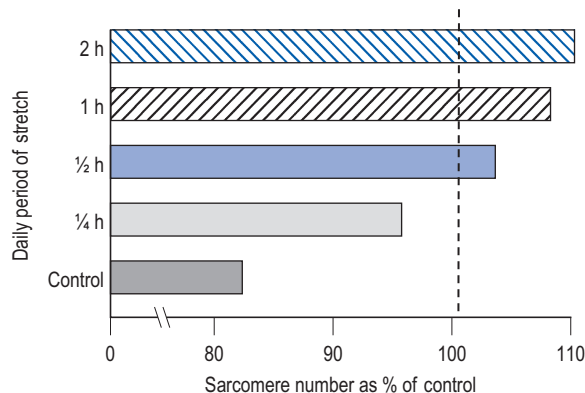
Remobilization has the added benefit of improving the tissue's tensile strength by recovering its unique architecture and also by compacting collagen fibrils into thicker and denser bundles.<sup>34,35,77-82</sup> In laboratory samples, stretched collagen was shown to be 10 times stronger, eight-fold denser, and eight times thinner than non-stretched samples.<sup>83</sup>

Generally, connective tissues tend to adapt over long time periods. After immobilization it can take connective tissues several months or longer to regain their mechanical properties.<sup>37,84</sup>

## Adaptive recovery in muscle

At a muscular level, ROM rehabilitation is all about shifting the angles of use from the immobilized to the functional ranges. This drives a muscle re-adaptation around newly recovered angles. This functional equilibrium is achieved by normalizing the number of sarcomeres and by muscle hypertrophy (Fig. 4.10). Such changes can be observed in muscle within days of remobilization and within a week there are demonstrable increases in the muscle's length and girth.<sup>23</sup>

The adaptation around the recovered ranges is more likely to occur during active than passive movement.<sup>85</sup> This was demonstrated in a study where subjects were either passively stretched or instructed to perform resistance exercise at the end-range.<sup>86</sup> A shift in the active force–angle curve towards the exercised position was only evident in the active group. This principle can be applied during ROM rehabilitation. Imagine a clinical scenario in which a patient has loss of external rotation in the shoulder. With assistance there is a 10° increase in external rotation. At this newly recovered angle the patient is then instructed to perform a variety of movements. These movements should resemble normal functional activities (Ch. 5). For example, “wash the wall” movement patterns can be used to challenge external rotation. Similarly, adaptation around internal rotation can be driven by “wash the back” movement patterns (see Ch. 12 and video demonstration).



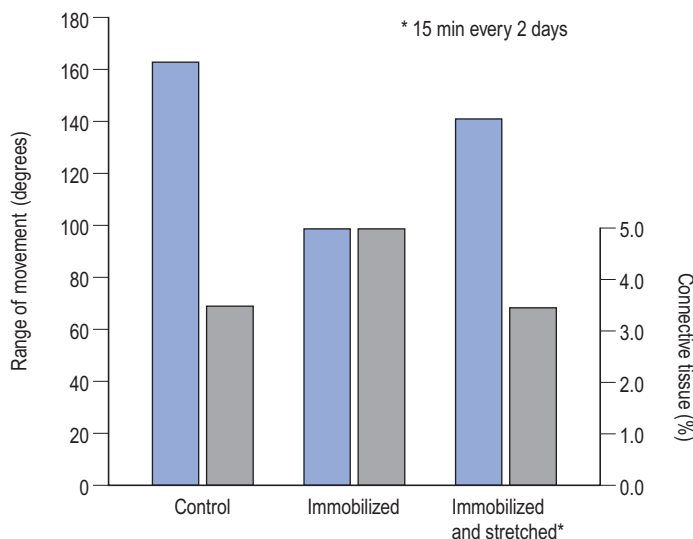
**FIGURE 4.10** Removal and deposition of sarcomeres in series during immobilization in the shortened position and daily remobilization in the lengthened position. Control animals were immobilized for 2 weeks. Experimental animals were also immobilized for 2 weeks but remobilized for daily periods of ¼, ½, 1 and 2 hours. Periods of stretching lasting half an hour or more were found to maintain normal dorsiflexion of the ankle as well as to prevent sarcomere loss. Reproduced from Williams PE. Use of intermittent stretch in the prevention of serial sarcomere loss in immobilised muscle. *Ann Rheum Dis* 1990;49:316–17 with permission from BMJ Publishing Group Ltd.

Should these challenges be dynamic or static? This probably depends on the activity that we aim to recover (see specificity of training, Ch. 5). However, there are some indications from laboratory studies that synthesis and deposition of myofilaments in muscle are enhanced by cyclical rather than static loading and more by active than by passive movements.<sup>15,87–90</sup> In animal studies, the synthesis of contractile proteins is dramatically increased when a muscle is stretched and electrically stimulated to contract rhythmically.<sup>15,87–89,91,92</sup> This stimulation is similar to muscle activation during rhythmic daily activities; in particular, when performed at the end-ranges.

### **Muscle connective tissue**

The mechanical properties and content of connective tissue tend to normalize during remobilization.<sup>16,59,60,67</sup> In animal studies, passive stretch of only 15 minutes every other day maintained a normal ratio of muscle to connective tissue as well as prevented the development of connective tissue contractures at the joint (Fig. 4.11).<sup>16</sup>

Here, too, there seems to be an advantage in cyclical, rather than static, loading. In muscle tissue cultures, connective tissue protein synthesis increases by 22% during static and by 38% during cyclical stretching.<sup>90</sup>



**FIGURE 4.11** Immobilization of a muscle in a shortened position results in a reduction of serial sarcomeres and the proportional increase in intramuscular connective tissue. Measurements of ankle ROM show that these changes resulted in a substantial loss of joint flexibility. Fifteen minutes of intermittent passive stretch, every other day was shown to prevent the accumulation of connective tissue in the muscle as well as preventing some of the adaptive connective tissue changes around the joint. Reproduced from Williams PE. Effect of intermittent stretch on immobilised muscle. *Ann Rheum Dis* 1988;47:1014–16 with permission from BMJ Publishing Group Ltd.

## ADAPTATION IN OTHER TISSUES/ SYSTEMS/DIMENSIONS

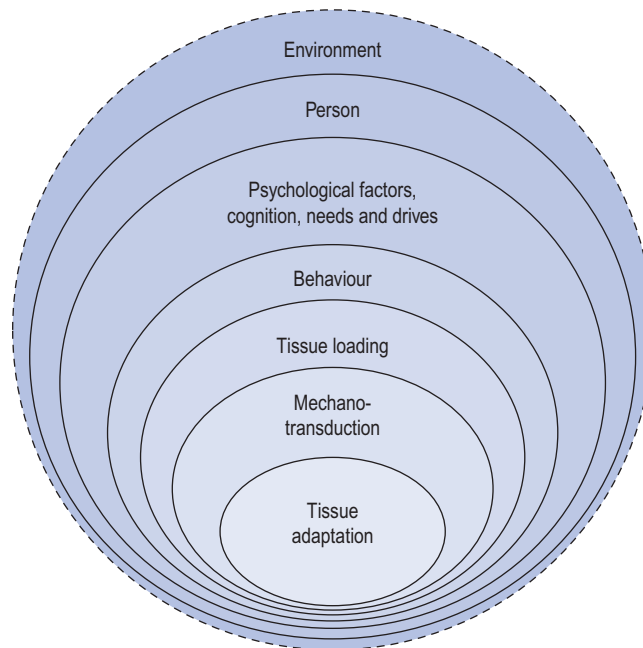
The effects of physical activity and stretching are whole body/person adaptation that can be seen in dimensions and tissues other than connective and muscle tissue.

- **Vascular adaptation** – The epithelial and smooth muscle cells that form the blood and lymph vessels also have mechanotransduction capacity.<sup>93–95</sup> Vascular and lymphatic system reorganization is also observed under tensional forces. In laboratory studies, externally applied stretching was shown to regulate the sprouting of new blood vessels, their length and their alignment in the tissue. In tendon repair studies, movement directs the revascularization and reorientation of the blood vessels in parallel to the tendon; an orientation which is well adapted to withstand the longitudinal forces and gliding of the tendon within its sheath. Conversely, immobilization produces a random misaligned vascular pattern that tends to fail when movement is reintroduced.<sup>35,96</sup>
- **Motor control adaptation** – The loss and recovery of the active ROM is closely related to the adaptive capacity of the motor system.<sup>97–99</sup> These adaptive control changes are extensive and can be observed throughout the central nervous system. This multilevel adaptation has been demonstrated during immobilization. Within the spinal cord there were changes in the firing patterns of the motoneurons as well as in the cortical and cerebellar representations of the immobilized limb.<sup>100–103</sup> Such adaptive motor changes are rapid, and are observed within the first 3 weeks, but probably begin within hours or days of immobilization and active remobilization.<sup>104</sup>  
 Motor control changes are expected to normalize rapidly if there are no central nervous system pathologies. In immobilization, the tissues in the periphery may be damaged, but, centrally, the system is fully intact, healthy and therefore has the full capacity to adapt.<sup>99</sup> It is expected that motor control should normalize once activity is resumed.  
 Motor control considerations during ROM rehabilitation are further discussed in Chapter 8. (For a full discussion of sensory–motor adaptation, see Lederman.<sup>99</sup>)
- **Nociceptive and sensitization adaptation** – Range sensitivity and desensitization are also associated with adaptation within the nociceptive system and psychological dimension. For a full discussion, see Chapters 9 and 11.
- **Psychological/cognitive “adaptation”** – Adaptation in the form of learned association and changes in behaviour is also observed in the psychological dimension. For a full discussion, see Chapter 11.



## WHAT (REALLY) DRIVES ADAPTATION IN RECOVERY

The fibroblasts' and myocytes' capacity to convert physical signals into biological processes suggests that physical loading drives adaptation. However, this can be a limited view. "Someone" has to carry out the physical loading, which brings us to behaviour. It is the actions of the individual, their movement patterns, that provide the necessary stresses required for adaptation, i.e. behaviour drives adaptation. But this still remains an incomplete view. We have to consider that behaviour is the product of the individual's mind, their emotions, moods, needs and drives. Whether they are anxious, depressed or motivated will influence their recovery behaviour. For example, a person with movement-related fears may fail to maintain the behaviour that drives this adaptation. Imagine what would happen to the adaptive process if the patient is elderly, has had a mild stroke, lives alone in a small flat, needs walking rehabilitation but is fearful to walk outside? Adaptation can be viewed as a cascade originating at the interface between the individual and their physical, social and cultural environment, their psychological state, expressed physically as behaviour and culminating with tissue loading and activation of mechanotransduction (Fig. 4.12).



**FIGURE 4.12** Adaptation occurs within the context of what the person does within their environment.

This cascade of influences defines the clinical management of ROM recovery. It is about co-creating with the patient environments in which their recovery can be enhanced. It is a multidimensional environment that encompasses lifestyle, social, psychological, cognitive and behavioural factors (Ch. 11). The important message here is that the locus of recovery is intrinsic to the individual and is subject to environmental circumstances. Hence, *the success of ROM rehabilitation is not inherent in any single stretching approach but in the overall management.*

## SUMMARY

- ROM loss and recovery is represented by several interlinked processes that occur in the tissue, neurological and psychological dimensions
- The musculoskeletal system has the capacity to adapt in response to changes in the physical environment
- Musculoskeletal adaptation is dependent on *mechanotransduction*: a physiological process by which the myocytes and fibroblasts convert mechanical signals into biological processes
- All musculoskeletal tissues can undergo adaptive change associated with mechanotransduction
- In immobilization and remobilization adaption can be seen in all musculoskeletal tissue
- Adaptive processes are driven by the individual's actions within their environment
- Do not lose sight of the person for the mechanocytes

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# Specificity in ROM Rehabilitation

Often individuals (as well as animals) overcome their injury and range of movement (ROM) losses by taking actions that resemble the movement patterns which they have lost: a person with a sprained ankle will attempt to gradually walk; a tennis player with a shoulder injury will attempt to gradually return to playing tennis. Similarly a patient with a frozen shoulder, given time and without any rehabilitation, will often regain their full ROM by daily use of their shoulder.<sup>1</sup> This behaviour can be considered to be Nature's "gold standard" for movement recovery – *practise what you aim to recover*.

However, in physical therapy we provide a curious management. Patients are often given exercise that has no resemblance to the movements that they wish to recover. This raises the possibility that what is prescribed in clinic may not provide the most effective ROM rehabilitation. For example, would floor exercise or manual stretching of the hip improve stride length?

This chapter will explore the following topics:

- Can commonly prescribed stretching exercise improve functional activities?
- Can manual stretching techniques improve functional activities?
- What kind of gain is expected to carry over from the ROM challenge to functional activities?
- How close to the goal task does the ROM challenge have to be?
- What factors can improve the carry-over between ROM exercise and functional activities?

## SPECIFICITY AND GENERALIZATION

In order to understand how to transform clinical gain into functional improvement we need to look at the specificity phenomenon in adaptation.

When we learn a new skill the motor, tissue and physiological adaptation is specific to that particular task (*specificity*).<sup>2–8</sup> This allows the task to be

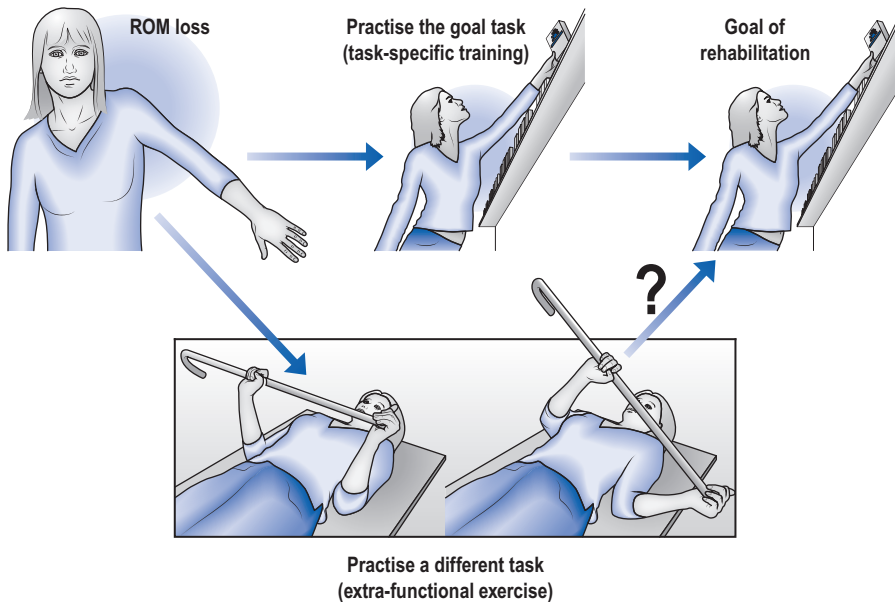


optimally performed with minimal energy expenditure, physical stress and error. This adaptation is unique, and optimized for that particular activity, but may be unsuitable for a different activity.<sup>9-12</sup> This is why the performance of cross country skiing does not improve by dancing practice.<sup>13</sup> However, if specificity in adaptation was absolute it would mean that we would have to learn the task as well as each of its infinite variations. This problem in adaptation is overcome by our ability to carry-over learning or training experiences to variations of *the same* activity/task (*generalization*). So once a movement has been learned it can be performed with many variations without having to practise them all.<sup>14-17</sup> Hence, throwing a ball can be performed in conditions that have never been encountered during the training. Similarly, we can drive an unfamiliar hired car without having to re-learn driving.

The generalization–specificity principle in learning and training has important implications for therapeutic stretching. In many stretching approaches it is expected that particular techniques or exercise will help to improve a wide range of functional activities. An example is core stability exercise in which specific trunk muscle training is believed to enhance performance in many different sports and daily activities. Similarly, there is a common expectation that stretching techniques would improve a variety of daily activities. For example, muscle energy technique (MET) applied to shoulder extensors would be expected to improve many functional overhead tasks.

On the other hand, specificity implies that the treatment has to closely resemble the goal activity,<sup>18,19</sup> i.e. walking should be rehabilitated by walking, standing by standing and balance by balancing. Equally, ROM challenges should replicate closely the movements being recovered; for example, shoulder ROM should be challenged during functional overhead activities (Fig. 5.1). Specificity implies that, if the stretching and goals of rehabilitation are dissimilar, there would be an ineffective carry-over of clinical gains to functional improvements. For example, it would be expected that MET of shoulder extensors would be ineffective in improving functional overhead activities. This is because there is no resemblance between the muscle recruitment sequences during MET and those of a functional movement such as reaching overhead.

From a therapeutic perspective, a generalization principle is very attractive and therefore prevalent in physical therapies; all that is needed is a particular set of universal exercises to improve a wide spectrum of daily activities. On the other hand, a specificity principle means that treatment has to focus on a wider selection of affected activities. The specificity–generalization issue is not well researched in physical therapies, and for answers we need to look at motor learning and training principles, in particular at the transfer principle in training.



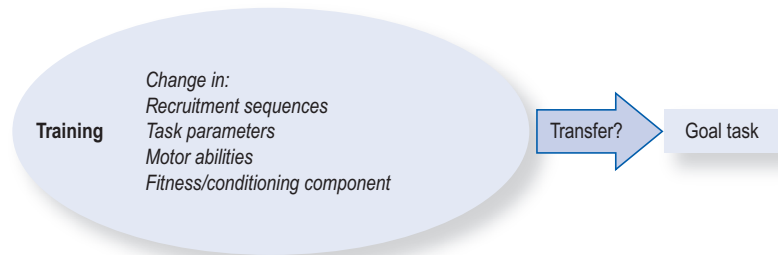
**FIGURE 5.1** Range of movement (ROM) rehabilitation: task specific or extra-functional training? Movement rehabilitation often uses exercises that are dissimilar to the goal task, rather than using the task itself. There is an assumption that something special is happening in the extra-functional but not the specific task training.

## Transfer of training

Imagine a clinical situation in which a patient with flexion contracture of the hip is given particular exercises to recover hip ROM; say, kneeling on all-fours quads stretch. The ultimate aim is to influence hip function during walking rather than improve the performance of this particular exercise. By prescribing such exercises we assume that there are some elements within the exercise that would generalize and carry-over to improve walking. This carry-over is called *transfer*; it is how the performance of a particular task (say, walking) is influenced by practise of another activity (quads stretch exercise).<sup>10,20–22</sup>

In physical therapies it is often *assumed* that several elements can be transferred between the exercise and the goal task; using hip exercise as an example (Fig. 5.2):

- **Recruitment sequences** – One common assumption is that particular recruitment sequences, such as relative on–off timing and duration of hip synergists, would transfer from the exercise to the task.
- **Task parameters** – Another assumption is that transfer could be one or several of the task parameters such as the force, velocity, range and endurance of hip muscles.



**FIGURE 5.2** The content of transfer. There is a widely held assumption in physical therapies that all these elements can be transferred between different tasks.

- **Motor abilities** – Motor abilities are movement traits of an individual that underlie skilled performance. There is a common belief that particular motor abilities, such as balance or coordination, could transfer between tasks. For example, hip coordination during walking would be normalized by improving trunk–pelvic–hip coordination exercise on the floor. Or, that balancing on a Swiss ball would transfer to improvements in balance during walking.
- **Fitness/conditioning component** – Another possibility is that the exercise could improve some localized atrophy or general fitness. This conditioning effect could carry-over to improve the target skill. For example, the all-fours hip extension exercise would help recover some of the extensor muscle wasting in the affected limb and therefore improve hip extension during walking.

The question that emerges is which of these movement elements can transfer between the exercise and the goal task? To answer this we need to look at the distance which the movement elements have to carry over, i.e. how close is training to its goals.

### Measuring similarities

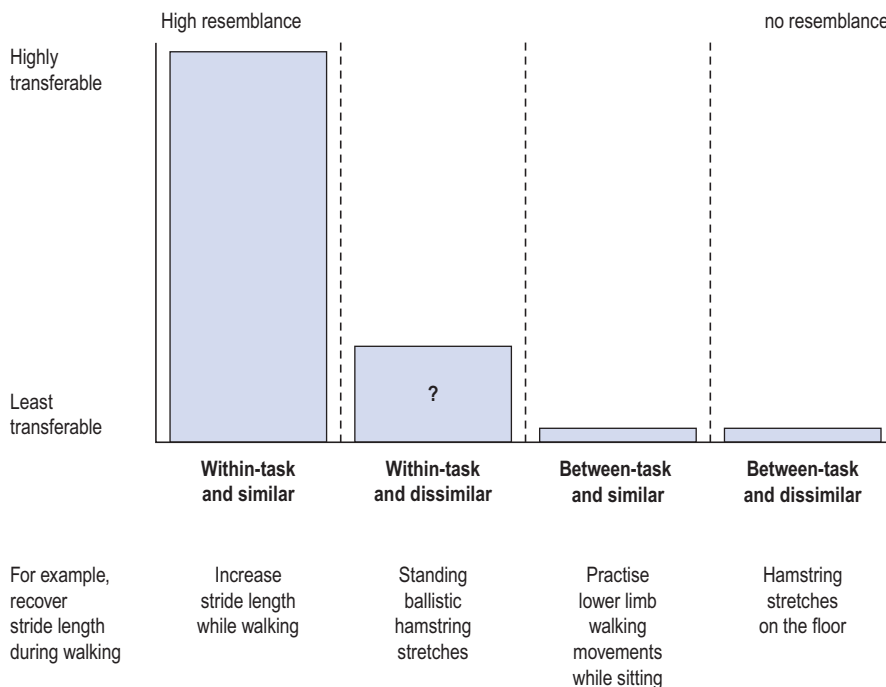
To explore resemblance we need some form of yard-stick to “measure” this distance. This can be assessed by looking at whether the training is within the same task (*within-task*), e.g. train in walking to improve walking, or between two dissimilar tasks (*between-task*), e.g. training on all fours to improve walking.

An example of exercise that aims to utilize within-task transfer is the common use of weights during walking or running. Here, the training and the task resemble each other but with the added overloading of force. Within-task transfer is represented in ROM rehabilitation by the expectation that improvement of force in one range would carry over to other, unpractised ranges.

Between-task training aims to improve a particular task by training or treating in a different task; for example, the common practice of balancing on a Swiss ball in order to improve balance during walking. Here, the focus is on balance transfer but the exercise is dissimilar to the goal task (walking). Another example would be to train for explosive force by vertical jumps (one task), but with the aim of improving sprinting (another task), an activity that also requires an explosive force. Between-task transfer is represented in ROM rehabilitation by the expectation that practising the all-fours hip extension exercise on the floor would improve walking hip ROM.

A further measure of resemblance is *similarity* and *dissimilarity* of the movement patterns between the exercise and the target task.<sup>23,24</sup> For example, does the movement of the leg during all-fours leg extension exercise resemble the movement patterns of the leg during walking?

Whether the training is within-task or similar provides four categories for assessing the “distance” between the ROM challenges and the goals of rehabilitation. The challenges can be (Fig. 5.3):



**FIGURE 5.3** Assessing similarity and transferability between the training and the rehabilitation goals.

- A. Within-task:
  - Within-task-similar
  - Within-task-dissimilar
- B. Between-task:
  - Between-task-similar
  - Between-task-dissimilar

Imagine again the patient who has reduced hip extension that limits walking. The training would be *within-task-similar* if the person is instructed simply to walk with a wider stride. Another possibility is to walk while performing pelvis-stabilizing exercises. In this case, the movement is within the task of walking but is somewhat dissimilar to it (*within-task-dissimilar*). Performing leg movements that resemble walking while sitting would be an example of an exercise which is *between-task-similar*. The rehabilitation would be *between-task* and *dissimilar* to walking if the patient is instructed to perform a hip extension exercise while lying prone.

Now that we have a way of measuring resemblance we can explore in which of these categories transfer is most likely to occur.

## STUDIES OF SPECIFICITY AND TRANSFER

Overall, several decades of studies in motor learning suggest that specificity is the dominant outcome of training/practice and transfer between tasks is mostly absent and if present is considered to be insignificant.<sup>25–32</sup>

Specificity in movement can already be observed in young children.<sup>5</sup> It seems that each task in their movement repertoire is learned specifically, with little or no transfer between tasks that share the same motor abilities. For example, dynamic balance skills do not transfer to static balance skills and vice versa. A high level of fine motor control in the hand may help in drawing but not in playing with Lego bricks, an activity that also depends on fine motor control. This lack of transfer of motor abilities between tasks has also been shown in adults.<sup>25,33</sup>

Some within-task transfer has been shown in sports training but it tends to be modest and unpredictable. Sprinting performance was shown to improve by single-leg horizontal jumps but not by vertical jumps using both limbs, such as jump squats.<sup>18</sup> Transfer may fail to occur even in trainings that seem to closely resemble the task. For example, resistance sprint training using a towing device fails to improve sprint performance.<sup>34</sup> Similarly, off-ice skating exercises do not improve on-ice performance in speed skaters.<sup>35</sup> Even activities that look identical, such as sprinting and endurance running, each have their unique, non-transferable knee force–angle profiles. This specificity is also observed

anatomically. The fascicle length of leg muscles is greater in sprinters than in distance runners.<sup>36,37</sup> That is why marathon runners are not great sprinters, although the movements they perform in running look very similar.

Even in within-task training some elements of the task parameters may not transfer well. For example, the gains of resistance training at one speed may not transfer well to another speed of the same movement.<sup>38–41</sup> Strength gains are greatest at the training velocity with some carry-over to other velocities.<sup>42</sup> Similarly, strength gains are greatest at the training angles with some transfer to other ranges (see more below).<sup>43–45</sup>

There is substantial evidence demonstrating that between-task training gains do not transfer well. Core stability exercises fail to improve sports performance (between-task-dissimilar).<sup>46–48</sup> Different forms of resistance exercise have failed to improve specific sports activities such as football kicks, sprinting, netball, hockey, throwing velocity in water polo and rowing.<sup>18,49–55</sup> Even resistance training in one particular posture may not transfer strength gains to other postures.<sup>56</sup>

In elite gymnasts, athletes, judo competitors and dancers, training to hold difficult, sport-specific postures does not transfer balance ability to commonly used unspecific standing postures.<sup>57–60</sup> Cross-training by cycling does not improve running and may even reduce running economy.<sup>61–63</sup> Training in isolated tasks, such as hip flexibility or trunk-strengthening activities, does not improve the economy of walking or running.<sup>64</sup> Vertical jumps are improved by training in vertical but not by training in sideways jumps.<sup>65</sup> Upper limb resistance exercises do not improve arm coordination,<sup>66</sup> and so on.

All these studies provide a very clear message: the greater the distance in resemblance the less likely is the transfer. Optimal training gains occur when the training is within-task and similar to its goals. Least effective are between-task and dissimilar training. But what about stretching? How likely is it to provide performance gains?

## Transfer in stretching

Most traditional stretching exercises represent training which is between-tasks and dissimilar to its goals (Ch. 1). Hence, we would not expect transfer to occur. Indeed, regular and warm-up stretching, in all its variations, has failed to demonstrate transfer of gains to sports performance.<sup>67–69</sup> One study demonstrated that 4 weeks of contract-relax stretch training (proprioceptive neuromuscular facilitation) of the knee improved flexion range but did not alter the active movement performance (peak isokinetic quadriceps torque).<sup>70</sup> In another study, 10 weeks of lower limb stretching had no effect on vertical jumps.<sup>71</sup> Similarly, 6 weeks of passive static stretching and contract-relax

stretching improved the ROM but neither had any significant effect on the drop jumps.<sup>72</sup> In contrast, one study has shown that 8 weeks of upper limb passive stretching was shown to improve bench presses.<sup>73</sup> However, a recent review found no benefit in acute bouts of static stretching for any form of muscular performance.<sup>69</sup>

These studies suggest that traditional, extra-functional stretching approaches are unlikely to provide performance gain because of their dissimilarity to the goal task. But what about ROM challenges that are within-task? Is generalization possible? Would an improvement in shoulder control of 0–90° flexion improve the control of other ranges, say, 90–120°? Or would improvements in reaching range in the frontal plane be generalized to improvement of the same movement but in the coronal plane?

Motor learning studies suggest that learning a task in one range can generalize/transfer to other angles of the same task. This was demonstrated in a study in which subjects had to catch a series of light and heavy balls with either a “bent” or a “straight” arm configuration.<sup>32</sup> It was found that the learning of catching in one configuration transferred 100% to the other. Here, the contents of transfer are the recruitment sequences of the movement (see Transfer of Training). Force training in one range seems to be angle/ROM specific.<sup>43–45</sup> However, there may be some carry-over of force gains to other untrained angles,<sup>42</sup> in particular if the full range is practised rather than specific angles.<sup>29,31</sup>

In summary, optimal transfer and generalization occur when the ROM challenges are within-task and similar to the movement goals. The four movement parameters, force, range, speed and endurance, are the most likely elements to be transferred or generalized during task-specific training.

## STUDIES OF SPECIFICITY AND TRANSFER IN PATIENTS

So far this chapter has explored the specificity in healthy individuals. The question that remains is whether adaptation principles apply to individuals with pathological ROM losses. In a limited number of studies transfer of rehabilitation gains has been examined in patients with musculoskeletal injuries and pain conditions and in patients with central nervous system damage.

In individuals suffering from chronic neck pain, extra-functional neck exercises do not transfer to improvement in functional head–neck movements (between-tasks and dissimilar).<sup>74</sup> In contrast, a positive transfer of postural stability was demonstrated in a study of balance in subjects with lateral ankle sprain. Training under moderately unstable conditions transferred to improvements

in postural control under more challenging stability conditions (within-task-similar).<sup>75</sup> However, we do not know whether these improvements would transfer to functional activities outside the research lab.

For stroke patients resistance cycling or seated strength exercise improves strength in these activities but has little or no effect on walking;<sup>76,77</sup> sitting and reaching training improves sitting and reaching and the production of vertical force through the leg as they lean forward.<sup>78</sup> The vertical force improvement in the leg seems to transfer to improvement in getting up from sitting, but nothing from that training transfers to walking. However, training of stroke patients in walking improves walking speed and distance but not balance.<sup>79–81</sup> Balance seems to be improved by challenging balance.<sup>82,83</sup> But challenging static balance in standing might not transfer well to dynamic balance during walking.<sup>84</sup> So here, too, transfer can be unpredictable and finicky.

Studies of individuals with age-related or pathological ROM losses suggest a lack of transfer between tasks. One study of postmenopausal women found no effect of regular exercise and stretching on walking performance.<sup>85</sup> In one study of older individuals with hip flexor contracture, 8 weeks of hip and ankle stretching provided a modest improvement in passive ROM (hip 6.8°, ankle 3.5°) but failed to improve stride length.<sup>86</sup> In a similar study, 10 weeks of hip and ankle stretching improved hip flexibility (1.5°) but failed to show significant improvements in gait performance. Twelve weeks of foot exercise that included ankle stretching failed to improve physical gait performance in elderly individuals.<sup>87</sup> In a recent study passive stretching was shown to increase passive hip ROM (5°) and stride length (by 2.7 cm) during comfortable but not during fast walking speeds.<sup>88</sup> However, at neither walking speed was there any improvement in peak hip extension or peak anterior pelvic tilt, i.e. there was no transfer of hip flexibility from the exercise to the walking.<sup>89,90</sup> This is likely to be due to the failure to emulate the complex intermuscular coordination of the hip during walking by passive stretching (Ch. 8). It would have been useful in all these studies to include a task-specific group that trained in walking faster or with a wider gait.


In 2011, a Cochrane systematic review reported that various forms of traditional stretching for contractures failed to improve functional activities.<sup>91</sup>

## IMPLICATIONS FOR ROM REHABILITATION

From the evidence discussed above there is a strong case for recommending training, exercise and treatment approaches that are task-specific and similar to the rehabilitation goals,<sup>26,92</sup> i.e. walking rehabilitates walking. It seems that the various contents of transfer may be generalized but only when they are practised within the same task (within-task and similar).<sup>17,93–96</sup>



**Table 5.1** Transferability in range of movement (ROM) challenges. Functional approaches resemble normal daily activities and are therefore more likely to transfer benefits to the tasks which are the goals of rehabilitation. Extra-functional approaches, comprising many traditional stretching methods, are often dissimilar to normal movement and are therefore unlikely to transfer gain to functional tasks

	Management/ROM challenge	Does it resemble functional tasks?	
Functional	Recovery behaviour	Yes	
	Managed recovery behaviour	Yes	
	Assisted recovery behaviour (functional stretching)	Yes	
Extra-functional	Ballistic stretching	No	
	Dynamic stretching	No (not often)	
	Muscle energy technique	No	
	Passive stretching	No	
	Spinal manipulation	No	
	Traction	No	
	Articulation	No	
	Harmonic	No	
	Strain counterstrain	No	
	Cranial	No	Least transferable

The specificity principle suggests that ROM rehabilitation should be closely tailored to the individual's movement repertoire.<sup>92</sup> Hence, ROM rehabilitation of the hip will differ between a footballer and a dancer. Initially, the ROM rehabilitation will aim to recover shared functional activities, such as stride length in walking or climbing stairs. However, at a particular point the rehabilitation would diverge to take into account the individual's unique movement repertoire. Footballers would be rehabilitated with end-ROM challenges during movements that resemble football passes, kicks, etc. Dancers would require end-ROM challenges in sequences that are selected from their dance repertoire (Chs 1 and 12).

At the bottom end of the transferability scale are training/treatments that are extra-functional and dissimilar to the goals of rehabilitation (between-task and dissimilar). Many traditional stretching techniques/exercises are often performed on either the treatment table or the floor and are therefore dissimilar to functional "real-life" movements (Table 5.1). The consequence is motor control and peripheral adaptation that is specific to these clinical practices but that is completely different from the complex intermuscular coordination required during functional activities (Ch. 8).<sup>96</sup> These approaches are unlikely to transfer improvements and may reduce the efficacy of rehabilitation, i.e. floor hip-extension exercise is unlikely to transfer any significant gains to

walking. Passive manual stretching approaches will fail to drive any motor control adaptation. They are therefore unlikely to promote any level of generalization or transfer of passive ROM gains into active ones (Ch. 8).

Some patients may be unable to perform task-specific activities because of pain, motor control losses, multiple injuries or simply fear. In these circumstances there may be a place for extra-functional ROM rehabilitation. The rehabilitation could commence on the treatment table or the floor. However, as soon as the patient demonstrates an ability to stand the treatment, should switch to that context level. In situations where deconditioning is present there may be a low-level transfer of the task parameters (force, endurance) to functional activities.<sup>40,97-101</sup> However, this seems to occur only when atrophy reaches a critically low level.<sup>102</sup> Even in these conditions, exercises that challenge the task parameters (force, endurance) and are practised within the goal task seem to provide better functional gains.<sup>92,103-108</sup>

In summary, there is potential for ROM recovery to generalize within a task but transfer is poor between tasks. Even within task-specific training/treatment, the potential and degree of generalization and transfer can be unpredictable. Providing ROM rehabilitation that is task specific is a simple clinical solution to overcome this unpredictability.

## PROMOTING GENERALIZATION AND TRANSFER IN ROM REHABILITATION

There are several clinical practices that could help promote generalization during ROM rehabilitation; in particular, the use of variable practice and random scheduling.<sup>25,92,109</sup>

Most functional activities contain numerous variations of particular tasks, and this should be reflected in the rehabilitation. It has been demonstrated that practising variations of a particular task tends to promote within-task generalization. Furthermore, transfer within-task tends to occur more readily when larger movement ranges are used during practice.<sup>94,110</sup> Practising within a narrow range tends to promote control that is more specific to the particular range but reduces the transfer to other ranges.<sup>29,30,43-45,56</sup> Applying these principles to the shoulder, a ROM rehabilitation could include reaching movements performed in a wide range of angles and different movement planes. It should also include variations in force, velocity and fatiguing challenges within a reaching task (see video demonstration).

ROM rehabilitation in one task may not necessarily improve the control in another; each activity has its own unique ROM control profile. Therefore, ROM should be challenged in as many tasks as possible. A reaching movement could

be mixed with other tasks such as lifting or pulling movements. Stride length could be challenged during walking, stepping over a high obstacle, stepping onto a high step, etc.

The task variations should be introduced in a random manner.<sup>24,25,111–115</sup> It was found that random training practices provide more effective motor learning and generalization than practices where each skill is performed repeatedly in blocks – *jumbled practices lead to better performance!*

Patients with central nervous system conditions, such as Alzheimer's and Parkinson's disease, may require more simplified scheduling practices.<sup>23</sup> They seem to improve their learning and transfer when the tasks are practised individually and repetitively.<sup>116–118</sup> Clinically, a pragmatic approach is probably useful for scheduling of training/treatment: using the order that the patient can cope with, rather than imposing a strict protocol.

There are other training factors that could help promote generalization, such as performing whole versus fragmented movement and using external versus internal focus of attention. These topics will be discussed further in Chapter 8.<sup>119,120</sup>

## A NOTE ON SENSORY SPECIFICITY

When we learn a certain movement it is stored as a unified sensory–motor representation, with each task/activity having a unique sensory–motor signature specific to that task.<sup>12,121–124</sup> How a certain task “feels” is memorized as a reference for future execution of a similar movement.<sup>125,126</sup> This sensory memory provides an error detection system that plays a role in correction of movement and motor learning.<sup>19</sup>

Sensory specificity may play a role in impeding transfer between dissimilar tasks or movement that have been practiced under different sensory conditions.<sup>24,127–134</sup> This was demonstrated in a study in which subjects were trained to walk across a balance beam either with or without vision. It was found that the participants improved their balance more in the sensory condition for which they trained.<sup>128,135</sup> Even learning tactile discrimination of a particular texture may fail to improve tactile discrimination of an unfamiliar texture.<sup>129–131,136</sup> This sensory specificity was demonstrated in blind individuals.<sup>137</sup> They outperformed sighted individuals on palpation tasks that use Braille-like dot patterns (a familiar pattern). However, they did not differ from sighted individuals when presented with a novel palpation discrimination task (a surface with ridges of different widths and orientations).

Sensory specificity suggests that task-specific training creates unique sensory-motor experience that may not transfer to other tasks.<sup>138–142</sup> This means that traditional stretching methods may imprint specific sensory-motor experiences that would not transfer to functional activities (see motor control, Ch. 8).<sup>142</sup>

## SUMMARY

- Specificity is the unique motor, muscular and tissue adaptation brought about by exercise/rehabilitation
- Generalization is the ability to carry-over the performance gains in a particular task to variations of the same task
- Transfer is the measure of how the performance of a particular skill is influenced by practice of another activity
- Transfer of training gains is more likely to occur if the ROM challenge resembles the goal activity (within-task and similar)
- Task-specific ROM rehabilitation is likely to be more effective than extra-functional training
- Generalization is more likely to occur in task-specific training
- Performing random variations of the task can facilitate generalization
- ROM challenges that are dissimilar to the goal activities are less likely to transfer gains and should only be used in conditions in which the patient is unable to perform functional activities
- Many traditional stretching approaches, active or passive, are often dissimilar and lack task specificity. They are therefore unlikely to promote functional recovery
- Message to the patient – practise what you aim to recover (a lot)

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# The Overloading Condition for Recovery

To write this book I have spent many hours sitting over several years, in mostly flexed slouched position. Yet, the flexion range of my back has remained unchanged. Nor do prolonged weight-bearing activities such as standing result in permanent flattening of the medial arches of my feet. In these and many other postural activities, prolonged high levels of stresses are imposed on the body, yet range of movement (ROM) does not seem to increase. If such levels of postural stress do not bring about a permanent range change why should we expect it to occur by manual stretching or exercise? Yet, paradoxically, yoga practitioners and ballet dancers seem to overcome this physiological barrier to gain remarkable flexibility. Is there something we can learn from them?

This chapter will explore the overloading condition for tissue adaptation, including:

- What force levels drive tissue adaptation?
- How much force is required to maintain the functional ROM?
- How much force is required during ROM rehabilitation?
- What are the safe levels of force during stretching? Can they be assessed?
- Can manual therapy techniques provide sufficient forces for long-term flexibility?

## LOADING LEVELS AND THRESHOLDS

Long ago, I trained in martial arts and later as a yoga teacher – two disciplines that required a high level of flexibility. The magnitude of force seems to have played an important role in this training. A full forward bending was achieved by pulling forcefully on my feet while the instructor sat on my back. That seemed to have worked well. From just being able to touch my knees, I was able to bend my back and flatten my chest against my outstretched legs, amongst other great feats of agility. These gains in flexibility took several months to attain and several years to perfect. This personal experience suggests that, *for effective long-term tissue elongation, the force of*

*ROM challenges must be above the forces imposed by normal functional demands.* Otherwise, we would gradually be turned into dysfunctional hyperflexible masses by the daily stresses imposed on our bodies. This experience also suggests that force interacts with the duration and frequency of stretching. This will be discussed in Chapter 7.

From the example above we can start exploring the forces that are required for tissue adaptation (Fig. 6.1). The first premise is that the functional ROM is maintained by the forces imposed on the body by daily activities, termed here *functional loading forces*. In order to increase performance/conditioning beyond the daily defaults, the intensity of the activity has to increase – *overloading*. For example, in the Achilles tendon, adaptation is only observed when loading forces exceed the normal daily values.<sup>1</sup> Forces below the functional level, *underloading*, result in atrophy and loss of ROM.<sup>2</sup> Between the functional and overloading levels is an *overloading threshold*. Between the functional and underloading levels is a *functional threshold*. So daily activity maintains functional ROM. To increase ROM the forces have to reach some overloading threshold, whereas reducing physical activities below the functional threshold will result in deconditioning.

The question that arises is how do we assess loading levels? Where is the threshold? Is there a way to identify it? Unfortunately, such an assessment is clinically improbable. The main feedback or guidance for loading is ultimately discomfort. As discussed in Chapter 2, functional activities are mostly performed within a comfortable movement range (comfort zone) (Fig. 6.1), whereas overloading is often associated with some level of discomfort. It is

Overloading	ROM increase	Discomfort zone
Overloading threshold		
Functional loading	Functional ROM	Comfort zone
Functional loading threshold		
Underloading	ROM loss/atrophy	

**FIGURE 6.1** Functional loading, overloading and underloading. Functional loading imposed during daily activities provides sufficient stimulation to maintain the functional range of movement (ROM). These stresses are often within a comfort zone of movement. To increase ROM beyond the functional ranges, overloading is required. These challenges are often within a discomfort zone. Underloading below a functional level often results in atrophy and loss of ROM.

often our main feedback during exercise but also during ROM challenges: we assume that patient discomfort represents the point at which overloading takes place. As will be discussed later in this chapter and in Chapter 9, discomfort is an imperfect and inaccurate guide, but there is little else we can use to estimate loading levels.

### Overloading in relation to ROM loss and recovery

It is well established that in frozen shoulder the patient will recover their ROM over time and without assistance.<sup>3</sup> This means that range improvement is possible by performing functional tasks, but where is the overloading threshold in this recovery?

There is the possibility that lower loading thresholds are required when ROM losses are present. In contractures, the restricted end-range may represent a lowered functional threshold. This means that normal daily activities that require greater ROM may provide the forces and ranges necessary to challenge this threshold (Fig. 6.2). For example, in the ankle during walking, the normal total dorsiflexion and plantarflexion range is about 30°. <sup>4</sup> If, because of contractures, this range drops to, say, 20°, this would represent a lowered functional threshold. In this situation, walking, which requires 30°, may generate sufficient loading forces to challenge the limited range. Walking on a steep, sloped surface and stairs could further raise the functional loading levels. <sup>4,5</sup>

In the presence of ROM losses there is often a shift in the discomfort zone to include the functional range of activities (Fig. 6.2). In the example above, the ROM losses in the ankle are likely to be accompanied by discomfort during functional activities such as walking or climbing stairs. The patient should be made aware that this is normal and even desirable.

Overloading	ROM increase	Discomfort zone
<i>Overloading threshold</i>		
Functional loading	Functional activity	Discomfort zone
<i>Functional loading threshold</i>		
Underloading	ROM loss/atrophy	Comfort zone?

**FIGURE 6.2** Functional loading may provide sufficient challenge in the presence of adaptive range of movement (ROM) losses. Under these circumstances the functional challenge will be within the discomfort zone.

Impediments to overloading

Sensitivity/pain and failure to provide sufficient force are common factors that may interfere with overloading during ROM rehabilitation.

ROM losses are often accompanied by pain and anxieties about movement (Chs 9 and 10). Under these circumstances, the patient may terminate the stretching well before it reaches the necessary loading thresholds. This can be resolved partly by dissociating the discomfort from the damage and by focusing on alleviating pain levels before commencing the ROM challenge programme (Ch. 9). For example, in frozen shoulder, the ROM challenges can start when the condition is no longer in the painful phase.

Another impediment is related to the failure of many traditional stretching approaches to generate sufficient forces to reach the loading thresholds (Table 6.1). For example, techniques such as side-lying flexion articulation or manipulation of the spine are unlikely to result in any permanent increase in range (except for the inconsequential elongation discussed below). Such manually applied forces are nowhere close to those imposed by bending and lifting or sitting. The capsular ligaments of the apophyseal joints can by themselves support twice the body weight.<sup>6</sup> Failure to generate sufficient forces can be encountered elsewhere in the body. The Achilles tendon or the plantar fascia can withstand considerable forces during functional activities. In walking, the vertical forces on the foot are 1–1.5 times the body weight, in running 2–3

**Table 6.1** Potential of different range of movement (ROM) challenges to provide sufficient loading for adaptation. With some of the passive approaches it may be possible but it depends on the therapist's ability to generate enough force and the area of the body being stretched

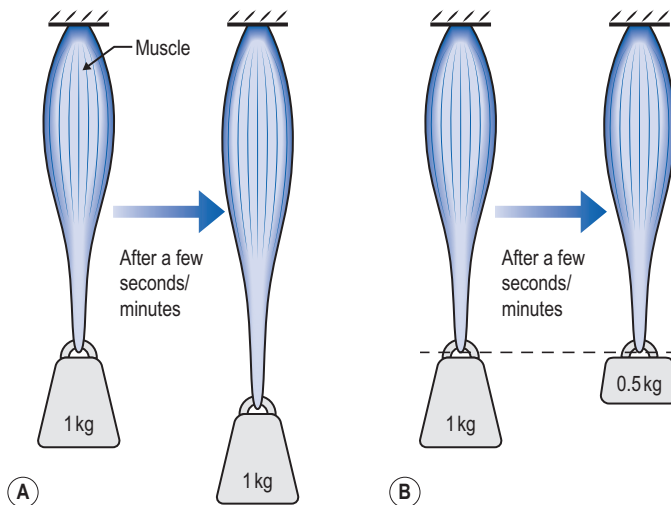
	Management/ROM challenge	Does it provide sufficient loading?	
Functional	Recovery behaviour	Yes	<div>Most effective</div> <div>↑</div> <div>↓</div> <div>Least effective</div>
	Managed recovery behaviour	Yes	
	Assisted recovery behaviour (functional stretching)	Yes	
Extra-functional	Ballistic stretching	Yes	
	Dynamic stretching	Yes	
	Muscle energy techniques	Yes	
	Passive stretching	No	
	Spinal manipulation	No	
	Traction	No	
	Articulation	No	
	Harmonic	No	
	Strain counter-strain	No	
	Cranial	No	

times the body weight and during a triple jump 7–12 times the body weight.<sup>7,8</sup> A therapist is likely to injure their hands long before the functional thresholds are reached during stretching. In patients with adaptive ROM losses, the practical solution is to exploit daily activities and to amplify them to provide the necessary loading forces (Ch. 12).

On the lower spectrum of loading inefficacy are manual therapy approaches that use minimal force to promote long-term tissue changes. They include techniques such as strain counter-strain and craniosacral and facial unwinding techniques. In cranial approaches, it is believed that the position and movement of the cranial bones can be modified by gentle manual handling/holding of the head. If such forces were effective then wearing a hat or resting the head on a pillow would result in serious distortions of the skull – if it does not happen by (recurrent) functional stresses, it will not happen by weaker (occasional) manual forces.

### The “inconsequential” elongation

Try this home experiment: stretch your index finger into full extension and maintain that angle. After a short while you will experience a certain “give” in resistance. When this happens the joint can be stretched further without any additional force (creep deformation; Fig. 6.3A) or maintained at the same position with less force (force relaxation; Fig. 6.3B).<sup>9–15</sup> This drop in resistance is related to a biomechanical property of muscle and connective tissues called



**FIGURE 6.3** A. Creep deformation. B. Force relaxation. Both are related to the viscoelastic properties of tissues.

*viscoelasticity*.<sup>16–18</sup> Musculoskeletal tissues are composed of fibres embedded within a viscous, gel-like medium.<sup>14,15,19–22</sup> The fibrous elements provide strength and resistance during loading. The viscous gel elements endow the tissues with a slow, flow-like elongation experienced during stretching (Box 6.1).<sup>23</sup>

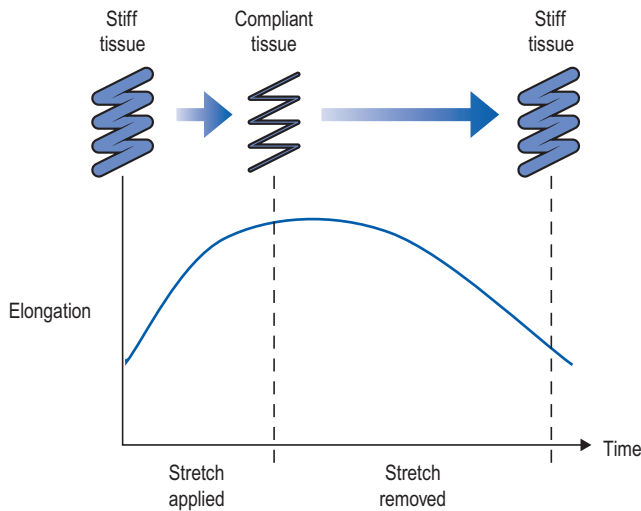
Creep deformation and force relaxation can be observed during all forms of tensional loading.<sup>24,25</sup> During sustained muscle stretching creep deformation accounts for 75–85% of the elongation that occurs within the first 15–20 seconds.<sup>23</sup> In cyclical stretching about 80% of the elongation will take place in the first four repetitions.<sup>19,26</sup> This is often experienced during stretching exercise; most of the range gains occur within the first three or four repetitions, after which the range gains tend to plateau. Force relaxation has been demonstrated in the anterior longitudinal ligament of the spine and during sustained dorsiflexion of the ankle. The force needed to maintain the longitudinal ligament at a given tension halved within the first minute of loading.<sup>16</sup> In the ankle joint it takes about 5 minutes to achieve full force relaxation.<sup>27</sup>

The viscoelastic behaviour of tissues can be deceptive to the therapist and patient. It gives the impression that stretching culminates in longer fibres. However, the immediate change in ROM during stretching is not due to true length changes in the tissue. All that happens is that the tissue has transformed from a stiff into a “softer”, more compliant spring, which means that for a given force it can extend further (Fig. 6.4). These viscoelastic changes in the tissue are transient. At the termination of stretching the tissues will gradually return to their original biomechanical/structural state (Fig. 6.4). The rate at which this recovery occurs varies between tissues. In the hamstrings force relaxation recovers within an hour, whereas in the Achilles tendon it will take several hours.<sup>9–11,27–29</sup>

These viscoelastic responses are biomechanical events. They are not associated with adaptive elongation, a process that occurs in the biological dimension (Ch. 5). Such viscoelastic length changes are therefore “inconsequential” for long-term ROM recovery. The inconsequential elongation is expected to be present immediately after any kind of manual stretching techniques, joint manipulation or exercise.<sup>30</sup> However, range increases that are present for longer than a few hours after the session are more likely to be associated with other physiological mechanisms, such as an increased tolerance to the sensation of stretching (Ch. 10), or contextual effects/placebos (Ch. 9).

The inconsequential elongation creates a paradox: how can long-term elongation take place if tissues return to their original length shortly after the cessation of loading? Long-term ROM adaptation occurs when this mechanical signal is repeated by successive episodes of tension loading (mechanotransduction, Ch 4). So, by itself, a single overloading episode will be insufficient.





**FIGURE 6.4** The inconsequential elongation. In acute bouts of stretching the immediate elongation is associated with a creep response, a transient biomechanical event associated with viscoelasticity. The elongation is due to a change in stiffness rather than a true length change in the tissues.

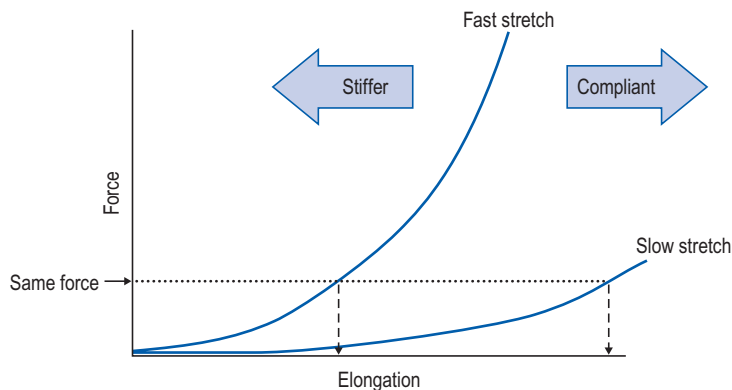
The duration and repetition element of the ROM challenge will be discussed in Chapter 7.

### Rate of stretching

The rate of stretching is another consideration that often troubles physical therapists. Should it be slow, as in yoga, or rapid, as in ballistic stretching?

The level of resistance in the tissue can change in response to different velocities of stretching.<sup>16,18,19</sup> During slow stretching the tissue undergoes a viscous, flow-like length change. At higher velocities of stretching the tissue behaves more like a stiff spring, with increasing velocities resulting in greater resistance (Fig. 6.5).<sup>31</sup> Furthermore, less force is required to achieve greater length during slow stretching.<sup>32</sup> In animal tendons, a low-load sustained stretching is more effective at producing elongation than a high-load brief stretch.<sup>33</sup> In flexion contractures in the knee, low-load sustained stretching was shown to be more effective than brief high-load stretching in producing short-term elongation.<sup>34</sup>

So which is better, spinal manipulation or a slow sustained stretch? Spinal manipulation is a high-velocity stretch, so from a biomechanical perspective a sustained stretch may be more effective. However, all this may be trivial. These velocity-dependent tissue responses are a transient biomechanical phenomenon associated with the inconsequential elongation rather than tissue adaptation.



**FIGURE 6.5** The rate of loading will influence the resistance experienced during stretching. At a given force, slower stretching will result in greater elongation than higher stretching velocities.

Where rate of loading may be important is in relation to specificity of training and the goal task. Slow stretching to the end-range may be suitable for yoga but not for fast kicking in martial arts. This is related to the specificity phenomenon in training and motor learning discussed in Chapter 5.

### The “undesirable” plastic ROM change

There is an enduring belief in manual therapy that tissue damage is essential for long-term length changes. It is hypothesized that stretching causes connective tissue or muscle damage. This in turn would initiate a repair process that, when combined with end-range challenges, would culminate in tissue elongation.<sup>35</sup>

Damage to connective tissue is expected to occur somewhere in the elastic and in the plastic range, depending on the tissue stretched (Box 6.2). At this point, some of the fibres will begin to tear. When stretching is removed the tissue will not return to its original length and would be more compliant, owing to a lower number of intact fibres. This would indeed result in a range increase but at the cost of tissue damage and inflammation. Whether such tissue destructive approaches are necessary is doubtful. It is known that ROM losses can often recover by normal functional use without evidence of damage–repair cycles.<sup>36</sup> Such biomechanical adaptation in muscle and connective tissue can occur by mechanotransduction, which is not associated with tissue damage. (Ch. 4). Hence, imposing damage as a therapeutic approach is not clinically justifiable.

Another common belief is that stretching can be used to tear adhesions and overcome contractures. However, within a few weeks, adhesions can have greater strength than the tissues to which they are attached. Similarly, contractures undergo biomechanical changes that result in less extensible tissue.

**Table 6.2** Mechanisms underlying range of movement (ROM) improvements. The biological adaptive process should be the target of ROM rehabilitation

		Duration	Tissue damage?	Permanent?
Biomechanical	<b>Creep deformation</b>	Few seconds to minutes	No	No
	<b>Plastic</b>	Few seconds to minutes	Temporary (recovery by repair but may leave permanent damage)	Yes
Biological	<b>Adaptation</b>	Weeks, months	No	Yes

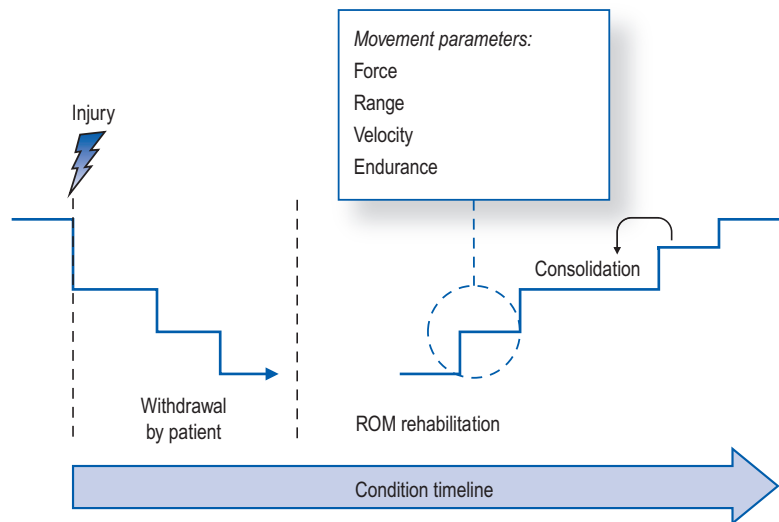
Hence, imposing an acute bout of stretching to break adhesions may cause damage to surrounding healthy tissues. In contractures, it will result in converting a stiff, but often intact, structure into a damaged one. For example, manipulation under anaesthesia for frozen shoulder results in extensive damage to multiple joint structures.<sup>37</sup> In a group of 30 patients it was found that after manipulation 11 had superior capsule ruptures, 24 had anterior capsule ruptures up to the infraglenoid pole, 16 had posterior capsular lesions, four had superior labrum tears, three had partial tears of the subscapularis tendon, four had anterior labral detachments and two patients had tears of the middle glenohumeral ligament. So damage does immediately increase the joint ROM but at a frightening cost to joint integrity.

The mechanisms underlying ROM improvements are summarized in Table 6.2.

## GRADED CHALLENGE AND THE TASK PARAMETERS

After an injury most individuals will return to pre-injury activities in a gradual manner. They take a series of graded challenges that are amplified over time. Positive movement experiences embolden them to increase the level of challenge. For example, a person with a shoulder injury will incrementally increase the *force*, *range* and *velocity* of lifting. As they improve they will also tend to increase the repetition of lifting. This represents the *endurance* parameter that is necessary to maintain or repeat the task.

This positive recovery behaviour can be applied clinically in the form of a graded ROM challenge (Fig. 6.6). In this approach these four movement parameters (force, range, velocity and endurance) are overloaded or amplified in an incremental manner (Fig. 6.7). For example, for the frozen shoulder patient the physical challenge can be to hold a bottle of water with the affected side and repetitively reach and place it on the therapist's hands, as if reaching to place it on a shelf (Ch. 13). During the reaching movement, the therapist changes the positions of the hands to challenge the four task parameters. The



**FIGURE 6.6** Graded overloading and amplification of the four task parameters: force, range, velocity and endurance. ROM, range of movement.

Date:  
Name:

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
Tennis	Distance from wall: 3m Duration: 5 min Frequency: x 3	Distance from wall: 4m Duration: 5 min Frequency: x 3	Distance from wall: 5m Duration: 5 min Frequency: x 3	Distance from wall: 5m Duration: 10 min Frequency: x 3	Distance from wall: 5m Duration: 15 min Frequency: x 3	Distance from wall: 5m Duration: 20 min Frequency: x 3	Distance from wall: Any distance Duration: 25 min Frequency: x 3	Start a 5–10 minute game with a partner, just passing the ball	Etc.

Amplifying force

Amplifying endurance

**FIGURE 6.7** Graded challenge in clinic using tennis as an example. Here, force and endurance are amplified within the task.

Date:  
Name:

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Tennis	Start here											
Swimming				Start here								
Cycling								Start here				

**FIGURE 6.8** Graded challenge for several activities using staggering. Patients dictate exercise priorities.

range parameter can be challenged by the therapist moving their hands further away from the patient to a position above their head (extension–flexion) and to their side (abduction–adduction). Velocity can be challenged by performing the reaching movements faster; endurance by increasing the number of repetitions; and force by using progressively heavier objects. Later, other activities can be added in a staggered manner (Fig. 6.8). So, the principle of overloading is extended to include amplification of the four movement parameters but also incrementally adding activities; overloading is not just about force.

The graded challenge provides a consolidation time for adaptation to take place and reduces the potential for re-injury.<sup>38,39</sup> This is achieved by the incremental overloading/amplification of the four movement parameters within comfortable/tolerable ranges. When an adverse reaction is encountered, the graded challenge can be dropped back a step (Fig. 6.6). During the consolidation period, the patient maintains the activity at that level. After, say, 2 or 3 weeks they are then encouraged to move up a step. An adverse reaction can be set as being greater than 2–3 points on a 0–10 pain scale and lasting more than, for example, a day or two. Incremental ROM is particularly important in situations where there is a history of recent tissue damage, such as after surgery. A graded challenge has an important role in reassuring the patient as well as the therapist that the movement is safe, and in providing positive movement experiences that contribute to the narrative of success (Ch. 11).

THE FALLACY OF SPECIFIC TISSUE STRETCHING/LOADING

Specific tissue stretching is often promoted as a valued clinical skill in physical therapy education. There is an enduring belief that individual muscles, fascias or joint capsules can be stretched/loaded to the exclusion of others. However, is such specificity therapeutically desirable and is it physically possible?

There is no obvious clinical rationale for specific tissue stretching. In contractures, all tissues undergo adaptive changes. Hence, it is far more beneficial to load simultaneously all the affected tissues.

It is doubtful whether stretching specificity is possible. It is a misconception largely derived from anatomy and physical therapy education. Anatomy books tend to illustrate structures that are well defined and separated from their surrounding tissues. This gives rise to the false impression that muscles, tendons and fascias are detached from each other and separated by anatomical voids. In reality, tissues and structures are extensively connected and closely compacted. When a force, such as stretching, is applied all the tissues are loaded simultaneously. Even if single muscle stretching were possible, it is expected that the tensional forces will be transmitted via the extensive fascial connections to adjacent and even antagonistic muscle groups.<sup>40-42</sup>

Specific tissue loading is improbable and clinically irrational. The focus of ROM rehabilitation should be on the movement affected rather than the tissues/muscles that impede this range. For example, in glenohumeral contracture the focus should be on recovering overhead arm movements rather than attempting to stretch each individual tissue that contributes to this restriction. Functional overhead challenges have the advantage of loading all the affected tissues simultaneously. This approach reduces clinical complexity and the need for muscle-by-muscle rehabilitation.

## SUMMARY

- Functional ROM is maintained by the forces imposed on the body by daily activities
- Overloading is a training condition for adaptation in which physical challenges are raised above functional levels
- Forces below the overload threshold will be ineffective at inducing long-term ROM change
- Underloading is the absence of sufficient forces required to maintain functional activities; it results in atrophy and adaptive ROM loss
- Functional activities may generate sufficient forces in conditions where adaptive ROM losses are present
- Many manual stretching approaches may fail to generate sufficient force for overloading; active, functional activities should be used whenever possible
- Functional activities and managed recovery behaviour may provide sufficient forces for adaptive ROM recovery
- The four movement parameters (force, range, speed and endurance) are the target of overloading and amplification
- Amplification and overloading should be introduced in a graded manner – a graded challenge
- Overloading is associated with the experience of discomfort

- Functional and overloading thresholds cannot be assessed clinically; discomfort is the principal feedback for loading
- Overloading is likely to be unpleasant. Patients who are in pain or who have movement-related fears may not tolerate stretching and may terminate it before the loading threshold is reached; pain alleviation may be necessary before vigorous ROM challenges commence
- Just because it feels like a stretch does not mean that it is effective
- Message to the patient – “just keep on moving, discomfort is OK, it will help it get better”

### BOX 6.1 STRETCHING TERMS EXPLAINED

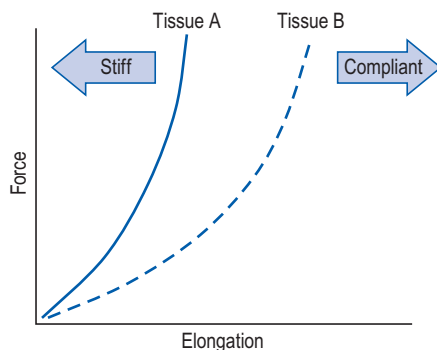
There are several terms that are often used to describe what happens during stretching which can be confusing and often get mixed up. They include tensile strength, stiff, compliant, elastic, flexible and force and strength.

Generally, the term *tensile strength* describes how much force a tissue can withstand before it fails. The term *strength* can often be mixed up with muscle strength, which is the force generated by muscle contraction. This mix-up can lead to misconceptions such as that spinal strength can be improved by exercise which increases trunk muscle strength. The spinal discs and ligaments have inherent tensile strength, which is not directly related to the person's ability to lift a heavy weight.

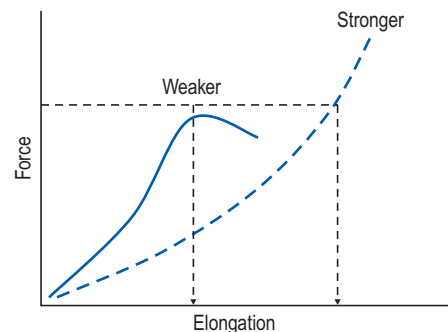
*Stiff* and *compliant* are terms used to describe the resistance of a tissue or joint during bending/stretching. Imagine stretching two different tissues using the same force (Fig. 6.9). One tissue will elongate more than the other. The tissue which elongates most is said to be compliant in comparison

with the one which elongated least – the stiffer tissue. However, this compliance does not necessarily relate to their tensile strength. A tissue can be highly compliant yet have higher tensile strength than a tissue that feels stiffer when stretched (Fig. 6.10).

There is another potential mix-up with the term *stiffness*. There is biomechanical and subjective stiffness. Biomechanical stiffness is the physical resistance of the tissue to an applied load. Subjective stiffness is the sense of effort or the level of discomfort that a person experiences when stretching or bending. It can be partly related to the underlying biomechanical stiffness; however, in many conditions a subjective sense of stiffness is due to increased sensitivity of the tissues under tension from injury or localized swelling, rather than shortening of the tissues. So although the tissue feels stiffer it might be damaged and weaker (Ch. 9). In this situation stretching should be avoided since nothing is stiffer or shorter; it just feels like that.



**FIGURE 6.9** Stiffness and compliance.



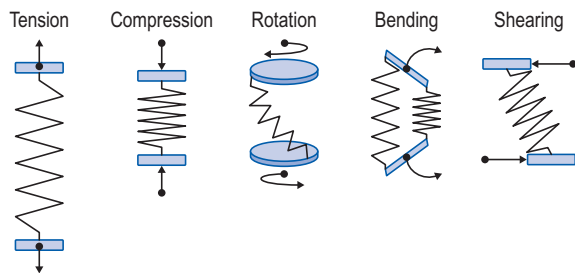
**FIGURE 6.10** Tensile strength.

## BOX 6.2 BIOMECHANICS OF STRETCHING

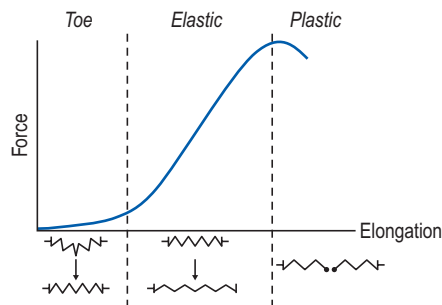
Physical forces can be applied to the body in the form of tension and/or compression. The outcome of these forces is tissue deformation in the shape of elongation, compression, shearing, bending and torsion, or any combination of these structural changes. Stretching in all its forms, whether active or passive, relies primarily on tension loading (Fig. 6.11).

When tension load is applied by stretching there is counter-resistance from the underlying tissues. This resistance tends to change in character as the loading forces increase.<sup>14,15</sup> It can be felt by stretching the index finger into extension. At the resting angle of the joint the tissues are slack and there is little resistance to the stretch. This is represented by the toe region on the force–elongation curve (Fig.

6.12).<sup>43,44</sup> Within this range there is no true elongation of the fibres. The observed length change is similar to pulling a slack rope into tension. It will just flatten it. As the stretching increases beyond the toe region the resistance in the tissues will rise and they will feel more bouncy. This range is called the *elastic region*. Further stretching beyond this range will bring the tissues to the *plastic region*, where there is a distinct barrier-like resistance and the experience of discomfort/pain. In this range there is progressive tissue damage that starts as microtears and that can develop into full rupture if the force exceeds the tissue's tensile strength.<sup>14,45</sup> The end-elastic/-plastic range can vary considerably between different tissues and their location in the body.<sup>14,46–49</sup>



**FIGURE 6.11** Tissue loading. Stretching relies on tension loading, which also takes place during rotation, bending and shearing loading.



**FIGURE 6.12** The force–elongation curve.

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# Exposure and Scheduling the ROM Challenge

Recently, I was standing on a beach and observing the wide range of sports activities that individuals were undertaking, in particular their warm-up routines. Whether they were about to run, swim or surf they all exhibited a similar warm-up behaviour. For a brief period, lasting no more than a few seconds, they stretched specific body areas. Further down the beach were a couple of people practising yoga. Their activity was strikingly different. Their movements were slow and, once in position, they sustained it for periods that ran into minutes. Presumably, both groups aimed to achieve a similar goal of maintaining or improving agility. Yet, increased flexibility is more likely to occur in one training condition than in the other, but which is it, and what is the optimum exposure for stretching?

This chapter explores the scheduling factor of the range of movement (ROM) challenge: the *duration* (single session), *frequency* (how often repeated) and *time span* (weeks/months), collectively termed here *exposure*. It will aim to provide answers to commonly raised question about the scheduling of stretching:

- What is the optimum duration for ROM challenges?
- How often should ROM challenges be repeated?
- Can clinical stretching or exercise provide sufficient exposure?
- How does scheduling of stretching change in the presence of pathology?
- Is there a scheduling difference between traditional and functional stretching approaches?

## DURATION OF CHALLENGE

The scheduling of the ROM challenge depends largely on the intrinsic physiological processes that underlie adaptation. From a physiological perspective there is probably some ideal frequency and duration that would optimize mechanotransduction. However, this quantity is currently indefinable, partly because of the lack of research but also because of the numerous extrinsic

influences that can affect this process, such as the nature and extent of the ROM pathology, the type of tissue affected and metabolic factors.

Currently, most of the information about scheduling of stretching is derived from studies of healthy young individuals. Many of the studies used passive stretching approaches, with a duration ranging from 6 to 60 seconds often quoted as being the most effective.<sup>1-8</sup> In the hamstrings, a daily episode of stretching for 30 seconds was found to be more effective than 15 seconds. However, there are no significant differences between stretches lasting 30 and 60 seconds,<sup>3,4</sup> implying that the most effective duration is about 30 seconds. This has become the unofficial duration standard for passive stretching; well, at least for the hamstring muscles.<sup>9</sup> Interestingly, increasing the stretching duration to 30 minutes per day, over several weeks, fails to provide any additional ROM gains.<sup>10-12</sup>

The 30-second duration creates a paradox. It implies that yoga practitioners and dancers might be wasting valuable training time. According to research, 30 seconds should suffice. Yet, runners who stretch for short periods are rarely able to perform the agility feats associated with flexibility training. Perhaps for adaptive changes we need to look at longer duration and extended time spans – scheduling practices that are observed in flexibility training. So the relationship between stretching exposure and gains in flexibility remains unresolved in healthy individuals. But the important question here is what happens to the stretching exposure in the presence of a ROM pathology? Does 30 seconds suffice or does it need to be raised considerably?

### **Duration in the presence of ROM pathology**

It seems that, in the presence of pathology, the duration of stretching has to increase dramatically. It was demonstrated that 6–12 hours of daily splinting is required to overcome flexion contractures in the proximal interphalangeal joint after surgery, and more days spent in the cast resulted in greater ROM improvements (60° at 3 days and 106° at 6 days).<sup>13,14</sup> Another study suggested that 8–12 hours per day for 8 weeks are necessary to effectively overcome similar contractures.<sup>15</sup> This phenomenon was also demonstrated in frozen shoulder, in which maximizing the total time spent at end-ranges tends to improve ROM.<sup>16</sup> In patients with contractures due to central nervous system damage, it is estimated that over 6 hours of daily stretching would be required to improve ROM.<sup>17,18</sup> Several studies have explored shorter duration in patients with spinal cord injuries. ROM challenges were applied daily to the ankle for 30 minutes, over time spans of 4, 6 and 12 weeks using either passive stretching or static standing on a wedge.<sup>10,19,20</sup> ROM improvements were not observed in any of these studies.

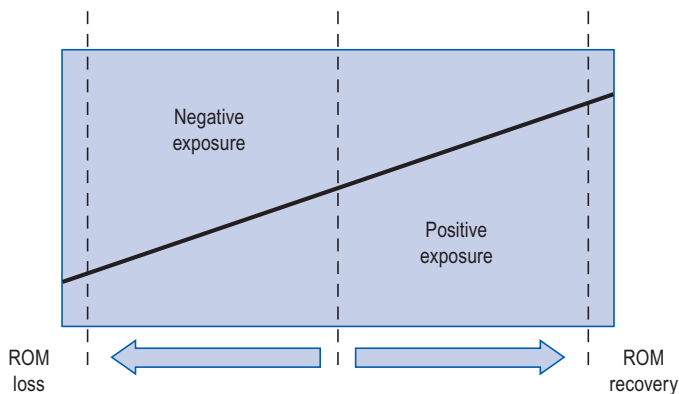
These studies suggest that, in the presence of pathology, ROM challenges may have to occupy up to half of the person's waking day, which of course is unattainable unless splints are used. Even if these studies overestimated the stretching duration by 2–3 times we would still be unable to fulfil this exposure quota. Is there a solution?

### Competition in ROM adaptation

Perhaps we should look at the exposure component in a different way altogether, and consider that ROM loss and recovery represent a competition in adaptation between the pathological process that maintains the condition and the ROM challenges that counteract it (Fig. 7.1).


As discussed previously, musculoskeletal adaptation tends to be specific to support movement efficiency and efficacy. Given two competing environments or training regimes, adaptation is likely to occur in the one the individual is most exposed to. This is why body-builders will find yoga difficult to perform and vice versa. It is also why those who train for flexibility need extensive stretching exposure to compete with the adaptation imposed by their daily activities. Hence, dancers seem to be in a constant state of stretching (I have seen a dancer sitting in a side-split at an air terminal while waiting for a flight, and the flight was delayed!). The question is what happens to this competition when an individual has some pathological condition which is competing with the ROM challenges?

Let us re-examine the post-surgical studies which suggest that several hours of daily splinting are required to overcome contractures. This can be viewed as a competition in adaptation between the post-surgical pathology that maintains the tissue shortening and the splinting that promotes tissue elongation/



**FIGURE 7.1** Competition in adaptation. ROM, range of movement.

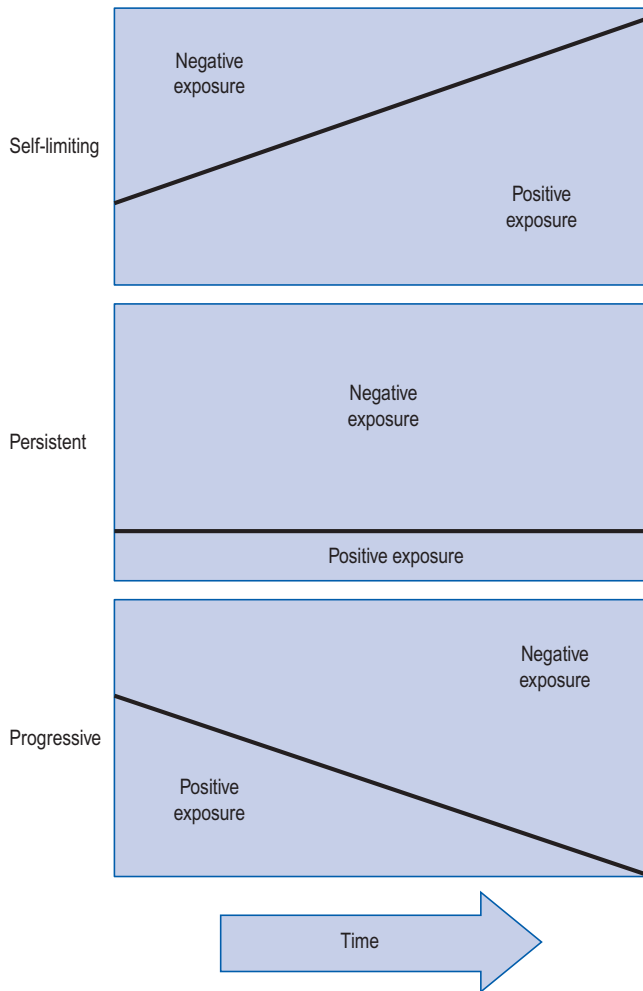
**Table 7.1** All approaches that are dependent on the therapist's assistance are unlikely to provide sufficient duration and repetition for range of movement (ROM) adaptation. However, even managed recovery behaviour may fail because of lack of adherence by the patient

	Management/ROM challenge	Does it provide enough repetition/exposure?	
Functional	Recovery behaviour	Yes	 <p>Most effective</p> <p>Least effective</p>
	Managed recovery behaviour	Yes	
	Assisted recovery behaviour (functional stretching)	No	
Extra-functional	Ballistic stretching	No	
	Dynamic stretching	No	
	Muscle energy techniques	No	
	Passive stretching	No	
	Spinal manipulation	No	
	Traction	No	
	Articulation	No	
	Harmonic	No	
	Strain counter-strain	No	
	Cranial	No	

extensibility. Since the pathology that maintains the shortening is present for 24 hours per day, it is likely to win this one-sided competition, unless the duration of ROM challenge is increased dramatically. As discussed above, this would be almost impossible to attain clinically or even by exercise, so is there some other practical solution?

The solution is to tilt the competition in favour of the ROM challenge. This can be achieved by making the ROM challenges a part of the person's habitual daily activities. For example, while writing this chapter, an elderly patient consulted me about a severe shoulder sprain that took place 2 weeks previously. During that period, the patient kept her arm in a sling and close to her body at all times, which resulted in a rapid loss of glenohumeral ROM (see fear avoidance, Ch. 11). Her shoulder ROM increased dramatically, and within days of the initial session, by the simple instruction to keep the arm away from the body during daily activities. The emphasis was to amplify daily tasks that promote such ROM challenges as often as possible over behaviour that favoured shortening. This does not exclude the use of specific exercises; however, from an exposure perspective, they would have a lower therapeutic value than persistent functional ROM challenges (Table 7.1).

A competition in adaptation also means that ROM rehabilitation is more likely to succeed in self-limiting conditions (as the "negative" competition is gradually receding); it will have to be permanently maintained in persistent



**FIGURE 7.2** Competition in adaptation in the presence of pathology.

conditions (“negative” competition maintained) and ineffective in progressive conditions in which the “negative” competition is increasing (Fig. 7.2).

### Ratio between maintaining and recuperating signals

A competition in adaptation suggests that there is an ideal ratio between the duration of ROM challenge and the behaviour that maintains the ROM loss.

In animal studies even short periods of passive stretching have been shown to compete with the deleterious effects of immobilization. In one of the studies the animals’ limbs were immobilized in a shortened position using a sports

tape.<sup>21</sup> Daily, the tape was removed and the limb was placed in the lengthened position and immobilized in this position using the same taping method. The immobilization duration ranged from 15 minutes to 2 hours. At the end of the lengthening procedure the animal was re-immobilized in the shortened position. It was found that 15 minutes daily of elongation was insufficient to counteract the loss of sarcomeres in series. Increasing the duration to 30 minutes daily increased the numbers of serial sarcomeres to pre-immobilization levels. Progressively longer duration of stretching resulted in further increases in the number of serial sarcomeres. In a similar immobilization study, even 15 minutes of stretching every second day was shown to be sufficient for normalizing the ratio of connective tissue to muscle fibres.<sup>22,23</sup> Shorter durations, such as a 40-minute stretch once a week, were not sufficient to prevent the loss of serial sarcomeres.<sup>24</sup>

These studies suggest that the competition in adaptation does not have to be in the same ratio, i.e. an hour of immobilization does not have to be matched by an equal duration of elongation. Clinically, it is impossible to estimate this ratio. The simple solution is for the patient to use the recovery behaviour as frequently as possible during the day. Is there a danger of overexposure to ROM challenges? Probably not: the more exposure, the better.

### Termination of ROM challenge

One question that often arises is whether regular stretching has any lasting effects. As discussed previously, stretching is not a physiological necessity (Ch. 1); from this perspective, it is mostly an extra-functional pursuit. This means that stretching is in permanent competition with daily movement needs. In normal healthy individuals, cessation of regular stretching would result in rapid return to the physiological default. That is why people/athletes who stretch can never stop. The return to the default is very rapid upon cessation of stretching. It was shown that a break of 4 weeks completely reversed the gains of 6 weeks of stretching.<sup>25</sup> I experienced this as a yoga teacher. Seven years of gains in flexibility were almost totally abolished within several months of cessation of practice.

In individuals with pathological ROM losses, early termination of ROM challenges may result in a longer recovery time by tilting the competition in favour of the pathology. However, as the condition is improving the balance in the competition tilts towards the positive exposures (as the individual is spending longer duration in functional activities that challenge their losses, Fig. 7.1). These are often sufficient to eradicate the remaining ROM loss and also to maintain permanently the ROM improvements (*functional loading maintains functional ROM*; Ch. 5). This means that treatment can be terminated when the patient returns to functionality or is able to self-maintain recovery behaviour. This principle was discussed in Chapter 2.



## SCHEDULING IN FUNCTIONAL AND EXTRA-FUNCTIONAL APPROACHES

We have still not been able to define the optimal duration and frequency of stretching. This is partly because we are looking at scheduling in two very different stretching approaches: functional and extra-functional.

In an extra-functional approach the challenges are distinct and dissimilar to normal daily activities, and as such they require specific set-aside times. Therefore, the duration and frequency of exposure have to be quantified clearly. However, there is a problem with quantifying. There are wide differences between individuals and the pathological processes that underlie their ROM loss. As a consequence, it would be almost impossible to reach a universal scheduling truth. Perhaps this is why, after half a century of research on stretching, we are still trying to solve the scheduling conundrum.

In a functional approach the scheduling is simpler. The challenges closely resemble the daily tasks and therefore there is no boundary between “exercising” and daily activities. There is no distinct set-aside exercise time and therefore quantifying the exposure is not essential. Here, the patient is given the simple advice to amplify certain daily activities as often as possible. A patient with limited stride length can be instructed to walk with a wider gait, as often as possible throughout the day. If they adhere to this simple management it could result in 10,000 repetitions of hip stretching per day. It is simple and therapeutically economical.

### A note on control of active ROM and task exposure

Increasing the daily exposure to a functional task is well supported by motor control research. It is well established that regular practice is a key training condition for motor learning/adaptation.<sup>26</sup> Frequent and regular practice plays a crucial role in the transformation of motor experiences from short- to long-term memory.<sup>27–30</sup> Frequent practice of a task reduces the error and strengthens the neural networks that control that particular task.<sup>31,32</sup> Increasing the task exposure is therefore important for recovering the control of active ROM.

From a motor control perspective it is also difficult to quantify the optimal exposure to the task. Research in this area suggests exposure that contains thousands to several millions repetition.<sup>33</sup> This supports the functional message that management should be expanded to encompass habitual daily activities in which the affected tasks are often repeated.

Although motor recovery shares the same neurophysiological mechanisms as motor learning, there is an important difference here. In ROM recovery the patient is not a learner. Most often they have lost the capacity to execute the movement for central or musculoskeletal reasons, rather than “unlearning” it.

This means that they do not have to learn the movement from scratch but to reorganize it optimally for functional use. It may also mean that the exposure to the ROM challenge can be lower than the one needed for learning a novel task. However, this motor optimization/reorganization still relies on numerous repetitions. How many? We do not know, but probably a lot.

## ADHERENCE TO THE PROGRAMME

A functional approach that promotes recovery behaviour is in essence a self-care programme which engages the patient's self-efficacy capacity and autonomy.<sup>34</sup> Self-care is essential for maintaining the rehabilitation programme; in particular because ROM recovery is expected to be in time scales of weeks or months. The success of self-care is highly dependent on the patient's adherence to the programme. Yet, it is well established that adherence tends to be low at best and reduces very rapidly.<sup>35,36</sup> So when we look at the exposure component we also have to consider the factors that could help to sustain the treatment programme.

Generally, attitudes, beliefs and self-motivation determine exercise compliance and adherence.<sup>34,37-40</sup> Included is the person's belief in their ability to succeed in a particular situation (self-efficacy),<sup>41</sup> enjoyment of physical activity, support from others,<sup>39</sup> positive beliefs concerning the benefits of physical activity,<sup>42</sup> and a lack of perceived barriers to being physically active.<sup>37,42</sup> These factors can be translated into attainable management strategies:

- **Keep the patient (positively) informed** about the condition and why their participation can help adaptation.<sup>42-44</sup> Often I will describe the principle of recovery behaviour and a bit about how the body converts physical activity into structural changes in the tissues. Adherence is also improved by information that empowers the patient (Ch. 11).<sup>45-47</sup>
- **Identify patient-centred goals.**<sup>42</sup> Focus on goals that are important to the patient, rather than on clinical goals. This will help to motivate the patient to maintain the ROM management.<sup>48,49</sup>
- **Develop ROM challenges not exercise.** I tend to use the phrase "daily challenges" rather than "exercise", particularly with individuals who are exercise-shy. The notion of exercise is often associated with activities that require set-aside time, specialized equipment and are carried out in a dedicated location such as a gym.<sup>50</sup> These elements tend to shift the locus of care further away from the individual's immediate environment. On the other hand, some patients need organized exercise regimes with defined daily schedules.
- **Make the challenges readily available.**<sup>48,51</sup> The ROM challenges are often amplification of end-range movements encountered during normal daily activities. Keep the challenges as close as possible to the patient's func-

tional repertoire, incorporated into their home, work and recreational activities. This approach brings the care within reach of the individual's environment and is therefore more likely to contribute to adherence.<sup>34,48</sup>

- **Keep it simple.** Avoid complex management protocols or exercise. Simple routines tend to increase compliance.<sup>52</sup> It has been found that patients may have difficulties in recalling information, in particular statements that contain instructions and advice.<sup>53</sup> So keeping it short and simple and repeating the message in subsequent sessions could be helpful.<sup>42</sup> Furthermore, it was found that patients who understand the management concepts are able to transfer and modify these principles to fit their lifestyles; they were able to devise their own exercises and further personalize the management of their condition.<sup>39</sup>
- **Provide ongoing support and feedback.<sup>42</sup> And make it fun.** The element of enjoyment is also important for exercise adherence. It is useful to create a wish-list of activities that the patient enjoys and would like to return to. Strive to develop ROM challenges within these activities.<sup>39</sup>

## SUMMARY

- This chapter explored the exposure and scheduling of the ROM challenge: duration, frequency and time span
- Currently, there are no clear guidelines on the scheduling of ROM challenges
- ROM rehabilitation represents a competition in adaptation between the pathological process that maintains the condition and the ROM challenge that counteracts it
- It is estimated that in the presence of pathology the daily ROM challenges should be for several hours
- A functional approach aims to tilt the competition in favour of physical environments or behaviour that drive ROM recovery. This can be achieved by incorporating the ROM challenge into the daily activities
- Long-term maintenance of the ROM rehabilitation programme is dependent on the patient's self-care ability
- Adherence to the programme may be helped by positive information about the condition, identifying goals that are important to the patient and simplifying and making the challenges readily available
- Adherence means that the patient has a shared responsibility/role in their recovery
- Message to the patient – “what ever you do, do more”

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# Rehabilitating the Active ROM: Neuromuscular Consideration

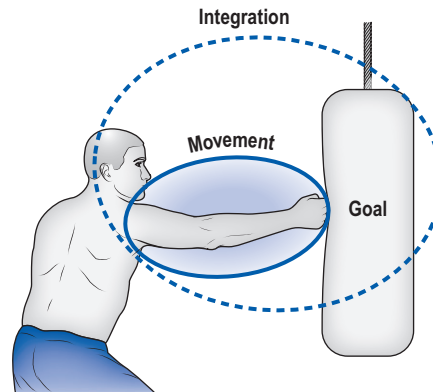
Imagine a common clinical scenario in which a treatment is about to commence for the stiff, non-painful frozen shoulder. Several questions come to mind as we plan the management. Should we begin treatment with passive stretching and later add the active challenges; start both simultaneously; or not bother with passive stretching? When using an active approach, should the movement be broken up to focus on specific shoulder or scapular muscles or focus on whole arm movements? What kind of active movement should be used, functional, extra-functional? Above all, what exactly is being rehabilitated in the active range and is there a way of making the process more effective?

This chapter will explore the active component of range of movement (ROM) rehabilitation and will aim to provide answers to these commonly raised questions:

- What is being rehabilitated in the active ROM?
- Which elements of motor control are the targets of ROM rehabilitation?
- Should rehabilitation be of part or whole movement?
- Should ROM rehabilitation be sequenced from passive to active rehabilitation or should they be concurrent?
- Can passive approaches help recover motor control?
- How does focus of attention influence recovery of active ROM?
- What is rehabilitated in task-specific rehabilitation?

## GOALS AND FOCUS OF ATTENTION

Curiously, what we focus on while we train or move can influence learning and the efficiency and effectiveness of our movements. When we observe human movement, a large selection of this repertoire is directed towards external goals: to reach for a cup, hit a ball or walk across a room. Movement goals are rarely internal to specific body parts; we do not set out to move our limbs, joints or contract specific muscles.<sup>1</sup> Whether the focus of attention is external or internal has important implications for ROM rehabilitation.



**FIGURE 8.1** The movement that typifies a task is integrated with its goals.

For an outsider observing a person performing a task, say lifting a cup, the action can be broken into two components (Fig. 8.1): the movement that typifies the task (unique arm movement) and the goal of this movement (to lift the cup). However, this separation is artificial. In most activities the movement and its goals are a unified response and not separate entities.<sup>2</sup> When we are learning a new task the movement and its goal are integrated and represented internally as images of the goal. The intention to attain the goal triggers the execution of the associated movement, including all the anticipatory postural adjustments that precede it.<sup>3-6</sup>

The integration of the movement with its goals and the direction of focus create an order of effect in ROM management (Fig. 8.2). Movement, motor

<i>Nature of ROM challenge</i>	<i>Focus of attention</i>	<i>Therapeutic effectiveness</i>
Goal movement (movement + goal)	External focus	Most effective
Movement only	Internal focus (correctness of movement)	
Part of the movement sequence	Internal focus	
Fragmented movement	Extreme internal focus	
		Least effective

**FIGURE 8.2** Hierarchy in range of movement (ROM) challenge. Motor learning and performance are enhanced by challenges that integrate the movement and its goals.



learning and recovery are most effective when the focus of attention is directed towards external goals, i.e. training or rehabilitation that engages this natural integration.<sup>7-14</sup> Less effective is rehabilitation in which the focus is internal, on movement itself and separated from its goals. Below this level is the “extreme” internal focus in which movement itself is fragmented into smaller units to become the focus and goal of rehabilitation. Here, the focus of attention is directed towards specific muscles or joints that make up the movement.

Internal focus is often represented in rehabilitation as “correctness of movement”, where faults in movement are identified and corrected. It can have a negative or positive influence on movement depending on the skill level of the individual. It tends to degrade task performance if the person is already skilled in the task. It has a positive effect when the individual is learning a novel task. However, in ROM rehabilitation the individual is often experienced in the task but is unable to perform it because of physical/motor constraints. Hence, external focus is more effective, whereas internal focus is mostly superfluous and may even be detrimental in ROM rehabilitation. Extreme internal focus is often represented in ROM rehabilitation by contract-relax methods or by muscle-by-muscle or muscle chain rehabilitation. From a motor control perspective it is considered to be the least effective form of training and rehabilitation.

The evidence to support the use of goal-orientated movement in rehabilitation is derived from focus-of-attention studies.<sup>7-14</sup> In these studies individuals are instructed to focus either on the goal/outcome of the movement (external focus) or on a particular part of the body (internal focus). It was demonstrated that even simple tasks such as biceps curls are executed more effectively and efficiently under external focus (concentrating on the curl bar) rather than internal focus (concentrating on the biceps muscle or movement of the arm). The group using internal focus had lower electromyography (EMG) activity than the external focus group, although both groups were lifting the same weight.<sup>15,16</sup> In a study of force production in the leg, subjects were instructed to either “push your foot against the plate” (external focus) or “push with the muscle of the calf” (internal focus).<sup>17</sup> Using external focus resulted in less error in force production, more efficient co-contraction and optimized EMG activity. Similarly, in studies on jump height, subjects were instructed to focus externally on the goal, “concentrate on the highest rungs”, or internally, “concentrate on your fingers”. The external focus group demonstrated increased jump height and greater force production while exhibiting lower EMG activity.<sup>18,19</sup> The effects of focus of attention have also been observed in trunk muscle activation during sudden load change. In this study, a load was applied to the subject’s back and then suddenly removed. Throughout that task subjects were instructed to resist the load either by their naturally chosen manner (external focus) or by abdominal bracing (internal focus).<sup>20</sup> The naturally selected

manner resulted in more effective muscle recruitment patterns of the spine. Conscious, voluntary overdriving of this natural pattern resulted in unbalanced muscular activation patterns and increased the loading on the spine to dangerously high levels.

Overall, the studies on focus of attention demonstrate that focusing on the outcome of the movement rather than on the body and its workings enables the individual to produce greater peak forces, execute faster movement, and increase joint movement accuracy with less muscular activity.<sup>14,15,18,19</sup> External, goal-focused training engages the individual in whole movement patterns that promote movement economy.<sup>17</sup> It also optimizes motor learning by promoting movement automatism earlier in the training as well as facilitating transfer of learning to novel situations (Ch. 5).<sup>18,21</sup> These studies suggest that an external focus of attention is a more effective strategy for rehabilitating the active ROM.

### External–internal focus in ROM rehabilitation

The difference between external and internal focus approaches has important practical manifestations in shaping the ROM challenges. This can be exemplified by flexion rehabilitation of the shoulder. In the internal focus approach, the patient is instructed to contract their anterior deltoid, elongate the pectorals, stabilize the scapula and so on. In the external goal approach, the patient is instructed simply to reach with their hand to the ceiling. The outcome is likely to be the same for both approaches – a full flexion range. However, in the goal approach the individual is training in more efficient movement patterns which are within task. This raises the potential for transfer of training gains from the rehabilitation to functional activities (Ch. 5).<sup>7–14</sup> Furthermore, external focus is clinically more economical. Minimum instruction is producing a maximum effect. The patient is not required to have any knowledge of anatomy or movement physiology; more importantly, they do not have to learn anything new. The rehabilitation is *using what the patient already knows*. In the external focus/goal approach, the patient needs only a modest training investment to recover control of the shoulder. In the internal approach the patient is required to learn a new complex movement pattern, which is less effective and efficient and which often demands greater therapist involvement and additional treatments.

### ***Regression from goal to movement level***

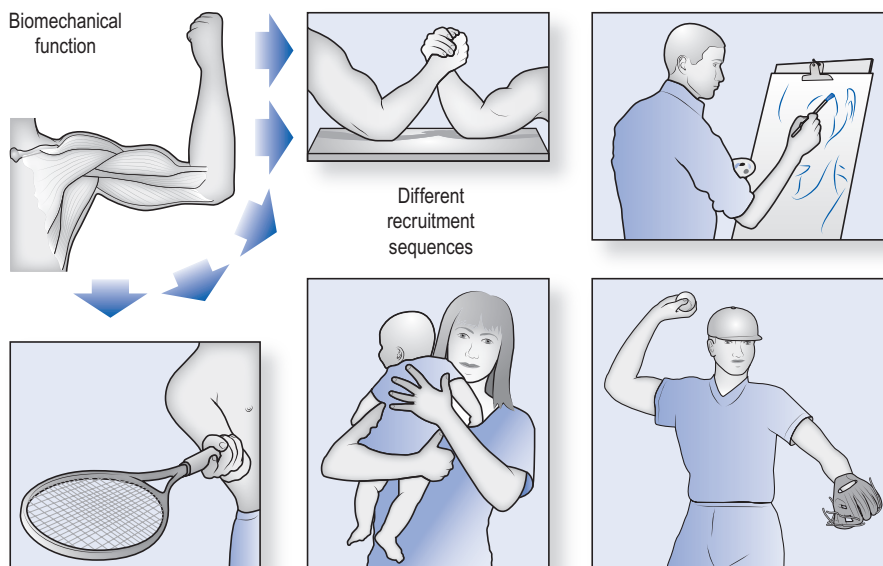
There are occasions when attention could regress from an external to an internal focus. Imagine a patient who has flexion contractures of the elbow. When attempting a goal movement, such as reaching, rather than extending their elbow the patient may compensate by twisting and bending forward. In this situation it could be useful to instruct the patient to focus internally, on the

elbow, and attempt to straighten the arm while reaching. However, even when the rehabilitation regresses to a movement level (“keep the elbow straight”) it should aim to be within the context of the overall goal (“keep your elbow straight while reaching for the cup”).

There are clinical solutions to limit postural compensations and minimize the need for internal focus. In the elbow scenario above, the forward trunk movement can be restrained by instructing the patient to hold the back of the chair with the opposite arm while performing the reaching movement (Ch. 13). Another strategy is to let the patient “cheat” and bend forward, but, then, place the target even further away until forward bending is no longer possible. In both of these examples the patient will be forced to extend the elbow maximally to reach the target. A similar tactic can be used to recover flexion and abduction range in a frozen shoulder (Ch. 13). Often, a seated patient will use trunk side-bending to compensate for abduction restriction, and trunk extension to compensate for flexion restrictions. This can be overcome by placing the target further away from the body, laterally or in front, forcing the patient to execute greater shoulder abduction and flexion movements.

## TASK-SPECIFIC MUSCLE RECRUITMENT

The organization of movement around its goals means that any given muscle will participate in many different tasks, rather than a specific one (Fig. 8.3).

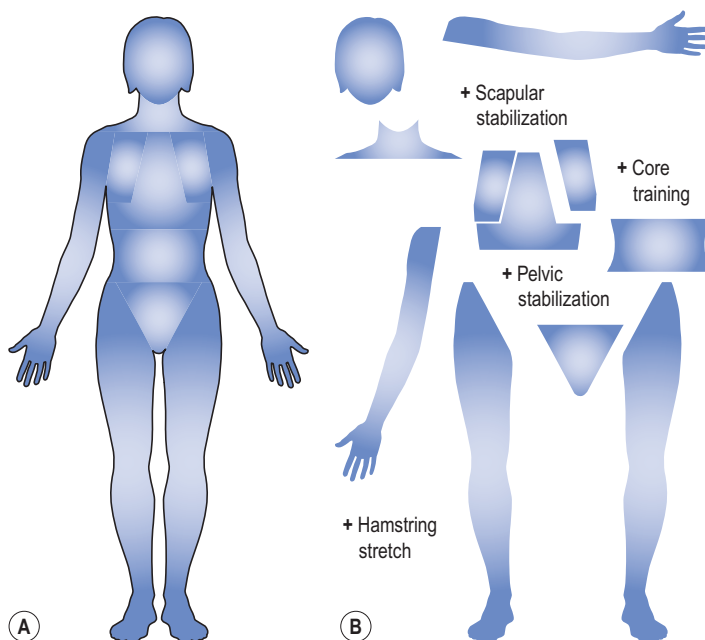


**FIGURE 8.3** Same muscle, many functions.

This means that muscle recruitment is *task specific*.<sup>22–27</sup> Task-specific recruitment can be likened to a speaker (the muscle) through which different music tracks (motor programmes) can be played. For example, there is a completely different recruitment pattern of the trunk muscles during standing, walking, reaching to the sides, forward bending or lifting or any other imaginable movement.<sup>26–30</sup> We cannot claim that the spinal multifidus muscle is exclusively designed for any one of these activities (as is often claimed in many physical therapy approaches). However, we could state that its anatomical location and mechanical function mean that it has a varying role in all these movements, and many more.

### Integrate or fragment?

Task-dependent muscle recruitment determines whether a movement should be rehabilitated as a whole or fragmented to smaller anatomical units (Fig. 8.4). Rehabilitating a specific muscle or muscle chain is unlikely to improve the performance or recover the control of the whole task. This is because the task determines the muscle's activation pattern and not the other way round. It would be like trying to learn a tennis serve by practising biceps activation,



**FIGURE 8.4** A. There is a whole system/person organization during movement. There are no closed or isolated muscle systems in the body. B. Fragmenting the body into specific anatomical/functional components does not reflect normal organization/control of movement.

*Integrate*                      *Coordinate*  
~~Fragment in order to integrate~~

**FIGURE 8.5** Changing the old physical therapy maxim ....

triceps and then forearm control, and so on. The only way to recover normal function is to practise the task itself, during which the whole recruitment sequence is rehearsed simultaneously.

Single muscle or muscle-chain activation simply does not exist in motor organization or in the physiology of movement. ROM rehabilitation that favours movement fragmentation is more likely to improve the specific fragmented activity but not the whole movement (Fig. 8.5).<sup>31</sup> For example, training that improves the local power at the ankle or at the ankle and knee fails to transfer to gains in vertical jumping, although this task depends on these neuromuscular components.<sup>31</sup> Likewise, exercises that isolate parts of the kicking action are not recommended because they do not appear to transfer well to kicking performance; training should be of the whole kicking action.<sup>32</sup> It has also been demonstrated that training in isolated tasks, such as hip flexibility or trunk-strengthening activities, does not improve the economy of walking or running.<sup>33</sup>

Further support for whole movement training comes from the focus-of-attention studies described above. Training that promotes external focus is essentially engaging the individual in whole movement training, whereas internal focus is closely related to movement fragmentation. As discussed, external focus, goal-orientated movement provides more effective and efficient movement patterns. By normalizing the task, adaptation occurs simultaneously throughout the neuromuscular axis: centrally as motor control changes and peripherally as muscle adaptation.

If Aristotle was alive now he would have pointed out that “The task is different from the sum of its muscles and joints”.

### Synergy in pathology

Take a task such as a high kick. It requires an explosive shortening contraction of the hip flexors. But the success of this movement also relies on the simultaneous “explosive relaxation” and elongation of the hip extensors.<sup>34</sup> So muscles do not work alone but in complex synergies.

Movement synergy means that when a muscle is affected it will inevitably alter the control of all its synergists. It has been demonstrated that induced fatigue in the hamstrings will influence the control of non-exercised quadriceps.

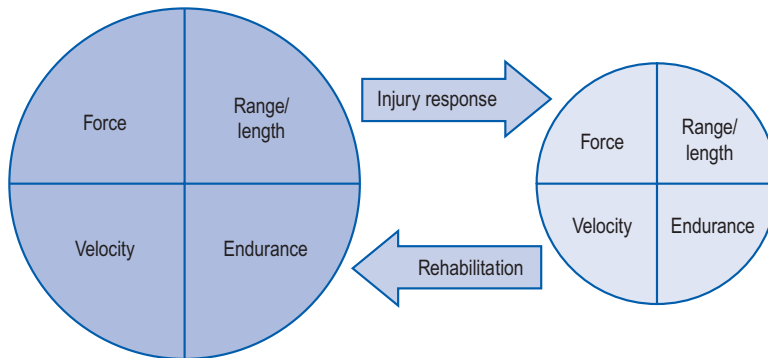
Similarly, induced fatigue in the biceps influences triceps control.<sup>35–37</sup> This effect was shown to spread even to more distant synergists. For example, fatigue in quadriceps will also influence the control of the non-exercised gastrocnemius muscle.<sup>38</sup> So, even in pathology, muscles do not work alone but are controlled in complex synergies.

The interplay between synergists suggests that, if one muscle group is pathologically shorter, the control of all the synergists is likely to change. Imagine a clinical situation in which a patient with reduced hip ROM tries to recover the ability to perform a high kick. There are two potential therapeutic approaches: traditional fragmentation of movement, treating each loss separately, or using task-specific whole movement approaches. In the traditional approach the patient might be given hip flexor resistance exercises to improve active hip flexion and hamstring exercises to increase antagonists' extensibility. However, such fragmentation cannot capture the complex intermuscular coordination of the synergists. The pattern of recruitment during this procedure is highly dissimilar and therefore non-transferable to a high kick (see specificity and transfer of training, Ch. 5). The complexity of intermuscular coordination and its specificity to particular exercise can be resolved by simply challenging the whole movement, in the context of the goal task, i.e. practising high kicks will challenge and normalize that task.

## FOCUS OF ROM REHABILITATION

We have so far identified that ROM rehabilitation should be of whole movement and practised within the context of the goal task. However, we are still left with the question of what is being rehabilitated within the task. To answer this question we need to explore what happens to the task parameters in the presence of injury and pain.

The task parameters are controlled centrally as part of normal movement organization. In the presence of injury, pain or even fear of movement the task parameters are attenuated as a protection strategy (Fig. 8.6).<sup>39–61</sup> This movement reorganization serves to reduce the physical stresses imposed on the injured areas. The outcome is the experience of force loss, slower movements, limitation in movement range and early onset of fatigue, which serves to reduce iteration of potentially damaging movements. This strategy is universal and can be seen throughout the body in various musculoskeletal conditions. It is a normal and advantageous motor control response; it does not represent a central pathology. The capacity for central adaptation and motor reorganization is preserved and therefore the likelihood for active ROM recovery remains high. The task parameters can also be affected by central nervous system (CNS) damage.<sup>62–65</sup> In these conditions central adaptive capacity is reduced and therefore the potential for ROM recovery is more limited (Ch. 3).



**FIGURE 8.6** The organization of movement in response to injury, pain or fear of movement. The four movement parameters tend to be attenuated. One role of range of movement rehabilitation is to amplify these movement components within task challenges.

The production of force, velocity, length and endurance are also peripheral phenomena of the muscle's structure and physiology. Fortunately, by challenging the task parameter there is concurrent stimulation and adaptation of the whole neuromuscular axis, central and peripheral, motor control and muscle. They cannot be targeted individually as is sometimes believed. This means that, in ROM rehabilitation, we do not have to focus specifically on the shortened muscle. Performing a task at end-range will drive simultaneously the central and the peripheral recuperative processes.

There are other movement components that can be the focus of ROM rehabilitation such as coordination and balance. These are outside the scope of this book and can be found in Lederman.<sup>42</sup>

## IMPORTANCE OF COGNITION

Cognition is a broad term to describe mental processes such as attention, understanding, remembering, thinking, rationalizing, memorizing, imagination, planning, decision-making and problem-solving. It has been demonstrated that these play an important role in motor learning and recovery of movement control in various musculoskeletal conditions and following CNS damage.<sup>66–70</sup>

Cognitive factors play an important role in ROM rehabilitation. Learning a movement pattern or recovering control requires conscious attention to particular aspects of the movement, being aware of the ranges affected and the daily tasks that could be used to challenge them.<sup>71,72</sup> Cognitive management also includes the patient's involvement in problem-solving, decision-making, goal-setting, planning and scheduling of practice/rehabilitation.<sup>18,69,70,73–76</sup> It



has been shown that treatment can be more effective if these factors are an integral part of the management.<sup>18,69,70,73–76</sup>

The successful integration of cognitive elements in the treatment depends on the cognitive state of the patient, the therapist's awareness of their importance and effective communication but also on the therapeutic relationship between the practitioner and patient (see psychological consideration, Ch. 11). For example, patients who have cognitive losses as a result of CNS damage may have difficulties in understanding instructions or making choices. Under these circumstances, movement rehabilitation may be prolonged or impeded.

### Cognition and feedback

Imagine you are learning a new task, such as a golf swing. The rate of learning and your skill of performance will partly depend on feedback from your own body and the instructor. In a similar manner, the recovery of active ROM can be enhanced or impeded by provision or withdrawal of feedback.<sup>77–86</sup> In ROM rehabilitation, feedback can take different forms: sensory feedback, task feedback and feedback on recovery progress.

*Sensory feedback* is the intrinsic, ongoing information provided from proprioceptors and other sensory modalities such as vision, auditory and vestibular (again, for full discussion, see Lederman<sup>42</sup>). It is a subconscious form of feedback, but it can be raised to a cognitive, conscious level by drawing attention to the body or to a particular sensory modality.<sup>87–89</sup> It is often used during stretching to raise awareness of tension or to promote relaxation in particular parts of the body. Although there is much interest in physical therapies in this form of feedback, it is fairly immutable to modification by physical means – you can become more aware of it but cannot change it..<sup>42</sup>

*Task feedback* is often provided by the therapist and contains information about the “correctness” of the movement (“hold the racket this way”), the movement sequences (“swing it like this”) or the quality in performance (“good shot”). Sensory and task feedback are often provided as verbal instructions, visual demonstration and physical correction of movement by the therapist/trainer.<sup>44,90</sup>

Generally, feedback is more effective if it promotes an active gathering of information and problem-solving by the patient.<sup>91</sup> For optimum learning, guidance should be kept to a minimum and rapidly reduced or fully withdrawn at the earliest opportunity.<sup>9,68,86,92–95</sup> Furthermore, training is found to be more effective when the feedback emphasizes successful performance and ignores less successful attempts.<sup>19,96</sup>

*Tracking recovery progress* is another important form of feedback which is usually set against specific treatment goals. Tracking can be of various treatment outcomes such as changes in ROM, pain and functional improvements.

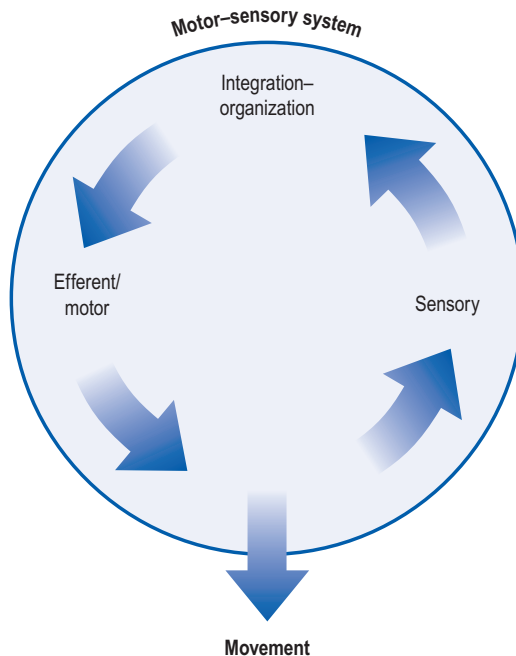


## LIMITATIONS OF EXTRA-FUNCTIONAL STRETCHING APPROACHES

So far this chapter has explored motor control and has suggested the importance of functional whole task movements. But what about other non-functional approaches? What role do they have in normalizing motor control? Do active approaches, such as muscle energy techniques (METs) and proprioceptive neuromuscular facilitation (PNF) stretching, have any role in helping the recovery of the active range? Similarly, do passive stretching approaches have any effect on motor control? To answer these questions we need to examine the physiological mechanism which these approaches purport to activate, in particular reflexive mechanisms such as autogenic inhibition and reciprocal inhibition.<sup>97</sup>

### Motor control during active and passive stretching

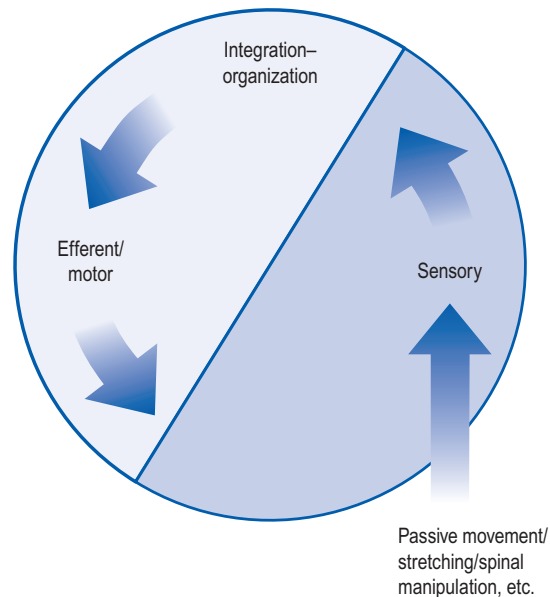
Being active is essential for motor learning and recovery.<sup>42</sup> Movement is organized in sequences that involve afferent sensory input, central integration and an efferent motor output (Fig. 8.7).<sup>68</sup> During active movement this sequence is fully engaged, whereas during passive movement there is an absence of



**FIGURE 8.7** The organization for movement. During active movement the efferent and afferent signals are coupled.

effluent motor activity (Fig. 8.8). This efferent activity is essential for encoding the movement sequences and without it motor adaptation/learning/reorganization is unlikely to occur (with the exception of motor visualization).<sup>98–108</sup> Indeed, human movement and motor learning is exclusively active in nature. In comparison, passive movements are rare and are mostly associated with physical therapy.

Furthermore, during motor learning, a unique sensory image is created for that particular movement – we become familiar with what the task “feels like”. Although this sensory experience will occur during both active and passive movement, it is different and likely to be non-transferable between the two (see sensory specificity, Ch. 5). The sensory experience during passive stretching will fail to match the sensory experience during a similar active movement. Another difference is that only during active movement is the sensory experience (afferent) coupled with motor processes (efferent). This sensory–motor coupling has important implications for correcting movement errors and consequently for enhancing motor learning and recovery.<sup>109–114</sup> This was demonstrated several decades ago in studies in which visual illusions were created by wearing special distorting lenses.<sup>81</sup> The ability of the subject to accurately position the arm was greatly enhanced by active (sensory–motor coupling) rather than passive (only sensory input)



**FIGURE 8.8** During passive techniques only the sensory element of the system is stimulated. There is no efferent activity and the motor–sensory coupling does not occur.

arm movement. This group of researchers concluded that an active form of movement is a prerequisite for motor learning. They stated that “active movement yields highly significant adaptive effects whereas passive movement yields either significantly less adaptation or none at all”.<sup>81</sup>

There is also a psychological consideration in treatments that engage the individual actively. The goal of ROM rehabilitation is to return the individual to functional movement, which is active in nature. The distance between being active and proactive is very small, and, therefore, the experience of being active during the session can translate more readily into daily activities. However, the distance between being passive and proactive can be large. Treatments that are predominantly passive may set up negative therapeutic conditions in which the patient becomes uninvolved and detached – a “passive” recipient of treatment.

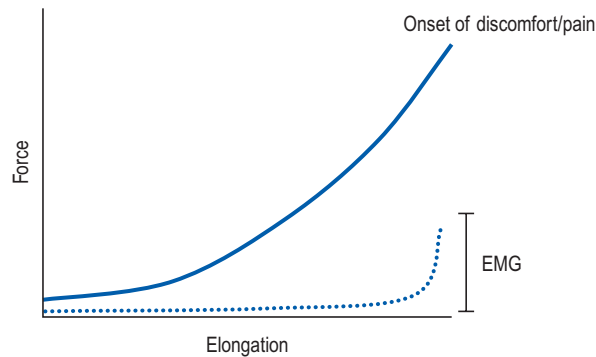
In summary, active ROM is unlikely to be recovered by passive stretching approaches.

### Autogenic inhibition

There is a commonly held belief that stretching can reduce motor tone in a muscle by a process of autogenic inhibition.<sup>115,116</sup> In this model, stretching stimulates muscle–tendon receptors, resulting in inhibition of the motoneurons which supply the same muscle. This inhibition causes muscle relaxation and consequently results in further ROM increase.<sup>115</sup>

This proposed mode of action contains an erroneous premise. Under normal circumstances, when a person is fully relaxed there is no motor tone in the muscles, i.e. there is no demonstrable activity on the EMG trace.<sup>117–120</sup> Similarly, when a person is stretched passively the muscle is motorically silent. If muscle activity is observed, it is usually when the stretching reaches the end-range of movement at the onset of discomfort and pain (Fig. 8.9).<sup>99,100,121</sup> This increase in motor activity is likely to be an evasive response to pain. It means that during the early phase of stretching the muscle is relaxed and therefore further inhibition is not possible – *cannot relax a relaxed muscle* – whereas, at the end-ranges, motor activity is likely to increase; an outcome which would defeat this particular treatment goal (muscle relaxation).

Another way to look at inhibition is to examine the gain of the spinal motoneurons. A high gain would suggest that the muscle is close to the threshold of being activated, whereas reduced gain implies central relaxation and reduced potential for activation. There are several studies that demonstrate a (very) transient gain attenuation of spinal motor centres during passive stretching.<sup>115,122–124</sup> However, these influences are unlikely to be physiologically or therapeutically significant. This is because the gain of spinal motor centres is



**FIGURE 8.9** During passive stretching the muscle is motorically silent. Electromyography (EMG) activity may be observed when stretching begins to be uncomfortable or painful.

heavily modulated by descending signals from higher motor centres, but only minimally by the reflexive influences from mechanoreceptors.<sup>125</sup> The dominance of the central process over peripheral stimulation has important implications for passive stretching. It means that the individual's intention to consciously relax the muscle will have a far more dominant inhibitory effect on spinal motoneurons than the peripherally induced inhibition. It is also more likely to outlast any reflexive stimulation.<sup>116</sup> A simple verbal, cognitive instruction to the patient to relax their muscle ("make the areas soft") may be far more beneficial than numerous repeated stretches.

Furthermore, spinal motoneurons are continuously varying their gain according to the background task (*task-dependent reflexes*) and not by peripheral mechanisms which serve to provide feedback.<sup>22,23,126,127</sup> For example, when the cutaneous afferents of the paw of a walking cat are stimulated during the swing phase (as the limb is moving into flexion) it reinforces the flexion movement. When the same stimulus is applied during leg extension it reinforces extension.<sup>128</sup> Similarly, the gain of the stretch reflex is modulated during the human walking cycle.<sup>129</sup> The amplitude of the quadriceps stretch reflex is increased while the limb is moving into extension but inhibited when the limb is moving into flexion. Even when the human cutaneous afferents in the leg are stimulated it results in inhibitory or excitatory motor responses depending on the current posture or activity.<sup>130</sup>

Another persistent misconception is that techniques such as METs can result in autogenic inhibition. This inhibition is believed to occur by stimulation of the Golgi tendon organ (GTO) during contraction.<sup>115,116</sup> These receptors are sensitive to muscle contraction and, indeed, in laboratory studies stimulation of GTOs has been shown to have a weak inhibitory influence on the spinal motoneurons (often when central or descending influences from higher

centres are eliminated).<sup>131–133</sup> However, in “real life” the descending influences override the peripherally mediated inhibition; if it were any different, humans would have reached an evolutionary dead-end long ago. Just imagine hanging over the side of a cliff. The muscle tendon units are now on maximum tension and the GTOs are fully excited. Under these circumstances there is full reflex inhibition from the GTOs. According to the autogenic inhibition assumption, the arm muscles should be relaxing, a response which would be extremely disadvantageous in this situation. Fortunately this scenario does not happen. The dominance of central motor centres overrides these mild peripheral influences.

What about post-contraction inhibition? Yes, it can be demonstrated in laboratory studies, but it is a very weak, transient response that occurs in milliseconds. It is completely overrun by the motor requirements of the successive task (see task-dependent reflexes above). Just imagine what would happen to the ensuing activity if inhibition was present every time we contracted a muscle – we would never be able to perform the next task as we would be in a state of inhibition sustained from the previous task.

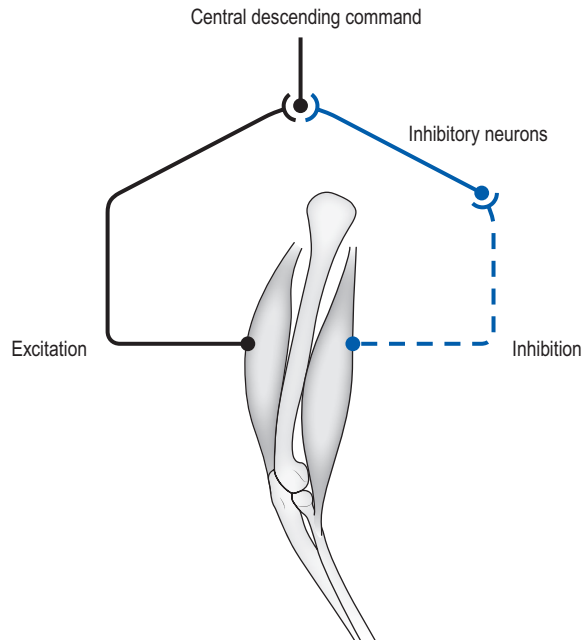
Overall, there is no support in the science (or more importantly logic) for autogenic inhibition as a mechanism for elongation in passive stretching or METs.<sup>116</sup>

## Reciprocal inhibition

There is another widespread belief in manual therapy that, during METs, the isometric contraction of agonists will reciprocally inhibit the antagonistic muscles. However, there are several factors which call into question the therapeutic value of reciprocal inhibition.

Reciprocal inhibition occurs when the tendon of an actively contracting muscle is tapped. It results in an observable drop in the antagonist muscle’s EMG amplitude and contraction force. This response is weak, non-functional and lasts only a few milliseconds; it cannot be induced continuously (tonically).<sup>134,135</sup> Furthermore, reciprocal inhibition is a research phenomenon, a physiological artefact observable during laboratory studies.<sup>131</sup> However, it does not occur during normal movement. Under normal circumstances, the control to synergistic pairs is simultaneous and centrally controlled (Fig. 8.10).<sup>1</sup> It is not controlled from the periphery by stimulation of mechanoreceptors.<sup>41</sup>

Furthermore, during movement there is often co-contraction of synergistic pairs, which means no reciprocal inhibition (Box 8.1). Such co-contraction has been demonstrated during the active phase of METs/PNF.<sup>98,136,137</sup> In a study of METs, we were able to demonstrate that concurrent triceps co-contract during biceps METs. The greater the force of biceps contraction, the greater



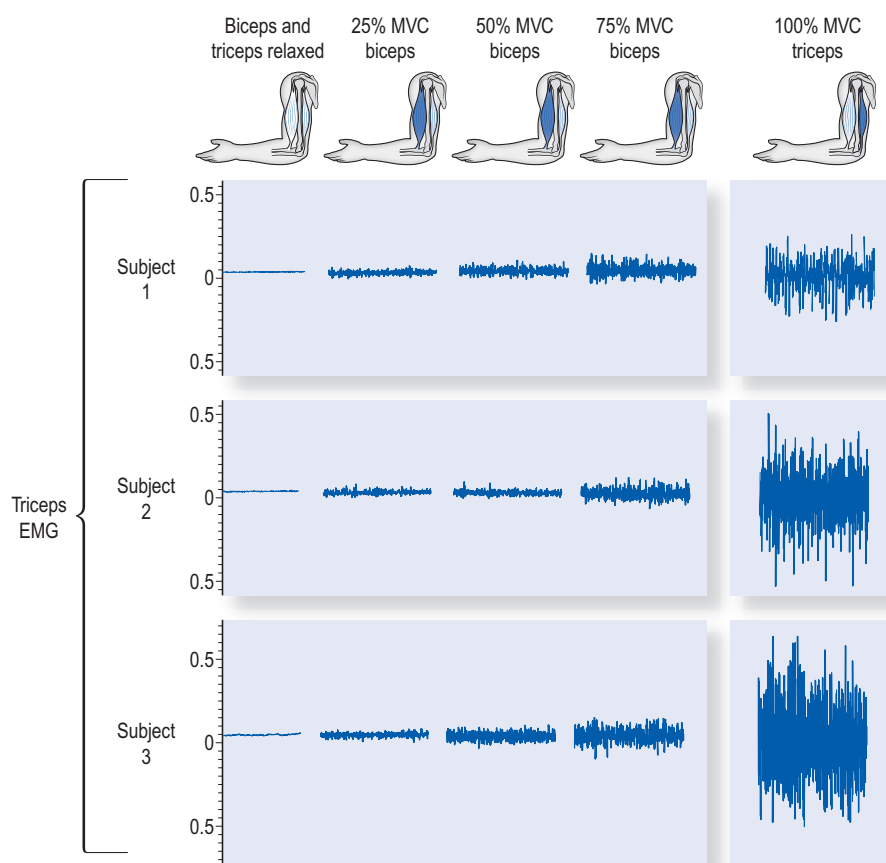
**FIGURE 8.10** Inhibition and excitation of the synergistic muscles by central command occurs simultaneously. It is not controlled from the periphery by mechanoreceptors.

the co-contraction in the triceps (Fig. 8.11).<sup>138</sup> If reciprocal inhibition were present, we should not have seen any EMG activity in the triceps muscle during biceps contraction.

Overall, manual techniques, active or passive, that rely on proprioceptive reflexes are unlikely to have any significant effect on movement control or play any significant role in active ROM recovery (see summary in Box 8.2).<sup>41</sup>

## SUMMARY


- The organization of movement is whole and integrated with its goals
- The use of an external focus of attention and goal-orientated movement strategies is more beneficial for control and recovery of movement
- Internal focusing strategies on specific muscles or joints turns them into the goal of movement and reduces the effectiveness of rehabilitation
- Regression to internal focus may be necessary in situations when task performance is not possible
- Muscle activity is task dependent: muscle recruitment sequences are unique to each task; training-specific control of muscles in one task may fail to improve the control of a different task



**FIGURE 8.11** Co-contraction of triceps during specific isometric biceps contraction in three subjects. As the force of biceps contraction increases, at 25%, 50% and 75% maximal voluntary contraction (MVC), there is a concurrent increase in triceps electromyography (EMG) activity. For comparison in the right column: EMG of triceps during 100% MVC. Co-contraction of triceps was present in all 30 subjects who participated in this study. *Reprinted from Lederman E. The Science and Practice of Manual Therapy, 2005, with permission from Elsevier.*

- There are four task parameters that can be challenged during ROM rehabilitation: force, velocity, range/angle and endurance
- The task parameters should be challenged within-task and not targeted as individual muscles or muscle chains
- Regression to focusing on single muscles, muscle chains or specific joints should be the last option in any treatment
- Active ROM should be rehabilitated with active movement ([Table 8.1](#))
- ROM rehabilitation should be of whole movement, goal orientated and within the context of functional tasks ([Table 8.1](#))
- *Think control not individual muscles*

**Table 8.1** The potential of different range of movement (ROM) challenges to help recover motor control

	Management/ROM challenge	Active?	Goal and whole?	
Functional	Recovery behaviour	Yes	Yes	<div>Most effective for active ROM</div>  <div>Least effective</div>
	Managed recovery behaviour	Yes	Yes	
	Assisted recovery behaviour (functional stretching)	Yes	Yes	
Extra-functional	Ballistic stretching	Yes	No	
	Dynamic stretching	Yes	No (not often)	
	Muscle energy techniques	Yes	No	
	Passive stretching	No	No	
	Spinal manipulation	No	No	
	Traction	No	No	
	Articulation	No	No	
	Harmonic	No	No	
	Strain counter-strain	No	No	
	Cranial	No	No	

## BOX 8.1 FEEL THE SYNERGY

There are two principal synergistic patterns that can be experienced by a simple exercise. While standing, draw large imaginary numbers, 0 to 10, with your arm in space; then repeat the same exercise, but now draw smaller numbers fast. You will notice that when drawing fast, small numbers the muscles around the shoulder and the trunk tend to stiffen. This pattern of recruitment is called co-contraction. This is different from the on-off, *reciprocal-activation* pattern experienced during the slow,

large number drawing. Co-contraction is the simultaneous activation of several muscle groups to stabilize joints during static postures (static stabilization or steadiness) or to stabilize during movement (dynamic stabilization). Co-contraction also has a role in refining movement, which is why it is felt during fast, small-amplitude movement. Reciprocal activation is often associated with the control of dynamic movement.<sup>22,23,139–143</sup>

## BOX 8.2

### Key points on passive and reflexive approaches

Manual techniques or exercise that relies on reflex mechanisms to improve range of movement are likely to be ineffective on several grounds:

1. The role of proprioceptors is to provide feedback; they are not control systems. Inhibition and excitation are their modes of communication.<sup>42</sup>
2. Higher centres dominate spinal motor centres and can modify or override the weaker proprioceptive influences.
3. The influence of proprioceptors on spinal motor gain is very transient. This gain would be reset completely by the control demands of any ensuing movement. This could even be in advance of the movement: spinal

motor centres are recruited in anticipation of movement, even before proprioceptive feedback becomes available from the movement.<sup>68</sup>

Passive stretching approaches are in conflict with several of the motor control principles:

1. Motor learning and functional movement is active. Motor control cannot be recovered by passive challenges (e.g. spinal manipulation). During passive techniques there is no active motor engagement.
2. Task-specific recruitment is not being practised.
3. There is an absence of movement goals.
4. Passive stretching represents a profoundly fragmented approach that reduces the movement to the level of the muscle and the (ineffective) reflexive.



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# Pain Management and ROM Desensitization

Imagine three clinical scenarios in which patients present with different knee conditions. The first patient presents with a knee sprain which happened 1 week ago. It is painful, swollen and stiff and on examination has only a limited range of movement (ROM). Another patient had a knee joint fracture. It is now 6 weeks later and the plaster has just been removed. The knee is painful, swollen, has restricted ROM and is very stiff. Finally, another patient had knee surgery 1 year ago. On examination the passive knee ranges have mostly recovered but pain and stiffness are still limiting the patient's functional ranges.

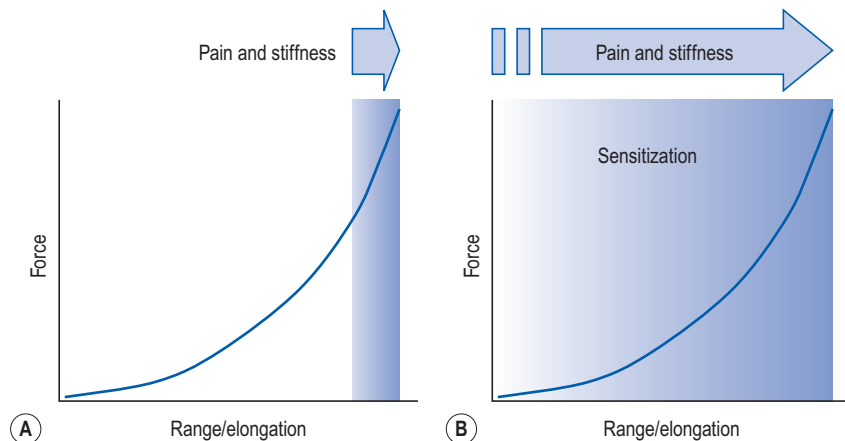
The clinical examples above represent three conditions in which pain, stiffness and ROM losses are shared symptoms. However, the ROM management will be different for each of these presentations. These scenarios raise several questions about ROM rehabilitation in the presence of pain:

- In the presence of pain, when is stretching/ROM challenge safe or useful?
- When is pain a signal to stop stretching?
- How soon after injury should ROM challenges commence?
- Can movement be stiff and painful without inflammation, damage or shortening?
- What is ROM sensitization?
- What can help to promote desensitization?
- Can stretching be used to control pain?

## ROM SENSITIZATION

Sensitization is a neurological process in which the central nervous system can change, distort or amplify the experience of pain in a manner that no longer reflects the noxious stimuli from the periphery.<sup>1</sup> ROM sensitization is the limitation in ROM owing to an increase in the subjective experience of stiffness and pain. It is a common phenomenon in acute and chronic musculoskeletal conditions.<sup>2</sup> Of particular focus here is ROM sensitization in which pain and





**FIGURE 9.1** Range of movement (ROM) sensitization. A. Under normal circumstances pain and stiffness are experienced at end-ranges. B. In the presence of sensitization, pain and stiffness are experienced within normal non-noxious ROM and as severe pain at end-ranges.

stiffness are experienced in functional ranges, in the absence of current tissue damage, inflammation or tissue shortening (Fig. 9.1). This phenomenon will be termed here *persistent ROM sensitization*.

Under normal circumstances sensitization is a *positive* protective response to injury. Following injury, the site of damage, as well as its surrounding area, will become hypersensitive to touch, movement or temperature. This sensitivity serves as a warning system to protect the weakened tissues from further damage.<sup>3</sup>

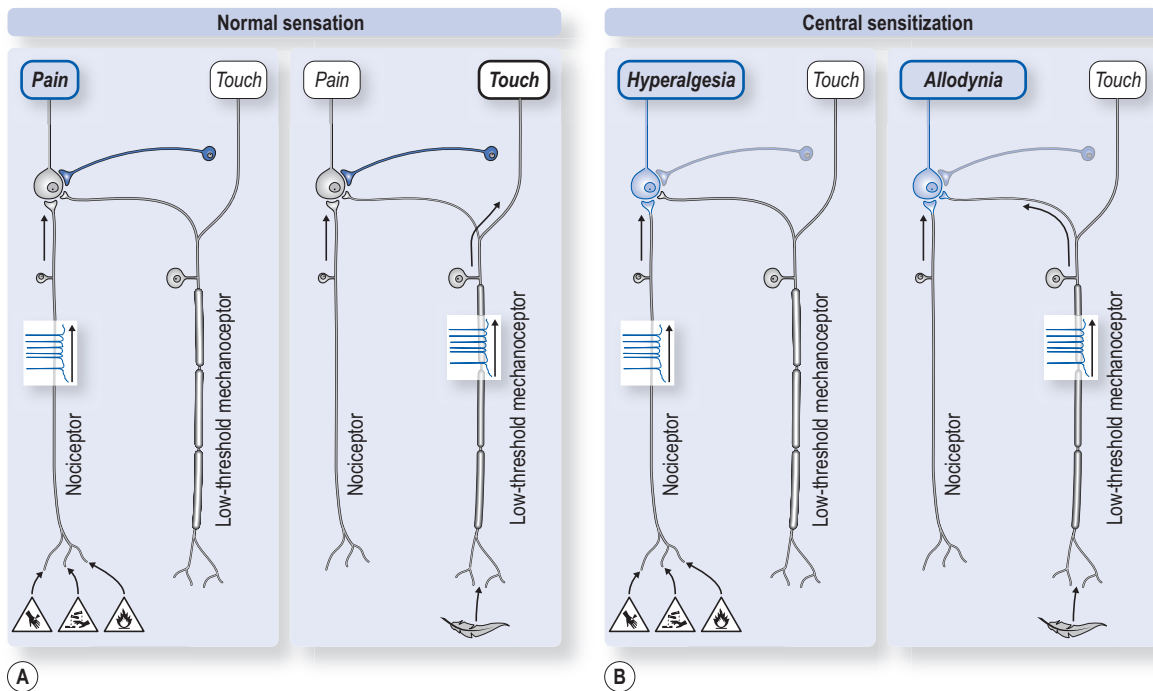
Sensitization is brought about by increased excitability of nociceptors in the periphery and central neurons that convey the nociceptive information. Peripherally, inflammatory by-products lower the nociceptors' threshold, resulting in their increased excitability.<sup>4–8</sup> Centrally, within the spinal cord and brain, sensitization is associated with complex biological and functional reorganization of sensory transmission and motor and autonomic responses. The outcome is facilitation and amplification of nociceptive signals throughout the nervous system.<sup>9–16</sup>

Sensitization tends to spread in the spinal cord to influence the receptive field of neurons that are not directly related to the site of injury. This spread can even affect the receptive fields of spinal neurons on the non-affected side.<sup>7,8</sup> This means that pain sensitivity can be experienced further away from the site of injury as well as on the opposite limb. For example, in some patients with osteoarthritis of the hip there is increased pain perception and skin sensitivity at locations distant to the joint and even on the non-affected side.<sup>17</sup>

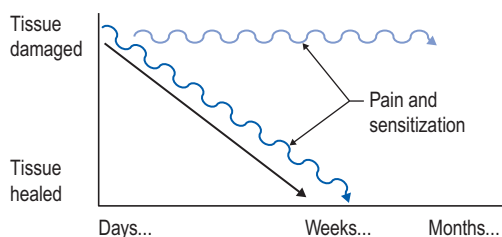
The consequence of sensitization is an elevated pain experience which is disproportionate to underlying tissue strain or damage (Fig. 9.2). Such hypersensitivity means that previously normal functional ranges are experienced as painful, and end-ranges which were uncomfortable become intolerably painful.

### Persistent sensitization

Under normal circumstances pain and sensitization tend to diminish as the individual recovers from their injury. However, for some individuals persistent central sensitization can be maintained long after tissue healing has taken place (Fig. 9.3). It can arise spontaneously, even without an obvious event of injury. Once central sensitization has taken place it does not seem to be dependent any longer on nociception from the damaged tissues.<sup>11</sup> Indeed, in many chronic pain conditions there is an absence of “fresh” tissue damage or inflammation.<sup>1,18</sup> Consequently, *persistent sensitization may lead the patient (and the therapist) to the erroneous belief that the painful area is damaged and inflamed.*



**FIGURE 9.2** Neural mechanisms of normal and central sensitization. With permission from Woolf C.J. Central sensitization: implications for the diagnosis and treatment of pain. *Pain* 2011;152(3 suppl):S2–15. These figures have been reproduced with permission of the International Association for the Study of Pain® (IASP). The figures may NOT be reproduced for any other purpose without permission.



**FIGURE 9.3** The experience of pain and sensitization tends to diminish in line with tissue healing. In some situations it can persist in the absence of tissue damage.

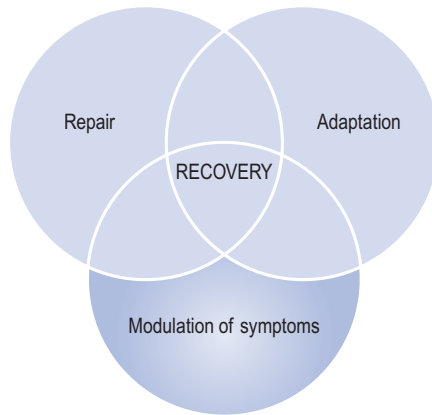
Persistent pain sensitization is a feature of many chronic musculoskeletal conditions.<sup>1</sup> It can be demonstrated in injury/post-surgical conditions,<sup>19</sup> chronic low back and neck pain, trapezius myalgia, whiplash conditions, painful jaw and post-immobilization.<sup>1,20–25</sup> Sensitization also plays a role in the various tendinopathies such as tennis elbow and supraspinatus, Achilles and patellar tendinopathies.<sup>26–31</sup> In arthritis, both joint nociceptors and related spinal nociceptive neurons show pronounced sensitization for mechanical stimulation.<sup>32</sup>

ROM sensitization has also been demonstrated in patients with chronic low back pain.<sup>33</sup> Although they experience pain and stiffness in forward bending their flexion ROM is no different from asymptomatic individuals.<sup>34–37</sup> This suggests that the range limitation was due to reduced tolerance to stretching rather than physical shortening of the muscles.<sup>33</sup> A similar example of ROM sensitization can also be observed in non-traumatic pain conditions such as chronic trapezius myalgia and chronic neck pain.<sup>22–25</sup> In these conditions, the patient may experience substantial loss of neck rotation. (I have seen patients who could no longer drive because they were unable to turn their head during reversing.) Yet, such restrictions are not evident when the patient is lying relaxed on the table. Often there is full pain-free neck rotation when the therapist passively moves the neck.

Central sensitization suggests that the experience of stiffness/pain during active movement or even manual stretching may be due solely to stretch sensitivity. It also implies that in some conditions ROM recovery can come about solely by desensitization (Fig. 9.4).

## ROM DESENSITIZATION

The causes underlying the transition from acute to chronic sensitization are not fully understood. Factors associated with persistent sensitization include greater degree and longer duration of injury and genetic and psychosocial factors, to name but a few.<sup>19,38</sup> This means that preventing or removing the



**FIGURE 9.4** In some conditions, range of movement recovery can be primarily by desensitization.

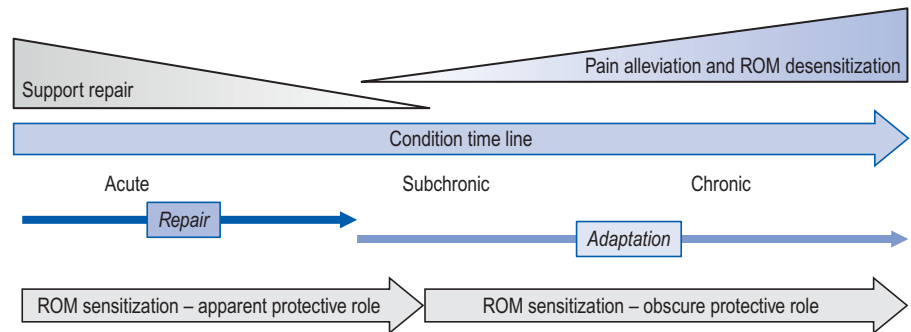
cause of sensitization can be clinically elusive. The central nature of sensitization makes it even more elusive for physical therapies since there is nothing to “fix” peripherally in the tissues. All this suggests that to promote desensitization we need to focus on central process, somehow engaging the potential adaptive capacity of the nociceptive systems.

Before we set out to promote desensitization we have to establish in which conditions it will be beneficial.

### When is ROM desensitization beneficial?

Whether ROM desensitization is beneficial depends on the role of pain within the patient’s condition. An important consideration is whether pain/sensitization serves a protective function, which is partly related to the duration of the patient’s condition, i.e. whether the condition is acute or persistent (Fig. 9.5).

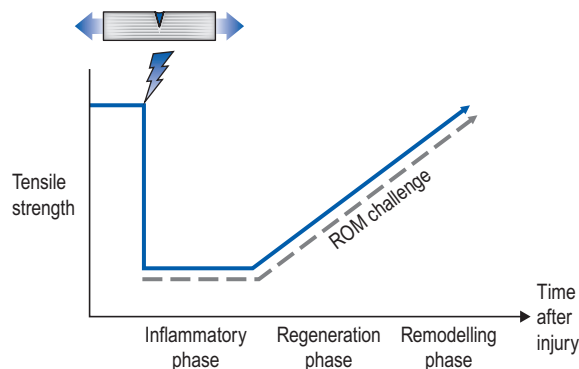
*Acute condition* – In acute conditions pain and sensitization are likely to be part of a protective strategy. In these conditions the subjective experience of stiffness may be due to localized swelling and sensitization. Improvement in pain and ROM sensitization are often spontaneous and related to the rate of tissue healing.<sup>39</sup> Therefore, desensitization is not a therapeutic priority and the focus should be on assisting tissue repair. During that period the patient should be advised to remain active and ROM challenges should be within tolerable pain ranges. Furthermore, acute injuries are associated with tearing/damage of fibres and reduced tensile strength rather than structural shortening of tissues (Fig. 9.6). Therefore, end-range challenges may be unnecessary and unsafe in recently acquired injuries.



**FIGURE 9.5** To desensitize or not: depends on the role of pain/sensitization in the condition. It may be more beneficial in persistent sensitization in which pain no longer provides a protective function. ROM, range of movement.

This raises the question of how long a condition is considered to be acute and when should the ROM challenges be introduced. Generally, tissue inflammation and regeneration are most marked within the first 2 weeks of injury. This duration may depend on the magnitude of damage and the type of tissue injured. A safety margin of 3–6 weeks is a useful time scale to consider a condition as acute.<sup>40</sup> Indeed, in many injuries or post-operative conditions the repair processes will resolve within this time frame.

However, pain relief, rather than optimized tissue healing, is often the patient's priority (most patients are not aware that inflammation is a positive aspect of repair). Some transient pain relief could be obtained by helping to minimize oedema and inflammatory by-products. Both of these therapeutic goals (healing and pain relief) can be achieved by the use of rhythmic movement



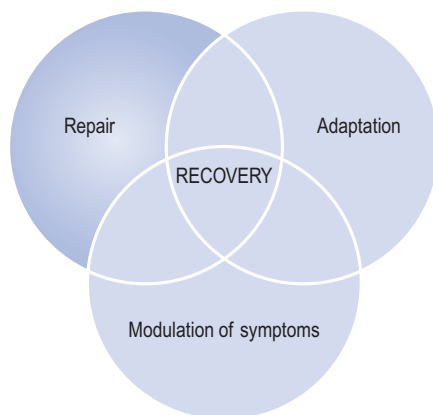
**FIGURE 9.6** Tissue tensile strength following injury may be reduced. Range of movement (ROM) challenges should not exceed these levels.

(active or passive) and external intermittent compression within pain-free ranges (for full exploration of this topic see Lederman<sup>41</sup>).<sup>42,43</sup> Stretching is unlikely to have a positive influence on these processes.<sup>41</sup>

So, in acute conditions, ROM recovery can come about primarily by repair processes (Fig. 9.7).

*Chronic conditions* – ROM desensitization can be beneficial in persistent musculoskeletal conditions. Here there is no obvious protective function for pain and sensitization (since there is an absence of tissue damage/inflammation). However, this clinical reasoning can be a bit more complicated; in asymptomatic, pain-free individuals it is common to find tissue damage without inflammation. For example, partial or full rotator cuff tears can be found in 34% of asymptomatic individuals.<sup>44</sup> Similarly, in the spine, the prevalence of tissue damage in asymptomatic individuals can be fairly high: 27% disc protrusion, 54% disc degeneration and 28% annular tears.<sup>45</sup> This means that tissue damage without pain is a fairly common occurrence. Another consideration is that pain does not always reflect the magnitude of tissue damage.<sup>46</sup> For example, non-perforated rotator cuff tears can be more painful than full-thickness tears.<sup>47,48</sup> In the spine, the degree of disc displacement, nerve root enhancement or nerve compression does not correlate with the magnitude of pain or disability.<sup>49</sup> It means that in more chronic conditions *the pain experience is (often) disproportionate or even unrelated to the underlying tissue damage.*

This brings us back to the original question: whether ROM challenges would be safe for chronic conditions in which “old” tissue damage is accompanied by pain/sensitization. In the spinal and shoulder conditions described above physical activities/exercise are considered to be both safe and beneficial for improvement/recovery.<sup>50–60</sup> From this it can be loosely concluded that, in



**FIGURE 9.7** In some conditions ROM recovery can be primarily from tissue repair.

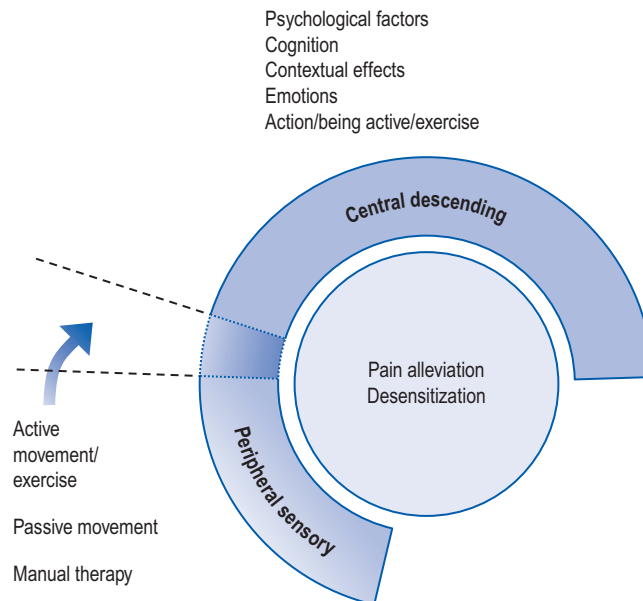
chronic conditions in which there is pain and potential underlying “old damage”, ROM challenges are both safe and likely to be beneficial.

This leaves us with the question of how physical therapy can facilitate ROM desensitization.

### Factors supporting ROM desensitization

Neural inhibitory mechanisms are inherent in all brain functions, including in the transmission of nociception and in desensitization processes.<sup>61</sup> Physical therapies often aim to exploit these inhibitory mechanisms in order to control/alleviate pain.

The modulation of nociception/pain can be largely by psychological/cognitive/emotional processes and partly by the physical sensory stimulation components of the treatment (Fig. 9.8). Although these mechanisms can be explored individually, in practice they are inseparable. It is difficult to specifically target one inhibitory system to the exclusion of another. Furthermore, the inhibition associated with desensitization is not exclusive to a particular aspect of the treatment, pathway or brain centre.<sup>62–64</sup> Pain alleviation and desensitization



**FIGURE 9.8** Pain alleviation and desensitization can arise by central descending inhibitory processes and peripherally induce inhibition by stimulation of mechanoreceptors. Peripheral mechanisms can modulate nociceptive transmission but also may be associated with descending inhibition through contextual effects (overlap area).

should be considered as whole-person responses to the entire therapeutic encounter – psychological and physical.<sup>65</sup>

### ***Psychological dimension***

Therapies that target psychological factors are known to have a potent influence on the experience of pain and sensitization.<sup>62,66</sup> The main psychological factors which may help mediate desensitization can be divided into three broad areas: emotional, cognitive and contextual factors.

#### **Emotional factors**

Sensitization and the experience of pain can be heightened by negative mood changes, such as depression, distress, anxiety and fear, whereas improvements in psychological well-being are often associated with alleviation of pain.<sup>67–73</sup> When patients with lower back pain experience negative moods they tend to report an increase in pain levels and decreased pain tolerance, with positive moods having the opposite effect.<sup>74</sup> This suggests that therapeutic interventions that help to improve psychological well-being may also have a positive impact on the pain experience.

There is a link between physical activities and a positive change in various psychological factors.<sup>75</sup> Even (the humble) walking can have a positive influence on psychological factors such as depression,<sup>76</sup> but also on chronic back pain.<sup>77–79</sup> One way to exploit the links between physical activity, psychological well-being and pain is to encourage the patient to return to physical activities, particularly those that they enjoy.<sup>80</sup>

#### **Cognitive-behavioural factors**

The patient's experience of pain and degrees of sensitization can be influenced by anxieties associated with their condition. Anxieties are often expressed as fears about movement, with the patient making inexact and disproportionate links between physical activities and the potential for greater pain and recurrence of injury (*catastrophizing*). When such anxieties were present, they were shown to have a negative influence on the experience of pain.<sup>37,80–86</sup> For example, patients who have a higher catastrophizing score before surgery tend to experience more pain following surgery.<sup>82,87</sup> Conversely, a decrease in pain catastrophizing can bring about a reduction in pain intensity and disability.<sup>88,89</sup>

These anxieties/fears can be alleviated by providing positive messages that reduce catastrophizing, empower the patient and promote self-efficacy in pain control.<sup>89</sup> It is useful to provide information about the nature of sensitization, highlighting the disparity between tissue damage and pain and the potential to modulate the pain experience through various cognitive and behavioural means (Ch. 11).<sup>89,90</sup> A patient with a chronic lower back condition who presents



with ROM stiffness/discomfort can be informed that the area may be sensitive but not necessarily damaged, that discomfort experienced during or after movement in certain ranges does not mean that the spine has been re-damaged, and so on. These messages can be delivered explicitly and cognitively by verbal communication, but equally by “unspoken” messages that are conveyed implicitly by positive physical experiences (see reassurance, Ch. 11). This could explain why outcomes are similar for physical and cognitive-behavioural therapies in the treatment of chronic low back pain.<sup>35,91–94</sup> It has been proposed that the improvements in both groups are mediated by alleviating the anxieties associated with pain.

Pain experiences can also be alleviated by diverting attention away from the area of pain.<sup>95–100</sup> This can be done by drawing attention to another part of the body or to a particular mental or non-painful physical task.<sup>101</sup> The immediate application of this clinically is to provide movement strategies that emphasize an external focus of attention. This can be towards an external goal or outcome of a task rather than focusing on the painful area. For example, patients with chronic low back pain can be instructed to perform reaching movements, at end-range, while focusing on the target rather than on the discomfort in the back (“forget the back therapy”).

Within the cognitive-behavioural dimension, relaxation techniques also have an important role in helping to control acute and chronic pain conditions.<sup>102–109</sup> Relaxation techniques can help distract attention from pain, support an internal locus of control and improve self-efficacy in managing pain.<sup>107,108</sup> Simple relaxation techniques, such as progressive muscle relaxation, have been found to be effective in managing chronic pain.<sup>107,108,110</sup>

### Contextual effects

Contextual effects are the environmental factors which influence the patient’s perception of the treatment. These factors can have a profound lasting effect on the patient’s experience of pain.<sup>111–115</sup> Often, these factors are not directly associated with the physical aspect of the treatment but associated with the therapeutic relationship,<sup>116</sup> the patient’s expectations, previous therapeutic experiences, treatment credibility and the patient’s preference for a particular treatment.<sup>35,92,94,111–113,117–119</sup> When these contextual factors are positive they provide the individual with internal narratives that engage them psychologically, behaviourally and physiologically in their recovery.<sup>114</sup>

Contextual effects can have a significant influence on neurophysiological processes including sensitization/desensitization.<sup>120</sup> For example, the individual’s expectation of pain, or, conversely, of pain relief, can determine the magnitude of spinal sensitization.<sup>121</sup> This was demonstrated in a study in which hypersensitivity to mechanical stimulation was induced by heating the skin of the

forearm.<sup>121</sup> The area of sensitization was smaller in subjects who received a placebo analgesic in the form of a sham magnet (a metal plate shaped like a magnet applied to the sensitive area). Brain and spinal imaging during such placebo analgesia has demonstrated that the subject's report of reduced pain coincides with decreased activity in the brain pain areas with a concurrent inhibition of nociceptive input within the spinal cord.<sup>115,120</sup> There is some evidence that contextual effects on pain are more prominent in treatments that contain physical events, such as manual therapy, than in interventions where medication or psychological approaches are used.<sup>122</sup>

### **Physical components**

#### **Active movement**

Active movement challenges can also play a role in ROM desensitization. Several studies have explored the effects of exercise on induced pain in healthy individuals.<sup>123</sup> Transient desensitization has been demonstrated during and after different forms of exercise. In dynamic, aerobic exercise desensitization is more likely to occur when the exercise is performed for more than 10 minutes and at above 70% of maximal aerobic capacity.<sup>124–126</sup> For isometric exercise it seems that less effort and duration is required for desensitization to take place.<sup>63,127,128</sup> It can be observed at an intensity as low as 25% of full contraction force and within a period of time as brief as 1 minute.<sup>129,130</sup>

Reduced hypersensitivity to activity has also been demonstrated in patients with chronic musculoskeletal conditions. In tennis elbow, active wrist movement combined with superimposed elbow joint mobilization demonstrated an immediate reduction in sensitization.<sup>26–28</sup> Similarly, in patients with chronic neck pain, 3 minutes of specific neck exercises, performed in non-painful ranges, was shown to reduce local hypersensitivity and improve cervical pain-free ranges.<sup>131</sup> Overall, these studies demonstrate that active forms of ROM challenges could be useful for inducing desensitization. This could be achieved both by rhythmic, cyclical movement and by static isometric-like activities. These challenges should be applied within the pain-free ranges of movement.

These principles can be applied clinically within the framework of a functional approach. For example, a patient with chronic low back pain can be instructed to perform a repetitive reaching movement, towards a target marked by the therapist's hand. The procedure starts by exploring the patient's pain-free range by moving the target hand to different positions. Once a comfortable sphere of movement is established the patient repeats the reaching movement towards these positions. After several reaching cycles the therapist surreptitiously moves the target hand further away. If there is no pain at the new position the patient is instructed to repeat the movement to this range, and so on (see accompanying Video).

### Passive movement and stretching

A wide range of manual therapy approaches use passive techniques to control pain and reduce sensitization. These include stretching, massage, manipulation and joint mobilization/articulation.

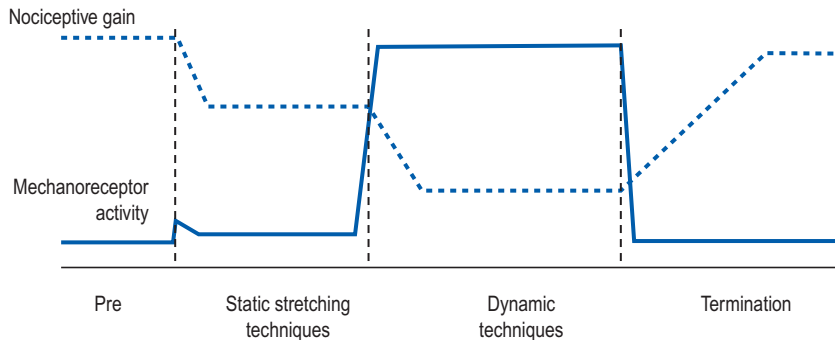
Passive manual approaches base their analgesic influences on the capacity of proprioceptors to modulate nociceptive signals (pain-gate phenomenon).<sup>132–134</sup> In one of the early studies of the pain-gate mechanism it was demonstrated that a noxious stimulus of the cat's paw can be modulated, in the spinal cord, by a simultaneous application of vibration to the paw (proprioceptive stimulus).<sup>133</sup> A similar phenomenon was later demonstrated in humans.<sup>133</sup> A special vibrator with a ring applicator was placed on the skin of the thigh and a noxious stimulus was applied through the centre of the ring. When the vibrator was switched on the subject experienced less pain and had difficulty in localizing it. However, the pain returned once the vibrator was switched off. A similar phenomenon was demonstrated with induced muscle pain (injection of an irritant into the muscle) and passive movement of a nearby joint.<sup>135</sup> During passive motion there was an immediate decrease in muscle pain (17–31%) and point pressure pain (17%). This desensitization by passive movement was also demonstrated in animals with chronic muscle and joint inflammation; mobilization of a nearby joint reduced the sensitization in the affected areas.<sup>136</sup>

This gating phenomenon was also demonstrated in manual therapy studies. Passive techniques applied remotely or close to the area of sensitization were shown to bring about immediate desensitization.<sup>135,137,138</sup> This has also been shown by various studies of spinal manipulation (which can be considered as a very rapid stretch at the end-range). A single manipulation has been shown to produce some form of desensitization segmentally at the spine and even distally in the limbs.<sup>137,138</sup>

Overall, it seems that desensitization is more likely to occur during dynamic rather than static stretching events.<sup>132–138</sup> This is probably due to the presence of a sustained proprioceptive barrage during dynamic events (Fig. 9.9). An example of dynamic stretching is passive cyclical joint oscillation/mobilization at end-ranges, such as a pendular swing of the limb/segment within the pain-free ranges. A gating effect is likely to be minimal during static stretching owing to a drop in the sensory barrage (static receptors are fast adapting and tend to be less numerous than dynamic receptors).

### Transient nature of desensitization

There are two physiological hurdles that need to be overcome for desensitization to be successful. The first is the transient nature of a physically induced



**FIGURE 9.9** Gating of nociceptive transmission by mechanoreceptor stimulation. Greater inhibition is expected during dynamic manual events. However at termination of stimulation nociception is expected to return to pre-session levels, unless maintained by descending inhibitory influences.

desensitization and the second is the neural plasticity associated with sensitization.

Pain relief and desensitization are likely to be significant only as long as the physical stimulation is present, with perhaps some transient after-effect.<sup>63,139–141</sup> For example, desensitization after exercise tends to taper off within 30 minutes after termination of the activity.<sup>126,128,139</sup> This may be even more critical for passive approaches in which inhibition depends on ongoing proprioceptive stimulation. It would be expected that desensitization would rapidly decrease during static events, such as at the termination of the dynamic phase of stretching or passive movement (Fig. 9.7). Desensitization that outlasts its physical stimulation is more likely to depend on sustained central inhibition from higher centres, i.e. contextual effects/placebos (see above).

The second hurdle is the competition between the short duration of therapeutic intervention and the persistent adaptive nature of sensitization. Chronic sensitization shares the same neurological processes that underlie learning.<sup>142,143</sup> It is associated with robust anatomical and physiological plasticity within the peripheral and central nervous systems.<sup>18,142–144</sup> The consequence is a physiological competition between the persistence of sensitization and the transient nature of the therapeutic intervention. The winner of this competition is likely to be the persistent state of sensitization: it is there all the time.

To overcome the problem of duration and competition we need to explore, with the patient, inhibitory processes that are both persistent and self-sustaining. The most realistic approach is to engage the patient in psychological and

cognitive processes, in particular reducing anxieties and promoting self-efficacy and self-care,<sup>118</sup> part of which can be exercise and relaxation. There are two other less favourable options – to identify and “remove” the pathological processes that maintain the sensitization or to increase the frequency of intervention. However, it can be difficult to identify the processes that maintain the sensitization and even more so to remove it. Increasing the frequency of treatment can be impractical and may even have negative consequences; as was shown in the management of whiplash injuries, too much treatment can promote chronicity and dependency.<sup>145,146</sup>

## STRETCHING AND PAIN CONTROL

One of the most common uses of stretching is to alleviate pain after exercise and injury and to control chronic musculoskeletal pain.

In sports and exercise, stretching is often used before and after training to relieve delayed onset muscle soreness (DOMS). Although frequently used, it is largely ineffective in reducing pain. Stretching before exercise has been estimated to reduce DOMS by 1 point on a 100-point scale and stretching after exercise is estimated to reduce it by 0.5 on the 100-point scale.<sup>147,148</sup>

Since stretching is ineffective for DOMS, which is a mild/benign form of muscular damage, it is unlikely to provide pain relief in more severe musculoskeletal injuries. In acute and sub-acute low back pain, stretching does not seem to add any benefit above the advice to keep active.<sup>149</sup> Stretching may even be harmful in acute conditions where there is tissue damage and where pain serves a protection strategy (see above). For example, passive stretching after rotator cuff repair surgery resulted in a greater number of re-tears (23%) than pain-free passive motion (8%).<sup>150</sup>

Stretching exercise to alleviate chronic pain has shown mixed results.<sup>151</sup> A recent review suggests that yoga may provide some alleviation in various musculoskeletal and other pain conditions:<sup>152,153</sup> labour pain,<sup>154</sup> hand osteoarthritis,<sup>155</sup> migraine,<sup>156</sup> carpal tunnel syndrome<sup>157</sup> and irritable bowel syndrome.<sup>158</sup> In particular for chronic low back pain, several studies have demonstrated greater pain relief with yoga than with other forms of exercise or standard care.<sup>159–162</sup> However, in yoga other elements of practice may also influence pain levels, such as raised self-efficacy, relaxation and breathing exercise. A recent large study with 228 subjects compared 12 weeks of yoga, conventional stretching exercises and self-care information for chronic low back pain.<sup>163</sup> Both yoga and stretching resulted in similar pain reductions that lasted several months; however, this effect seems to be modest and did not reach clinical significance.<sup>163</sup> In another recent study, six sessions of yoga had no effect on low back pain.<sup>164</sup>

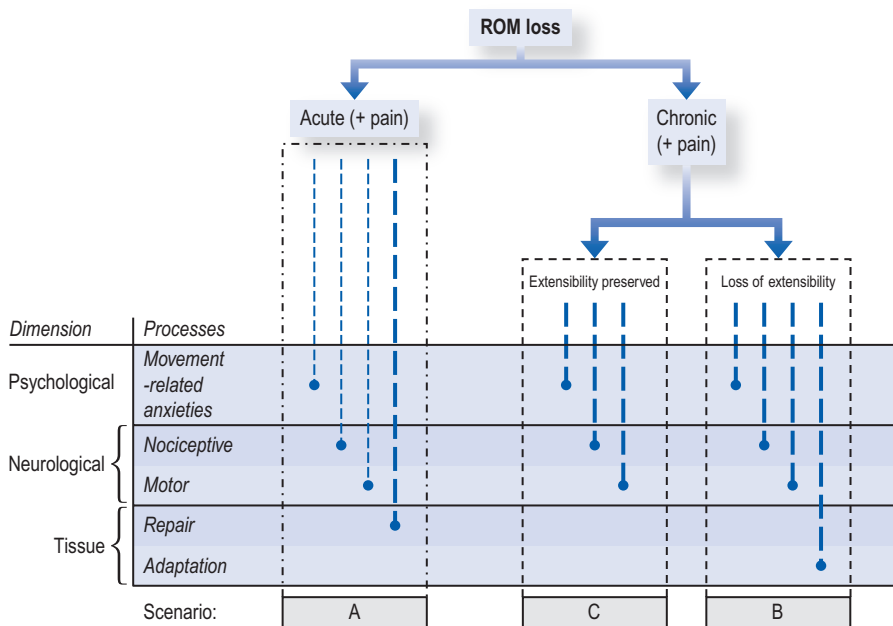
For chronic, non-specific neck pain regular stretching exercise shows mixed results.<sup>151</sup> Some studies show pain reduction in the short term (4–12 weeks),<sup>165,166</sup> some show improvement in the long term when intensively maintained with other forms of exercise,<sup>167</sup> while others have not demonstrated any additional benefit.<sup>168–171</sup>

One study has demonstrated that stretching may increase sensitization of tender points in patients with various musculoskeletal pain conditions.<sup>172</sup>

In a systematic review carried out in 2010, stretching was shown to have no effect on pain levels in subjects who experience pain and loss of ROM due to various musculoskeletal, neurological and surgical complications.<sup>173</sup>

## CLINICAL REASONING IN ROM REHABILITATION IN THE PRESENCE OF PAIN

With all the information discussed above we can now return to the case scenarios described at the beginning of this chapter and explore the clinical reasoning for management (Fig. 9.10):



**FIGURE 9.10** Clinical reasoning in patients presenting with various forms of range of movement (ROM) loss in the presence of pain. Heavier dashed lines imply prioritizing.

*Patient A presents with a knee sprain which happened 1 week ago. It is painful, swollen and stiff and on examination has only a limited ROM.*

In this clinical scenario the priority is to support the tissue repair processes. It is estimated that ROM sensitization and pain will subside as the condition improves. This can be achieved by a variety of passive and active movement approaches. Stretching (tissue overloading) is not indicated and may be unsafe in this case.

*Patient B had a knee joint fracture. It is now 6 weeks later and the plaster has just been removed. The knee is painful, swollen, has restricted ROM and is very stiff.*

In this case, the focus is on all three dimensions. The priority, however, is in the tissue dimension promoting local adaptive recovery of ROM but with an emphasis on active challenges to recover motor control (neurological dimension). Pain alleviation and desensitization can be both engaged in the psychological (e.g. reducing the condition-related anxieties) and neurological (e.g. modulation of symptoms using dynamic movement approaches) dimensions.

Here, tissue repair is likely to have been resolved. Overloading of tissue, although uncomfortable, is likely to be safe and even beneficial.

*Patient C had a knee surgery 1 year ago. On examination the passive knee ranges have mostly recovered but pain and stiffness are still limiting the patient's functional ranges.*

In this clinical scenario the priority is to reduce ROM sensitization, processes that are predominantly in the psychological–neurological dimensions. Here, tissue loading/stretching is unlikely to be beneficial for recovery (no point in stretching something which is not shortened). Varying levels of pain alleviation and desensitization can be achieved by the methods discussed throughout this chapter (see also psychological consideration, Ch. 11).

## SUMMARY

- Sensitization is a neurological process in which the central nervous system can change, distort or amplify the experience of pain
- ROM sensitization is a neurological process in which pain, discomfort or stiffness are experienced in normal ROM
- In acute conditions, sensitization and pain have a positive protective role in limiting the ROM
- In acute conditions, stretching or challenging end-ranges is unlikely to be useful and may even increase the likelihood of re-injury. The therapeutic focus should be on supporting recovery

- In some conditions, ROM recovery may be associated primarily with the repair process
- In chronic conditions, ROM sensitization can be the primary cause of ROM losses; it can be present in the absence of inflammation, tissue damage or tissue shortening
- Desensitization is likely to be useful and beneficial in chronic conditions, in which pain and sensitivity have no obvious protective function
- In persistent conditions, ROM recovery may come about primarily by symptomatic relief and desensitization
- ROM sensitivity can be reduced by approaches that incorporate psychological and physical means
- Alleviating the condition-related anxieties is one of the key components in managing pain in the psychological-behavioural dimension
- Psychological and behavioural means are more likely to provide/sustain long-term desensitization and pain alleviation
- Stretching techniques are ineffective in managing acute pain. It is unclear whether stretching is useful for chronic pain; if it has an effect it is likely to be modest
- Pain processes are part of complex systems that produce complex responses; the outcome can be variable, disproportionate and unpredictable in relation to the therapeutic intervention

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## Stretch-tolerance Model

In clinic we may sometimes find that yoga and martial arts practitioners who are “stretch experienced” may be less concerned about painful stretching positions than those who are “stretch naïve”. This difference in attitude is the basis of the stretch-tolerance model. This model proposes that flexibility training has a psychological desensitizing influence, in which the individual becomes more familiar, less fearful and therefore more tolerant of stretching discomfort/pain.<sup>1,2</sup> In the last decade the stretch-tolerance model has gained popularity and has been used to explain gains in flexibility following acute bouts of stretching and regular stretching, and to explain range of movement (ROM) differences between stiff and flexible individuals.<sup>3–14</sup>

A stretch-tolerance model suggests a learning process in which the individual dissociates pain from injury. Studies on conscious humans apply tensional forces that are well within tolerable pain levels. These forces are probably within safe, non-damaging ranges. Hence, the individual quickly learns that within the tolerable ranges there are no negative consequences to the stretch-pain experience (except for an occasional mild delayed onset muscle soreness (DOMS)).<sup>15</sup> The stretch-tolerance model is in contrast to the previously held assumptions that ROM gains after stretching are the result of adaptive tissue changes.<sup>16</sup> Although there is substantial support for the stretch-tolerance model it raises several paradoxes which will be discussed in this chapter.

This chapter will aim to answer the following questions:

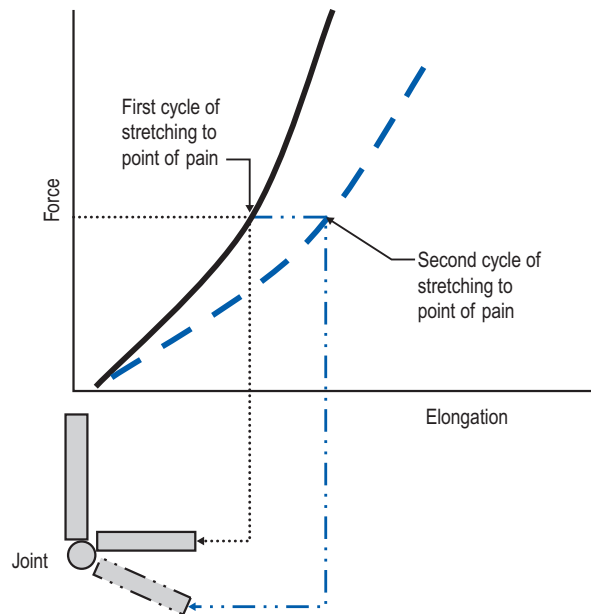
- Can this model explain ROM loss and recovery?
- Does it have any implications for ROM management?
- Does it have any implications for flexibility training?

### ORIGIN OF STRETCH-TOLERANCE MODEL

As discussed in Chapter 6, an acute bout of stretching is associated with a transient increase in tissue compliance (or reduced stiffness). This means that the joint can be stretched further using the same level of force

(creep deformation). This change in stiffness would be expressed as a right shift in the force–elongation curve (Fig. 10.1). However, these viscoelastic responses are transient, lasting several minutes to an hour (Ch. 6).<sup>9</sup> It has been assumed that regular stretching has a cumulative effect in which this right shift would become permanent, i.e. the tissue would undergo lasting changes becoming longer and more compliant.

Contrary to this expectation, numerous studies demonstrated that the force–elongation profile at the onset of training remained unchanged following several weeks of stretching.<sup>5–14</sup> A right shift was not evident following regular stretching; all that happened was that the point at which a person experienced discomfort shifted to a point further along the force–elongation curve (Fig. 10.2). These findings led to the current view that the increase in ROM is a psychological–sensory phenomenon rather than an adaptive tissue change. However, several other studies using similar testing methods have suggested that regular stretching does bring about adaptive tissue changes.<sup>16–19</sup> So is there a reason why there is such disparity in views in studies that use similar methods?

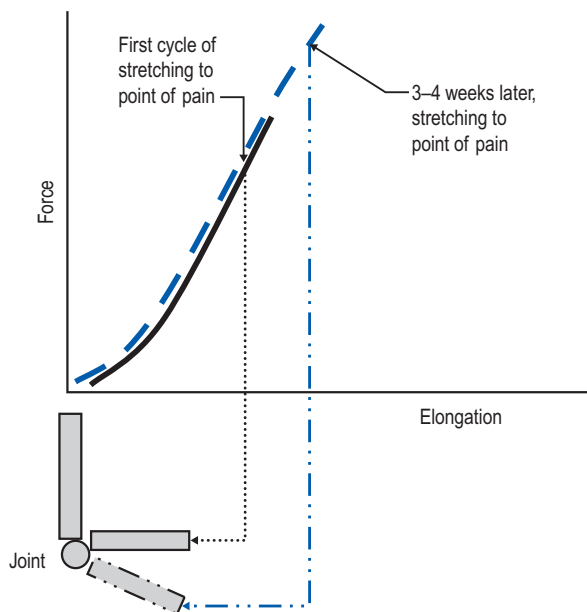


**FIGURE 10.1** Range of movement increases owing to a change in tissue stiffness.

## STIFF VERSUS LONG

In normal joints a long-term increase in ROM can come about either by an adaptive reduction in the stiffness of the tissues or by an increase in their length, i.e. making the spring softer or longer. Many of the studies that support the stretch-tolerance model measured stiffness, not length (the force–elongation curve is a measure of muscle–tendon stiffness, not length). They are different measures. For example, a 1- metre rope has the same stiffness profile as a 2-metre rope, but of course they are not the same length. An alternative explanation to the stretch-tolerance model is that stiffness remains unchanged but now the muscle is longer. As a consequence the interval between pain and damage has shifted up along the curve, hence the shift in pain experience to a new tension point (Fig. 10.2). It could be argued, therefore, that the stretch-tolerance studies have demonstrated length adaptation, but instead have been interpreted as a pain tolerance phenomenon.

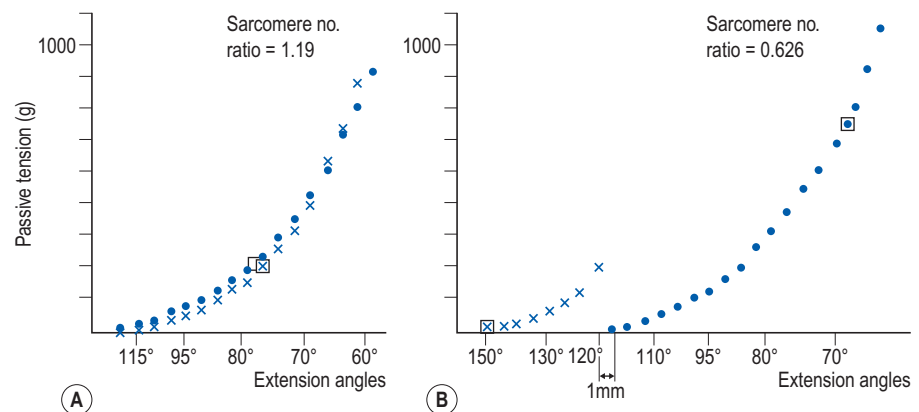
Is it possible for a muscle to undergo adaptive length change while maintaining the same stiffness? As discussed previously, paired muscle groups strive to reach a functional equilibrium at new angles of immobilization or habitual



**FIGURE 10.2** Range of movement increase as a shift along the force–elongation curve.

use (Ch. 4).<sup>20–22</sup> At these angles they have to achieve optimal force production while maintaining their passive mechanical properties. Such adaptive reorganization has been demonstrated in several animal studies. In one study, immobilization of the muscle in the lengthened position resulted in a 19% increase in the number of sarcomeres in series.<sup>23</sup> Yet there was no significant difference in the stiffness profile between the longer muscle and the control limb (Fig. 10.3). In other words, the normal muscles of the control limb displayed the same stiffness characteristics as the longer (immobilized) muscle.<sup>23</sup> In one study, the animals were still able to maintain isometric contractions of the muscles pertaining to the immobilized joint.<sup>24</sup> It was found that after several weeks the stiffness properties of the muscles returned to values similar to those of normal muscles, although these muscles had undergone adaptive length changes.

Further evidence supporting length versus stiffness differences comes from studies on elderly women and patients with diabetes mellitus and peripheral neuropathy. It was found that older women and patients with these conditions had an ankle stiffness profile similar to the control group. However, the older women and the patient group had a reduced ankle ROM, suggesting “shorter” rather than “stiffer” plantar flexor muscles.<sup>25,26</sup>



**FIGURE 10.3** Force–elongation curve for muscles immobilized in lengthened (A) and shortened (B) positions. X = immobilized muscle and (•) = control limb. In the lengthened position there is an increase in sarcomere ratio yet the stiffness profile is very similar to the control. In B, there is a reduced ratio of serial sarcomeres with a left shift on the curve, implying increased muscle stiffness. Reprinted from Tabary JC, Tabary C, Tardieu C, et al. Physiological and structural changes in the cat's soleus muscle due to immobilization at different lengths by plaster casts. *J Physiol* 1972;224(1):231–44, with permission from John Wiley & Sons.

## IS A TOLERANCE MODEL LOGICAL?

Although the tolerance model is well supported by research it creates paradoxes which question its validity or clinical usefulness.

The place to start looking at these contradictions is the relationship between stretching pain and tissue damage – the pain–damage interval. Presumably, the pain associated with stretching is the body's signal that elongation is approximating the upper limits of the tissue's tensile strength. For this reason, high-force, acute bouts of stretching can result in a mild form of DOMS.<sup>15</sup> Assuming that no extensibility or length adaptation has taken place following stretching, the first question is why would our body switch off this protective system after a few weeks of stretching; wouldn't subsequent stretching to a new angle exceed these original dangerous end-limits?

Let us for a minute accept the stretch-tolerance model and perform a hypothetical experiment. Thirty years ago I trained to perform full splits as part of my yoga practice. It took about 2 years of daily training to achieve this yoga posture. However, this agility was completely lost several months after the cessation of stretching. Currently, I have become inflexible to the point that during forward bending I can hardly reach beyond my knees. According to the stretch-tolerance model the flexibility gains of 30 years ago and my current state of inflexibility are the result of stretch tolerance, unrelated to adaptive tissue changes. If this model is correct, I could be anaesthetized from the waist down and perform a full split, at present, without any re-training and without any muscle damage. Furthermore, using the same reasoning and with a dose of anaesthetic, I should have been able to perform a full split, again without any tissue damage, 30 years ago before I even trained for this posture.

Some researchers have also proposed that ROM differences between flexible and stiff individuals are largely the result of their stretch-tolerance differences rather than tissue differences. In two studies that support the stretch-tolerance model it was found that hypermobile women and flexible individuals have greater ROM than their less agile controls, as would be expected.<sup>27,28</sup> However, there was no difference in muscle stiffness between the groups, i.e. no right shift on the force–elongation curve. From these findings the researchers drew the conclusion that the observed differences were due to stretch-tolerance differences rather than physical tissue differences. Re-phrased, they suggest that pain-tolerant individuals are more flexible than pain-“intolerant” individuals. These conclusions can be explored with the same hypothetical exercise used above. Take a group of individuals of similar size and build, and of varying flexibility. Anaesthetize and stretch them to angles which are likely to cause tissue damage. According to the stretch-tolerance model their muscles should fail uniformly at exactly the same angle (since the only difference between individuals is their conscious tolerance of pain, not muscle length or stiffness).

How likely is that? A more reasonable conclusion is that in normal individuals (passive) flexibility is determined by tissue resistance. This will influence the angle at which the person will experience pain and discomfort. This angle will be engaged earlier in individuals with shorter and stiffer tissues. How far a person will stretch beyond that point will depend on their stretch tolerance.

Another paradox of this model is related to the associative nature of stretch tolerance and the extinction of tolerance. It is known that the ROM gains of stretching are lost very rapidly after termination of regular stretching. For example, a break of 4 weeks completely abolishes the ROM gains of 6 weeks of stretching.<sup>29</sup> From a stretch-tolerance perspective it would mean that the associative learning achieved during the 6 weeks of training becomes extinct within 4 weeks of terminating the stretch training. Although such “forgetting” is possible, it is unlikely to occur within a relatively short break of 4 weeks. The fluctuation in ROM in relation to training is more reminiscent of tissue adaption. This was demonstrated in one of the studies that have shown ROM increases and adaptive tissue changes following intensive stretching programme. Re-testing a month after cessation of stretching demonstrated a partial loss of some of these tissue and ROM gains (suggesting a return to the default functional setting; see competition in adaptation, Ch. 12).<sup>17</sup>

The stretch-tolerance model also implies that regular, long-term stretching is the only form of training/physical behaviour that fails to bring about any adaptive tissue changes. Are we comfortable with this notion?

## **STRETCH-TOLERANCE RELEVANCE TO ROM REHABILITATION**

The stretch-tolerance model can be useful clinically in informing us about ROM management in conditions where sensitization may be evident (Ch. 9). However, in conditions where adaptive ROM losses are present this model can be problematic.

Let us apply the anaesthetic experiment clinically. Now imagine a patient with a frozen shoulder who presents with glenohumeral contractures. Is the recovery of ROM the result of a change in stretch tolerance or the result of adaptive elongation? If recovery is all about stretch tolerance we should be able to repeat the experiment suggested above: anaesthetize the glenohumeral joint and stretch it to the anatomical end-range in one go. Although this may seem like a cruel experiment, manipulation under anaesthetic is a common medical procedure to improve ROM in a frozen shoulder. However, the consequence is a catastrophic plastic recovery of ROM in which every tissue in the shoulder is damaged (the “undesirable” plastic elongation, Ch. 6). The list of damage is long: superior, anterior, posterior capsule ruptured, labrum

tears, partial tears of the subscapularis tendon, anterior labral detachments and tears of the middle glenohumeral ligament.<sup>30</sup> Hence, applying a tolerance model clinically in conditions where ROM losses are associated with adaptive tissue changes can have disastrous treatment consequences. However, this does not exclude the possibility of concurrent tissue shortening with sensitization and the stretch-tolerance phenomenon (Ch. 9).

## IMPLICATION FOR AGILITY TRAINING

The tolerance model can explain some of the ROM gains seen in normal healthy individuals who participate in short-term stretching programmes. However, it cannot explain the profound ROM increases seen in individuals who train regularly for many years. Furthermore, it is unclear how a stretch-tolerance model can inform training practices for individuals who aim to increase their agility, such as in yoga, dance, martial arts or athletic activities that require flexibility. Far more important to flexibility training is an adaptive-behavioural model that includes specificity, overloading and repetition principles.

## SUMMARY

- Stretch tolerance is a “learned dissociation” between the experience of stretching pain and injury
- Immediate and short-term ROM gains may be associated with an increase in stretch tolerance
- ROM gains following long-term regular stretching may be associated with stretch tolerance but also with adaptive tissue changes
- A stretch-tolerance model fails to explain ROM loss or recovery in conditions where adaptive tissue changes have taken place
- The stretch-tolerance model is important in conditions in which ROM losses are associated with sensitization (Ch. 9)
- A stretch-tolerance model fails to elucidate the mechanisms underlying long-term gain of flexibility by regular stretch training
- The stretch-tolerance model has no training implications for healthy individuals who aim to increase their agility
- Adaptive-behavioural models are far more informative for agility training and managing recovery in conditions where ROM losses are associated with adaptive tissue changes

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# Psychological and Behavioural Considerations in ROM Rehabilitation

A dancer presented in my clinic complaining of severe shoulder range of movement (ROM) limitation and pain. He was previously diagnosed as having “joint damage”. He consequently became fearful of re-injury and withdrew from activities which challenged the full shoulder ranges. However, on examination it emerged that his condition was likely to be the stiff phase of frozen shoulder. It was explained to him that frozen shoulder, although a painful condition, is not associated with damage; the joint and its tissues are fully intact, shortened/thickened and sensitive. In the following session, a week later, the patient demonstrated a dramatic increase in shoulder ROM. He explained that once he realized that movement would not damage the joint he could tolerate the discomfort and used the arm in full range during the daily activities.

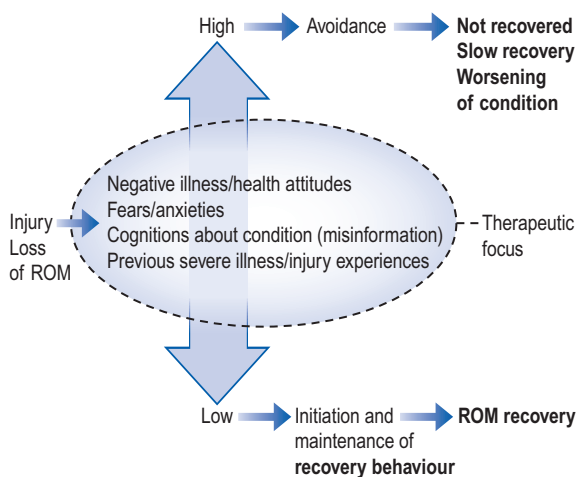
This example serves to highlight that movement limitations can be self-imposed by beliefs and anxieties associated with injury and pain. These psychological and cognitive factors can be as ROM limiting as physical or neurological impediments (Fig. 11.1). Sometimes treatments that successfully restore the physical limitations of ROM may fail to improve functional activities unless these anxieties are addressed.

This chapter will explore the following topics:

- Can ROM limitations have psychological–behavioural origins?
- Could psychological factors influence ROM recovery?
- How can we reassure the patient that end-range movement is OK?

## ACTIVITY AVOIDANCE AS ROM LIMITATION

The patient described above is probably no different from other individuals who have been injured or are in pain. There is a natural fear that movement may cause re-damage or increase the pain intensity.<sup>1</sup> As a consequence, individuals may avoid certain ranges of movement and withdraw from activities which they believe will be painful or harmful.<sup>2–10</sup> Such self-imposed



**FIGURE 11.1** Psychological and cognitive factors and previous illness experiences can impede the recovery behaviour. ROM, range of movement.

limitations can be seen in spinal conditions as reduced trunk ROM, restricted overhead use of the arm in shoulder conditions and reduced stride length in lower limb conditions. This behaviour would have a negative impact on ROM recovery. It would sustain the dysfunctional motor and tissue adaptation associated with the ROM loss (Ch. 4).<sup>11–14</sup> In contrast, behaviour that frequently challenges movement to the full is essential for recovery. Habitual use of the body drives the positive adaptive processes that underlie ROM normalization (Ch. 4).

Activity avoidance can arise from several factors (Table 11.1):<sup>15</sup> negative beliefs about the condition resulting from inaccurate, misleading or conflicting information from individuals with similar conditions, various health-care practitioners and the media. Activity avoidance can also come about through the experience of pain during specific activities, forming a learned association between pain and movement.<sup>15</sup> This association may be transferred to movement ranges or tasks which are neither harmful nor painful.<sup>7</sup> For example, patients who recover from back pain tend to maintain a restricted movement strategy even when they are pain-free.<sup>7</sup>

Psychological factors that predate the patient's condition could also contribute to avoidance behaviour. Individuals who are naturally anxious may transfer their fears and avoidance behaviour to their current condition.<sup>15</sup> This phenomenon was demonstrated in a large population study on whiplash injury.<sup>16,17</sup> Individuals who exhibit more fear avoidance, who were anxious and depressed and those who had negative illness behaviour *pre-injury* tended to increase their reporting of a whiplash injury, experience more pain and were more

**Table 11.1** Characteristics of subclassification of patients with problematic fear-avoidance beliefs

Element	Misinformed avoiders	Learned pain avoiders	Affective avoiders
Emotions	Discouraged	Discouraged	Fearful and highly distressed
Beliefs	Pain indicates harm, and the spine is vulnerable	Pain is benign; spine is sound; and pain should be avoided	Distorted significance of pain and concerns about conditions of the spine
Basis of beliefs	Past experiences with back pain. Information from multiple sources	Inherent value of pain versus function	Emotionally charged misinterpretation of medical information
Behaviours	Hypervigilant but usually willing to perform painful activities in a limited way	Choose to stop activities when they are painful	Profound pain inhibition for movements. Will not attempt activities that might induce pain
Disability	Mild to moderate	Mild to moderate	Severe
Co-morbidities	Uncommon	Uncommon	Catastrophizing, anxiety, depression, concurrent musculoskeletal complaints
Treatment	Information and experiences (exercise) that challenge beliefs about the importance of pain and restore confidence in the spine	Unknown (exercises that desensitize the pain response to physical stimuli might be considered)	Address dysfunctional cognitions and catastrophic thinking. Disconfirm fears through gradual exposure to feared activities

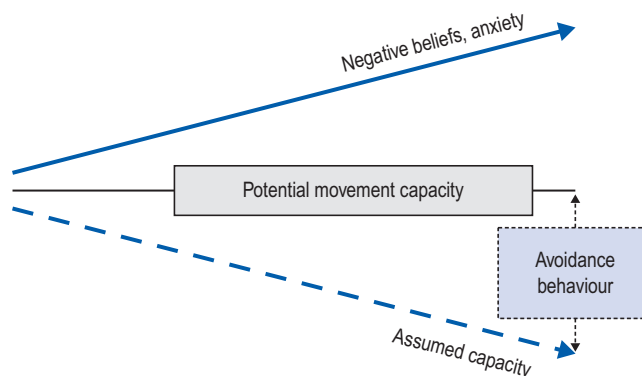
*Modified and reprinted from: Rainville J, Smeets RJ, Bendix T, et al. Fear-avoidance beliefs and pain avoidance in low back pain: translating research into clinical practice. Spine J 2011;11(9):895–903, with permission from Elsevier.*

likely to receive disability support.<sup>16–18</sup> Similarly, the development of serious back pain disability can be predicted more accurately from the psychosocial history of the individual than from structural/degenerative changes in the spine.<sup>19</sup>

The cognitions and anxieties about movement may feed a widening gap between an assumed incapacity and the current “potential” physical capacity (Fig. 11.2). For example, in patients with acute low back pain, pain-related fears and catastrophizing can be more indicative of their physical ability to lift than pain intensity itself.<sup>20</sup> This gap tends to widen with conditions of longer duration or greater intensity.<sup>12,13,21,22</sup> Hence, an important component of ROM management is to narrow this gap by redefining and exploring with the patient what degree of loss is assumed and what is real; and this can sometimes be difficult to establish.

## REASSURANCE

It was demonstrated in patients with chronic back conditions that pain and functionality can improve as much with cognitive–behavioural approaches as

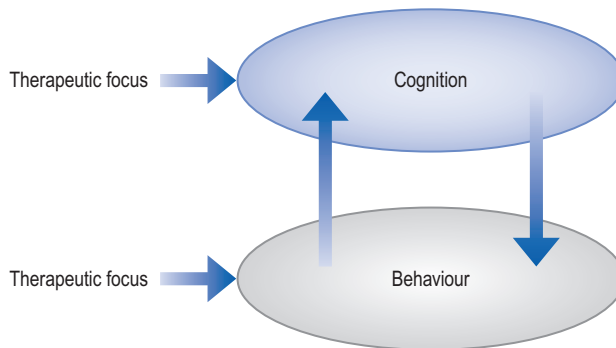


**FIGURE 11.2** Cognitions and anxieties about the condition may feed the avoidance behaviour, widening the gap between the assumed and potential physical capacity. This gap can be reduced by cognitive and behavioural interventions.

with physical exercise.<sup>23,24</sup> It seems that both treatment modalities share a similar underlying process for improvement. They both convey a message to the patient that movement is OK, alleviating the anxiety/fear/catastrophizing associated with the condition.<sup>23,25,26</sup> Reassurance can have a profound influence on recovery. Cognitive, psychological and behavioural transformations can help to reduce pain, improve movement capacity, facilitate a return to more normal occupational and recreational activities and reduce health-seeking behaviour.<sup>23,27–33</sup>

Reassurance can be provided in different forms depending on the factors that underlie the avoidance behaviour. Cognition-related avoidance can be managed by providing the patient with information about the condition.<sup>15</sup> Experience-related avoidance can be alleviated by a gradual reintroduction of tasks and movement ranges from which the patient withdrew (graded exposure), as well as cognitive reassurance.<sup>15,34</sup> Patients who exhibit affective, anxiety-related avoidance may partly respond to behavioural forms of reassurance but may not respond well to reasoning or cognitive reassurance. These patients may benefit from psychological counselling as part of their overall management.<sup>15</sup>

*Cognition and behaviour are inseparable* – a change in cognitions about the condition will influence the person's recovery behaviour. Equally, challenging behaviour by introducing non-aggravating movement experiences can influence how a person perceives their condition and embolden them to experiment with movement which they fear (Fig. 11.3).<sup>35</sup> Hence, reassurance can be provided cognitively or behaviourally, but usually it is a mixture of both.



**FIGURE 11.3** Reassurance can be provided cognitively and/or behaviourally. A change in cognition can bring about a change in behaviour, and equally challenging movement behaviour can bring about a change in condition-related cognitions.

### Cognitive reassurance

When an individual experiences pain or movement limitation they create a personal story about their condition. This internal narrative is derived from numerous sources and previous experiences. It often contains negative messages that are mixed with anxiety and catastrophic thoughts (“shoulder is damaged, seen torn capsules on the internet, a friend had surgery and was unable to play tennis again, will I ever be able to return to playing tennis?”...). An important part of management is to help the patient turn negative narratives into positive ones.

There are several ways in which patients can be helped to transform their cognitions/narratives. Providing patients with relevant information about their condition is an important part of this process;<sup>36–38</sup> in particular, information which they can do something about.<sup>39</sup> Individuals who have a better understanding of their condition are more likely to take up activities that challenge their losses. For example, the patient with the frozen shoulder was given information that emphasized the positive aspect of the condition – that it was self-limiting and unlikely to result in any disability. There was an emphasis on describing the mechanism associated with tissue adaptation and how this process could be facilitated by their behaviour and daily activities. There was also a detailed explanation of the difference between the pain of injury and the pain of sensitization – thereby, *dissociating pain from damage*. Using the same approach, patients who have tissue damage underlying their ROM losses can be informed about tissue repair processes and the importance of movement in supporting these processes, rather than focusing on the extent of tissue damage.

Generally, there is little therapeutic value – and potentially even a negative effect – in using anatomical and biomechanical models for pain or diagnosis that do not support return to function.<sup>40</sup> Patients' fears and anxieties may be increased by a detailed description of underlying damage, and use of terms such as "deterioration" or "degeneration". This may be partly due to the disempowering nature of this form of information which focuses on factors that are outside the patient's control.

Focusing on the "abled self" rather than the "disabled self" can also be part of reassurance – pointing out to patients what they can do, rather than what they cannot do. For example, patients with chronic back pain can be virtually symptom-free during demanding physical activities such as gardening, playing football or even windsurfing. This would be pointed out during the session, focusing on these "abled" activities.

### **Behavioural reassurance**

Behavioural reassurance aims to provide movement experiments in which the patient can reassess what is real and assumed loss. A useful clinical tool to reinforce such positive messages is the graded challenge described in Chapter 6. These movement challenges are performed mostly within pain-free, comfortable ranges, amplifying the four task parameters. It is hoped that through these positive experiences the individual will learn to dissociate movement from pain and injury.

Beyond the session the behavioural reassurance aims to gradually expose the patient to the activities which they fear and avoid.<sup>29–31,41,42</sup> The patient can be invited to make a wish-list of exercise or activities, in order of importance to them. If, for example, the chosen exercise is to return to tennis after shoulder surgery, this would be set as one of the therapeutic goals. The graded challenge can start with serving a tennis ball against a wall for, say, 5 minutes a day, with the serving position below shoulder height. The range parameter can be challenged by incrementally raising the tennis stroke towards shoulder height and gradually above it. The force parameter can be increased by standing further away from the wall, say, doubling the distance. The velocity parameter can be gradually increased by performing the movement faster and endurance by increasing the duration/repetition of strokes. It is important to consult and involve the patient in developing the graded challenge, including the scheduling of the exposure and the setting of short- and long-term goals and time scales for the return to activity.<sup>43</sup>

### ***Reassurance for the therapist***

A common clinical concern for the therapist is the safety of the ROM challenge, i.e. the therapist's anxieties may also create a clinical gap between the real and assumed loss. This is partly associated with assessment and diagnostic uncer-

tainties. Even a simple test such as ROM examination can be misleading. It is often affected by the patient's fear of pain/re-injury, or from the simple fact that physical examinations can be low on either validity or reliability.<sup>44–52</sup> Hence, the actual level of damage can remain undetermined and there is always the possibility that the patient's fears may represent real, safety-related limitations. There is added uncertainty as to how the patient will respond to the treatment. These uncertainties could erode the therapist's own confidence in the safety of the treatment and negatively influence management. It could also feed into the patient's negative beliefs and avoidance behaviour.<sup>53</sup> So therapists also need reassurance.

The solution to this conundrum is not easily achieved during examination. It can be partly determined by understanding pain and tissue repair processes, as was discussed in Chapter 9. However, there is always the niggling thought that we may have missed something during the assessment. Another solution is to accept that uncertainty and plan a management programme within a graded challenge model. With this form of clinical management the physical capacity of the patient can be safely established during the behavioural experiment.

*Clinical note* – in my clinical experience graded challenge has been an invaluable therapeutic tool. Over the years I have managed to help patients return to various activities which they (and I) never imagined they could do again.

## ROM LOSS AND PSYCHOLOGICAL DISTRESS

As a consequence of ROM loss and functionality loss, patients often experience feelings such as disappointment, anger, frustration, grief, helplessness and depression. They may feel that their body has let them down. Such physical losses are often also associated with a negative change in body and self-image.<sup>54–56</sup>

The therapeutic relationship can have an important role in alleviating the psychological distress associated with the condition and in supporting the patient to return to functionality.<sup>37,57,58</sup> Clinical attitudes that include being attentive to the patient's emotional state, empathy, being non-judgemental, caring and encouraging should be the bedrock of management.

Working in the psychological dimension and with body image is discussed in more detail in Lederman.<sup>59</sup>

## SUMMARY

- ROM loss can be maintained by avoidance behaviour due to fear of pain and re-injury



- Anxieties about movement can be due to misinformation, a learned association between pain and movement or from anxiety traits that predate the condition
- The alleviation of movement-related anxieties can be in the cognitive and behavioural dimensions
- In the cognitive dimension, reassurance can be given by providing information about the condition, in particular positive messages that increase the individual's belief in their ability to care for and control their condition
- Reassurance in the behavioural dimension can include a gradual reintroduction of activities which are important for the patient
- Activities can be introduced using the graded challenge
- ROM losses are often associated with psychological distress and should be acknowledged in the patient's management
- Reassurance – it is all about focusing on the “half-filled glass” ...
- What you say can be as important as what you do with the patient

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## Towards a Functional Approach

This chapter will explore how to integrate the various principles discussed in previous chapters into a unified, functional range of movement (ROM) rehabilitation approach.

The principal aim in ROM rehabilitation is to plan a management that takes into account various patient-related processes. They include the processes underlying the ROM loss, such as the dimension in which the ROM loss occurs – are they related to adaptive tissue changes (tissue dimension), motor control losses or sensitization (neurological dimension), or are they related to fear of movement (psychological dimension)? We also need to consider the patient's ability to execute the recovery behaviour. This will determine the level at which the management is pitched – managed, assisted, functional or extra-functional.

This chapter will explore the following topics:

- How is ROM management matched to the patient's condition?
- When do we use functional or traditional stretching?
- When do we use managed or assisted approaches?
- Do different conditions need specific ROM rehabilitation?
- How can we create a recovery environment beyond the session?

### THE POTENCY OF ROM CHALLENGE

Imagine for a moment that ROM rehabilitation is some form of medication rather than a physical procedure. As such, its potency depends of several ingredients which have been identified in the previous chapters: specificity of the challenge (Ch. 5), overloading or amplifying activity at end-range (Ch. 6) and the need for frequent repetition of the ROM challenge (Ch. 7). Added to these is the importance of active versus passive ROM challenges, use of whole rather than fragmented movement and the importance of goal-orientated movement (Ch. 8). ROM management is likely to be more successful when it contains

**Table 12.1** The therapeutic potential of various forms of range of movement (ROM) management. Approaches at the top of the table are likely to be more effective than approaches at the bottom. Traditional stretching approaches are within the shaded area. “Yes/no” implies that the challenge may only provide the effective ingredient in certain situations

	Management/ROM challenge	Effective ingredients for ROM adaptation				
		Specificity	Overloading	Repetition	Active	Whole and goal
Functional	Recovery behaviour	Yes	Yes	Yes	Yes	Yes
	Managed recovery behaviour	Yes	Yes	Yes	Yes	Yes
	Assisted recovery behaviour (functional stretching)	Yes	Yes	No	Yes	Yes
Extra-functional	Ballistic stretching	No	Yes/no	No	Yes/no	Yes/no
	Dynamic stretching	No	Yes/no	No	Yes/no	Yes/no
	Muscle energy techniques	No	Yes/no	No	Yes	No
	Passive stretching	No	No	No	No	No
	Spinal manipulation	No	No	No	No	No
	Traction	No	No	No	No	No
	Articulation	No	No	No	No	No
	Harmonic	No	No	No	No	No
	Strain counter-strain	No	No	No	No	No
	Cranial	No	No	No	No	No

the maximum number of these ingredients and less so as their number declines (Table 12.1).

Using this table, ROM challenges can be grouped into functional and extra-functional approaches and their therapeutic efficacy can be evaluated. The recovery behaviour is at the top of this table as it contains the maximum number of ingredients, providing the ideal conditions required for ROM recovery; it is natural, free and works for most people most of the time. It is followed by managed and assisted recovery behaviour (functional stretching). Below the functional approaches are all the traditional stretching techniques. At this point there is also a drop in the number of the effective ingredients, suggesting a decline in therapeutic potential.

This hierarchy of effectiveness can be exemplified in the active stretching approaches, such as muscle energy techniques. They contain only some of the effective ingredients (overloading and active) and are missing others, such as specificity and repetition. The absence of these ingredients is likely to reduce their therapeutic effectiveness in assisting ROM recovery (see Ch. 1). However, more research is required to explore the relationship between the effective ingredients and therapeutic success. In the meantime, this can be resolved by

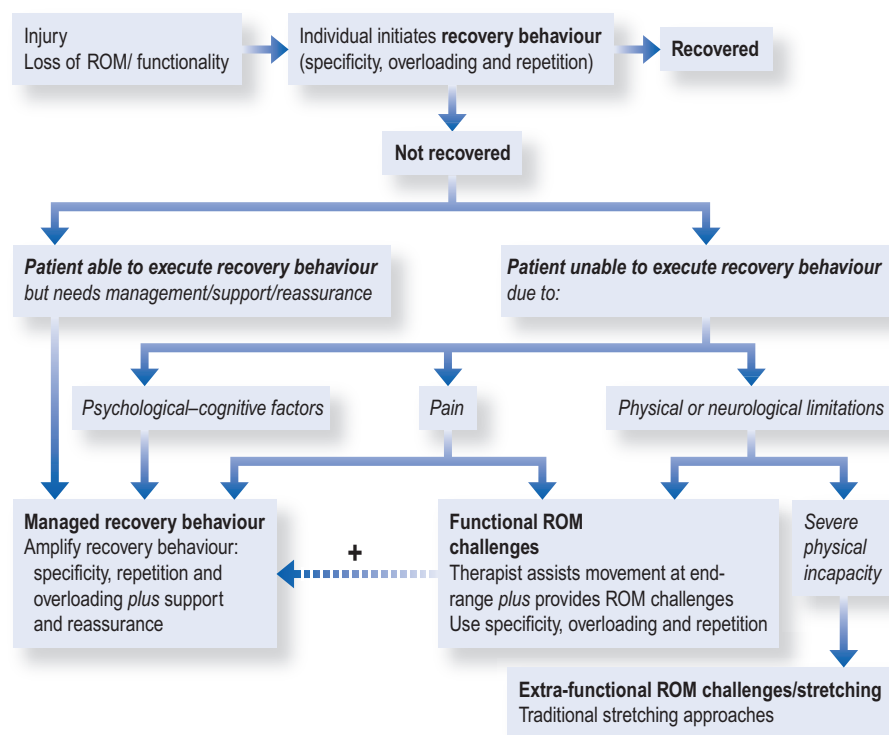
striving to provide the functional ROM management which contains the full set of effective ingredients.

## DETERMINING THE LEVEL AND FORM OF ROM REHABILITATION

Assuming that the patient has a condition which is likely to respond to ROM rehabilitation, the next clinical task is to determine the level of ROM rehabilitation: whether it should be functional (managed or assisted) or extra-functional using traditional stretching methods (Fig. 12.1).

### Recovery behaviour

All patients should be made aware of the benefits of a functional approach, highlighting the importance of specificity, overloading and repetition, i.e. “whatever you do, do more, to the end-limit and more often”. Patients who have the capacity to engage in this behaviour, who are autonomous and who



**FIGURE 12.1** Clinical reasoning in range of movement (ROM) rehabilitation: determining the level and form of ROM challenges.

have high self-efficacy and who are already challenging their movement ranges may need only this general advice.

### ***Managed recovery behaviour***

At a managed level the primary task is to identify daily tasks that provide effective ROM challenges, e.g. for a patient with restricted hip – “do more walking”. It may include focusing and amplifying specific task parameters within these daily activities (force, speed, range and endurance) – “do more walking taking wider steps” (range parameter). It could also include rectifying compensatory patterns that result in underloading of the affected joints, e.g. “avoid swinging the leg to the side when walking”. Within a managed level we also provide psychological–cognitive reassurance, in particular if the patient’s recovery behaviour is impeded by movement-related anxieties – “it might be uncomfortable as you walk but its not causing any damage”.

### ***Assisted recovery behaviour***

This level is important if the patient is capable of performing whole movement, but unable to provide sufficient overloading to effectively challenge their ROM losses. This level of management would be suitable in the early stages after immobilization or when multiple injuries or co-morbidities impede the recovery behaviour. Under these circumstances the end-range can be reached with assistance by the therapist. Once in this position, the patient is encouraged to “take over” and performs different functional tasks (see graded challenge and the task parameters, Ch. 6, and the accompanying video).

Management at the assisted level can result in the patient becoming dependent on the therapist. Since self-care is essential for ROM rehabilitation such attitudes may impede their recovery. Therefore, once the patient demonstrates an ability to perform the ROM challenge effectively they should rapidly progress to a managed approach. This progression may be difficult for patients who have a tendency for low autonomy or low self-efficacy or who have an external locus of health. They will often steer the treatment towards or wish to remain within an assisted approach. Sometimes this attitude of dependency can be difficult to modify. However, it does not represent a significant drawback in minor and short-term ROM losses. At worst the patient may need a few extra treatments. However, dependency becomes a problem in conditions that require longer treatment durations.

### **Management at extra-functional level**

Generally, ROM rehabilitation at the extra-functional level should be reserved for situations in which the patient has lost their movement capacity to a level at which they are unable to carry out the recovery behaviour or whole movement patterns.



Active approaches can be used when a patient is still able to execute an active movement at a particular joint but not whole functional tasks. Passive ROM challenges are provided in full by the therapist. As such, they will only be useful if the patient is unable to execute any active movement. This clinical scenario is seen in motor control losses and contractures following peripheral and central nervous system damage. However, such losses are often persistent and the therapeutic effects of passive stretching are expected to be very limited.

In summary, classifying the challenges by their effective ingredients suggests a therapeutic hierarchy with functional approaches at the top and extra-functional ones at the bottom. This hierarchy is independent of the causative condition, but is dependent on the individual's movement ability, i.e. *the treatment always seeks to be at a functional level regardless of the cause.*

## PROGRESSIVE AND REGRESSIVE MANAGEMENT

A patient has arrived in your clinic complaining of reduced ROM of the hip as a result of a long-term injury. The patient has driven to the clinic, walked in, perhaps having to deal with a few steps on the way. At which level do we start the treatment? Is there any point in treating the patient lying down if they can already walk?

There is no therapeutic value in challenging movement at a level below the patient's capacity. Whenever possible the patient should be treated or trained within their movement capacity. If the patient can stand then rehabilitation of the hip should be in weight-bearing activities. Exercising on the floor or treatment table would be a regressive approach. Below are some considerations for developing a progressive ROM management:

- Avoid extra-functional challenges if the patient is able to perform functional tasks
- Avoid assistance if the patient is able to fully carry out the recovery behaviour
- Avoid fragmentation if the patient is able to perform whole movement
- Avoid a passive approach if the patient is active

Is there a place for a regressive management? It is reasoned that it is easier to train in a recumbent position or to fragment movement and then transfer this experience to more complex functional tasks. Such a training/rehabilitation approach is likely to be ineffective as it is in conflict with specificity and motor control principles (Chs 5 and 8). Another common argument is that regressive management may help to reassure the patient that movement is safe. There may be some merit in this form of reassurance. However, it can also convey the opposite message – that movement is unsafe, especially if the patient is

already able to execute more demanding daily activities. Ideally, reassurance in the form of regressive management should be quickly replaced by the reassurance of progressive management.

In summary, ROM management should always be progressive, striving up to the next level (Table 12.1).

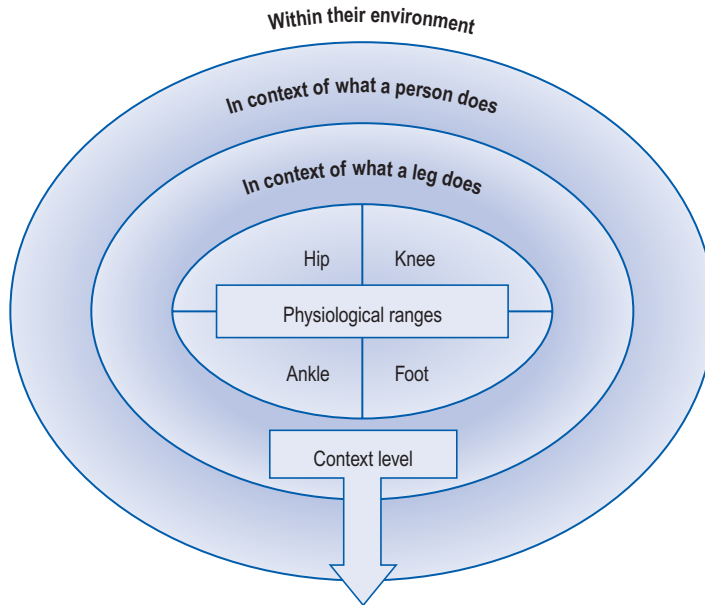
THE CONTEXT SHORT-CUT

The specificity principle provides us with a useful planning short-cut: a context principle. This principle allows grouping of the body into areas that can be rehabilitated in a similar manner.

The body can be divided into areas that typify their role during functional movement (Table 12.2): upper and lower limbs, trunk, and head and neck. The upper limbs are associated with reaching–retrieving, carrying, lifting, manipulation of objects, etc. The lower limbs are associated with weight-bearing activities and locomotion. The trunk is more difficult to classify as it plays a part in all movements. We often associate it with bending, twisting, supporting movements of the limbs such as reaching and stationary positions such as sitting. The head and neck are mostly associated with movement related to the senses, following the gaze or a sound, feeding actions and so on. So, at the basic level of movement context, a joint does what a joint does. A hip, knee, ankle and foot all have their distinct patterns of anatomical movement (physiological range). At the next movement level, all the leg joints move in patterns that reflect what the whole leg does, within the context of what the person does with their legs, within the context of their environment, e.g. stand, run, squat,

**Table 12.2** The context short-cut in managing range of movement (ROM) recovery. Different body areas have typical roles during shared functional movement. Within each area, the ROM challenges are largely universal regardless of the joint affected. Many daily activities can be exaggerated to challenge ROM losses at home. Challenges are an extension of the area's functional role

Body area	Typical role during shared functional movement	Joints affected	Home ROM challenges
Upper limb	Reaching–retrieving, holding, lifting, manipulating objects, etc.	Shoulder, elbow, wrist and hand	Same as functional role but exaggerated (overloading and amplification)
Lower limb	Walk, stand, step over obstacles, stairs, run, etc.	Hip, knee, ankle and foot	Same as functional role but exaggerated (overloading and amplification)
Trunk	Support all movement, bending, side reaching/bending, twisting, sitting, etc.	Lumbar and dorsal spine	Same as functional role but exaggerated (overloading and amplification)
Head and neck	Follow eye movements and sound, feeding, etc.	Cervical joints	Same as functional role but exaggerated (overloading and amplification)



**FIGURE 12.2** Context principle in the leg. All lower limb joints have their unique physiological range of movement (ROM). However, at a functional level ROM rehabilitation is similar for all joints.

climb stairs, play tennis (functional context). Hence, any particular area or joint is rehabilitated in the context of what it does functionally (Fig. 12.2).

Now, let us make an obvious observation: what we do with our arms that we do not do with our legs. This means that, for the joints of the upper limb, the rehabilitation will be unique to that body area, and similar to all the area's joints. Reaching, lifting and manipulating objects can be used to challenge ROM losses in the shoulder but also in the elbow. The choice of challenges would be very different for the legs. Here, weight-bearing and locomotion activities can be used to rehabilitate ROM loss in the hip but equally in the knee or ankle. This line of reasoning can be applied to the trunk and neck. Regardless of the location of ROM restriction, a functional task such as sitting and reaching forwards or sideways will challenge the spine as a whole, dorsal and lumbar. Similarly the neck can be challenged with the head leading the movements. For example, rotation ROM can be challenged by holding a book further to the left or right while reading.

There is a further management advantage in a contextual line of reasoning. The movement challenges will be mostly the same for restrictions due to meniscus or anterior cruciate ligament surgery or contractures following immobilization. Regardless of the cause, the knee still has to move within its

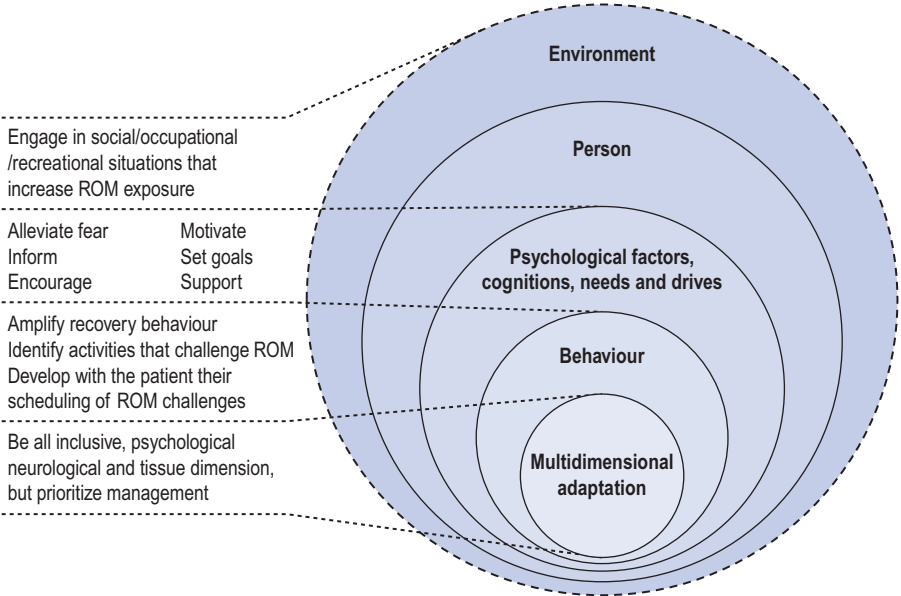
physiological ranges, which in turn need to be challenged within the context of what the person does with the leg in their environment (get up, walk, play tennis, etc.).

Overall, the context principle promotes management economy. It only requires the awareness of the functional role of the area being rehabilitated rather than having to learn and apply a range of specific exercises for each joint or for different conditions.

CO-CREATING A ROM RECOVERY ENVIRONMENT

All adaptation processes associated with ROM recovery depend on the individual’s actions within their environment. ROM rehabilitation should therefore be all-inclusive, multidimensional and addressing the person within their environment (Fig. 12.3).

At the interaction of the person and their environment the patient can be encouraged to identify social, occupational or recreational situations that would increase their exposure to ROM challenges. In the psychological and cognitive dimensions management focuses on alleviating fear, providing information about the condition, which empowers the patient, setting goals and supporting the patient in the journey of recovery.



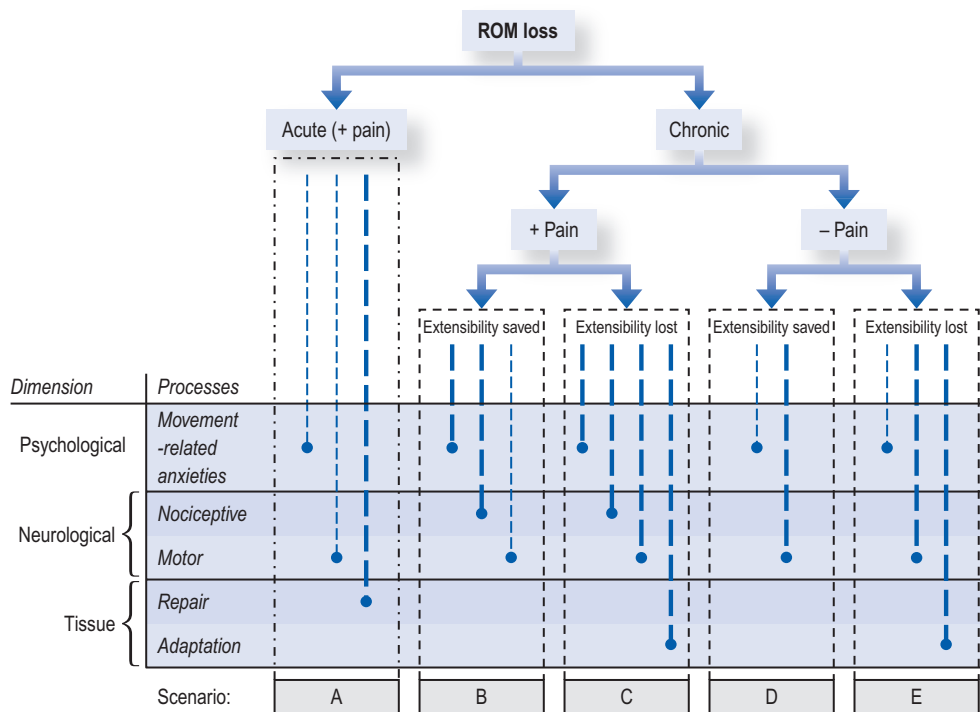
**FIGURE 12.3** Co-creating a multidimensional environment for range of movement (ROM) recovery.

In the behavioural dimension the focus is on amplifying the specificity, overloading and repetition components of the recovery behaviour. Behavioural management also includes engaging the patient in daily activities and amplifying them to provide effective ROM challenges. The scheduling of the ROM challenges – how often and for how long – are also within this behavioural sphere.

### Prioritizing management

The general aim of a functional approach is to be all-inclusive, exploring the multidimensional processes associated with the patient's condition. However, management that is all-inclusive can be too complex to execute and can come at the cost of being unfocused and even ineffective. Hence, in clinic, we are often required to prioritize management and focus on particular processes.

Generally, prioritizing works on what process requires most immediate attention: it is about short- and long-term treatment goals. This is exemplified in Fig. 12.4:



**FIGURE 12.4** Prioritizing and minimizing management. Different forms of range of movement (ROM) losses require unique management (dashed lines) and prioritization (heavier dashed lines).

- A: Represents an acute injury. Here, the priority is to support repair processes (tissue dimension). In these conditions, rehabilitation of motor control is not urgent and can be added at a later date if active ROM losses are present (neurological dimension). All that is needed is to reassure the patient that movement is beneficial and to maintain daily activities (psychological dimension).
- B: In this scenario, ROM losses are chronic and are associated with pain and sensitization, but there are no obvious adaptive tissue changes, for example chronic low back and neck pain. Here, the priority is within the neurological and psychological dimensions, working with nociceptive processes and desensitization as well as with psychological–cognitive and behavioural factors associated with pain experience. Rehabilitation of motor control ROM could wait, but daily activity should be maintained to prevent disuse. In this scenario, ROM challenges directed at tissue processes are unlikely to be therapeutically useful, e.g. passive stretching.
- C: In this scenario, the patient presents with ROM loss associated with adaptive tissue shortening and pain, e.g. “fresh” post-surgical contracture. This is probably the most complex management. It often requires working simultaneously in all three dimensions. However, if the pain is moderate to severe, desensitization and pain alleviation may become the treatment priority. The treatment can progress to the tissue dimension (adaptive tissue changes) and neurological dimension (motor control) when pain levels become more tolerable.
- D: This example may represent a patient who has active ROM losses, such as muscle weakness, but not associated with adaptive tissue shortening or pain. The treatment priority in this case would be on motor control / neuromuscular recovery (neurological dimension).
- E: This scenario is commonly observed after immobilization. Here, the priority is to drive the adaptation in the tissue and to recover motor control. If psychological factors are present, such as fear avoidance, they should also be addressed in the management.

## SUMMARY

- This chapter discusses how to plan a ROM rehabilitation treatment using a functional approach and how to match the management to the patient’s condition
- ROM challenges that contain effective ingredients from the recovery behaviour are likely to be more effective than approaches that have fewer of these components
- ROM challenges are likely to be more effective if they are task-specific, repetitive, active, provide overloading and use goal and whole movement

- Functional ROM challenges, including managed and assisted approaches, all contain the effective ingredients necessary for ROM adaptation
- Extra-functional ROM challenges, including all traditional passive and active stretching approaches, provide only a few or none of the effective ingredients
- Passive approaches provide no effective ingredients and may therefore, be least effective for ROM recovery
- ROM rehabilitation should strive to function at a level that matches the individual's movement capacity
- Regressing to a lower level, below the patient's current capacity, is likely to reduce effectiveness and may prolong recovery
- Joints should be challenged within their role in the overall movement of the limb and in the context of the movement repertoire of the individual
- Many daily activities can be exaggerated to challenge ROM losses at home. This should be the emphasis of the management
- Message to the patient - your everyday activities play a crucial role in your recovery

# Demonstration of Functional Approach in ROM Rehabilitation

This chapter explores the use of functional range of movement (ROM) rehabilitation within a clinical setting. The demonstration will focus on the ROM rehabilitation of the upper limb (shoulder and elbow) and trunk. The management approach described for these areas can be applied elsewhere in the body. The book is accompanied by a video demonstration of the ROM challenges, which can be viewed online at: [www.therapeuticstretch.com](http://www.therapeuticstretch.com).

## GENERAL PRINCIPLES FOR FUNCTIONAL STRETCHING

There are several principles to consider during functional ROM challenges:

- Use movements that resemble normal daily activities
- Use external goals – provide instructions such as “Reach for my hand” or “Reach for the opposite wall”. Avoid internal prompts such “Bend your elbow” or instructions that are directed to particular muscles. If internal instructions become necessary, incorporate them into the overall task, e.g. “While reaching for my hand try to straighten your elbow”.
- Amplify the four movement parameters within the task, in particular the ones most affected
- Mix ranges and planes
- Mix end- with full-range challenges
- Mix dynamic and static tasks
- Mix all of the above – this will enhance generalization within the task

## CONTENTS OF THE DEMONSTRATION

- 13.1. Demonstration of principles
  - 13.1.1 Amplifying movement parameters during a dynamic task
  - 13.1.2 Amplifying movement parameters during a static task
  - 13.1.3 Alternating between dynamic and static tasks



- 13.1.4 Context and localization of amplification
- 13.1.5 Mixing ranges and planes
- 13.1.6 Overcoming compensatory movement patterns
- 13.1.7 Therapist's stance and patient handling
- 13.2. Shoulder ROM challenges
  - 13.2.1 ROM challenge during dynamic tasks
  - 13.2.2 ROM challenges during static tasks
  - 13.2.3 Guided challenge within a functional task
  - 13.2.4 Assisted supine ROM challenges
- 13.3. Elbow ROM challenges
  - 13.3.1 Assisted supine
- 13.4. Trunk ROM challenges
  - 13.4.1 Standing challenges
  - 13.4.2 Seated challenges

## 13.1. DEMONSTRATION OF PRINCIPLES

### 13.1.1 Amplifying the movement parameters during a dynamic task

Fig. 13.1A–D: Challenging the force parameter in the task, such as reaching and retrieving. Resistance can be provided by use of heavier objects or varying degrees of resistance from the therapist (See further in this chapter).







Fig. 13.2A–D: Challenging the range parameter with the reaching–retrieving task. Here, the range parameter is challenged within the same plane (range-on-range), flexion–extension.









Fig. 13.3A,B: Challenging the range parameter of the same task but in a different plane, i.e. reaching and retrieving within abduction-adduction.





Notes on task parameters:

- For the velocity parameters any of the above movements can be performed at slower or greater speeds.
- The endurance parameter can be challenged by repetition of the same movement.
- Task parameters can be mixed. For example, the force can be combined with the velocity challenges, for instance by using the heavier bottle at progressively greater speeds.

### 13.1.2 Amplifying movement parameters during a static task

Fig. 13.4A–D. Many functional activities contain static tasks. This is reflected in challenges where the patient is instructed to hold the same position. In the following example the patient is instructed to hold the bottle and maintain it in the same position.

Fig. 13.4A,B: Challenging the force parameter during a static task.



Fig. 13.4C: Here, the range parameter is challenged in different ranges, abduction and full flexion (in Fig. 13.4D).





Notes about task parameters during static activities:

- Static endurance parameters can be challenged by maintaining the position for longer durations.
- Static velocity is how rapidly a person can generate a peak force while maintaining their position. This can be achieved by adding an external perturbation (by the therapist) while the patient maintains their position (see Fig. 13.16B). This challenge is demonstrated in the accompanying video.

### 13.1.3 Alternating between dynamic and static tasks

Fig. 13.5A,B: Alternating between a dynamic task (Fig. 13.5A) and a static task (Fig. 13.5B). In the dynamic task the patient is instructed to touch the therapist's hand. In the static task the patient is instructed to maintain the position and the therapist applies anterior-posterior perturbation in the same plane as the dynamic task. The alteration between dynamic and static task is often introduced at a progressively faster rate and can eventually be applied randomly.





Fig. 13.6A,B: Another example of alternating between dynamic (Fig. 13.6A) and static (Fig. 13.6B) challenges. The instruction in the dynamic task is “Place the bottle on my hands”, whereas in the static task the instruction is “Hold the bottle in the same position. Stop me from moving it”.





#### 13.1.4 Context and localization of amplification

The context principle suggests that tasks that typify arm movement can be used to challenge all the joints in the upper extremity (and the rest of the body). Some localization to specific areas/joints can be achieved by positioning of the limb or changing the nature of the task. However, it should be noted that such localization of movement can be difficult to achieve clinically, in particular when ROM limitation in specific joints is compensated for by excessive movement in adjacent areas. This is further discussed in section 13.1.6 (overcoming compensatory movement patterns).

Fig. 13.7A,B: Localizing a dynamic challenge to the elbow. The therapist supports the patient's elbow and instructs them to gently tap the rolled up paper against the therapist's hand. This produces end-range flexion-extension cycles in the elbow with little dynamic activity from the shoulder (however, the shoulder is statically active).





Fig. 13.8A,B: Localizing the dynamic challenge to the shoulder (flexion-extension cycles, but also in the elbow). The patient is instructed to alternately tap the rolled up paper between the therapist's hands.



### 13.1.5 Mixing ranges and planes

Normal functional movement is highly variable and often involves multiple planes. Generalization of training may occur more readily when end-ranges are mixed with the whole-range challenges, as well as performing the same task in different planes (this is better demonstrated in the accompanying video).

Patients who are unable to perform a movement in a particular range can be still challenged in that range (primary challenge) but with movements in another plane (secondary challenge). This principle of primary and secondary challenges is demonstrated in this section.

Fig. 13.9A–C: Imagine a clinical situation in which the patient is unable to elevate the arm in abduction above shoulder height. In this situation they are instructed to raise the arm to their end-range (primary challenge). While in that range they can be instructed to perform a movement challenge (secondary challenge). In this example, internal–external rotation (secondary challenge) is imposed on the abducted shoulder (primary challenge).







Fig. 13.10A–C: In this example, the primary challenge is external rotation with superimposed secondary abduction–adduction challenges.







Fig. 13.11A–D: In this example, the primary challenge is internal rotation. The patient is instructed to imagine that they are “washing their back”. This task produces secondary abduction–adduction cycles (superimposed on internal rotation).



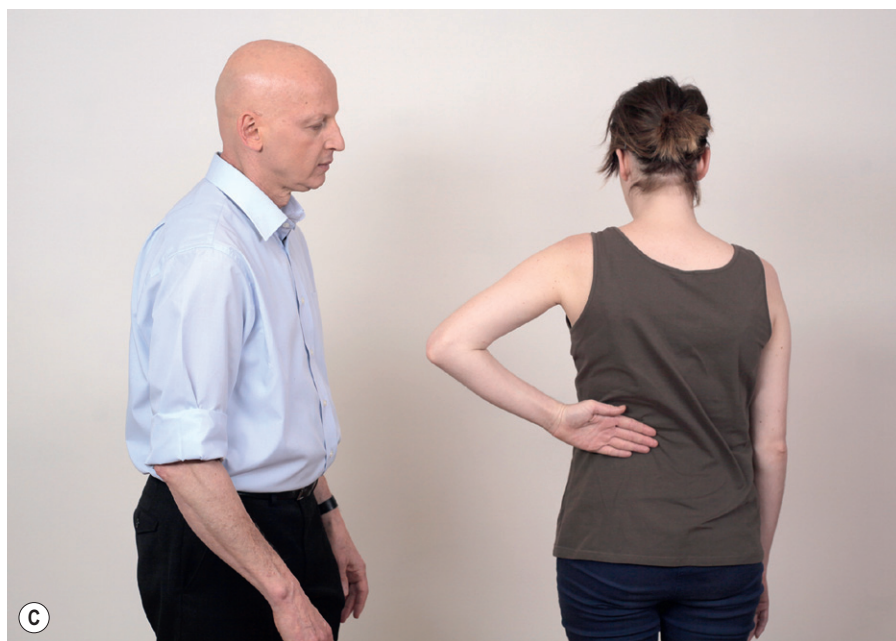




Fig. 3.12A,B: Primary and secondary challenges exemplified in the elbow. Imagine a patient who has a flexion contracture in the elbow. They are encouraged to extend to their end-range (primary challenge). They are then instructed to perform a task such as “closing and opening a lid”, imposing a secondary pronation–supination challenge on the elbow.







### 13.1.6 Overcoming compensatory movement patterns

One common problem with ROM loss is compensatory movement patterns elsewhere, which may reduce the efficacy of rehabilitation. Often, these compensatory patterns can be overcome by small modifications of the task, while keeping the focus of attention towards external goals.

Fig. 13.13A: A person with shoulder abduction ROM loss will often compensate by side-bending when reaching up (see angle between thorax and upper arm).



Fig. 13.13B: The compensatory side-bending can be overcome by placing the movement goal further to the side.

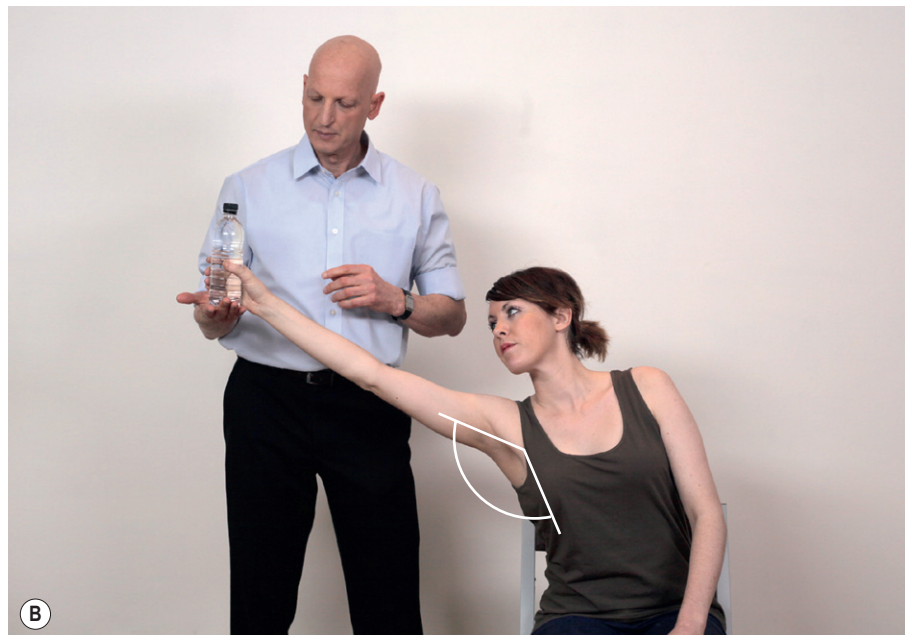


Fig. 13.14A: Shoulder flexion restrictions are often compensated for by the patient arching back.

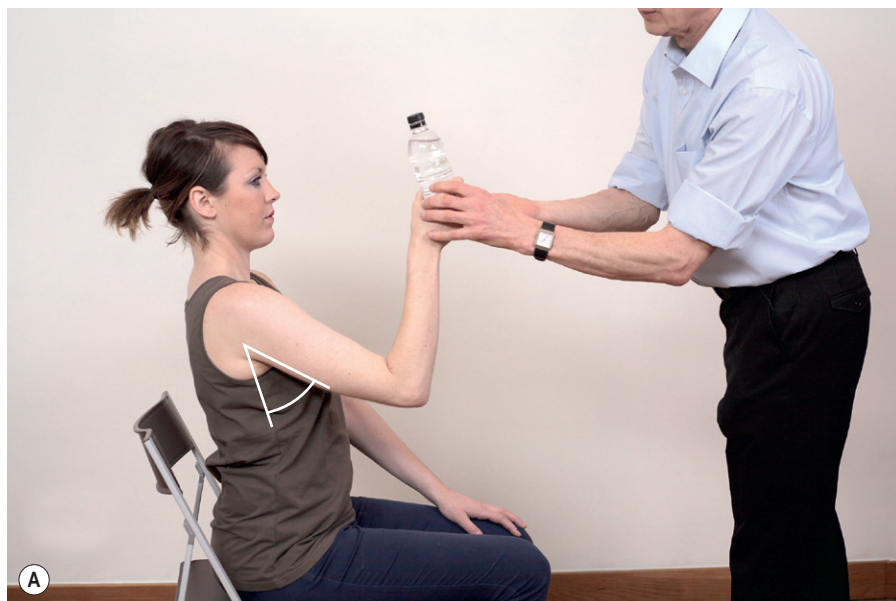


Fig. 13.14B: The extension compensation can be overcome by placing the movement goal further to the front.





Fig. 13.15A: A movement such as reaching back is often compensated for by rotation of the whole body.



Fig. 13.15B: Trunk rotation can be overcome by instructing the patient to hold the back of the chair with the opposite arm. The patient is then instructed to reach over to touch the therapist's hand as in Fig. 13.15A



### 13.1.7 Therapist's stance and patient handling

Fig. 13.16A,B: Demonstrating the hand-hold in challenges in which the therapist is providing the resistance.





Fig. 13.17A,B: Keep the hand-hold close to your body, using your own body to provide the resistance force. Keep this close contact throughout the movement cycle.



Fig. 13.18: Avoid hand-holds that are away from your body. Such hand-holds are more fatiguing for the therapist.



Fig. 13.19A,B: Throughout the movement cycle, shift your body weight between the legs. Avoid bending with your trunk or working with the top of your body.





## 13.2. SHOULDER ROM CHALLENGES

### 13.2.1 ROM challenge during dynamic tasks

Fig. 13.20A–F: Range challenge/single plane/free movement/flexion–extension cycles. Demonstrating progressive increase in flexion range. Instructions to patient: “Reach and tap my hands”.











Fig. 13.21A,B: Range + force challenge/single plane/flexion–extension cycles. Instructions to patient: “Pull and push me”.







Fig. 13.22A-E: Range challenge/single plane/free movement/adduction-abduction cycles. Demonstrating progressive increase in abduction range. Instructions to patient: "Tap my hands".









Fig. 13.23A,B: Range challenge/single plane/free movement/adduction–abduction cycles. The range challenge should be mixed between end- and full-range challenges to promote generalization of training gains. Here, full range is introduced following the end-range challenges seen in Fig. 13.22E.





Fig. 13.24A,B: Range + force challenge/single plane/adduction–abduction cycles. Instructions to patient: “Pull and push me”.



Note: hand-hold close to the body and the use of body weight to provide resistance.

Fig. 13.25A–D: Range challenge/single plane/free movement/internal–external rotation cycles. Demonstrating a progressive increase in shoulder rotation range. Instructions to patient: “Touch your tummy and then reach for my hand”, or “Touch your tummy, and reach for the wall behind”.



Fig. 13.25C: Note: patients tend to rotate with the trunk to compensate for loss of rotation range in the shoulder. This can be overcome by instructing the patient to hold the back of the chair with the opposite arm.





Fig. 13.26A,B: Range challenge/free movement/internal–external rotation cycles. Instructions to patient: “Touch your tummy, reach for my hand”.





Fig. 13.27A–D: Range + force challenge/single plane/internal rotation cycles. Demonstrating the hand-hold: using the hand closer to the table, the therapist holds the patient's wrist. The elbow is supported with the other hand.



Fig. 13.27B: It is important that the therapist keeps their elbow tucked into the side of their body to provide resistance to the movement.



Fig. 13.27C: Throughout the movement, the therapist resists both internal and external rotation. Instructions to patient: "Touch your tummy, touch your back".



Fig. 13.28A-D: Range + force challenge/mixed planes/internal rotation to flexion cycles. Therapist provides resistance through the cycle. Instructions to patient: "Touch your back, reach for my hand".







Fig. 13.29A,B: Range + force challenge/mixed planes/internal rotation to abduction cycles. Therapist provides resistance throughout the cycle. Instructions to patient: "Touch your back, reach for my hand".



Fig. 13.30A,B: Range + force challenge/mixed planes/internal–external rotation cycles. Therapist provides resistance throughout the cycle. Instructions to patient: “Touch your back, touch the top of your head”.





Fig. 13.31A: Seated position shoulder challenges. Demonstration of therapist stance and patient handling. The therapist rests the length of their forearm along the upper border of the patient's scapula, to reduce excessive scapular compensation/elevation during overhead arm movements. The therapist's hip should be in contact with the lateral border of the scapula to further reduce scapular winging.





Fig. 13.31B: Demonstration of hand-hold. Instructions to patient: "Reach for the ceiling" (Fig. 13.31B), "Reach for your head" (Fig. 13.31C), "Reach for the wall beside you" (Fig. 13.31D) and "Reach to the wall in front" (Fig. 13.31E). Therapist provides resistance throughout the movements. Once in full flexion (primary challenge), the patient can be instructed to "Draw circles on the ceiling" (circumduction movement), "Imagine you are waving a flag" (adduction-abduction movements), "Imagine you are painting the ceiling" (flexion-extension movement), or "Draw numbers from 0 to 10 on the ceiling" (combination of movements). Variation: draw larger numbers, more vigorous large-amplitude waving, etc. Mix the sequence of all these movements.





Fig. 13.31D: Once in abduction the patient can be instructed to “Draw circles on the wall to the side”, “Imagine you are painting the wall” or “Draw numbers from 0 to 10 on the wall to the side”. In essence, the instruction should be associated with daily tasks that challenge the particular movement patterns.





Fig. 13.32: Range + force/primary challenge internal rotation/secondary challenge adduction–abduction. Instructions to patient: “Wash your back” or “Pull and push me”.





### 13.2.2 ROM challenges during static tasks

Fig. 13.33A,B: Range + force/static/flexion–extension cycles. Patient maintains position while the therapist introduces perturbations in the lateral plane. Instructions to patient: “Hold your arm in this position. Stop me from moving you”.



Fig. 13.34A,B: Range + force/static/abduction–adduction cycles. Patient maintains position while the therapist introduces perturbations in the lateral plane. Instructions to patient: “Hold your arm in this position. Stop me from moving you.”



### 13.2.3 Guided challenge within a functional task

The guided challenges are the most important group in ROM rehabilitation as they closely resemble normal daily challenges of reaching and retrieving. A close resemblance between the clinical challenges and the affected functional tasks can help the patient conceptualize and apply the ROM rehabilitation principles in their home and work environment.

Fig. 13.35A–D: Range + (low) force/free movement/flexion–extension cycles. Demonstrating progressive increase in flexion range. Instructions to patient: “Place the bottle on my hands” or “Move the bottle from one shelf to another”.











Fig. 13.36A–C: Range + (low) force/free movement/abduction–adduction cycles. Demonstrating progressive increase in abduction range. Instructions to patient: “Place the bottle on my hands” or “Move the bottle from one shelf to another”.





Fig. 13.37A,B : Range/primary challenge abduction/secondary challenge internal–external rotation. Instructions to patient: “Put the bottle on the shelf and then pour it onto the other hand”.





Fig. 13.38A–D: Range + force/flexion–extension cycles. The therapist instructs the patient to “Put the bottle on the hand/shelf” while providing resistance throughout the upward and downward movement. Variations: this challenge can also be performed in abduction–adduction ranges, rotation, etc.





Fig. 13.39A,B: Range/free movement alternating with resisted movement/ flexion–extension cycles. The therapist holds the bottle at the end-range of the patient’s reach. The patient has to grab the bottle and pull it to the “lower shelf” against the therapist’s resistance (Fig. 13.39B).





Fig. 13.40A,B: Range/free movement alternating with resisted movement/abduction–adduction cycles. The therapist holds the bottle at the end-range of the patient’s reach. The patient has to grab the bottle and pull it down to the “lower shelf” against the therapist’s resistance (Fig. 13.40B).





### 13.2.4 Assisted supine ROM challenges

Assisted supine techniques can be useful to localize the tissue loading to the glenohumeral joint. This is particularly useful in shoulder conditions in which there are excessive compensatory scapular movements owing to glenohumeral contractures (e.g. frozen shoulder).

Fig. 13.41: Patient positioning, handling and operator stance. The patient is positioned on the table diagonally with their affected shoulder overhanging the edge of the table. The therapist makes contact with their hip and the patient's lateral border of the scapula. This serves to limit scapular protraction–abduction. Using the fist the therapist then depresses the scapula from above. The therapist then leans and rests their fist firmly into the table surface. This serves to prevent scapular elevation. At this point the scapula is locked into position and movement of the shoulder will largely take place in the glenohumeral joint.



Fig. 13.42: Range/free movement/primary challenge flexion. From the locked position described in Fig 13.41, the patient is instructed to reach to the wall behind and given instructions such as "Draw circles on the wall behind" or "Draw numbers from 1 to 10".



Fig. 13.43: Range/free movement/primary challenge abduction. From the locked position described in Fig 13.41, the patient is instructed to reach to the wall to the side. In this position they are given instructions such as “Draw circles on the wall behind” or “Draw numbers from 1 to 10”.



Fig. 13.44: Range + force/primary challenge flexion. The scapula is locked in position as in Fig 13.41. The therapist holds and resists the patient's arm movements. In this position, the patient is instructed to reach to the wall behind and given instructions such as "Draw circles on the wall behind", "Draw numbers from 1 to 10", "Imagine you are waving a flag", etc.



Fig. 13.45: Range + force/primary challenge abduction. Scapular locking: as in Fig. 13.41. Resistance and instructions to patient: as in Fig. 13.44.



Fig. 13.46: Range + force/external rotation to abduction and flexion. The patient is instructed to touch the top of their head (external rotation) while the therapist provides resistance throughout the range. From this position, the patient is instructed to touch the wall behind (external rotation to flexion) or the wall to the side (external rotation to abduction). This challenge can be mixed with the static challenges or with challenges such as drawing numbers on the wall to the side or behind the patient.





Fig. 13.47A,B: When glenohumeral contractures are present the patient may experience difficulties in touching their head while maintaining external rotation. The therapist can reinforce/assist the external rotation by holding the elbow down while the patient attempts the movement.



Fig. 13.48A,B: Range + force/flexion–extension cycles. In this position, the shoulder is taken into full possible flexion and the patient is instructed to perform small amplitude flexion–extension cycles against the therapist’s resistance. Note the therapist’s hand-hold and position, using their body weight to provide the resistance. Instructions to patient: “Push me away and then pull me towards you”, “Repeat this movement”.



Fig. 13.49A,B: Range + force/abduction–adduction cycles. In this position, the shoulder is taken into full possible abduction and the patient is instructed to perform small-amplitude abduction–adduction cycles against the therapist’s resistance. Note the therapist’s hand-hold and position, using their body weight to provide the resistance. Instructions to patient: “Push me away and then pull me towards you”, “Repeat this movement”. Variation: this small end-range movement can be challenged in different ranges by the therapist walking in an arc from standing behind to standing to the side of the patient (see video).







Fig. 13.50A,B: Range + force/primary challenge: abduction/secondary challenge: flexion–extension cycles. The shoulder is abducted to the possible end-range. In this position, the patient is instructed to push up towards the ceiling (flexion) and pull down towards the floor (extension). The therapist provides resistance throughout the movement. As the condition improves, the shoulder can be taken further into abduction.





Note the therapist's hand-hold and position, and use of body weight to provide resistance.

### 13.3. ELBOW ROM CHALLENGES

Fig. 13.51A,B: Range/free movement/primary challenge: elbow extension/secondary challenge: pronation–supination. The elbow is extended to the full possible end-range. In this position, the patient is instructed to “Open and close the lid” from one hand to the other.







Fig. 13.52: Range + velocity/free movement/primary challenge: elbow extension/secondary challenge: pronation. The elbow is extended to the full possible end-range. Holding a paper roll by the end, the patient is instructed to tap the therapist rapidly and repeatedly. In conditions in which pronation is limited, the elbow may need to be supported to reduce compensatory internal rotation of the shoulder.



Fig. 13.53: Range + velocity/free movement/primary challenge: elbow extension/secondary challenge: supination. The elbow is extended to the full possible end-range. Holding a paper roll, the patient is instructed to tap the therapist rapidly and repeatedly. In conditions in which supination is limited the elbow may need to be supported to reduce compensatory movement of the shoulder.



Fig. 13.54A,B: Range + force/primary challenge: elbow extension/secondary challenge: elbow pronation–supination. The elbow is extended to the full possible end-range. Holding a paper roll by the middle, the patient is instructed to “Open and close the lid” repeatedly. The therapist provides resistance throughout the movement.





Fig. 13.55: Range + force/primary challenge: supination/secondary challenge: elbow flexion–extension cycles. Instruction to patient: “In this position pull me towards you and then push me away from you”.



Fig. 13.56: Range/free movement/primary challenge: supination/secondary challenge: elbow flexion–extension cycles. Instruction to patient: “Maintain the hand position, tap my top and bottom hand”.



Fig. 13.57: Range/free movement/primary challenge: pronation/  
secondary challenge: elbow flexion–extension cycles. Instruction to  
patient: “Tap my hand”.



Fig. 13.58A,B: Range + velocity/free movement/flexion–extension cycles  
at end-range. Instructions to patient: “Tap my hand with the paper roll  
as fast as you can”.





Fig. 13.59A,B: Range + force/primary challenge: flexion–extension (or supination)/secondary challenge: supination (or flexion–extension). Instructions to patient: “Push and pull me”. Variation: to add the force parameter, use another target and instruct the patient to hit it as hard as they can.







Fig. 13.60A,B: Range + force/primary challenge: flexion–extension (or pronation)/secondary challenge: pronation (or flexion–extension). Instructions to patient: “Push and pull me”.





### 13.3.1 Assisted supine

Assisted supine elbow challenges are useful for localizing the force to that joint and to reduce excessive compensatory shoulder movements.

Fig. 13.61A: Close-up of the practitioner's handling position and stance. The therapist fixes the patient's shoulder with their forearm. This will check compensatory movement of the shoulder.



Fig. 13.61B: Next, the therapist cups and holds the patient's elbow and the arm is rested on the table.



Fig. 13.62: Range + force/flexion–extension cycles. In this position the patient is instructed: “Reach for the top of the table and then to the shoulder; keep repeating that movement”.





Fig. 13.63A,B: Range + force/primary challenge: flexion–extension cycles/  
secondary challenge: pronation–supination. The elbow is extended to  
the possible end-range. Instructions to patient: “Touch your tummy.  
Touch the table with the back of your hand” (Fig. 13.62B).



## 13.4. TRUNK ROM CHALLENGES

### 13.4.1 Standing challenges

The trunk challenges serve two purposes: to challenge end-range and to promote ROM desensitization. It is well established that, in many chronic back pain conditions, ROM losses may be associated with sensitization and fear avoidance rather than true shortening or stiffening of joints/tissues. In my clinical experience it is very rare to see individual who have severe tissue related spinal ROM losses. Often the challenges demonstrated below are used for trunk ROM desensitization. These challenges are preformed within the pain-free ranges. During successive cycles, the therapist (surreptitiously) moves the target further away to increase the range. Often, there is an increase in the pain-free end-range after a few repetitions of the same movement. This form of challenge can also be used to reassure the patient that the movement is safe (Ch. 11).

Fig. 13.64A,B: Range/free movement/rotation. Instructions to patient: "Keep the hands together, keep the arm straight. Touch my hands".





Fig. 13.65A,B: Range/free movement/flexion–extension cycles.







Fig. 13.66A,B: Range/free movement/complex mix of spinal movement ranges.





Fig. 13.67A,B: Range/free movement/primary challenge: extension/  
secondary challenge: side-bending and rotation.





Fig. 13.68: Range/free movement/complex side-bending, flexion-extension and rotation. The patient is instructed to draw numbers on the opposite wall (0–10). As the patient's pain-free range increases the movement can progress from small- to large-amplitude numbers.



Fig. 13.69: Range/free movement/primary challenge: rotation/secondary challenge: complex side-bending and flexion–extension cycles.  
Instructions to patient: “Draw numbers from 0 to 10 on the opposite wall”. As in Fig. 13.68, but the patient draws the number while fully rotated.





Fig. 13.70: Range/free movement/primary challenge: side-bending. As in Figs 13.68 and 13.69, the patient is instructed to reach for the therapist's hand and draw numbers on the wall to the side.



Fig. 13.71A,B: Range/free movement/different forms of life-like side-bending.





Fig. 13.72A–C: Range/free movement/rotation. Variation of trunk rotation challenge using reaching movements. Often, side-bending exercises given during rehabilitation are dissimilar to movement patterns observed during daily activities. In this example, the patient is reaching towards the therapist's hand, producing more functional side-bending movements of the trunk (this is also useful for shoulder rehabilitation). Instructions to patient: "Reach and touch my hands".





Fig. 13.73A,B: Same as challenge in Fig 13.71 but using an everyday object to highlight the functional purpose of the challenge.



### 13.4.2 Seated challenges

Seated trunk challenges can be useful to localize the movement to the trunk. However, patients with low back pain may find these challenges aggravating. They should be used only in conditions where there are tissue-related ROM losses.

Fig. 13.74A,B: Range/free movement/flexion–extension cycles.

Instructions to patient: “Move the bottle from one hand to the other”.







Fig. 13.75A,B: Range/free movement/rotation. Instructions to patient: "Move the bottle from one hand to the other".





Fig. 13.76A,B: Range/free movement/side-bending. Instructions to patient: "Place the bottle from one hand to the other".





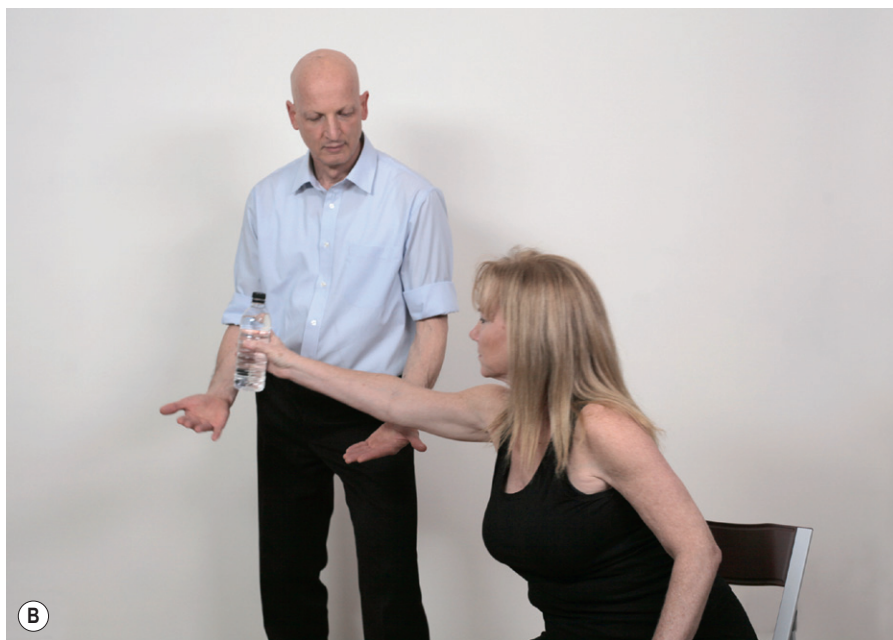


Fig. 13.77A,B: Range/free movement/mix of ranges. Instructions to patient: "Place the bottle from one hand to the other".





# Summary

## WHAT IS THERAPEUTIC STRETCHING?

- Stretching is the behaviour a person adopts to recover, increase or maintain their range of movement (ROM)
- Therapeutic stretching is the process used to recover or improve ROM
- ROM challenges are the different techniques and methods used to achieve ROM change

## WHAT MODEL IS USED FOR THERAPEUTIC STRETCHING?

- The therapeutic stretching promoted in this book uses a functional model for ROM rehabilitation
- A functional approach aims to employ the patient's own movement repertoire to facilitate ROM recovery
- It is based on the principles of recovery behaviour. It is the behaviour a person adopts to recover their functionality after injury or immobility
- The recovery behaviour contains three traits that are important for ROM recovery: specificity, overloading and repetition
- Specificity is how closely the ROM challenge resembles the affected functional movement. Overloading is the progressive increase in physical demands on the affected movement, and repetition is the overall exposure to the challenge
- ROM recovery is associated with three recuperative processes in the body: repair, adaptation and symptomatic relief; processes that encompass the tissue, neurological and psychological-behavioural dimensions
- ROM rehabilitation aims to engage the patient in behaviour that facilitates these recuperative processes
- ROM recovery is a multidimensional process intrinsic to the individual but also highly influenced by their environment. Hence, in functional

rehabilitation we aim to co-create with the patient environments that challenge their ROM losses

## HOW ARE THERAPEUTIC STRETCHING TECHNIQUES CLASSIFIED?

- ROM challenges can be either functional or extra-functional
- Functional challenges are active approaches that resemble daily movement patterns. Extra-functional challenges are dissimilar to normal daily patterns
- The functional approach contains managed and assisted recovery behaviour
- In managed recovery behaviour the therapist helps the patient to develop a self-care daily programme using specificity, overloading and repetition components of the recovery behaviour
- In assisted recovery behaviour, the therapist provides physical assistance during functional tasks
- All traditional stretching methods, whether active or passive, are extra-functional

## WHY DO WE NEED A FUNCTIONAL APPROACH?

- A functional approach is needed because traditional stretching approaches have been shown to be ineffective for recovering ROM in many musculoskeletal conditions
- Functional ROM challenges, including managed and assisted approaches, all contain the effective ingredients necessary for engaging the recuperative processes (repair, adaptation and modulation of symptoms)
- Extra-functional ROM challenges, including all traditional passive and active stretching approaches, provide only a few or none of the effective ingredients necessary for repair, functional adaptation and long-term management of pain

## WHEN DO WE USE A FUNCTIONAL APPROACH OR TRADITIONAL STRETCHING?

- ROM rehabilitation should strive to be functional at a level that matches the individual's movement capacity
- Regressing to a lower level, below the patient's current capacity, is likely to reduce effectiveness and may prolong recovery
- If the patient is able to perform functional tasks, avoid extra-functional challenges, i.e. traditional methods

- Extra-functional challenges can be used if the patient is unable to perform functional tasks
- Extra-functional passive challenges can be used if the patient is unable to perform active movements
- A functional approach does not exclude the use of extra-functional exercise or stretching techniques

## WHAT DEFINES END-RANGE?

- ROM contains active and passive components set within variable and (often) ill-defined end-ranges
- In healthy individuals active ROM is often determined by the capacity of agonist muscles to overcome antagonistic tissue tension
- Passive ROM is determined by tissue resistance. This will influence the angle at which the person will experience pain and discomfort. How far a person will stretch beyond that point will depend on their pain tolerance
- Most daily activities are performed within a small percentage of the full active ROM

## WHEN IS MOVEMENT CONSIDERED FUNCTIONAL (NORMAL) OR DYSFUNCTIONAL (ABNORMAL)?

- Functional movement is the unique movement repertoire of an individual
- Functional movement contains shared activities which are universal to all and special activities which are unique to each individual
- Functional ROM is defined as the ROM required to perform functional activities effectively, efficiently and comfortably
- Dysfunctional ROM is defined as the ROM limitation that impedes the ability to perform functional movement
- Clinical-anatomical ROM ideals strive for anatomical ROM perfection
- Functional ROM is a patient-centred goal associated with recovering functionality
- Functional ROM goals are often more important than clinical ones. Most individuals judge their improvement by their ability to carry out daily activities.

## WHAT CAUSES ROM LOSS?

- ROM loss is often the outcome/symptom of a condition
- Loss is often multidimensional with changes seen in the tissue, neurological and psychological dimensions

- In the tissue dimension ROM losses can be due to adaptive tissue changes and mechanical and chemical irritation
- In the neurological dimension, it can be due to loss of motor control and nociceptive processes such as sensitization
- In the psychological dimension, movement-related anxieties may also contribute to ROM loss

## WHAT IS THE POTENTIAL FOR ROM RECOVERY?

- The potential for ROM recovery is dependent on the prognostic nature of the causative condition and the body's recuperative processes of repair, adaptation and modulation of symptoms
- The conditions that cause ROM loss can be classified as self-limiting, persistent or progressive
- ROM recovery is more likely in self-limiting conditions in which the recuperative processes are saved
- ROM rehabilitation will have a diminishing effect in persistent and progressive conditions, in particular if the adaptive or reparative capacity of the affected tissue is reduced, or when symptoms cannot be alleviated

## WHAT HAPPENS IN ADAPTIVE ROM LOSS AND RECOVERY?

- The musculoskeletal system has the capacity to adapt to the physical environment
- Tissue adaptation is associated with *mechanotransduction*: a process by which the myocytes and fibroblasts convert mechanical signals into biological processes
- In immobilization and remobilization, adaptive processes can be seen in all musculoskeletal tissue
- Adaptive ROM loss is associated with shortening and stiffening of connective tissue, adhesion and muscle shortening and atrophy
- During ROM recovery the deleterious effects of immobilization are reversed and normalized

## WHAT DRIVES ADAPTIVE RECOVERY?

- The drive for adaptation is multidimensional: it contains psychological and behavioural factors
- Adaptive processes are driven by the individual's actions within their environment



- The person's behaviour determines tissue loading and the stimulation of mechanotransduction
- ROM challenges in the form of amplified recovery behaviour, exercises and stretching can be seen as part of a physical environment that drives adaptation
- The success of ROM rehabilitation is not inherent in any single stretching approach but in the overall management

## WHY IS SPECIFICITY IMPORTANT?

- Specificity is the unique motor, muscular and tissue adaptation brought about by exercise/rehabilitation
- Transfer is the measure of how the gains from the ROM challenge carry over to improve the goal task
- Transfer is more likely to occur if the training/rehabilitation resembles the goal activity, i.e. overhead reaching is improved by overhead reaching.
- Training which is dissimilar to its goals is unlikely to transfer any gains to that task, i.e. biceps curls may not be as effective in improving overhead reaching
- Many traditional stretching approaches, active or passive, are often dissimilar and lack task specificity, and as such they are unlikely to be therapeutically effective
- Task-specific rehabilitation is likely to be more effective than extra-functional/traditional stretching methods

## HOW MUCH FORCE IS REQUIRED FOR STRETCHING?

- Functional ROM is maintained by the forces imposed on the body by daily activities
- Overloading is a training condition for adaptation in which physical challenges are raised above functional levels
- Underloading is the absence of sufficient forces required to maintain functional activities; it results in atrophy and adaptive ROM loss
- Forces below the overloading threshold will be ineffective at inducing long-term ROM change
- In ROM pathologies, functional activities may generate sufficient forces for adaptation
- Manual stretching approaches may fail to generate sufficient force for overloading
- Functional activities and managed recovery behaviour may provide sufficient forces for adaptive ROM recovery

### **CAN TISSUE LOADING BE MADE SAFE?**

- Tissue loading can be made safe by gradual introduction and amplification of forces over several weeks – graded challenge
- During the graded challenge, all four movement parameters are incrementally amplified (force, speed, range and endurance), and there is also an incremental increase in the number of activities
- A gradual challenge is useful for monitoring for adverse reactions, but also for reassuring the patient and the therapist that movement is safe
- The graded challenge can be dropped back a step if an adverse reaction is encountered

### **HOW LONG AND HOW OFTEN SHOULD THE EXPOSURE TO STRETCHING BE?**

- ROM recovery represents a competition in adaptation between the pathological process that maintains the condition and the ROM challenge that counteracts it
- It is estimated that, in the presence of pathology, the daily ROM challenges should be for several hours
- Currently, there are no clear guidelines on the scheduling of traditional stretching approaches
- In patients with ROM pathologies, traditional stretching approaches are unlikely to provide sufficient exposure for adaptation to take place
- Only by incorporating the ROM challenge into the daily activities is there a possibility that sufficient exposure will take place

### **WHAT DO WE AIM TO RECOVER IN THE ACTIVE RANGE?**

- The aim of rehabilitation in the active range is to drive neuromuscular adaptation
- The focus is on movement control and, in particular, on control of the four task parameters (force, range, speed and endurance)
- In many musculoskeletal, pain and central nervous system conditions the control of the task parameters is attenuated
- In functional rehabilitation the aim is to recover functional movement by amplifying the four task parameters
- Amplification takes place while performing the affected tasks

## **SHOULD MOVEMENT BE FRAGMENTED OR REHABILITATED AS A WHOLE?**

- The organization of movement is whole and integrated with its goals
- ROM rehabilitation should be of whole movement, goal-orientated and within a functional task
- Internal focusing strategies on specific muscles or joints turns them into the goal of movement and reduces the effectiveness of rehabilitation
- Regression to focusing on single muscles, muscle chains or joints should be the last option in any treatment

## **CAN PASSIVE MOVEMENT OR STRETCHING IMPROVE THE ACTIVE RANGE?**

- Motor learning and functional movement and recovery are all active events
- Motor control cannot be recovered by passive challenges
- During passive techniques there is no active motor engagement
- Task-specific muscle recruitment is not being practised
- Passive stretching represents a profoundly fragmented approach that reduces the movement to the level of the muscle and the (ineffective) reflexive
- Passive approaches should only be used if the patient is unable to execute an active movement
- Active ROM should be rehabilitated with active movement

## **CAN TRADITIONAL ACTIVE APPROACHES IMPROVE MOTOR CONTROL AND FUNCTIONALITY?**

- Muscle energy techniques and proprioceptive neuromuscular facilitation stretching as well as dynamic and ballistic stretching are all extra-functional approaches. They do not resemble “real” functional movement. As a consequence they may fail the specificity condition for adaptation
- Active extra-functional approaches are often therapist-dependent and therefore are unlikely to meet the extensive exposure needed for adaptation, particularly in the presence of an adaptive ROM pathologies
- Active extra-functional approaches promote movement fragmentation
- Active extra-functional approaches may be useful in conditions in which the patient has lost the capacity to execute a recovery behaviour or perform whole movement

## IS IT POSSIBLE TO HAVE ROM LOSS WITHOUT TISSUE CHANGES?

- ROM loss can come about by increased sensitivity (sensitization) in the affected area
- Sensitization is a neurological process in which the central nervous system can change, distort or amplify the experience of pain
- ROM sensitization is a neurological process in which pain, discomfort or stiffness are experienced in normal ROMs
- In many chronic musculoskeletal conditions, ROM sensitization can be the primary cause of ROM losses; it can be present in the absence of inflammation, tissue damage or adaptive changes
- In these conditions, the patient's experience of stiffness does not reflect adaptive tissue changes; stretching is therefore ineffective for recovering ROM in conditions in which sensitization is evident

## HOW DO WE DESENSITIZE ROM OR ALLEVIATE PAIN?

- Persistent ROM sensitivity may be alleviated by approaches that incorporate psychological and physical means
- Physical approaches including active and passive approaches may provide some transient pain alleviation and desensitization
- Sustained, long-term desensitization is more likely to occur by psychological and behavioural interventions that may include self-maintained exercise
- Stretching techniques are ineffective in managing acute pain
- It is unclear whether stretching is useful for alleviating chronic pain; any effect it produces is likely to be modest

## STRETCH OR WAIT?

- In acute conditions, pain and sensitization have a useful protective function; improvement in pain and sensitization are often linked to overall recovery
- In acute conditions, stretching or challenging end-ranges is unlikely to be useful and may even increase the likelihood of re-injury
- During the acute phase the therapeutic focus should be on supporting recovery. Stretching is counter-indicated; it is neither beneficial nor safe
- Maintaining functionality within comfortable ranges is essential for supporting repair. Instruct the patient to maintain their daily activities as far as possible

- In chronic conditions, pain and sensitivity have no obvious protective function
- Desensitization is likely to be safe and beneficial in chronic conditions
- Overloading is likely to be safe in chronic conditions in which there are adaptive tissue changes and desensitization
- As a safety measure the ROM challenges should be introduced in a graded manner (graded challenge)

## WHAT IS STRETCH TOLERANCE?

- Stretch tolerance is a “learned dissociation” between the experience of stretching pain and injury
- ROM gains following long-term regular stretching may be associated with stretch tolerance but also with adaptive tissue changes
- A stretch-tolerance model fails to explain ROM loss or recovery in conditions in which adaptive tissue changes have taken place
- This model is important in conditions in which ROM losses are associated with sensitization (Ch. 9)
- A stretch-tolerance model fails to elucidate the mechanisms underlying long-term gain of flexibility by regular stretch training
- The stretch-tolerance model has no training implications for healthy individuals who aim to increase their agility
- Adaptive-behavioural models are far more important for agility training and managing recovery in conditions where ROM losses are associated with adaptive tissue changes

## WHAT IS THE CONTRIBUTION OF PSYCHOLOGICAL FACTORS TO ROM LOSS AND RECOVERY?

- ROM loss can be maintained by avoidance behaviour due to fear of pain and re-injury
- Anxieties about movement can be due to misinformation, a learned association between pain and movement or to anxiety traits that predate the condition
- The alleviation of movement-related anxieties can be in the cognitive and behavioural spheres
- In the cognitive sphere, reassurance can be given by providing information about the condition, in particular positive messages that increase the individual's belief in their ability to care for and control their condition
- Reassurance in the behavioural dimension can include a gradual reintroduction of activities which are important for the patient

## HOW CAN WE IMPROVE ADHERENCE?

- Keep the patient positively informed
- Identify goals that are important to the patient
- Make the challenges readily available
- Provide ongoing support and feedback
- Keep it simple
- Make it fun

## WHAT'S NOT IN THIS BOOK?

- 50 different techniques to stretch the hamstrings or any other muscle in the body
- Detailed anatomy of every muscle in the body
- Long lists of joint assessments
- Dry biomechanics
- Muscle chains
- Muscle-by-muscle rehabilitation
- Movement fragmentation
- Specific tissue mobilization
- Fascial network and stretching
- Evidence-based protocols
- Clinical certainty

## FINALLY

- Use what the patient already knows for the rehabilitation. It is effective and economical
- Construct the ROM challenge as part of the habitual daily movement repertoire
- Many daily activities can be exaggerated to challenge ROM losses at home. This should be the emphasis of the management
- No two patients or conditions are alike, but they share management similarities
- Be creative-devise the management with the patient
- The ultimate message is – promote self-care, whenever possible



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