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Association of Lower Limb Muscle Strength and Walking Ability in individuals with incomplete Spinal Cord Injury

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Abstract

To quantify relationship among lower limb muscle strength and walking ability in individuals with incomplete SCI. Twenty-one participants were recruited in the present study (aged between 21 to 50 years; AIS levels C and D) with iSCI. Physical therapy was delivered in the form of activity based therapy to all of the participants for a period of 24 weeks and association between lower limb muscle strength and walking ability was determined. Lower limb muscle strength and walking ability as measured through Spinal Cord Functional Ambulatory Index was found to be co-related both at baseline and at the end of 24 weeks protocol. Significant co-relation exists between lower limb muscle strength and SCI-FAI and is suggestive of important implication on designing protocol for rehabilitation of individuals with SCI.

Keywords: Spinal cord injuries; Activity based therapy; Lower limb muscle strength; Spinal cord functional ambulatory index; Walking

Introduction

Walking is of high precedence for individuals with spinal cord injury (iSCI) in spite of severity of the spinal injury, duration after injury age at the time of injury [1] and it is a propounding determinant of quality of life. In incomplete spinal cord injury (iSCI), some amount of muscle function is still preserved below the level of injury, which is variable widely on individual basis and significant impairments and limitations specifically related to walking ability often persist. One of the most common impairments after spinal cord injury (SCI) is muscle weakness and hence limited or no functional activities. Although a number of mechanisms likely contribute, lower limb muscle strength is one factor that has been accounted to be associated to walking ability after iSCI [2-4].

Numerous studies support correlations between walking ability and gross lower limb muscle strength (e.g. lower extremity motor scores [LEMS] as measured during American Spinal Injury Association Impairment Scale [AIS] evaluation) [3,5]. Research studies have typically documented the co-relation between lower limb muscle strength and walking ability in iSCI. But this has been observed during a short duration. However, authors believe that strength is peculiarly gained after repeated, accurate and optimal use of muscle typically for a long duration.

Numerous therapeutic interventions are used and have been implied to improve and develop strength [6]. However, the most common type of strength training is progressive resistive exercise training. This involves increasing the ability of muscles to generate force by maximally contracting muscles against high levels of resistance in a progressive manner. Typically, this is done in sets of ten-twenty contractions. The sets are repeated three times in one training session, and training is performed three times a week for at least 12 weeks. The basis for the belief that progressive resistance training is effective comes largely from trials involving people without paralysis [7,8].

There are limited studies on this context, therefore the present work attempted to determine association of lower limb muscle strength and walking ability in iSCI over 24 weeks duration.

Purpose of study

To determine correlation between lower limb muscle strength and walking ability in individuals with incomplete spinal cord injury.

Methods

Before the commencement, the study was approved by institutional review board and ethical committee of department of physiotherapy, Punjabi University, Punjab, India. Written consent was obtained from all the participants. Participants were adults (males, n = 20; females, n = 1) with i SCI. These were recruited through contacts and SCI community groups, and were willing to participate in the 24 weeks long protocol. Participants ranged in age from 21 to 50 years, were classified as either AIS C or AIS D, and with level of injury from C3 to T10. Participant characteristics are shown in Table 1.

No participants exhibited complex co-morbidity and spasticity and all were at least 6 months post injury.

Lower extremity motor score (LEMS)

Upon initial evaluation, LEMS was evaluated using the AIS classification system of impairment [9]. The LEMS is a composite score

Patient demographics	Mean + SD
N	21
Females	1
Males	20
Age	31.76 ± 9.15
Time since injury	2.83 ± 1.74

Table 1: Demographics of the study participants.

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based on bilateral manual muscle strength tests of key muscle groups that include hip flexors, KE, ankle dorsiflexors, long toe extensors, and ankle PF. Each muscle group is scored from 0 (total paralysis) to 5 (active movement, against full resistance), thus total LEMS scores can range from 0 to 50.

Spinal cord injury functional ambulation inventory (SCI-FAI)

It is an observational gait assessment scale. It includes 3 key domains of walking function and 2 minute walk test. Maximum score of the scale is thirty nine points. Higher scores denote better levels of function in each subscale. The subscales include: gait parameters, assistive devices and temporal parameters [10].

All the participants underwent an intensive 24-weeks duration thrice weekly program of Activity –Based Therapy (ABT). ABT includes any therapy activity, or intervention, that is focused on improving muscle function and sensory perception below the level of injury, and not simply accommodation or compensation for the paralysis and sensory loss due to the spinal cord injury, in order to improve overall function after SCI [11]. Sessions of ABT were according to the physical capacity of the participant (3-4 hours per day). It also included locomotor training using Body weight support treadmill training (BWSTT) for thirty minutes to one hour in each ABT session. This study followed the ABT guidelines [11] depicting the principles as following:

Phase I/II: Reactivation/Re-organization and development/ stabilization Phase: Stimulate the nervous system with active assisted exercises and use developmental sequencing to develop joint stabilization.

Phase III: Strength: Initiate eccentric and concentric muscle contractions through positional movement or stimulation.

Phase IV: Function and co-ordination-Improve co-ordinated movement through all planes of movement and motion. Most exercises are performed in load bearing position. Mainly free standing.

Phase V: Gait training- Focus on proper gait mechanics and the ability to move over ground in multiple planes of motion.

A normal functioning adult spinal cord is the result of appropriate activity dependant plasticity in early developmental stages and subsequent years of life. Similarly, a newly regenerated spinal cord is not in an optimal state to deliver accurate function. It is most likely to show diffuse patterns, forms of infantile reflexes and dysfunctional patterns of behaviour. And thus, comes up the essentiality of re-educating the newly regenerated cord through specific, repetitive, progressive and accurate inputs.

Statistical analysis

The statistical analysis was performed using SPSS v20. Simple correlations were used to examine the relationship between indices of muscle strength (LEMS) and walking variables (SCI-FAI). Level of significance was set at α=0.05 and expected co relation value, r was expected to be 0.55.

Results

Nineteen subjects completed data collection. Descriptive statistics for participant characteristics are presented in Table 1.

Significant correlations were found between lower extremity muscle strength and parameters of SCI-FAI including 2 minute walk test (Figures 1-10).

The strongest co-relation is found to be between lower limb muscle strength (ASIA motor scores) and gait parameter of SCI-FAI score at baseline.

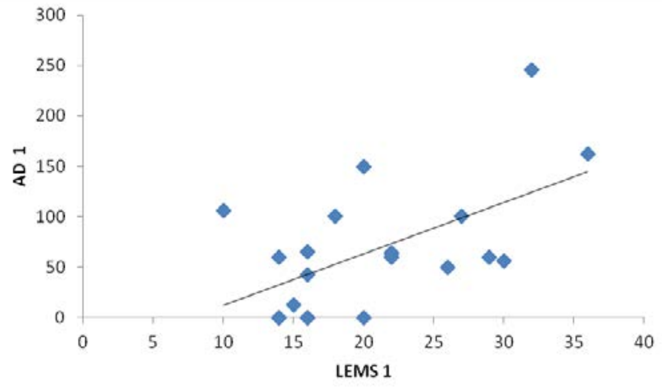

Figure 1: Relationship between LEMS and Gait parameter of SCI-FAI at baseline (r=0.749).

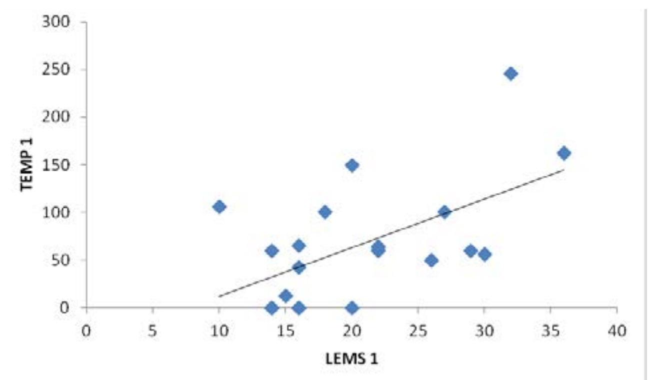

Figure 2: Relationship between LEMS and assistive devices parameter of SCI-FAI at baseline (r=0.504).

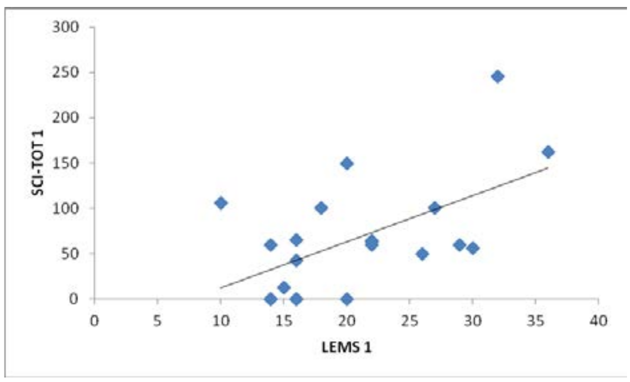

Figure 3: Relationship between LEMS and temporal parameters of SCI-FAI at baseline (r=0.629).

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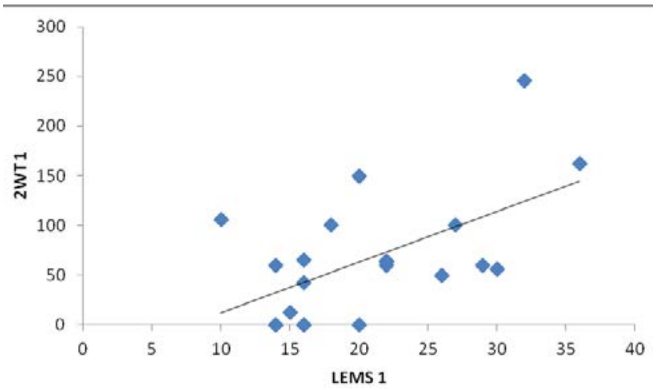

Figure 4: Relationship between LEMS and total score of SCI-FAI at baseline (r=0.685).

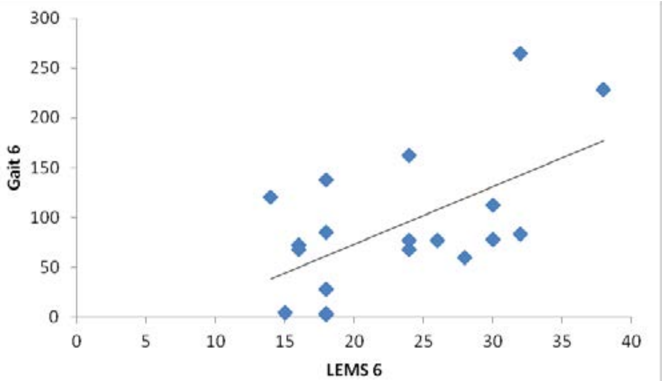

Figure 5: Relationship between LEMS and total score of 2minWT at baseline (r=0.564).

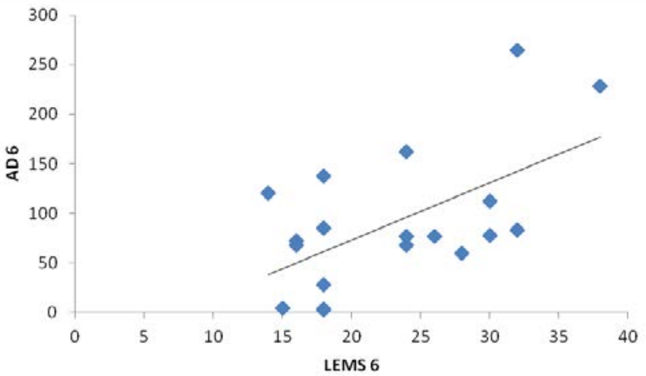

Figure 6: Relationship between LEMS and Gait parameter of SCI-FAI at 24 weeks (r=0.583).

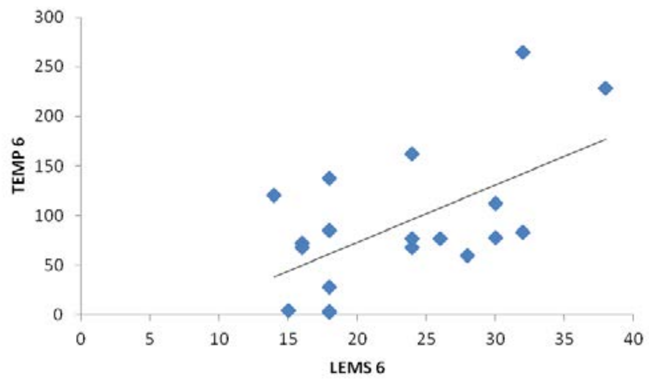

Figure 7: Relationship between LEMS and assistive devices parameter of SCI-FAI at 24 weeks (r=0.543).

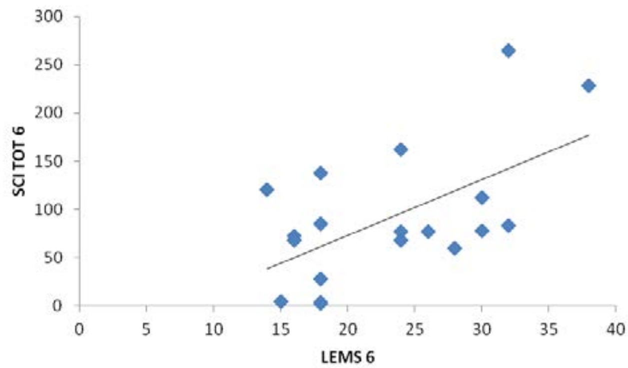

Figure 8: Relationship between LEMS and temporal parameters of SCI-FAI at 24 weeks (r=0.499).

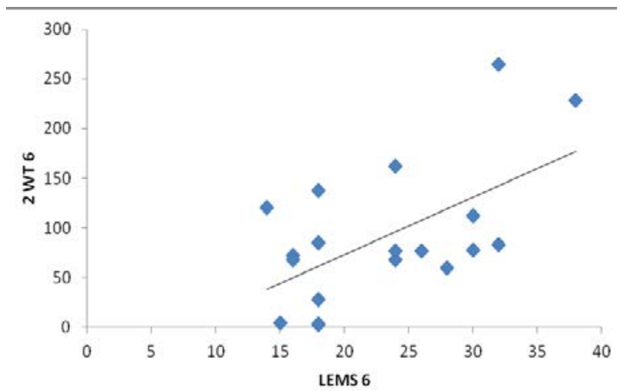

Figure 9: Relationship between LEMS and total score of SCI-FAI at 24 weeks (r=0.619).

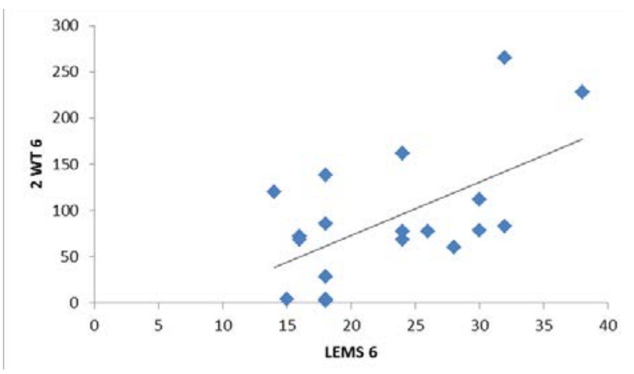

Figure 10: Relationship between LEMS and total score of 2minWT at 24 weeks (r=0.584).

Discussion

After SCI, there is a significant physiological breakdown in the body of an individual. This is partially caused by reduction of earth's gravitational force on the body. Gravity affects the body by providing constant resistance to the axial skeleton during weight bearing movements (i.e. kneeling, standing, walking, etc.). The first muscles to feel the effect of non-weight bearing are the anti-gravity muscles of the back and legs. These muscles lose strength disproportionately more than others [12,13]. Physiological breakdown leaves no room for functional capacity to be optimum.

Previous studies have demonstrated that persons with iSCI present with significant strength deficits, as well as slow walking speeds; however, the relationship between these variables is not well described [14-16]. Data from the present study indicate that in individuals with chronic iSCI, strength of the lower limb muscle groups are significantly correlated with parameters of walking viz; gait, use of assistive devices temporal measures and walking speed in 2minute walk test.

In the present work strong co relations have been found between LEMS and all the sub parameters of SCI-FAI. With increment in lower extremity muscle strength over a period of time, the quality of movement also improved (weight shifting, step width, step rhythm, step height, foot contact, and step length). Measuring the mentioned quality parameters makes SCI-FAI a distinctive walking ability measure for individuals with SCI.

Assistive devices increase, maintain, or improve the functional capabilities including balance, in weight bearing positions (e.g. walker, crutches), or as a means of compensating for loss of function in lower extremity, strength and control (e.g. ankle foot orthosis). With improvements in strength the requirement for use of devices also decreased. Alongside it was also found that the strength and walking ability relationship also improved depicting transformation of an individual's functional capacity as walking for exercise to community walker. Walking puts high metabolic demand and additional use of devices increases this demand. Increase in strength improved the ability thereby decreasing the metabolic demands.

The 2 minute walk test, a measure of walking speed and endurance showed to be improved and related significantly with strength of muscles of lower limb. There is a significant difference in gait score following intervention, this verifies that the lower limb muscle strength and walking function are associated positively and SCI-FAI is sensitive to change in strength of muscles of the lower extremity. Although there are previous studies describing co relation between lower limb muscle strength and walking abilities using dynamometry, present work is an attempt to determine the relation between muscle strength and function performed by these muscles (example, walking). Despite the obvious difference in pattern the neural pathways functioning is the same in functional activity like walking and mechanical testing. Present work is an attempt for translating laboratory based outcomes to functional activity.

Conclusion

The results of the present study suggest that lower limb muscle strength and walking ability function significantly correlates following iSCI. The present study focused on individuals with AIS C/D, ambulatory individuals but still the authors believe that the findings are important and have potential implications for rehabilitation design. Nevertheless, rehabilitation programs targeting walking function may benefit from focused intervention aimed at improving muscle function likewise activity based therapies.

Limitations

A number of limitations of the study should be noted. First, we were limited in our sample size due to financial constraints and availability of voluntary participants with AIS C and AIS D. Activity-based therapy is time and labour-intensive, and was the primary driver of our research work. But despite the small *n*, we were able to demonstrate statistically significant co-relation in the longitudinal framework.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors: PKB conducted the present work and prepared the manuscript. Narkeesh Arumugam outlined the experimental design.

Acknowledgment

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Key Points

Walking is of high priority for individuals with spinal cord injury (SCI) in spite of severity of the spinal injury, duration after injury age at the time of injury.

Activity Based Therapy focuses on developing muscle function below the level of injury rather than teaching compensatory mechanisms.

Re-education of the newly regenerated cord through specific, repetitive, progressive and accurate inputs is possible. There is significant co relation between lower limb muscle strength and walking ability function.

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