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Invited Topical Review

Physiotherapy rehabilitation for people with spinal cord injuries

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Introduction

The most obvious consequence of spinal cord injury (SCI) is paralysis. However, SCI also has widespread consequences for many body functions, including bladder, bowel, respiratory, cardiovascular and sexual function. It also has social, financial and psychological implications, and increases people's susceptibility to late-life renal complications as well as musculoskeletal injuries, pain, osteoporosis and other problems.

People with SCI require not only initial medical care and rehabilitation, but also ongoing access to wheelchair-friendly environments and appropriate homecare, equipment, transport, employment and financial support. The management of people with SCI is therefore complex, involving many healthcare professionals, organisations and government services. Physiotherapists treat an array of different problems related to SCI and these involve many body systems, even though the underlying pathology is neurological in nature.

This review outlines the principles of physiotherapy rehabilitation for people with SCI and the evidence underpinning the effectiveness of commonly used physiotherapy interventions. It focuses on three common problems: weakness, contractures and poor motor control. Only the rehabilitation phase is discussed here, although physiotherapists also have an important role to play immediately after injury and in the community once patients are discharged from hospital.

Types of spinal cord injuries

Spinal cord injuries are defined as complete or incomplete according to the International Standards for the Neurological Classification of SCI[1] and the American Spinal Injuries Association Impairment Scale (AIS). Complete lesions are defined as AIS A, and incomplete lesions are defined as AIS B, AIS C, AIS D or AIS E. This classification system was introduced in 1982 to replace the original, but perhaps more intuitive, Frankel system whereby a person was classified as having an incomplete SCI if they had any motor or sensory preservation more than three levels below the level of injury. In contrast, the International Standards for the Neurological Classification of SCI[1] distinguishes between complete and incomplete injuries on the basis of sensory and motor preservation in the S4/5 segments. A lesion is classified as complete if a person has no voluntary anal contraction (indicative of S4/5 motor preservation) and/or sensation in or around the anus (indicative of S4/5 sensory preservation), regardless of how much motor or sensory function they have below the level of the lesion. The distinction between different types of incomplete lesions is based on a detailed motor and sensory assessment. The precise definitions of different types of SCIs are surprisingly complex and contain ambiguities that continue to be debated.

Principles of management

Acute medical management of people with SCI focuses on minimising further neurological damage to the spinal cord and optimising recovery. Stability of the spine is clearly a priority. This is established either conservatively with bed rest (with or without traction) or surgically (typically with decompression and fusion). While surgical management is now more common than conservative management, there is still a lot of debate about the superiority of each approach. However, management of the spine is just one aspect of acute medical care. There are many other aspects related to maintaining blood pressure, circulation, respiration, bladder drainage, bowel care, nutrition and body temperature, and minimising psychological distress for patients and their families. During this stage, physiotherapy is predominantly focused on treating respiratory complications and preventing secondary musculoskeletal problems related to prolonged bed rest. Readers interested in the physiotherapy management of people in the period immediately after injury are directed to the official textbook[2] or online learning modules (www.elearnSCI.org)[3] of the International Spinal Cord Society.

Rehabilitation following SCI commences as soon as the patient is medically stable after injury. This can vary from a few days to many weeks, depending on whether the patient suffered other injuries at the time of the accident or subsequently developed medical or respiratory complications. Rehabilitation involves a team and patient-centred approach. The overall aim of rehabilitation is to enable the person to return to a productive and satisfying life. This means different things to different people. For example,

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some people place a high priority on independence and/or walking, while others do not. Studies have attempted to identify the priorities of people with SCI, although none have used representative samples and therefore all need to be interpreted with caution. A widely cited study from a sample of over 650 people in the USA found that those with tetraplegia placed the highest priority on regaining hand and upper limb function, and those with paraplegia ranked return of sexual function as their most important priority.[4] Regaining the ability to walk was also a high priority for both groups of people but, contrary to what is often assumed, it was not the highest priority.

Physiotherapy during the rehabilitation phase focuses on goals related to motor tasks such as walking, pushing a wheelchair, transferring and using the upper limbs.[5] The setting of goals for a person with SCI is fraught with difficulties because it relies, at least in part, on physiotherapists' and patients' predictions of likely outcomes. Much has been written about likely outcomes (see the paper by Scivoletto and Di Donna for a summary)[6] but the best estimates of outcome come from a European cohort study in which data were collected within 15 days of traumatic SCI and then 1 year later.[7] Unfortunately, data were only available for 492 of the original 1282 eligible patients, thereby limiting the confidence in the derived prediction rule. Nonetheless, the results indicated that the ability to walk at 1 year is best predicted from five variables collected within 15 days of injury: age, quadriceps strength, gastrocnemius strength, light touch sensation at L3 and light touch sensation at S1 (area under the curve (AUC) 0.956, 95% CI 0.936 to 0.976). There are other studies based on large databases looking at factors predicting outcomes other than walking, but they are less rigorous and invariably do not reflect the population at large.

A recent study examined physiotherapists' ability to predict the likelihood of patients walking (and performing an array of other motor tasks) at 3 months[8] and then 1 year from injury;[9,10] this was based on physiotherapists' assessments of patients at the time of admission to rehabilitation. The predictions were made a median of 45 days (IQR 31 to 73) after injury. Importantly, 50 of the potentially eligible 67 participants were included in the analysis. The results of this study indicated that physiotherapists were good at predicting the likelihood of walking at 1 year. The positive likelihood ratio associated with predictions of walking around the home at 1 year was 5.7 (95% CI 2.3 to 14.4) and the negative likelihood ratio was 0.2 (95% CI 0.1 to 0.5). Patients were also asked to predict their own future mobility. Interestingly, but perhaps unsurprisingly, there was an obvious discord between patients' expectations of walking and final mobility, with patients expecting to attain a higher level of mobility than the mobility predicted by their physiotherapists. The authors have since hypothesised that this discord may, in part, be due to the recent tendency of the media to encourage the public to believe that recovery and walking is now a realistic outcome for all people with SCI regardless of the severity of the injury.[10–12] This is clearly not the case and physiotherapists need to play their role in educating the media on this issue.

Assessment

The assessment of a patient with SCI is an important initial step in physiotherapy management. This step is not only important for setting realistic goals, but also for identifying key problems. Often, assessments conducted for this purpose are subjective. For example, a physiotherapist may subjectively assess a patient's ability to transfer from a wheelchair to a bed in an attempt to identify any underlying problems. The assessment may involve watching and analysing a patient's attempts at transferring, in order to determine which part of the transfer the patient is having difficulties performing and to isolate the underlying problems. This type of assessment helps to guide treatment.

Assessments are also used to provide an objective way of monitoring improvement over time. More standardised and objective assessments are required for this purpose. So, rather than observing a patient's attempts at a transfer, a therapist may quantify the amount of assistance the patient requires to transfer or measure the time taken to transfer using a standardised assessment that captures these constructs. Of course, some standardised and objective assessments can also be used to identify underlying problems and guide treatment, particularly assessments of impairments.

Standardised assessments of impairments are similar to those used across all areas of physiotherapy, although there are some that are specific to SCI. For example, assessments of sensation are performed according to the International Standards for Neurological Classification of SCI and are specific to SCI.[13] In this assessment, only one precise spot is tested to represent each dermatome. So to determine if the C6 dermatome is intact, a very small and precise spot is tested on the dorsal aspect of the thumb just distal to the metacarpophalangeal joint. Light touch and pinprick are separately scored on a 3-point scale, where a score of 0 reflects no sensation, a score of 1 reflects altered sensation and a score of 2 reflects normal sensation. The sensation of all 56 dermatomes needs to be compared with sensation on the face for both light touch and pinprick. The test is therefore very time-consuming. Studies have reported reasonable reliability of the sensory tests with better reliability for the light touch test than the pinprick test.[14,15]

Assessments of impairments are of limited interest to a physiotherapist without accompanying assessments of activity limitations to quantify a person's ability to move and complete purposeful motor tasks. There are just as many different standardised assessments of activity limitations as there are assessments of impairments, and again some are generic assessments while others are specific to SCI. The most commonly used assessments that are specific to SCI and physiotherapy include the Spinal Cord Independence Measure (SCIM)[16,17] and the Walking Index for SCI (WISCI).[18] The SCIM is equivalent to the Functional Independence Measure and provides a score out of 100 to reflect a person's ability to live and move independently.[19] It includes items that address a person's ability to transfer, walk, dress, feed, breathe and maintain bladder and bowel continence. There is a self-report version of the SCIM that has good reliability and is simple to administer.[20] The WISCI is a 21-point scale that summarises a person's ability to walk after taking into account need for assistance, orthoses or walking aids.[21] The WISCI also includes a 10-m timed walk test. Both the SCIM[19] and WISCI[21] have problems with their scoring algorithms, but nonetheless they are widely used in most SCI units around the world.

Despite the obvious importance of assessments for physiotherapists, there is no general international consensus on the most appropriate battery of physiotherapy-specific assessments.[22] However, representatives of the Spinal Cord Injury Group of the American Physical Therapy Association have put together a list of their recommendations,[23] and the international SCI community has developed basic datasets for people with SCI.[24] Some of the basic datasets are relevant to physiotherapists[25,26] and include assessments that could be used to both guide treatment and monitor improvements over time (see www.iscos.org.uk/international-sci-data-sets).

Physiotherapy interventions

The results of the assessment and goal-setting process are used to guide treatment. Clearly, treatments need to be based on evidence, but this poses a real challenge for the physiotherapy profession because of the surprisingly few high-quality and conclusive randomised, controlled trials involving people with SCI.[27] A recent count put the number of clinical trials at approximately 60 (excluding trials designed to determine the effectiveness of interventions for respiratory function or trials involving education or the provision of mobility-related equipment).[28] Most of these trials have been conducted in recent years and focused on interventions such as treadmill walking with overhead suspension, robotic gait training, electrical stimulation and other high-technology and potentially costly interventions. Interestingly, an audit of three typical SCI units in Europe and one in Australia indicated that therapists still devote most of their time to administering simpler interventions commonly used to treat impairments such as weakness, limited joint mobility, restricted fitness, pain and respiratory compromise, with time also being devoted to teaching people to walk, move about the bed, mobilise in a wheelchair and use their upper limbs.[29] This situation indicates a disconnect between researchers' priorities and the treatments provided by clinicians. This does not mean that clinicians are not providing optimal or appropriate treatments, but it does mean that the treatments clinicians are providing are not always based on high-quality clinical trials involving people with SCI and that researchers are not always testing the effectiveness of the treatments commonly administered by clinicians.

In the absence of high-quality trials involving people with SCI to guide treatment, physiotherapists need to look further afield and be guided by what is known from other areas of physiotherapy. The results of high-quality trials in other patient groups may often provide more accurate evidence about likely responses of people with SCI to treatments than looking at non-randomised or poorly conducted trials in people with SCI; both of which often provide biased estimates of treatment effects.[30] In addition, physiotherapists need to be guided by a logical problem-solving approach to treatment selection. For example, if a person with C6 tetraplegia wants to learn to transfer independently from a wheelchair to a bed, they need to be taught how to do this and the physiotherapist needs to understand the biomechanics of appropriate movement strategies. Clinical trials involving people with C6 tetraplegia learning to transfer are probably not required to guide treatment decisions. Instead, physiotherapists can apply what is known about the biomechanics of moving with C6 tetraplegia and the principles of effective teaching of motor skills.

One of the challenges for physiotherapists working in SCI is not only the lack of high-quality direct evidence but also the extensive scope of practice. For example, physiotherapists working in SCI: treat pain and respiratory complications; use electrical stimulation to treat pressure ulcers; formulate fitness training programs; encourage people with SCI to adopt healthy lifestyles; teach disabled sports; provide patients with various types of orthoses, splints and aids; prescribe wheelchairs; advise on strategies to prevent shoulder pain and pressure ulcers; and administer various electrotherapeutic interventions. Consequently, physiotherapists treating people with SCI need diverse clinical skills. The other challenge for physiotherapists working in this area is maintaining an open mind about new interventions such as stem cell therapy and robotics, while resisting the temptation to embrace these interventions until high-quality evidence proves their effectiveness. New interventions should not be rolled out on the basis of low-quality evidence, because they may waste time, money, resources and patients' efforts, and they may give patients an unrealistic expectation of recovery.[11] In addition, they quickly become entrenched as standard practice, particularly if they involve commercial interests and people with SCI perceive them to be beneficial. Once these interventions are rolled out, a window of opportunity closes to scrutinise these interventions within clinical trials.

The following paragraphs focus on three key problems: weakness, contractures and poor motor control. No attempt is made to review the full scope of physiotherapy practice in SCI. Readers interested in learning more about all aspects of physiotherapy management are directed elsewhere.[2,3,5]

Physiotherapy interventions to increase strength

Weakness is the most obvious impairment that prevents people with SCI from performing motor tasks. Consequently, strength training interventions are widely administered by physiotherapists.[31] Limited strength in people with SCI can be neurologically induced, as seen in people with Grade 2 or 3 strength in the quadriceps muscle who are trying to walk. Alternatively, limited strength may be due to insufficient muscle mass (or, more accurately, insufficient physiological cross-sectional area) in neurally intact muscles such as the upper limb muscles of people with paraplegia trying to master a floor-to-wheelchair transfer.

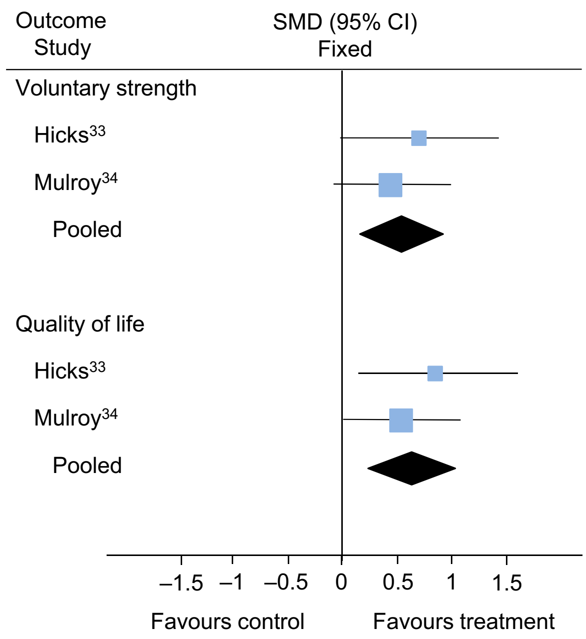

Figure 1. Standardised mean difference (SMD) of the effect of progressive resistance training versus control on voluntary strength of non-paralysed muscles and quality of life in people with SCI.

There is no reason to believe that the neurologically intact muscles of a person with SCI would respond to strength training any differently than the muscles of an able-bodied person. So for example, the appropriate upper limb strength training program for a person with paraplegia aimed at improving the ability to lift from the floor to a wheelchair needs to follow the same principles of strength training as would be applied to an able-bodied person. That is, the person requires a progressive resistance training program in which the load is appropriately and progressively increased. Such training is often best performed within the context of a functional skill, provided the principles of progressive resistance training can be maintained. There are many clinical trials in able-bodied people to guide evidence-based practice in this area.[32] In addition, two clinical trials[33,34] involving 92 participants with SCI have demonstrated that progressive resistance training for non-paralysed muscles not only increases strength but also increases quality of life (see Figure 1).

The situation is not so clear with partially paralysed muscles directly affected by SCI. There is strong evidence to indicate that people with partial paralysis following SCI get stronger with time. This evidence comes from longitudinal studies,[35] which show changes in strength and neurological status with accompanying changes in function. In addition, the within-group changes of clinical trials and non-randomised studies all consistently point to increases in strength of partially paralysed muscles over time. It is generally assumed that these increases are due to a combination of central and peripheral factors. The peripheral factors include muscle hypertrophy, and the central factors include neural adaptations either at the site of the injured spinal cord or even possibly within the brain. It is unclear how much of the observed increases in strength of partially paralysed muscles can be attributed to physiotherapy interventions as opposed to natural recovery.

The optimal training paradigm to increase strength in partially paralysed muscles is unclear. In particular, it is unclear whether strength is best improved by applying the principles of progressive resistance training or by focusing on high repetitions with limited

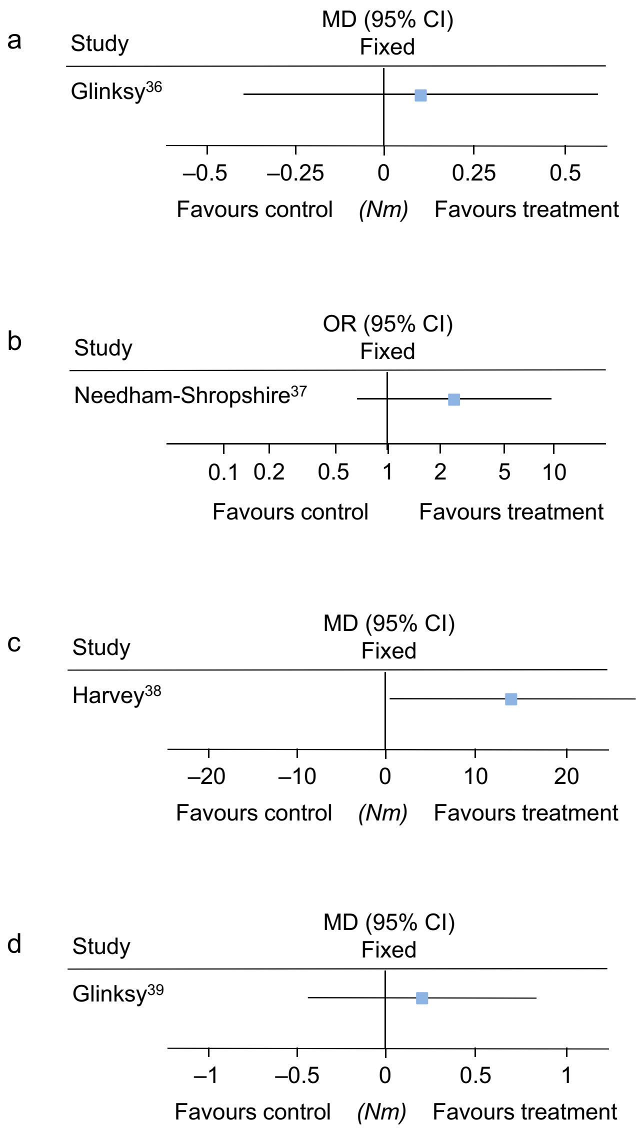

Figure 2. (a) Mean difference (MD) of the effect of electrical stimulation versus control on torque of partially paralysed muscles in people with SCI. (b) Odds ratio (OR) of the effect of electrical stimulation versus control on upper limb American Spinal Injuries Association Impairment Scale A (AIS A) motor score of partially paralysed muscles in people with SCI. (c) Mean difference (MD) of the effect of electrical stimulation and progressive resistance training versus control on torque of partially paralysed muscles in people with SCI. (d) Mean difference (MD) of the effect of progressive resistance training versus control on torque of partially paralysed muscles in people with SCI.

resistance. It is also unclear whether strength training programs are enhanced by electrical stimulation.

Four randomised, controlled trials[36–39] have specifically looked at the effectiveness of progressive resistance training and electrical stimulation or a combination of the two interventions. They have conflicting results (see Figure 2). The most promising results come from a trial[38] of an 8-week strength training program comprising progressive resistance training and electrical stimulation compared with no intervention for the partially paralysed quadriceps muscles of people with SCI (mean between-group difference 14 Nm, 95% CI 1 to 27). The estimate of the treatment effect was imprecise but nonetheless indicates a potentially clinically important increase in strength. The results of the other three trials investigating different combinations of progressive resistance training and electrical stimulation in very weak muscles give less grounds for optimism.[36,37,39] One of these trials involved electrical stimulation and arm ergometry with resistance[37] but it is unclear whether the principles of progressive resistance training (particularly the use of high resistance) were strictly adhered to.

Another eight trials[40–47] have examined the effect of some type of low load and repetitive practice on the strength of partially paralysed muscles of the upper or lower limbs: two in the upper limbs and six in the lower limbs. The interventions in these trials included robotic gait training, overhead gait training, intensive hand practice with sensory stimulation, and various combinations of these. Importantly, all of the interventions involved high repetitions so, whether stated or not, the interventions did not include high loads typical of progressive resistance training. Most of the trials measured strength using manual muscle testing to derive an overall motor score. Importantly, therefore, these scores largely reflect increases in strength of partially paralysed muscles and not increases in strength of neurally intact muscles. Interestingly, only two of these trials indicated a treatment effect on strength.[40,47] The first trial compared robotic gait training with overground gait training[40] (MD 5 points on a 50-point scale, 95% CI 2 to 9) and the second trial compared intensive hand training with no training (between-group differences were not provided and are not calculable).[47] The latter trial measured hand strength with a pinch meter, which may reflect changes in strength of the non-paralysed wrist extensor muscles of some participants, so the results may not be indicative solely of changes in strength of partially paralysed hand muscles.[47] In addition, it was the only trial to include a control group that received no intervention. The other trials compared different types of interventions.

Taken together, this evidence indicates how little is known about the response of partially paralysed muscles to different strength training paradigms. In the absence of clear guidance, the most sensible approach may involve a combination of progressive resistance training interspersed with repetitive practice of functional tasks involving low loads and high repetitions. It may also be reasonable to administer electrical stimulation in combination with high resistance and maximal voluntary effort. However, there is little evidence to suggest that electrical stimulation alone will increase voluntary strength,[36,48] although it may be therapeutic for other purposes, including minimising atrophy in paralysed muscles,[49] preventing secondary peripheral nerve deterioration,[50] encouraging neural repair[51] and promoting healing of pressure ulcers.[52] Unfortunately there are no large high-quality trials involving electrical stimulation for any of these purposes, so there are no unbiased estimates of its possible therapeutic effects.

Physiotherapy interventions to treat and prevent contractures

Contractures are a common problem after SCI. At least two cohort studies have followed representative samples of people with SCI over a 1-year period in an attempt to quantify the extent of the problem. One study indicated that 66% (95% CI 55 to 77) of people who sustain a SCI will have at least one notable contracture within a year of injury,[53] and the other study indicated that 70% (95% CI 57 to 81) of people with tetraplegia will have loss of shoulder range of motion 1 year after commencing rehabilitation.[54] No study has followed patients for more than 1 year, but anecdotal evidence suggests that contractures become increasingly problematic, with some patients developing severe contractures.

Passive movements and stretch are widely used to treat and prevent contractures. However, uncertainty remains about whether these interventions are effective. Three clinical trials with useable data have examined the effect of stretch, and one trial has examined the effect of passive movements on joint mobility in people with SCI (see Figure 3). Pooling the results of the three stretch trials gives a mean between-group difference of 2 deg (95% CI 1 to 4). These results are consistent with a meta-analysis of 25 trials involving 812 participants with all types of neurological conditions (mean pooled between-group difference 1 deg, 95% CI 0 to 3).[55,56] They are also similar to the results of the one trial on passive movements.[57] Together they indicate the possibility of a very small treatment effect that most would not consider to be

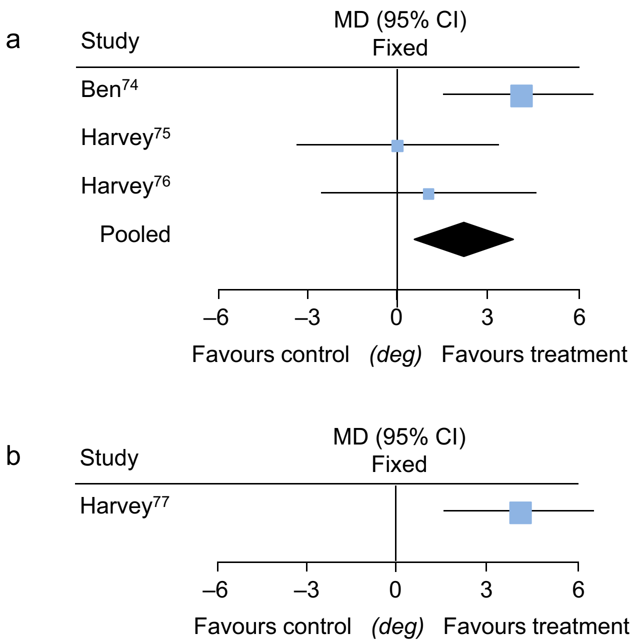

Figure 3. Mean difference (MD) of the effect of (a) stretch and (b) passive movements versus control on joint range of motion in people with SCI.

clinically worthwhile. However, there is a difficulty with the interpretation of these data because none of these studies provided stretch or passive movements for more than 6 months, and most only provided stretch or passive movements for between 4 weeks and 3 months. Therefore, the effectiveness of stretch or passive movements administered every day over very long periods is unknown, although stretch and passive movements are often provided over the course of a person's life. Even a 1-deg benefit every 6 months would transpire to a 40-deg benefit after 20 years. Of course, it cannot be assumed that treatment effects accumulate over time, but nor can this possibility be dismissed. It is also unknown how long stretches need to be maintained each day or how many times a joint needs to be passively moved. In all trials to date, the stretches and passive movements were administered in very large dosages that are not typically administered in clinical practice. Therefore, many uncertainties remain, although it would seem that we can only hope to have an effect if stretches and passive movements are administered in high doses and over long periods of time.

If stretches and passive movements are to be administered in high doses and over long periods of time then they need to be part of people's daily regimens. That is, passive movements need to be self-administered as far as possible, and stretches need to be incorporated into an appropriate positioning program. However, this can be time-consuming for people with SCI, so clinicians need to prioritise attention to where contractures are most likely to occur and to where contractures are likely to have profound effects on quality of life. Therefore, physiotherapists require skills in predicting contractures and their implications for each person.[58] For example, people with C6 tetraplegia are highly vulnerable to elbow flexion contractures because they have paralysis of the triceps muscles. Even slight loss of elbow extension will prevent a person with C6 tetraplegia from lifting his/her bodyweight through the upper limbs. The inability to lift renders a person incapable of transferring and, hence, dependent on others. This has major implications on quality of life. Therefore, preventing elbow flexion contractures in people with C6 tetraplegia should be a high priority and patients should be educated about appropriate positioning programs for the elbow (eg, sleeping with the elbows extended). This may take priority over other joints and soft tissue structures. It is possible to use similar clinical reasoning to prioritise contracture management programs for people with all types of SCI.[58] However, the emphasis for contracture management needs to be on simple and sustainable strategies that do not require large time commitments from people with SCI. Readers are directed to www.physiotherapyexercises.com for practical home stretching regimens for people with different types of SCI.

Physiotherapy interventions to improve the performance of motor tasks

Much of physiotherapy is directed at improving patients' abilities to perform motor tasks such as walking, transferring, pushing a wheelchair and using the upper limbs. Therapy is typically based on principles of motor learning. For example, if a person with motor complete T4 paraplegia wishes to learn to transfer from a seated position, then he/she will learn best with repetitive practice that incorporates part practice along with appropriate use of instructions, feedback and manual guidance.[59] But of course there are many subtleties involved with applying these learning principles in an effective way for people with SCI. Evidence about the effectiveness of these training strategies is unlikely to come from clinical trials in people with SCI. Instead we need to rely on theories of motor control built on the findings of experiments and randomised trials in similar patient and able-bodied populations.

The principles of motor learning can also be used to train gait in people with the potential to walk. Again, repetitive practice is a key component. If a patient has extensive paralysis and the goal is to walk with orthoses and walking aids, then the patient needs to practise walking with orthoses and walking aids. In contrast, if a patient has potential for neurological recovery and the goal is to walk as an able-bodied person, then the patient needs to practise walking as closely as possible to an able-bodied person. Treadmills and robotic devices can be used to make gait training easier and to provide an opportunity for intensive repetitive practice using a gait strategy that mimics that of an able-bodied person. This is clearly a good development. There are, however, two controversial and unresolved issues related to the use of these devices. Firstly, who has the potential for neurological recovery and secondly, is treadmill and robotic training inherently superior to overground training?

The evidence about the superiority of treadmill training and robotic devices compared with overground training comes from animal studies, some of which date back to the 1980s and show therapeutic effects of cyclic walking.[60] It is believed that cyclic walking promotes neural plasticity within the spinal cord and the 'training' of central pattern generators; a complex reflex of the spinal cord.[51,61,62] Non-randomised trials, single case studies or studies using historical controls also suggest that these treatments are therapeutic, particularly in those with motor incomplete lesions.[63] However, clinical trials have failed to replicate these promising results. Figure 4 shows the results of the six randomised, controlled trials involving 263 participants comparing treadmill training with overground training.[42–46,64] The pooled mean between-group difference for gait velocity was –0.01 m/s (95% CI –0.09 to 0.08). These results are equivalent to those of a 2012 Cochrane review[65] (which does not include a recent trial)[64] and to the results of two clinical trials comparing robotic gait training with overground gait training (see Figure 5).[40,46] These findings also parallel the results of similar trials in stroke[66] and other neurological conditions, all pointing to the conclusion that gait training in these devices is not superior to overground gait training, provided patients have the opportunity for repetitive practice. This has prompted a rethink of beliefs and assumptions, and is the source of considerable controversy.[12,67] It suggests that there is nothing intrinsically therapeutic about cyclic walking on treadmills or with robotic devices, although both may provide a convenient and safe way for therapists to provide intensive repetitive practice.

Regardless of the type of gait-training strategies used, there is still the unresolved question of who should be encouraged to walk and who has the potential for neurological recovery.[11,67,68] Some argue that all patients should be provided with the opportunity for gait training with treadmills or robotic devices with or without electrical stimulation and therapists to move the paralysed legs, even if the chances of ultimately walking are slim. They argue that

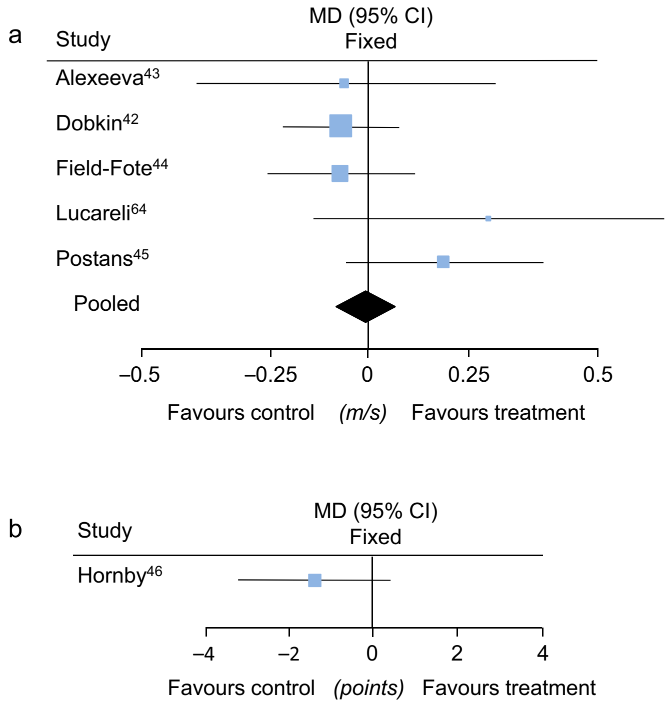

Figure 4. Mean difference (MD) of the effect of treadmill gait training with overhead suspension versus control on (a) walking speed and (b) walking index of SCI (WISCI, 21-point scale) in people with SCI.

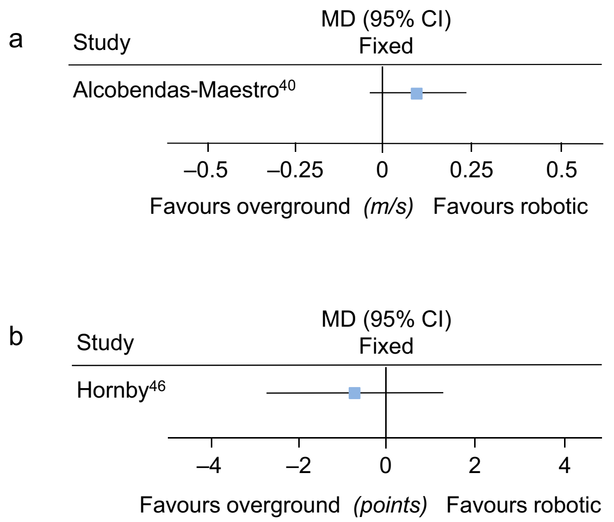

Figure 5. Mean difference (MD) of the effect of robotic gait training versus overground training on (a) walking speed and (b) walking index of SCI (WISCI, 21-point scale) in people with SCI.

even if patients do not regain the ability to walk, this type of therapy has other health benefits related to standing and strenuous exercise. Those who are more pragmatic argue that it is not economically feasible for most healthcare systems to provide such costly treatments for everyone without some rationalisation. They also argue that it may even be potentially harmful to encourage all patients to believe that walking is likely when clearly it is not. A sole focus on walking diverts attention away from gaining independence from a seated position; a skill that is currently essential for those who ultimately do not walk.[12,69] There is clearly a need for some balance between the two positions.

Future directions

The recent focus on neural plasticity and neural recovery following SCI has led to the emergence of a new term, 'activity-based therapy'.[70] Activity-based therapy has been heralded by some as a novel approach to physiotherapy for people with SCI,[71] yet it is surprisingly difficult to get a clear definition of what is meant by this term.[72] A key aspect of activity-based therapy is context-specific and task-specific intensive practice involving many hours of exercise a day, which is not dissimilar to what was advocated by Carr and Shepherd in the 1980s.[73] However, it also includes 'developmental sequencing' exercises, strength training, and treadmill or robotic walking with or without electrical stimulation (see Appendix S1 of the paper by Jones et al[70]). Its proponents argue that it is novel because it focuses on optimising function and neural recovery below the level of the injury. It is argued that this type of therapy is in stark contrast to 'conventional' or 'traditional' therapy, which some believe solely focuses on teaching compensatory strategies with no therapeutic attention directed below the level of injury. Anecdotal evidence suggests that this is not an accurate contrast and that physiotherapists have been directing therapeutic attention below the level of injury long before the emergence of activity-based therapy, albeit primarily in those with at least some signs of motor function. However, regardless of the terminology, there is now evidence from at least one trial indicating that intensive physiotherapy improves gait and strength in people with AIS C and D lesions 3 years after SCI.[70] Some claim that this supports a new type of therapy, while others believe that the therapy provided in this trial is not dissimilar to the therapy that has been provided to people with these types of lesions for many years now and, as such, the trial provides long-overdue evidence to indicate the therapeutic benefits of an intensive and comprehensive physiotherapy program.

Physiotherapy practice may change considerably over the next decade. Exoskeletons are currently available and enable people with lower limb paralysis to walk overground. They are not yet sufficiently versatile to replace the wheelchair, but no doubt this will change as technology improves. Stem cell therapy may also one day open up doors for those with SCI. The future is unknown but there are many reasons for optimism. However, there is still a need to direct research attention to some of the fundamental principles underpinning physiotherapy management of people with SCI. For example, more clinical trials are needed to examine the effectiveness of widely used treatments for the management of different impairments, including weakness, spasticity, pain, osteoporosis, contracture and respiratory compromise. A firm evidence base and understanding of optimal treatments for these key impairments will be essential for future breakthroughs in stem cell therapy, neuroplasticity, robotics or other innovations that the future may bring. However, it will be important that future interventions are not rolled out to become entrenched as standard practice without appropriate scrutiny within clinical trials.[11] The emphasis must remain on high-quality trials to guide evidence-based physiotherapy for people with SCI.

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