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Physiotherapy Management for Spinal Cord Injuries: A Comprehensive review

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ABSTRACT

Spinal cord injury (SCI) has far-reaching consequences beyond paralysis, affecting various bodily functions and leading to significant social, financial, and psychological repercussions. Physiotherapy plays a pivotal role in the rehabilitation of individuals with SCI, addressing key challenges such as weakness, contractures, and impaired motor control. While many physiotherapy interventions rely on established motor learning principles and techniques like strength training and repetitive practice, evidence for their effectiveness in SCI-specific contexts remains limited. For neurologically intact muscles, progressive resistance training with systematically increasing loads is recommended. However, the optimal training protocol for partially paralyzed muscles affected by SCI is less clear, with mixed evidence supporting the efficacy of progressive resistance training, high-repetition low-resistance approaches, or electrical stimulation. Stretching and passive movements are commonly used to prevent and manage contractures, but their long-term efficacy is uncertain. Emerging approaches such as activity-based therapy, exoskeleton-assisted walking, and neural recovery interventions hold promise, yet their integration into standard practice must be supported by high-quality evidence. Future advancements in technology, stem cell therapies, and neuroplasticity offer hope for enhanced recovery, but continued emphasis on evidence-based practices and rigorous clinical trials remains crucial. Physiotherapists must develop skills to predict outcomes, prioritize interventions, and strike a balance between embracing innovation and resisting premature adoption of unverified techniques. Ultimately, the physiotherapy management of SCI must prioritize patient-centered care and leverage innovative interventions judiciously to optimize functional independence and foster realistic expectations for recovery.

KEYWORDS: Physiotherapy, Spinal Cord Injuries, SCI.

1. Introduction

The most apparent consequence of spinal cord injury (SCI) is paralysis. However, SCI has far-reaching effects on various bodily functions, including bladder, bowel, respiratory, cardiovascular, and sexual function. Additionally, it has significant social, financial, and psychological repercussions, increasing susceptibility to complications in later life such as renal issues, musculoskeletal injuries, pain, osteoporosis, and other health problems.

Individuals with SCI require not only initial medical treatment and rehabilitation but also ongoing access to wheelchair-accessible environments, appropriate home care, adaptive equipment, transportation, employment opportunities, and financial assistance. Managing SCI is therefore multifaceted, requiring collaboration among numerous healthcare professionals, organizations, and government services. Physiotherapists address a wide range of issues associated with SCI, which affect multiple body systems, despite the neurological nature of the primary condition.

This review discusses the principles of physiotherapy rehabilitation for individuals with SCI and examines the evidence supporting commonly employed physiotherapy interventions. It focuses on three prevalent issues: weakness, contractures, and impaired motor control. The discussion is confined to the rehabilitation phase, although physiotherapists also play a critical role in the acute post-injury phase and within the community following hospital discharge.

Types of Spinal Cord Injuries

Spinal cord injuries are categorized as complete or incomplete according to the International Standards for Neurological Classification of Spinal Cord Injury (Waring III et al., 2010) and the American Spinal Injuries Association (ASIA) Impairment Scale (AIS). Complete injuries are classified as AIS A, while incomplete injuries fall under AIS B, C, D, or E. This classification system, introduced in 1982, replaced the older Frankel system, which categorized an injury as incomplete if there was any preservation of motor or sensory function more than three levels below the lesion.

In contrast, the International Standards for Neurological Classification of SCI differentiates between complete and incomplete injuries based on sensory and motor preservation in the S4/5 segments. A lesion is considered complete if the individual has no voluntary anal contraction (indicating S4/5 motor preservation) or sensation in or around the anus (indicating S4/5 sensory preservation), regardless of motor or sensory function below the injury level. The classification of incomplete injuries relies on a detailed motor and sensory evaluation. The definitions of SCI subtypes are intricate and contain ambiguities, which continue to be a subject of debate.

Principles of Management

Acute medical management of SCI aims to minimize further neurological damage and maximize recovery. Ensuring spinal stability is a critical priority, achieved through conservative measures such as bed rest (with or without traction) or surgical interventions, including decompression and fusion. While surgical management has become more prevalent, debates regarding the relative advantages of conservative versus surgical approaches persist. Nevertheless, spinal stabilization is only one facet of acute care.

Other important aspects of acute management include maintaining blood pressure, ensuring adequate circulation and respiration, facilitating bladder and bowel function, managing nutrition and body temperature, and alleviating psychological distress for both patients and their families. During this phase, physiotherapy primarily addresses respiratory complications and prevents musculoskeletal problems arising from prolonged immobility. Those interested in further details on physiotherapy management in the immediate post-injury phase may refer to the official textbook (Chhabra, 2015) or online resources from the International Spinal Cord Society (Chhabra et al., 2013).

Rehabilitation begins once the patient achieves medical stability, which can vary from days to weeks depending on the presence of additional injuries or complications, such as respiratory issues. Rehabilitation adopts a team-based and patient-centered approach, with the goal of enabling individuals to lead fulfilling and productive lives. This goal is subjective and varies among individuals. For instance, some prioritize independence or walking, while others have different aspirations.

Studies have explored the priorities of people with SCI, though these findings should be interpreted cautiously due to the non-representative nature of the samples. A frequently cited study involving over 650 participants in the United States revealed that individuals with tetraplegia prioritized regaining hand and upper limb function, whereas those with paraplegia ranked restoring sexual function as their top priority (Anderson, 2004). The ability to walk was also a significant concern for both groups but, contrary to common assumptions, it was not their highest priority.

Physiotherapy during rehabilitation primarily focuses on achieving goals associated with motor tasks such as walking, propelling a wheelchair, transferring, and utilizing upper limbs (L. Harvey, 2008). Setting goals for individuals with SCI presents challenges as it depends, at least partially, on physiotherapists' and patients' predictions of potential outcomes. Extensive literature exists on expected outcomes, as summarized by Scivoletto and Di Donna (Scivoletto & Di Donna, 2009), but the most reliable predictions stem from a European cohort study. This study collected data within 15 days of traumatic SCI and revisited the participants one year later (Van Middendorp et al., 2011). However, out of 1,282 eligible participants, only 492 were included in the analysis, which limits confidence in the resulting prediction model. The findings indicated that the ability to walk at one year could be predicted using five variables assessed within 15 days post-injury: age, quadriceps strength, gastrocnemius strength, light touch sensation at L3, and light touch sensation at S1 (AUC 0.956, 95% CI 0.936–0.976). Other studies using large datasets have explored predictors for outcomes beyond walking, but these are often less robust and do not represent the general population.

A recent study investigated physiotherapists' ability to predict the likelihood of patients walking and performing various motor tasks at three months and one year post-injury (L. A. Harvey et al., 2012, 2013). Predictions were based on assessments conducted at admission to rehabilitation, with a median of 45 days (IQR 31–73) post-injury. Of 67 eligible participants, 50 were included in the analysis. The study demonstrated that physiotherapists were adept at predicting walking capability at one year. The positive likelihood ratio for predicting the ability to walk around the home was 5.7 (95% CI 2.3–14.4), and the negative likelihood ratio was 0.2 (95% CI 0.1–0.5). Patients also made predictions about their mobility, which were frequently discordant with physiotherapists’ assessments. Patients tended to have higher expectations of their mobility than what physiotherapists predicted. This discrepancy has been hypothesized to result, in part, from media narratives suggesting that recovery and walking are achievable for all individuals with SCI, regardless of injury severity (L. A. Harvey et al., 2011; L. Harvey & Wyndaele, 2011). Physiotherapists have a role in educating the public to address these misconceptions.

Assessment

Assessment is a critical initial step in the physiotherapy management of SCI. It not only aids in setting realistic goals but also helps identify key issues requiring intervention. Often, assessments are subjective. For instance, a physiotherapist may observe a patient transferring from a wheelchair to a bed to identify difficulties in specific aspects of the movement and the underlying problems. Such evaluations help direct treatment strategies.

Objective assessments are also necessary to monitor progress over time. Standardized and objective measures are often employed for this purpose. Instead of merely observing a transfer attempt, a physiotherapist may quantify the assistance required or measure the time taken to complete the transfer using standardized tools. Some standardized assessments also help identify underlying impairments, guiding treatment.

Impairment assessments in SCI share similarities with those used in other areas of physiotherapy, although certain assessments are specific to SCI. For example, sensory assessments are conducted following the International Standards for Neurological Classification of SCI, which requires testing one precise spot in each dermatome. For instance, to evaluate the C6 dermatome, the dorsal thumb just distal to the metacarpophalangeal joint is tested. Sensory modalities like light touch and pinprick are scored on a 3-point scale: 0 indicates no sensation, 1 indicates altered sensation, and 2 indicates normal sensation. These tests compare dermatomal sensations to facial sensation for light touch and pinprick across all 56 dermatomes, making them time intensive. Studies indicate reasonable reliability for these tests, with higher reliability for light touch than for pinprick (L. Harvey & Graves, 2011; Marino et al., 2008).

Impairment assessments are of limited utility without complementary evaluations of activity limitations that quantify an individual's ability to perform functional motor tasks. There are numerous standardized tools for assessing activity limitations, some of which are specific to SCI. Notable tools include the Spinal Cord Independence Measure (SCIM) (Catz et al., 2001; Itzkovich et al., 2007) and the Walking Index for Spinal Cord Injury (WISCI) (Ditunno Jr. et al., 2013). The SCIM, analogous to the Functional Independence Measure, scores out of 100 to reflect an individual's ability to live and move independently (L. A. Harvey & Anderson, 2015). It evaluates tasks such as transferring, walking, dressing, feeding, breathing, and managing bladder and bowel continence. A reliable self-reported version of the SCIM is also available (Fekete et al., 2013). The WISCI uses a 21-point scale to summarize walking ability, accounting for the need for assistance, orthoses, or walking aids, and includes a 10-meter timed walk test (L. Harvey & Marino, 2009). While both SCIM and WISCI have limitations in their scoring systems, they remain widely utilized globally in SCI rehabilitation.

Despite the importance of assessment, there is no universal consensus on the most appropriate set of physiotherapy-specific tools (Alexander et al., 2009). However, representatives from the Spinal Cord Injury Group of the American Physical Therapy Association have provided recommendations. Additionally, the international SCI community has developed basic datasets for SCI assessments (Biering-Sørensen et al., 2006). Some of these datasets are relevant to physiotherapists and can be used to guide treatment and track progress over time (Biering-Sørensen et al., 2012, 2014).

Physiotherapy Interventions

The outcomes of assessment and goal setting inform physiotherapy treatment strategies. Ideally, these treatments should be evidence-based; however, this remains a significant challenge within physiotherapy for SCI due to the limited number of high-quality randomized controlled trials (RCTs) specific to this population (L. A. Harvey et al., 2009). A recent estimate identified approximately 60 clinical trials addressing interventions unrelated to respiratory function, education, or mobility-related equipment provision (L. A. Harvey et al., 2014). Most trials have been conducted in recent years and focus on interventions like treadmill walking with overhead suspension, robotic gait training, electrical stimulation, and other high-cost, high-technology approaches. Interestingly, an audit of three European SCI units and one Australian unit revealed that therapists primarily allocate their time to simpler interventions targeting impairments such as weakness, reduced joint mobility, limited fitness, pain, and respiratory issues. Time is also spent teaching skills such as walking, bed mobility, wheelchair use, and upper limb function (Van Langeveld, Post, Van Asbeck, Gregory, et al., 2011). This observation highlights a discrepancy between the priorities of researchers and the treatments typically provided by clinicians. While this does not imply suboptimal care, it underscores that clinical treatments often lack robust support from high-quality SCI-specific trials, and research does not always evaluate the treatments clinicians commonly use.

In the absence of sufficient high-quality SCI-specific evidence, physiotherapists must rely on findings from other fields of physiotherapy. Evidence from high-quality trials in other populations can often provide more reliable insights into treatment efficacy than non-randomized or low-quality SCI-specific trials, which frequently produce biased effect estimates (L. A. Harvey, 2015). Furthermore, physiotherapists can adopt a logical problem-solving approach to treatment selection. For instance, if a person with C6 tetraplegia aims to transfer independently from a wheelchair to a bed, understanding the biomechanics of appropriate transfer techniques and teaching motor skills effectively may be more pertinent than awaiting specific clinical trial data for this scenario.

Physiotherapists working in SCI face additional challenges beyond limited evidence. The extensive scope of practice required includes addressing pain, respiratory complications, and pressure ulcers; designing fitness programs; promoting healthy lifestyles; teaching adaptive sports; providing orthoses, splints, and aids; prescribing wheelchairs; preventing shoulder pain and pressure ulcers; and administering electrotherapeutic interventions. This demands a wide range of clinical skills. Moreover, physiotherapists must remain open to new interventions, such as robotics and stem cell therapies, while resisting premature adoption of these approaches without high-quality evidence. Interventions introduced based on weak evidence risk wasting resources, creating unrealistic recovery expectations, and becoming entrenched without proper clinical validation (L. Harvey & Wyndaele, 2011). The involvement of commercial interests and perceived patient benefits often accelerates the adoption of unproven interventions, closing opportunities for rigorous evaluation through clinical trials.

This section focuses on interventions addressing three primary challenges: weakness, contractures, and impaired motor control. For further exploration of the full scope of physiotherapy management in SCI, refer to other sources (Chhabra, 2015; Chhabra et al., 2013; L. Harvey, 2008).

Physiotherapy Interventions to Increase Strength

Weakness is a major impairment that limits the ability of individuals with SCI to perform motor tasks. Consequently, strength training is a common intervention in physiotherapy for SCI (Van Langeveld, Post, Van Asbeck, Ter Horst, et al., 2011). Weakness in SCI may stem from neurological impairment, such as in individuals with quadriceps muscle strength graded at 2 or 3 attempting to walk, or from insufficient muscle mass in neurally intact muscles, such as in the upper limbs of individuals with paraplegia mastering floor-to-wheelchair transfers.

For neurologically intact muscles, there is no reason to assume that their response to strength training differs from that of able-bodied individuals. Thus, strength training for these muscles should follow established principles, such as progressive resistance training with systematically increasing loads. Functional skills can often be integrated into this training if the principles of progressive resistance are maintained. Evidence from numerous clinical trials in able-bodied populations supports these approaches (Munn et al., 2005). Additionally, two RCTs involving 92 participants with SCI demonstrated that progressive resistance training of non-paralyzed muscles improves both strength and quality of life (Hicks et al., 2003; Mulroy et al., 2011).

In contrast, the response of partially paralyzed muscles affected by SCI is less well understood. Longitudinal studies (Ditunno Jr. et al., 2000) and within-group changes in clinical trials consistently show strength improvements in partially paralyzed muscles over time, likely resulting from central and peripheral mechanisms. Central mechanisms may involve neural adaptations at the spinal cord injury site or the brain, while peripheral mechanisms include muscle hypertrophy. However, it remains unclear how much of this strength gain is due to natural recovery versus physiotherapy interventions.

The optimal training protocol for partially paralyzed muscles is not yet established, particularly regarding the efficacy of progressive resistance training versus high-repetition, low-resistance approaches, or the potential benefits of electrical stimulation. Four RCTs (Glinsky et al., 2008, 2009; L. A. Harvey et al., 2010, 2010) investigated progressive resistance training, electrical stimulation, and their combination, yielding mixed results. The most promising findings come from a trial involving an 8-week program combining progressive resistance training and electrical stimulation, which improved quadriceps strength in people with SCI compared to no intervention (mean between-group difference 14 Nm, 95% CI 1–27) (L. A. Harvey et al., 2010). Although the treatment effect estimate was imprecise, it suggests a clinically meaningful strength increase. Conversely, the other three trials, which explored different combinations of progressive resistance training and electrical stimulation in weak muscles, reported less favorable outcomes (Glinsky et al., 2008, 2009; Needham-Shropshire et al., 1997). One study incorporating electrical stimulation and arm ergometry with resistance did not clearly adhere to the principles of progressive resistance training, particularly the use of high resistance.

Physiotherapy Interventions for Strengthening Partially Paralyzed Muscles

Eight additional trials have investigated the effects of low-load, high-repetition interventions on the strength of partially paralyzed muscles in the upper and lower limbs (Alcobendas-Maestro et al., 2012; Alexeeva et al., 2011; Beekhuizen & Field-Fote, 2008; B. Dobkin et al., 2006; E. C. Field-Fote & Roach, 2011; J. Harvey & Min, 2011; Hornby et al., 2005; Postans et al., 2004). These trials included two focused on upper limbs and six on lower limbs. The interventions examined encompassed robotic gait training, overhead gait training, intensive hand practice with sensory stimulation, and combinations of these. Notably, all interventions involved high repetitions, meaning that they did not incorporate the high-load principles characteristic of progressive resistance training. Strength was predominantly assessed using manual muscle testing to derive an overall motor score, which primarily reflects strength changes in partially paralyzed muscles rather than in neurally intact muscles.

Of these eight trials, only two reported a treatment effect on strength (Alcobendas-Maestro et al., 2012; Beekhuizen & Field-Fote, 2008). The first trial compared robotic gait training with overground gait training, yielding a mean difference of 5 points on a 50-point scale (95% CI 2 to 9). The second trial compared intensive hand training with no training but did not provide or allow calculation of between-group differences. This trial measured hand strength with a pinch meter, which may have reflected improvements in the strength of non-paralyzed wrist extensor muscles in some participants rather than exclusively reflecting changes in partially paralyzed hand muscles. Additionally, it was the only trial to include a control group receiving no intervention, whereas the other trials compared different types of interventions.

This body of evidence underscores the limited understanding of how partially paralyzed muscles respond to various strength training paradigms. In the absence of clear evidence, a reasonable approach may be to combine progressive resistance training with repetitive practice of functional tasks involving low loads and high repetitions. Electrical stimulation combined with high resistance and maximal voluntary effort may also be appropriate. However, there is limited evidence to suggest that electrical stimulation alone significantly enhances voluntary strength (Glinsky et al., 2007, 2009). While electrical stimulation may have therapeutic benefits such as minimizing muscle atrophy in paralyzed muscles (Baldi et al., 1998), preventing peripheral nerve deterioration, encouraging neural repair, or promoting pressure ulcer healing there are no large, high-quality trials evaluating its effectiveness for these purposes. Consequently, unbiased estimates of its therapeutic effects are unavailable.

Physiotherapy Interventions for Managing Contractures

Contractures are a prevalent issue following SCI. Two cohort studies have tracked representative samples of individuals with SCI over one year to quantify the problem's extent. One study reported that 66% (95% CI 55 to 77) of individuals with SCI develop at least one notable contracture within a year of injury (Diong et al., 2012), while another found that 70% (95% CI 57 to 81) of individuals with tetraplegia experience a loss of shoulder range of motion within one year of starting rehabilitation (Eriks-Hoogland et al., 2009). Although no studies have extended follow-up beyond one year, anecdotal evidence suggests contractures worsen over time, with some individuals developing severe contractures.

Stretching and passive movement are commonly used to prevent and manage contractures, but their efficacy remains uncertain. Three trials have investigated the impact of stretching, and one trial has assessed the effect of passive movements on joint mobility in individuals with SCI. Pooled results from the stretching trials showed a mean between-group difference of 2 degrees (95% CI 1 to 4), which aligns with findings from a meta-analysis of 25 trials involving 812 participants with various neurological conditions (mean between-group difference 1 degree, 95% CI 0 to 3) (Katalinic et al., 2010, 2011). Similarly, the single trial on passive movements reported comparable results (Prabhu et al., 2013). These findings suggest a minor treatment effect that is unlikely to be clinically meaningful.

However, interpreting these results is challenging because none of the studies provided stretching or passive movements for more than six months; most interventions lasted only 4 weeks to 3 months. The effectiveness of daily stretching and passive movements over extended periods remains unknown. Even a modest 1-

degree improvement every six months could accumulate to 40 degrees over 20 years, though it cannot be assumed that effects compound over time. Similarly, it remains unclear how long stretches should be maintained daily or how frequently joints should be passively moved.

In the trials reviewed, stretching and passive movements were administered in large dosages not typically seen in clinical practice. Therefore, the possibility of greater effects with high doses and long durations cannot be dismissed. For stretches and passive movements to be effective in these circumstances, they must become part of daily routines. Passive movements should, as much as possible, be self-administered, and stretches integrated into positioning programs. However, these activities can be time-intensive, so clinicians must prioritize interventions for areas most susceptible to contractures or where contractures would significantly impact quality of life.

Physiotherapists must develop skills to predict contracture development and its consequences for individual patients (L. A. Harvey & Herbert, 2002). For instance, individuals with C6 tetraplegia are at high risk of elbow flexion contractures due to triceps muscle paralysis. Even minimal loss of elbow extension can prevent weight-bearing through the upper limbs, rendering transfers impossible and resulting in dependence on others. This profoundly affects quality of life, making the prevention of elbow flexion contractures in this population a priority. Patients should be educated on appropriate positioning programs, such as sleeping with the elbows extended, as this may take precedence over other joints or tissues. Similar clinical reasoning can guide contracture management for all SCI types (L. A. Harvey & Herbert, 2002). Emphasis should be placed on simple, sustainable strategies that minimize the time demands on individuals with SCI.

Physiotherapy Interventions to Improve Motor Task Performance

Physiotherapy often aims to enhance individuals' abilities to perform motor tasks such as walking, transferring, wheelchair propulsion, and upper limb activities. These interventions are grounded in motor learning principles. For instance, a person with motor-complete T4 paraplegia who wishes to learn to transfer from a seated position will benefit most from repetitive practice incorporating part practice, along with the appropriate use of instructions, feedback, and manual guidance (GENTILE, 2000). However, applying these principles effectively for people with spinal cord injury (SCI) requires attention to numerous subtleties. Evidence for the efficacy of these strategies is unlikely to be derived from clinical trials exclusively involving individuals with SCI. Instead, insights are drawn from motor control theories supported by experiments and randomized trials conducted in comparable populations, both able-bodied and those with similar conditions.

The principles of motor learning also inform gait training for individuals with the potential to walk. Repetitive practice is again a critical component. For patients with extensive paralysis aiming to walk with orthoses and aids, practice using these devices is essential. Conversely, patients with the potential for neurological recovery and the goal of walking unaided need to practice gait patterns closely mimicking those of able-bodied individuals. Treadmills and robotic devices can facilitate gait training by enabling intensive, repetitive practice of able-bodied gait strategies, which represents a significant advancement. However, two contentious issues persist regarding the use of these devices: determining who has potential for neurological recovery and whether treadmill or robotic training offers inherent advantages over overground training.

Evidence supporting the superiority of treadmill and robotic training over overground training originates from animal studies, some dating back to the 1980s, which demonstrated therapeutic benefits of cyclic walking (Lovely et al., 1986). It is believed that cyclic walking fosters neural plasticity within the spinal cord and trains central pattern generators, a complex spinal cord reflex (Edgerton et al., 2001; Harkema et al., 2000; Young, 2015). Non-randomized trials, case studies, and studies with historical controls have similarly suggested therapeutic effects, particularly for individuals with motor-incomplete lesions (Wernig et al., 1995). Nevertheless, randomized controlled trials have failed to replicate these promising findings. Six trials involving 263 participants compared treadmill training with overground training, revealing a pooled mean between-group difference in gait velocity of –0.01 m/s (95% CI –0.09 to 0.08) (Alexeeva et al., 2011; E. C. Field-Fote & Roach, 2011; Hornby et al., 2005; Lucareli et al., 2011; Postans et al., 2004). These results align with a 2012 Cochrane review and findings from two trials comparing robotic and overground gait training (Mehrholz et al., 2012) (Alcobendas-Maestro et al., 2012; Hornby et al., 2005). Similar outcomes have been reported in stroke populations (Moseley et al., 2005) and other neurological conditions, collectively suggesting that gait training using treadmills or robotic devices is no more effective than overground training, provided sufficient repetitive practice is achieved. These findings challenge longstanding assumptions and have generated considerable debate (B. H. Dobkin & Duncan, 2012; L. A. Harvey et al., 2011). They indicate that cyclic walking on treadmills or with robotic devices may not have intrinsic therapeutic value but can serve as a practical and safe means for therapists to deliver intensive, repetitive practice.

Irrespective of gait training methods, the question of who should undergo gait training and who possesses neurological recovery potential remains unresolved (B. H. Dobkin & Duncan, 2012; L. Harvey & Wyndaele, 2011; Wolpaw, 2006). Some advocate for offering gait training to all patients using treadmills or robotic devices, with or without electrical stimulation or therapist assistance to move paralyzed legs, even when the likelihood of walking is minimal. Proponents argue that such therapy offers broader health benefits, including those associated with standing and vigorous exercise, even for patients unlikely to walk independently. Pragmatists, however, highlight the economic constraints of providing costly treatments to all patients without clear justification and caution against fostering unrealistic expectations about walking (Riggins et al., 2011). They argue that an exclusive focus on walking may detract from developing essential seated independence skills for those unlikely to regain walking ability. Striking a balance between these perspectives is crucial.

Future Directions

The growing focus on neural plasticity and recovery following SCI has led to the introduction of "activity-based therapy." (Jones et al., 2014) While some hail it as a novel approach to physiotherapy for individuals with SCI (Behrman & Harkema, 2007), the term lacks a universally agreed definition (E. Field-Fote, 2014). A key element of activity-based therapy is intensive, context-specific, task-specific practice involving many hours of daily exercise, reminiscent of the approaches advocated by Carr and Shepherd in the 1980s (Carr & Shepherd, 1982). Activity-based therapy also encompasses "developmental sequencing" exercises, strength training, and treadmill or robotic walking with or without electrical stimulation. Its proponents claim its novelty lies in optimizing function and promoting neural recovery below the level of injury, contrasting it with "conventional" therapy, which they characterize as focusing solely on compensatory strategies above the injury level. Anecdotal evidence, however, suggests this distinction may be overstated, as physiotherapists have long directed therapeutic efforts below the level of injury, particularly in patients with some degree of motor function. Regardless of terminology, at least one trial has demonstrated that intensive physiotherapy improves gait and strength in individuals with AIS C and D lesions up to three years post-SCI. Proponents view this as evidence supporting a new therapeutic approach, while others see it as validation of longstanding practices, highlighting the benefits of comprehensive and intensive physiotherapy.

Physiotherapy practices are likely to evolve significantly in the coming decade. Exoskeletons, which currently allow individuals with lower-limb paralysis to walk overground, may become versatile enough to replace wheelchairs as technology advances. Stem cell therapies may eventually offer new possibilities for individuals with SCI. While the future holds promise, it remains essential to focus research efforts on the fundamental principles underpinning physiotherapy management for SCI. More clinical trials are needed to evaluate the efficacy of widely used interventions for managing impairments such as weakness, spasticity, pain, osteoporosis, contractures, and respiratory dysfunction. Establishing robust evidence for effective treatments of these impairments will be crucial for harnessing future breakthroughs in stem cell therapies, neuroplasticity, robotics, and other innovations. However, it is vital that emerging interventions undergo rigorous scrutiny through high-quality clinical trials before becoming standard practice. The emphasis must remain on evidence-based physiotherapy for individuals with SCI.

2. Conclusion

Physiotherapy plays a pivotal role in the rehabilitation of individuals with spinal cord injury (SCI), addressing key challenges such as weakness, contractures, and impaired motor control. While many physiotherapy interventions rely on established motor learning principles and techniques like strength training and repetitive practice, evidence for their effectiveness in SCI-specific contexts remains limited. This necessitates the application of insights from broader physiotherapy research and logical problem-solving to guide treatment.

Emerging approaches such as activity-based therapy, exoskeleton-assisted walking, and neural recovery interventions hold promise, yet their integration into standard practice must be supported by high-quality evidence. Physiotherapists face the dual challenge of embracing innovation while resisting premature adoption of unverified techniques. Future advancements in technology, stem cell therapies, and neuroplasticity offer hope for enhanced recovery, but continued emphasis on evidence-based practices and rigorous clinical trials remains crucial.

Ultimately, the physiotherapy management of SCI must balance the goals of improving functional independence, promoting neural recovery, and fostering realistic expectations for patients. By prioritizing patient-centered care and leveraging innovative interventions judiciously, physiotherapy can continue to advance as a cornerstone of SCI rehabilitation.

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