Locomotion Training in Patients with Spinal Cord Injury: A Systemic Review

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Abstract: Spinal cord injury leads to affection of quality of life. This quality of life affection is heightened to the extent that patient might end up with spasticity, reduced mobility and complete dependence through out the life. Hence, proper training affecting neurophysiological mechanism is necessary. Hence, this study is conducted so as to come-up with best possible method so as to restore locomotion in spinal cord injury. In this systemic review, in total 654 articles were reviewed. Out of these 645 articles were excluded as they did not meet the inclusion and exclusion criteria. The study concluded that there are many effective treatment approaches available so as to guide the physiotherapist. Also, out of all the studies reviewed-Lokomat training is more commonly used for locomotion training.

Keywords: Spinal cord injury, Locomotion training

1. Background

Locomotor ability is frequently affected in people with SCI, and decreased mobility after SCI is associated with a heightened risk of a decrease in both life satisfaction and quality of life [1]. Locomotor training focuses on retraining the motor function via plastic change [2], and the neurophysiological mechanism underlying the restoration of human locomotion after SCI involve enhancing the afferent input to the spinal cord and activating central pattern generators (CPG) embedded within the lumbosacral spinal cord.

Motor learning brings improvements to the biomechanics of the lower limbs, such as the pelvis and ankle, by means of an increased range of motion of the joints involved and the strength of the lower limbs, ensuring greater stability during gait [3]. These peripheral changes contribute to improve motor control, something which is reflected on an increased speed [4] and the independence of gait [5].

Locomotor training focuses more on the retraining of motor function via plastic change. This is consistent with current knowledge of CNS recovery. For the purposes of this review, locomotor training is defined as any "therapeutic program aimed at the recovery of walking through intense practice of the task of walking." Possible interventions included body-weight supported treadmill training (BWSTT), treadmill training with or without manual assistance and/or functional electrical stimulation (FES), overground walking training with or without body-weight support (BWS), manual assistance and/or FES, robotic gait training, and conventional gait training approaches.

With a large amount of literature available on this topic, an overview of current high-quality evidence is essential to support clinical reasoning and decision making of rehabilitation professionals aiming to maximize gait improvements after SCI. Based on the preliminary analysis of the relevant literature it was thought to frame the research question as 'What is the best treatment intervention available in the literature for locomotor training for gait rehabilitation in adults with SCI'. Thus , in line with the research question aim of the systematic review was to provide best possible evidence for most effective locomotor training approach for gait rehabilitation in adults with SCI. Secondary objectives of the study were 1.To explore the literature related to locomotor training for gait rehabilitation, available in last 10 years. 2.To describe the locomotor training approaches used in various research studies. To describe the outcome measures used in various studies for measuring the effectiveness of an intervention.3.To analyze the studies for details about the intervention and its effectiveness.

2. Methodology

All studies related to locomotion training for patients with spinal cord injury were included. To achieve this a systematic literature search was conducted in November 2017 through the most commonly used search engine that is Pubmed.

Study selection: Full text articles from peer-reviewed journals were included. Intervention based studies in the form of Clinical Trials, Experimental Studies, Quasi experimental studies, RCTs were included. Due to Language and appropriate translation issue, only studies published in English language were considered. Two independent reviewers reviewed the abstracts of the articles to begin with.

Studies were included with the Study participants with an incomplete, traumatic, or nontraumatic SCI, as defined by the American Spinal Cord Injury Association (ASIA) Impairment Scale grades B, C, or D were included for the study. Further inclusion criteria was a) A minimum age of 16 for all participants because most neurologic development is complete once adolescence is reached. b) All locomotor therapies aimed at improving locomotor function after SCI, and training parameters specified in detail to help compare trials. C) Studies making use of one or more interventions. d) Trials with at least 1 type of subsequently listed outcomes. Studies conducted on animal or invasive procedures were excluded.

Types of outcome: The outcomes were gait speed, walking endurance, level of independence of walking, use of assistive devices and walking aids, step length, symmetry of gait, or balance during sit, stance, or locomotion.

Data sources: Articles published in PUBMED from 2009 to 2017were included with keywords, medical subject headings, and search terms suggested by PUBMED. The key words were locomotor training, locomotor therapy, gait training, Spinal cord Injury.

List of abbreviations: ASIA-American Spinal Injury Association, BWS-body-weight support, BWSTT- body-weight supported treadmill training, CG- control group, CNS-central nervous system, EG- experimental group, FES-functional electrical stimulation, PED- Physiotherapy Evidence Database, PT- physiotherapy, RCT- randomized controlled trial ,SCI- spinal cord injury.

Data collection and analysis: PUBMED was searched by the both investigators. The titles and abstracts of all retrieved results were then screened for eligibility. The first screening process was aimed at narrowing down the volume of articles by rejecting all studies that are not relevant or appropriate according to the previously stated criteria. Duplicates were removed. Full-text versions of all relevant articles were evaluated by both investigators.

3. Discussion

This systematic review aimed to provide an overview of the current treatment approaches for Locomotion Training in Patients with Spinal Cord Injury. Of total 9 studies, Lokomat training was given in 5 studies.In other studies various other approaches were used for improving the locomotion in patients with spinal cord injury such as Tizanidine, Intermittent Hypoxia Body weight-supported treadmill training.

In a study conducted by Amanda E. Chisholm in patients with Spinal Cord Injury-Over Ground Robotic Gait Training was given to Improve Sitting Balance In People With Motor-Complete Spinal Cord Injury and showed significant improvement in seated balance. The outcomes used were EMG, Baseline postural sway, static seated balance control with eyes closed. The main reasoning may be due to enhance trunk muscle activity thus result in improved postural stability, which is important for performing functional activities in the seated posture after SCI. Another reason may be that it engages the trunk muscles through weight shifting movements that are require to position the body over the appropriate foot to initiate step.[1,10]

Robot-Assisted Gait Training (Lokomat) Improves Walking Function And Activity In Spinal Cord Injury patients. The outcome measures used were ambulatory function measured as speed and capacity of walking, Leg strength measured as lower extremity motor score of the neurological examination according to the American Spinal Injury Association International Standards level range 0 to 50 of functional mobility and independence measured by WISCI-II (assesses the amount of physical assistance needed, as well as devices required.), FIM-L (independence of gait.), functional mobility and balance measured by TUG and spasticity measured as Modified Ashworth scale. The main reasoning may be early initiation of gait training in severely dependent patients, less effort for physiotherapist, longer duration and higher intensity of gait more physiological and reproducible gait patterns, and the possibility to measure patient's performance. These factors further contribute to spinal and central neuroplasticity.[2]

As per the study done by X. NiuRobot-Assisted Locomotor and tizanidine Training improves Walking Speed. The outcome measures used were 10MW test. The main reasoning may be the Individuals respond differently to the Lokomat training based on their individual characteristics, such as baseline measurements. The GMM analysis provides a way to identify the differential effect of the Lokomat training on ambulation capacity. Patients with incomplete SCI benefited from ongoing Lokomat training, with a consistent pattern of improvements to their ambulation. It implies that the recovery pattern can be modeled for the patients with SCI who receive the Lokomat training.[3,11]

Intermittent Hypoxia and body weight-supported treadmill Training Enhances Dynamic Balance In Incomplete SCI Patients. The outcome measures used were Instrumented Sway (iSway), Instrumented Timed up and go test (iTUG), EMG. The main reasoning may be dynamic balance needs more of concentric and eccentric contraction. This dynamic ability is better treated with task specific approach in the dynamic situation.[4]

Advanced Reciprocating Gait Orthosis with TLSO will improve ability of paraplegic patients to walk at relatively higher speed and lower energy consumption The outcome measures usedwere Heart Rate at steady-state walking (HRss) and the Heart Rate at rest (HRar) were measured, 6-min walking test. The main reasoning behind it may be wearing a TLSO with an ARGO to provide trunk extension improved energy consumption compared to wearing an ARGO alone in SCI patients. In this study, joint flexion associated with increased energy expenditure and resulted in increase hip flexion movement during swing through action of reciprocal link. Use of TLSO helps to bring the center of gravity of trunk over the base of support for stability Along with this, TLSO application also help to increase the speed of walking, this in turn demanded lesser energy thus lowering the physiological cost of index.[5,13]

Locomotor training with a Robot-Assisted Gait Orthosis, transcranial Direct Current Stimulation improves ability of

SCI patient to improve and maintain balance during various activities The outcome measures used were MMT, 10MWT, 6MinWT, Timed Up and Go Test (TUG), Berg Balance Scale (BBS), and Spinal Cord Independence Measure-III (SCIM-III). The main reasoning behind it may be LT-RGO protocol used can improve LE motor function in cases of chronic incomplete SCI and that tDCS may enhance this improvement TDCS result in enhanced cortical excitability that is increase amplitude of motor action potentials in the Tibialis anterior muscle this corticospinal excitability may persist for maximum 60 minutes post anodal stimulation.[6,12]

Activity-Based Therapy has potential to promote neurologic recovery and enhance walking ability in some individuals with chronic, motor-incomplete SCI. The outcome measures usedwere10-meter walk test and 6-minute walk test, timed Up and Go test. This may be due greater impact on walking endurance than on speed as indicated by improvements in distance on the 6MWT. This may be expected because the multifocused ABT intervention included progressive resistance training, which distinguishes this approach from locomotor training only. Secondary analyses suggest that it is possible to identify likely responders to ABT on the basis of injury characteristic AIS classification, time since injury, and initial walking ability. These factors, along with information about preliminary responsiveness to therapy (gains at 12wk), can help predict the degree of recovery likely from an intensive ABT intervention.[7,14]

Functional Electrical Stimulation (FES), body weight support treadmill and harness system tailored exercise program affect the Body Composition in SCI patients The improvement may be the result of long-term preservation of muscle when compared with exercise FES is also perceived to have health related benefits in the form of improved body composition.Also FES assisted walking may promote muscular endurance and may also result in increased muscle size. FES also helps to improve muscle strength due to increase in muscle size.[8,15]

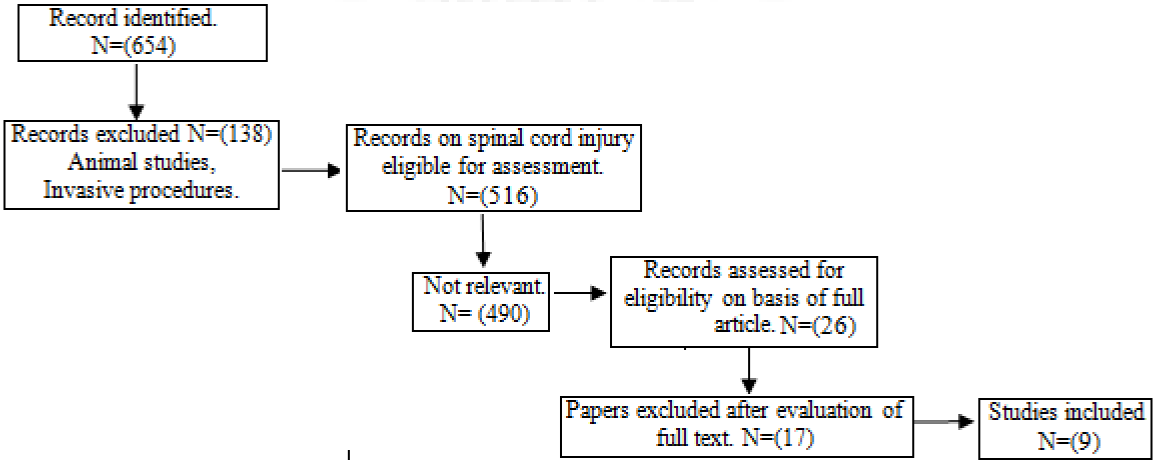
Daily Intermittent Hypoxia Enhances Walking in Chronic SCI patients and has significant improvements in walking speed ,and walking endurance. The main reasoning behind it may be AIHinduced recovery of breathing and walking function after spinal injury is a result of increased synaptic strength and/or motor excitability. Although facilitative respiratory plasticity may partially contribute to improve walking endurance by increasing cardio respiratory reserve, it is likely accompanied by changes in somatic motor areas more closely related to locomotor control. Serotonin and BDNF have been linked to spinal locomotor recovery after SCI.[9]

4. Conclusion

From the present study it can be concluded that -

- Various treatment approaches have been investigated such as Over Ground Robotic Gait Training, Treadmill-Based Robotic Gait Training, Robot-Assisted Gait Training (Lokomat), Robot-Assisted Locomotor Training On Walking Speed And Tizanidine (LOKO+TIZ), Intermittent Hypoxia And Locomotor Training With Body Weight-Supported Treadmill Training (BWSTT) And Placebo Protocolin The Form Of Continuous Normoxia, Advanced Reciprocating Gait Orthosis ,Isocentric Reciprocating Gait Orthosis (IRGO), TLSO, Locomotor Training With A Robot-Assisted Gait Orthosis, Transcranial Direct Current Stimulation, Activity-Based Therapy, Functional Electrical Stimulation Body Weight Support Treadmill And Harness System Tailored Exercise Program, Daily Intermittent Hypoxia.
- Out of all thee interventions, Lokomat i.e. Robotic assisted Gait Training is more commonly used and also have been proved to be more effective.

Flow Chart



Statistical Analysis: Descriptive statistics was used for analyzing various parameters used in the included studies.

Table 1: Summary of the related studies

Author name.	Intervention	Duration	Effective treatment	Reasoning	Outcome measures
Amanda E. Chisholm.	Overground robotic gait training, Lokomat walking.	30 sessions	Overground robotic gait training is effective than Lokomat.	case report has shown that overground robotic gait training in the Ekso enhances trunk muscle activity relative to Lokomat, which may lead to improve seated postural control in motor-complete SCI.	EMG, Baseline postural sway, static seated balance control with eyes closed.
Ki Yeun Nam.	Robot-assisted gait training	10 trials involving 502 participants to meta-analysis	acute RAGT groups showed significantly greater improvements in gait distance, leg strength, and functional level of mobility and independence	Review provides evidence that the acute RAGT group showed significantly greater improvements in gait distance, strength, and functional level of mobility and independence than the OGT group. In the chronic RAGT group, significantly greater improvements in speed and balance were observed than in the group with no intervention. RAGT treatment in incomplete SCI patients showed promise in restoring functional walking. An improvement in locomotor ability in persons with SCI using RAGT might enable them to maintain a healthy lifestyle and increase their level of physical activity.	Ambulatory function measured as speed (m/s, 10 m walk test) and capacity of walking (meters walked in 6 min or 2 min). leg strength measured as LEMS (lower extremity motor score of the neurological examination according to the American Spinal Injury Association International Standards level range 0 to 50) of functional mobility and independence measured by WISCI-II (assesses the amount of physical assistance needed, as well as devices required) FIM-L (independence of gait) functional mobility and balance measured by TUG and spasticity measured as MAS(Modified Ashworth scale)
X. Niu.	Lokomat Training, combined intervention of the Lokomat training and tizanidine (LOKO+TIZ).	1-hour Lokomat training 3 times a Week for 4 weeks.	participants in the LOKO+TIZ group that had a low baseline walking capacity could achieve higher improvement in walking speed than subjects who had high baseline walking capacity in both LOKO and LOKO+TIZ groups. On the other hand, subjects with high baseline walking capacity did not show a difference in improvement in their walking speeds between the LOKO and LOKO+TIZ groups.	individuals respond differently to the Lokomat training based on their individual characteristics, such as baseline measurements. The GMM analysis provides a way to identify the differential effect of the Lokomat training on ambulation capacity. Patients with incomplete SCI benefited from ongoing Lokomat training, with a consistent pattern of improvements to their ambulation. It implies that the recovery pattern can be modeled for the patients with SCI who receive the Lokomat training.	Wilcoxon signed ranks test. Linear Mixed Model analysis, Growth Mixed Model, *10MW test*
Angela Navarrete-Opazo.	Intermittent Hypoxia (IH) plus body weight-supported treadmill training (BWSTT), placebo (*Placebo protocol*: it consists of continuous normoxia (Nx, 21% O2) for 181 45 minutes for 5 consecutive days and then 3 times per week for 3 weeks. Total time: 4	every day for 5 consecutive days, and then 3 times per week for 3 weeks. Total time: 4 weeks	Intermittent Hypoxia combined with BWSTT does not enhance standing balance. Intermittent Hypoxia combined with BWSTT enhances dynamic balance	due to the lack of task-specific standing rehabilitation training.	Mobility Lab software, *Instrumented Sway (iSway), Instrumented Timed up and go test (iTUG)*, EMG

	weeks.)(continued normoxia) plus BWSTT				
Mokhtar Arazpour.	Advanced reciprocating gait orthosis (ARGO), isocentric reciprocating gait orthosis (IRGO), TLSO		PCI(measure of alteration of heart rate during exercise.) during orthotic walking with an ARGO and TLSO in a small-sample-sized study and showed that paraplegic patients could walk at relatively higher speed and lower energy consumption compared with the ARGO alone.	Wearing a TLSO with an ARGO to provide trunk extension improved energy consumption compared to wearing an ARGO alone in SCI patients in this study.	Polar Heart Rate Monitor , heart rate at steady-state walking (HRss) and the heart rate at rest (HRar) were measured. 6-min walking test
Ravi Raithatha.	Locomotor training with a robot-assisted gait orthosis, transcranial direct current stimulation	subject received 36 sessions of tDCS paired with LT-RGO (3 times per week for 12 weeks).	overall improvement on all outcome measures for both treatment groups. the active tDCS group showed more improvement on the primary outcome measure (MMT) than the shamtDCS group.	LT-RGO can improve balance, tDCS may not enhance this improvement. LT-RGO protocol used in his study can improve LE motor function in cases of chronic incomplete SCI and that tDCS may enhance this improvement.	MMT, 10MWT, 6MinWT, Timed Up And Go Test (TUG), Berg Balance Scale (BBS), and Spinal Cord Independence Measure-III (SCIM-III).
Michael L. Jones.	Activity-Based Therapy (developmental sequence activities, resistance training, and locomotor training.)	9h/wk for24 weeks	18%, 26%, and 32% of the participants demonstrated clinically significant improvements on the TUG test, the 10MWT, and the 6MWT, respectively. Intensive ABT has the potential to promote neurologic recovery and enhance walking ability in some individuals with chronic, motor-incomplete SCI	ABT program appears to have a greater impact on walking endurance than on speed as indicated by improvements in distance on the 6MWT. This may be expected because the multifocused ABT intervention included progressive resistance training, which distinguishes this approach from locomotor training only. Secondary analyses suggest that it is possible to identify likely responders to ABT on the basis of injury characteristics AIS classification, time since injury, and initial walking ability. These factors, along with information about preliminary responsiveness to therapy (gains at 12wk), can help predict the degree of Recovery likely from an intensive ABT intervention.	10-meter walk test and 6-minute walk test, timed Up and Go test
Lora Giangregorio.	FES stimulation, functional electrical stimulation, body weight support treadmill and harness system tailored exercise program	45 minutes per session, 3 days per week, for 4 months (48 session's total).	FES-assisted walking had no significant effect on lower-limb muscle, there was no significant change over time and there were no differences between the groups	4-month FES-assisted walking intervention did not result in a significant increase in muscle mass or CSA, nor did it reduce body fat compared to a standard exercise program. Our data suggest that FES may result in long-term preservation of muscle when compared with exercise	spasticity, muscle atrophy, and bone loss no primary outcome was identified
Heather B. Hayes.	Daily intermittent hypoxia	2 weeks	dAIH induced significant improvements in walking speed (10MWT). While improvements also were seen in walking endurance (6MWT)	AIH-induced recovery of breathing and walking function after spinal injury is a result of increased synaptic strength and/or motor excitability. [9],[12],[27] Although facilitative	6MWT , 10MWT

				respiratory plasticity may partially contribute to improved walking endurance by increasing cardio respiratory reserve, it is likely accompanied by changes in somatic motor areas more closely related to locomotor control. Serotonin and BDNF have been linked to spinal locomotor recovery after SCI	

Table 2: PEDro criteria and scores of included studies. (n=8)

Study	Eligibility criteria	Random allocation	Concealed Allocation	Groups Similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropouts	Intention-to- treat analysis	Between – group difference reported	Point estimates and variability reported	Total (0-11)
Amanda E. Chisholm,2017	N	Y	Y	N	N	N	N	Y	Y	Y	N	5
X.Niu, 2012	N	N	N	N	N	N	N	Y	Y	Y	Y	3
Angela Navarrete-Opazo A,2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Mokhtar Arazpour2015	Y	N	N	Y	N	N	N	Y	Y	Y	Y	6
Ravi Raithatha2016	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	9
Michael L. Jones,2014	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Lora Giangregorio, 2012	Y	Y	Y		N		Y	Y	Y	Y	N	8
Heather B. Hayes,2014	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7

Note: The studies excluded from Pedro scale due to study itself is systemic review.

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Dr. Suvarna Ganvir, professor, DVVPF's college of physiotherapy AHMEDNAGAR. Approved UG and PG teacher of MUHS since 1998, has vast experience of 20Yrs in teaching profession. A member of UG and PG board of studies in MUHS. Received FAIMER fellowship in 2011 and completed post graduate diploma in epidemiology from Indian institute of public health New Delhi in 2015.Have guided students for their research projects in UG as well as PG curriculum has been interested in treating patients with neurological dysfunction specially spinal cord injury. Is committed towards updating of knowledge and professional growth in all aspect.