CASE STUDY

BODY-WEIGHT SUPPORTED TREADMILL TRAINING COMBINED WITH ELECTRICAL MUSCLE STIMULATION EFFECTIVE IN IMPROVING LOCOMOTION AFTER INCOMPLETE SPINAL CORD INJURY: A CASE STUDY

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ABSTRACT

Introduction: Although body weight supported treadmill training (BWSTT) and electrical muscle stimulation (EMS) have demonstrated substantial efficacy as standalone interventions, their combined therapeutic potential remains underexplored. This study investigates the synergistic effects of BWSTT and EMS on locomotor and functional recovery in a patient with incomplete spinal cord injury (SCI).

Material & Methods: A 47-year-old male with an L2 ASIA C SCI from a T12 fracture presented with significant lower limb weakness. Initial assessments showed a WISCI-II score of 9, 6MWT distance of 30 meters, 10MWT speed of 0.074 m/s, and a SCIM score of 43/100. Rehabilitation included 12 weeks of BWSTT (three 60-minute sessions/week) and EMS (twice daily on alternate days), targeting lower limb muscles.

Results: At the 6th-week of reassessment, the patient's neurological level improved to L3 ASIA C, with increases in WISCI-II (12), 6MWT (50 meters) and improved 10MWT speed (0.15 meter/seconds). By the 12-week mark, the WISCI-II increased to 18, 6MWT to 125 meters, and 10MWT increased to 0.58 m/s. The SCIM score increased significantly to 91/100.

Conclusion: The combination of BWSTT and EMS in rehabilitation improved locomotion, endurance, and independence in an incomplete SCI patient, highlighting the need for further research.

Keywords: Body Weight, Electrical Stimulation, Locomotion, Spinal Cord Injury, Treadmill Training.

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INTRODUCTION

Spinal cord injury (SCI) is a debilitating condition and can lead to partial or complete paralysis of the lower limbs, severely impairing or eliminating the ability to walk.[1] Various rehabilitation approaches have been devised to address these profound effects, with some demonstrating significant success in mitigating functional impairments.

These rehabilitation approaches have evolved from traditional interventions, such as stretching, strengthening, range of motion exercises, and gait training, to more focused approaches that target specific functional goals.[2] New rehabilitation strategies, including task specific training, ambulatory assistive devices (AADs), exoskeletons, robotics, and BWSTT, have been developed and shown effectiveness in ambulation

outcomes.[3,4]
Exoskeletons and robotic devices assist with mobility by mimicking natural limb movements through sensors, thereby improving quality of life.[5] AADs help alleviate pressure on affected limbs, reduce pain, and compensate for muscle weakness in the lower extremities.[6] However, the use of these devices increases cognitive load and places a substantial metabolic burden on patients, which can negatively impact gait speed and endurance—factors that are critical for daily activities and participation in community life.[7]
Besides, BWSTT is a therapeutic intervention aimed at promoting walking recovery in people with incomplete SCI. It has been reported that BWSTT improves bone health, mitigates muscle atrophy through weight-bearing, and enhances overall ambulatory function.[8,9]
Rehabilitation post SCI presents a significant global economic burden, with restoring ambulatory function remaining a critical challenge. This study aims to assess the efficacy of combining body-weight supported treadmill training (BWSTT) and electrical muscle stimulation (EMS) in enhancing functional ambulation. While BWSTT has demonstrated improvements in gait in prior research, data on the synergistic effects of combined BWSTT and EMS remain limited.

MATERIAL AND METHODS

A 47-year-old male presented in the sub-acute phase of a spinal cord injury (SCI) after being struck by a falling cupboard, following acute care at a local hospital. Upon admission, a multidisciplinary team conducted a comprehensive assessment, confirming the patient is vitally stable. MRI findings revealed a T12 vertebral fracture, with a neurological level of L2 ASIA C, and bowel and bladder continence. Muscle strength evaluations, measured with a handheld dynamometer as given in table 1.
Considering the patient's muscle strength, a combined BWSTT and EMS approach was proposed to promote neuroplasticity, enhance motor recovery, and prevent muscle atrophy. BWSTT enables repetitive gait training with reduced muscle load, while EMS stimulates paralyzed muscles, encouraging stronger, natural movement patterns. Together, these interventions improve walking ability, cardiovascular fitness, and overall functional outcomes, proving effective in restoring locomotion in SCI patients.
The protocol consisted of 1-hour sessions, 3 days per week, for 12 weeks, totaling 36 sessions. EMS was administered using a Beurer EM 49 digital TENS/EMS unit, with parameters set at 50Hz frequency, 300 microseconds pulse width, and 100mA stimulation amplitude. EMS was applied for 30 minutes per session, targeting key lower limb muscles, with a total of 72 sessions over 12 weeks (6 sessions per week).
Informed written consent was obtained for participation, including explicit consent for the use of images, in a 12-week intervention study during which outcome measures were periodically re-evaluated. At baseline, the patient scored 9/20 on the Walking Index for Spinal Cord Injury-II (WISCI-II), indicating the ability to walk 10 meters with a walking frame and ankle foot orthosis (AFOs), without assistance. Initial results from the 6-minute walk test (6MWT) showed 30 meters covered in 6 minutes, indicating limited aerobic capacity and endurance. His 10-meter walk test (10MWT) time was 80.84 seconds, reflecting slow walking speed, while the Spinal Cord Independence Measure (SCIM) score was 43/100, highlighting significant impairments in activities of daily living (ADLs).

RESULTS

After 6 weeks of training, the patient's neurological level improved to L3 ASIA C, and the WISCI-II score increased to 12. Pain levels rose to 6/10 on the visual analogue scale (VAS), likely due to muscle strain and fatigue. The 6MWT showed improved aerobic capacity, with 50 meters walked in 6 minutes, and the 10MWT time reduced to 40.74 seconds.
At the end of 12 weeks, the patient demonstrated further improvements. The WISCI-II score increased to 18, indicating ambulation without a walking frame, using

only AFOs and no assistance. Pain decreased to 1/10 on the VAS. The 6MWT improved to 125 meters, and the 10MWT time reduced to 10.41 seconds. ADL performance, as measured by the SCIM, improved from 43/100 at baseline to 82/100 mid-study and 99/100 at final assessment.

Comparison of baseline and results revealed significant improvements in muscle strength and pain levels along with enhanced independence. Notable gains were observed in gait endurance, aerobic capacity, and walking speed as given figure 1&2.

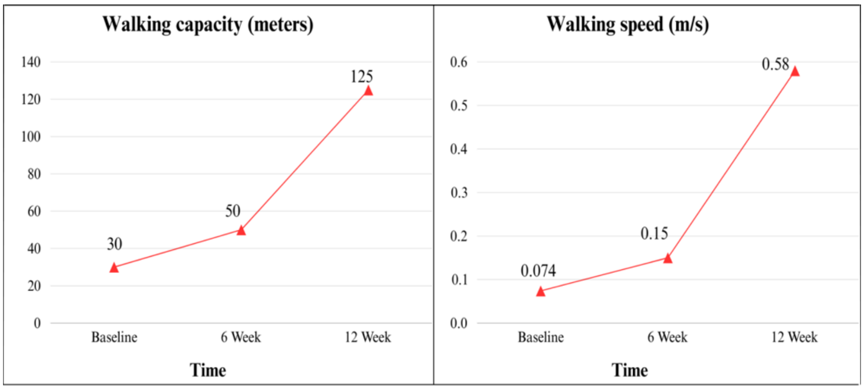

Figure 1: Walking Capacity via the Six-Minute Walk Test and Ten-Minute Walk Test for Speed across Three Time Points

Figure 2: Body-weight supported treadmill training

Table 1: Summary of outcomes: WISCI-II, VAS, SCIM, Muscle Strength, and Neurological Level Across Three Time Points

Characteristics		Baseline	6 Week	12 Week
Walking Index for Spinal Cord Injury (WISCI-II)		9.00	12.00	18.00
Neurological Level		L2 ASIA C	L3 ASIA C	L3 ASIA C
Lower Extremity Motor Score (LEMS)		27.00	29.00	35.00
Visual Analog Scale (VAS)		3.00	6.00	1.00
Spinal Cord Independent Measure (SCIM)	Self-care	17.00	17.00	20.00
	Respiration and sphincter management	11.00	11.00	40.00
	Mobility	15.00	15.00	31.00
	Total SCIM score	43.00	44.00	91.00
Muscle Strength through Dynamometer	Hip flexors right	0.25	0.27	0.25
	Hip flexors left	0.23	0.25	0.26
	Knee extensors right	0.30	0.32	0.24
	Knee extensors left	0.24	0.26	0.27
	Ankle dorsiflexors right	0.001	0.001	0.001
	Ankle dorsiflexors left	0.001	0.001	0.001
	Long toe extensors right	0.0005	0.0005	0.0005
	Long toe extensors left	0.0005	0.0005	0.0005
	Ankle planter flexors right	0.06	0.07	0.13
	Ankle planter flexors left	0.06	0.06	0.14

ASIA: American Spinal Cord Injury Association Scale
LEMS was assessed through Manual Muscle Testing (MMT)

DISCUSSION

BWSTT combined with ES has demonstrated efficacy in enhancing walking functionality in patients with SCI. Effing et al. conducted a study, delivering a 12-week intervention to assess its effects on performance in ADLs, and walking abilities. Their findings revealed significant improvements in walking performance with the use of BWSTT.[10] Our case study aligns with these findings, reinforcing the efficacy of BWSTT with EMS. However, a notable difference lies in the outcome measures: Effing et al. used a 7-meter walk test due to space limitations, while our study employed a 10-meter walk test to assess speed. Despite this variance, both approaches indicate improved locomotor function, further validating the initial hypothesis.

A study on BWSTT's effectiveness in SCI

patients found improvements in postural sway after 6 weeks but no significant gains in gait independence, unlike the 12-week intervention in our study. The extended duration in our research is likely to account for the greater improvements in gait independence, suggesting that longer interventions may yield more substantial functional outcomes.[11]

Melanie et al. conducted a pilot study investigating the effectiveness of BWSTT and functional electrical stimulation (FES) on skeletal muscle morphology and highlighted that prolonged muscle disuse leads to atrophy, contributing to increased pain. These outcomes align with our study, particularly in relation to the observed reduction in pain.[12]

In a systematic review by Thomas and Gorassini, outcome measures such as the WISCI-II and the 6-MWT were utilized, showing significant improvements when the intervention lasted 17 weeks (5 days per week, 60 minutes per session). The study's positive outcomes may be attributed to the higher frequency and longer duration of sessions. In contrast, two studies by Dobkin et al. employed WISCI-II, the Functional Independence Measure (FIM), and gait velocities as assessment tools. However, with a 12-week intervention (5 days per week, 50 minutes per session), no significant improvements were observed. [13,14] These differences in intervention duration highlight the potential for extended BWSTT to further enhance walking abilities, suggesting that longer treatment periods may lead to more pronounced functional gains.

Kapadia et al. demonstrated that BWSTT combined with FES in chronic incomplete SCI significantly improved gait, balance, and walking speed. FES, applied during treadmill walking, effectively activated paralyzed or weakened muscles to facilitate ambulation.[15]

Similarly, Postans et al. found that partial weight-bearing treadmill training with FES enhanced walking endurance and speed in acute incomplete SCI, accelerating gait recovery.[16]

Field-Fote and Roach's comparative analysis of locomotor training methods revealed that BWSTT with ES led to significant gains in walking speed and distance, especially in individuals with severe impairments.[17]

Todd, Kendra R., et al. highlight that exercise may alleviate neuropathic pain and enhance mood in adults with SCI, potentially via modulation of inflammation. Moreover, exercise intensity appears to significantly influence these pain, inflammation, and mood outcomes.[18] Overall, the consistent evidence across these studies supports the conclusion that BWSTT combined with ES significantly improves walking functionality in SCI patients.

CONCLUSION

BWSTT combined with EMS is an effective intervention for improving functional recovery and reducing pain in SCI patients. BWSTT serves as an accessible, cost-effective treatment, enhancing mobility and independence, and offering a practical alternative to advanced technologies like exoskeletons and robotic therapies. The therapy's efficacy is primarily driven by its promotion of neuroplasticity and facilitation of neural pathways related to locomotion. Evidence supports BWSTT's ability to enhance motor function, increase muscle strength, and improve mobility in SCI patients. However, further studies are required to confirm these findings and establish the broader clinical relevance of BWSTT in SCI rehabilitation.

REFERENCES

1. Bennett JDas JM, Emmady PD. Spinal cord injuries. StatPearls [Internet]: StatPearls Publishing; 2024.

2. Sawada T, Okawara H, Matsubayashi K, et al. Influence of body weight-supported treadmill training with voluntary-driven exoskeleton on the quality of life of people with chronic spinal cord injury: a pilot study. International Journal of Rehabilitation Research. 2021;44(4):343-349.

3. Yamamoto R, Sasaki S, Kuwahara W, et al. Effect of exoskeleton-assisted Body Weight-Supported Treadmill Training on gait function for patients with chronic stroke: a scoping review. Journal of neuroengineering and rehabilitation 2022;19(1):143.

4. Yang FA, Chen SC, Chiu JF, et al. Body weight-supported gait training for patients with spinal cord injury: a network meta-analysis of randomised controlled trials. Sci Rep. 2022;12(1):19262.
5. Gil-Agudo Á, Megía-García Á, Pons JL, et al. Exoskeleton-based training improves walking independence in incomplete spinal cord injury patients: results from a randomized controlled trial. Journal of neuroengineering and rehabilitation. 2023;20(1):36.
6. Webb AANgan S, Fowler JD. Spinal cord injury I: A synopsis of basic science. The Canadian Veterinary Journal. 2010;51(5):485.
7. Saensook W, Phonthee S, Srisim K, et al. Ambulatory assistive devices and walking performance in patients with incomplete spinal cord injury. Spinal cord. 2014;52(3):216-219.
8. Giangregorio L, Hicks A, Webber C, et al. Body weight supported treadmill training in acute spinal cord injury: impact on muscle and bone. Spinal cord. 2005;43(11):649-657.
9. Hicks A, Adams M, Martin Ginis K, et al. Long-term body-weight-supported treadmill training and subsequent follow-up in people with chronic SCI: effects on functional walking ability and measures of subjective well-being. Spinal cord. 2005;43(5):291-298.
10. Effing T, Van Meeteren N, Van Asbeck F, et al. Body weight-supported treadmill training in chronic incomplete spinal cord injury: a pilot study evaluating functional health status and quality of life. Spinal cord. 2006;44(5):287-296.
11. Covarrubias-Escudero F, Rivera-Lillo G. Effects of body weight-support treadmill training on postural sway and gait independence in patients with chronic spinal cord injury. 2019;42(1):57-64.
12. Adams MM, Ditor DS, Tarnopolsky MA, et al. The effect of body weight-supported treadmill training on muscle morphology in an individual with chronic, motor-complete spinal cord injury: a case study. The journal of spinal cord medicine. 2006;29(2):167-171.
13. Dobkin B, Apple D, Barbeau H, et al. Weight-supported treadmill vs over-ground training for walking after acute incomplete SCI. Neurology. 2006;66(4):484-493.
14. Dobkin B, Barbeau H, Deforge D, et al. The evolution of walking-related outcomes over the first 12 weeks of rehabilitation for incomplete traumatic spinal cord injury: the multicenter randomized Spinal Cord Injury Locomotor Trial. Neurorehabil Neural Repair. 2007;21(1):25-35.
15. Kapadia N, Masani K, Catharine Craven B, et al. A randomized trial of functional electrical stimulation for walking in incomplete spinal cord injury: Effects on walking competency. J Spinal Cord Med. 2014;37(5):511-524.
16. Postans NJ, Hasler JP, Granat MH, et al. Functional electric stimulation to augment partial weight-bearing supported treadmill training for patients with acute incomplete spinal cord injury: A pilot study. Arch Phys Med Rehabil. 2004;85(4):604-610.
17. Field-Fote EC, Roach KE. Influence of a locomotor training approach on walking speed and distance in people with chronic spinal cord injury: a randomized clinical trial. Phys Ther. 2011;91(1):48-60.
18. Todd KR, Van Der Scheer JW, Walsh JJ, et al. The Impact of Sub-maximal Exercise on Neuropathic Pain, Inflammation, and Affect Among Adults with Spinal Cord Injury: A Pilot Study. Front Rehabil Sci. 2021; 2:700780.