Original Research Article

# Effect of Passive and Active Upper limb Movements on Muscles of the Lower limbs in Spinal Cord Injury Patients


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## Abstract

**Background:**The coordination of limb movements during locomotion is by the central pattern generators (CPG's) in spinal cord, regulated by supraspinal centers. Stimulation/Movement of upperlimb muscles elicited electrical activity in lower limb muscles in neurologically intact subjects. The present study aims to record electrical activity in lowerlimbs of acute spinal cord injury (SCI) patients during passive and active coordinated upper limb movements. **Materials & methods:** Seventeen acute spinal cord injury patients in the age group of 30-60 years were involved in the present study.7 acted as control and 10 were in the study group. Electromyographic (EMG) activity was recorded in Quadriceps femoris, Hamstring, Tibialis anterior, Soleus, Gastrocnemius muscles of the lower limbs after different patterns of coordinated movements of the upper limbs using scorpio 2p/4p EMG, Allengers medical system limited, Chandigarh. Results were analysed with Fisher's Exact Test. **Results:** EMG activity in paretic lower limbs was greater for active (2kg > 1kg load) than passive upper limb movements**. Conclusion:** Rhythmic arm movements could generate activity in paretic lower limb muscles by stimulating CPG's and this would be an additional effective rehabilitative therapy.



**Keywords:**EMG, limb movements,spinal cord Injury



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## Introduction

The neural connections between the cervical and lumbo sacral networks in spinal cord is responsible for mediating the rhythmic coordinated movements of the arms with the legs during walking in normal individuals.[1] Central pattern generators (CPG's) are group of interneurons present in spinal cord and midbrain that activate the motor neurons resulting in alternate contractions of flexors and extensors of limbs resulting in stepping like movements during locomotion. There are two spinal cord CPG's: one in cervical region for upper limbs and another in lumbar region for lower limbs. CPG's in spinal cord are activated by impulses from midbrain locomotion generator.

Due to these connections muscle stimulation in either right or left upper limb causes activation of muscles in right or left lower limb.[2] Studies had shown that active muscle movements produced in one leg lead to muscle stimulation in the opposite leg due to inter neuronal circuits as evidenced by bursts of electrical activity in Electromyogram (EMG).[3] One muscle can be a part of multiple muscles synergies and one synergy can activate multiple muscles which is measured in EMG.

Pattern of co-activation of Muscles is recruited by a Single neural command Signal. Strengthening exercises to one limb also increases the voluntary strength of homologous contra lateral limb and the interaction between the legs is stronger than the interaction between arms.[4] Rhythmic arm movements were shown to increase the EMG activity in leg muscles, specifically with increased load by stimulating proprioceptive activity in normal subjects.[5]

SCI is the injury from the foramen magnum to the cauda equina. Motor vehicle accidents and sports injuries were the commonest causes. In spite of the modern advances in treatment modalities, it still results in permanent disability. Paraplegia occurs due to impairment of motor /sensory function in thoracic, lumbar and sacral spinal cord segments. [6]According to ASIA impairment scale (revised 2000), in incomplete spinal cord injury, there is still some retention of sensory and motor function below the point of injury. In complete spinal cord injury, there are no motor or sensory functions preserved in sacral segments $S_4$-$S_5$.

As a result of paralysis, rapid atrophy of paralyzed muscle occurs increasing the formation of protein degradation by-products, causing more demands on the kidneys. Along with that, loss of muscle force also contributes to bone demineralization resulting in hypercalciuria, renal calculi aggravating renal failure.[7]Other frequent complications include pressure ulcers, orthostatic hypotension, fractures, deep vein thrombosis (DVT), spasticity and contractures.

The rehabilitative treatments are primarily focused on direct stimulation of paralyzed muscles using electrical stimulators eg. continuous vibration of the quadriceps and hamstring muscle groups ,continuous electrical stimulation of the peroneal or sural nerve, and magnetic stimulation of the spinal cord .Recently, the focus is on training the Central Pattern Generators using Assisted treadmill techniques by sensory patterned feedback mechanism.[8] Sensory stimuli from legs stimulate the CPG's directly and also indirectly by stimulating sensory cortex.The purpose of the present study was to show another possibility that regular practice of active upper limb exercises in paraplegic patients can stimulate and strengthen paretic lower limb muscles apart from lower limb strength training. Hence the present study was done to evaluate the influence of arm movements on lower limb paretic muscles.

**Objectives**

Among Spinal cord injury patients, using Electromyogram,

1. To record the baseline electrical activity in both study and control group

2. To measure the effect of Passive upper limb movements on right and left lower limb muscles in study group

3. To measure the effect of Active upper limb movements on right and left lower limb muscles in study group

4. To measure the electrical activity after 2 hours of rest on right and left lower limb muscles in control group

**Methodology**

This interventional study was conducted in the department of Neurology in a private Medical college &Hospital in Madurai, after obtaining Institutional Ethical clearance. The present study involved 17 acute SCI subjects between the age group of 30-60 years selected over a period of July-October 2017 who attended Neurology, Physiotherapy and Orthopedics Departments. They were randomly divided into control group (n=7) who did not undergo any intervention and study group (n=10) who underwent intervention in the form of passive and active simultaneous upper limb movements. Informed written consent was obtained from all the participants.

**Inclusion criteria**

Patients with weakness of both the lower limbs (ASIA scaling B & C), patients with injury duration within 12 months, and patients who come to physiothethapy department for the first time were included in the study.

**Exclusion criteria**

Old aged patients, patients with injury duration more than a year, patients on antispasmodic medication, patients with metabolic disorders and with viral infections were excluded from the study.

EMG activity in lower limb muscles of SCI subjects of both control and study group (after passive & active upperlimb movements) was recorded using **SCORPIO 2P/4P EMG (ALLENGERS MEDICAL SYSTEM LIMITED, CHANDIGARH).** The features of this EMG are Simultaneous display of 2/4 channel EMG acquisition , EMG data can be stored, reviewed and replayed with audio and with more than 80 pre-stored muscle site.

The skin was cleaned with alcohol before the needle insertion. After identifying the individual muscle location using anatomical landmarks, EMG electrodes were placed on the muscles in order to get sharp and crisp multi unit action potentials (MUAP) and inter electrode resistance was checked.

Needle electrodes were placed on Quadriceps femoris, Hamstring muscles, Tibialis anterior, Soleus, Gastrocnemius of the lower limbs as in these muscles the innervations zones are distributed in a narrow band around the muscle belly. For soleus, the needle was inserted medial to the tibia, slightly distal to the midpoint between ankle and knee.

For gastrocnemius, the needle was inserted into the rostral, medial posterior calf. The electrodes were placed along the muscle fiber direction and the reference electrode was placed close to the active electrode.

Initially spontaneous activity for each muscle was assessed at rest with a sensitivity of 50 µV per division. Spontaneous activity was defined as any activity at rest lasting for longer than 3 seconds. Once this is over, the sensitivity was changed to 200 µV per division for recording MUAP of each muscle, after each prescribed form of passive upper limb movement.

The muscle movements involved include Adduction, Abduction, Flexion, Extension and Circumduction movements of both the arms simultaneously.

The electrode array was moved from location to location at intervals of about 5mm to record MUAP. Active upper limb movements were then recorded initially against a load of 1kg in each hand followed by 2 kg in each hand. Values displayed on the computer were then recorded after each movement. The time required for recording a single subject was around 2hours.

**Results**

**Statistical analysis**

The data was entered into MS excel and analysed using SPSS v16.0. The EMG readings before and after upper limb movements were analysed using FISHER'S **EXACT TEST** &movement specific correlation with Spearman Rank Correlation analysis.p value $< 0.05$ was the cut off to determine statistical significance

According to Table 5, there was a strong positive relationship among the passive movement with 1kg and 2kg in the flexion movement in quadriceps femoris of left limb of the respondents but not in the right limb. For abduction movement in quadriceps femoris and tibialis anterior of right limb of the respondents, passive movementand 2kg was correlated.

Passive movement has linear relationship with 1kg and 2kg for abduction movement in hamstrings, gastrocnemius and soleus of left limb. But, these relationships were notstatistically significant in the right limb of the respondents.

Analogously, passive movementhas linear relationship with 1kg and 2kg circumduction movement in hamstrings of rightlimb.Passive movement, 1kg and 2kg were correlated with one another in the adduction movement in gastrocnemius and extension movement in soleus of left limb of the respondents.

**Table 1: Effect of upper limb movements on Quadriceps femoris muscle**

| **QUADRICEPS FEMORIS MUSCLE** | P Value **RIGHT LIMB** | P Value **LEFT LIMB** |
|---|---|---|
| Spontaneous | 1.000 | 0.303 |
| Flexion passive | 1.000 | 1.000 |
| Flexion 1kg | 0.070 | 0.656 |
| Flexion 2kg | 0.020* | 0.020* |
| Extension passive | 1.000 | 1.000 |
| Extension 1kg | 0.020* | 0.170 |
| Extension 2kg | 0.020* | 0.045* |
| Abduction passive | 0.070 | 1.000 |
| Abduction 1kg | 0.070 | 0.045* |
| Abduction 2kg | 0.020* | 0.045* |
| Adduction passive | 0.370 | 1.000 |
| Adduction 1kg | 0.070 | 0.170 |
| Adduction 2kg | 0.020* | 0.045* |
| Circumduction passive | 0.370 | 1.000 |
| Circumduction 1kg | 0.020* | 0.170 |
| Circumduction 2kg | 0.020* | 0.042* |

Table 1 shows significant difference with active movements flexion 2 kg, extension 1 & 2 kg, abduction 1& 2 kg, adduction 2 kg and circumduction 1 &2 kg

**Table 2: Effect of upper limb movements on Hamstrings muscle**

| **HAMSTRINGS MUSCLE** | P Value **RIGHT LIMB** | P Value **LEFT LIMB** |
|---|---|---|
| Spontaneous | 1.000 | 0.582 |
| Flexion passive | 0.170 | 0.650 |
| Flexion 1kg | 0.023* | 0.070 |
| Flexion 2kg | 0.005* | 0.027* |
| tExtension passive | 0.350 | 0.020* |
| Extension 1kg | 0.023* | 0.020* |
| Extension 2kg | 0.005* | 0.020* |
| Abduction passive | 0.070 | 0.020* |
| Abduction 1kg | 0.005* | 0.020* |
| Abduction 2kg | 0.005* | 0.020* |
| Adduction passive | 0.070 | 1.000 |
| Adduction 1kg | 0.023* | 0.179 |
| Adduction 2kg | 0.005* | 0.020* |
| Circumduction passive | 0.028* | 0.370 |
| Circumduction 1kg | 0.025* | 0.070 |
| Circumduction 2kg | 0.005* | 0.020* |

According to Table 2, Significant difference was observed with active movements flexion 2 kg, extension 1 & 2 kg, abduction 1& 2 kg,adduction1& 2 kg and circumduction 1 &2 kg & Also with passive movements like extension ,abduction and circumduction.

**Table 3: Effect of upper limb movements on Gastrocnemius muscle**

| **GASTROCNEMIUS** | P Value **RIGHT LIMB** | P Value **LEFT LIMB** |
|---|---|---|
| Spontaneous | 0.303 | 1.000 |
| Flexion passive | 0.057 | 0.628 |
| Flexion 1kg | 0.001* | 0.023* |
| Flexion 2kg | 0.001* | 0.005* |
| Extension passive | 0.005* | 0.070 |
| Extension 1kg | 0.001* | 0.005* |
| Extension 2kg | 0.001* | 0.005* |
| Abduction passive | 0.001* | 0.023* |
| Abduction 1kg | 0.001* | 0.005* |
| Abduction 2kg | 0.001* | 0.005* |
| Adduction passive | 0.020* | 0.023* |
| Adduction 1kg | 0.001* | 0.005* |
| Adduction 2kg | 0.001* | 0.005* |
| Circumduction passive | 0.057 | 0.170 |
| Circumduction 1kg | 0.001* | 0.005* |
| Circumduction 2kg | 0.001* | 0.005* |

Table 3 shows significant difference with all active movements in both the limbs & also with passive movements like extension, abduction and adduction.

**Table 4: Effect of upper limb movements on Soleus muscle**

| **SOLEUS MUSCLE** | P Value **RIGHT LIMB** | P Value **LEFT LIMB** |
|---|---|---|
| Spontaneous | 0.141 | 0.582 |
| Flexion passive | 0.001* | 0.057 |
| Flexion 1kg | 0.001* | 0.037* |
| Flexion 2kg | 0.001* | 0.005* |
| Extension passive | 0.020* | 0.005* |
| Extension 1kg | 0.001* | 0.001* |
| Extension 2kg | 0.001* | 0.001* |
| Abduction passive | 0.020* | 0.005* |
| Abduction 1kg | 0.001* | 0.001* |
| Abduction 2kg | 0.001* | 0.001* |
| Adduction passive | 0.005* | 0.037* |
| Adduction 1kg | 0.005* | 0.001* |
| Adduction 2kg | 0.001* | 0.001* |
| Circumduction passive | 0.020* | 0.057 |
| Circumduction 1kg | 0.001* | 0.001* |
| Circumduction 2kg | 0.020* | 0.001* |

According to Table 4, significant difference was observed with almost all the active movements and most of the passive movements.

**Table 5: Effect of upper limb movements on Tibialis anterior muscle**

| **Tibialis Anterior** | p value **Right limb** | p value **Left limb** |
|---|---|---|
| Spontaneous | 0.301 | 1.000 |
| Flexion passive | 0.003* | 0.087 |
| Flexion 1kg | 0.001* | 0.003* |
| Flexion 2kg | 0.001* | 0.001* |
| Extension passive | 0.033* | 0.003* |
| Extension 1kg | 0.003* | 0.001* |
| Extension 2kg | 0.001* | 0.001* |
| Abduction passive | 0.001* | 0.001* |
| Abduction 1kg | 0.001* | 0.001* |
| Abduction 2kg | 0.001* | 0.001* |
| Adduction passive | 0.003* | 0.003* |
| Adduction 1kg | 0.001* | 0.001* |
| Adduction 2kg | 0.001* | 0.001* |
| Circumduction passive | 0.005* | 0.011* |
| Circumduction 1kg | 0.001* | 0.003* |
| Circumduction 2kg | 0.001* | 0.001* |

According to Table 5, significant difference was observed for both active movements and passive movements of both the limbs except for flexion passive in left limb

**Spearman Rank Correlation analysis**

| | | **Left Limb** | | | **Right Limb** | | |
|---|---|---|---|---|---|---|---|
| | | **Passive Vs 1Kg** | **Passive Vs 2Kg** | **1kg Vs 2Kg** | **Passive Vs 1Kg** | **Passive Vs 2Kg** | **1kg Vs 2Kg** |
| QUADRICEPS FEMORIS | Flexion | 0.816** | 0.655** | 0.802** | 0.408 | 0.272 | 0.667* |
| | Extension | 0.408 | 0.272 | 0.667** | 0.218 | 0.218 | 1.000** |
| | Adduction | 0.500 | 0.333 | 0.667** | 0.102 | 0.408 | 0.667* |
| | Abduction | 0.333 | 0.333 | 1.000** | 0.375 | 0.667* | 0.667* |
| | Circumduction | 0.408 | 0.272 | 0.667** | 0.408 | 0.102 | 0.667* |
| HAMSTRINGS | Flexion | 0.478 | 0.500 | 1.000** | 0.612 | 0.408 | 0.667 |
| | Extension | 0.509 | 0.509 | 1.000 | 0.500 | 0.333 | 0.667* |
| | Adduction | 0.535 | 0.272 | 0.509 | 0.218 | 0.509 | 0.667* |
| | Abduction | 0.667* | 1.000** | 0.667* | 0.509 | 0.509 | 1.000** |
| | Circumduction | 0.612 | 0.408 | 0.667* | 1.000** | 0.667* | 0.667* |
| GASTROCNEMIUS | Flexion | 0.408 | 0.272 | 0.667* | 0.408 | 0.408 | 1.000** |
| | Extension | 0.509 | 0.509 | 1.000** | 0.667* | 0.667* | 1.000** |
| | Adduction | 0.667* | 0.667* | 1.000** | 0.509 | 0.509 | 1.000** |
| | Abduction | 0.667* | 0.667* | 1.000** | 1.000** | 1.000** | 1.000** |
| | Circumduction | 0.408 | 0.408 | 1.000** | 0.408 | 0.408 | 1.000** |
| SOLEUS | Flexion | 0.802** | 0.408 | 0.509 | 1.000** | 1.000** | 1.000** |
| | Extension | 0.667* | 0.667* | 1.000** | 0.509 | 0.509 | 1.000** |
| | Adduction | 0.509 | 0.509 | 1.000** | 1.000** | 0.667* | 0.667* |
| | Abduction | 0.667* | 0.667* | 1.000** | 0.509 | 0.509 | 1.000** |
| | Circumduction | 0.408 | 0.408 | 1.000** | 0.509 | 0.048 | 0.509 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TIBIALIS ANTERIOR | Flexion | 0.535 | 0.272 | 0.509 | 0.509 | 0.509 | 1.000** |
| | Extension | 0.764* | 0.509 | 0.667* | 0.333 | 0.333 | 1.000** |
| | Adduction | 0.509 | 0.509 | 1.000** | 1.000** | 1.000** | 1.000** |
| | Abduction | 1.000** | 1.000** | 1.000** | 0.667* | 0.667* | 1.000** |
| | Circumduction | 0.756* | 0.500 | 0.661* | 1.000** | 1.000** | 1.000** |

**P<0.01; *P<0.05

**Discussion**

The present study shows that passive upper limb movements showed significant difference for extension, abduction in left and circumduction in right hamstrings muscle (Table 2),for extension, adduction, abduction in right and adduction & abduction in left gastronemius muscle (Table 3), for all the movements in right &extension, adduction ,abduction in left soleus muscle (Table 4),for all the movements in right & left (except for flexion) in tibialis anterior muscle(table 5) and no significant difference in quadriceps femoris muscle (Table1).

According to Tables 1-5, Active upper limb movements with 1 Kg weight elicited significant electrical activity for all the movements in right and left gastrocnemius, soleus and tibialis anterior muscle. For extension and circumduction movements in right and abduction in left quadriceps femoris muscle, for all the movements in right and extension, abduction in left hamstrings muscle. Significantly increased activity is observed for all the active upper limb movements on all the five tested lowerlimb muscles with 2 Kg weight (Tables 1-5).

The results of this study coincides with the results of a previous study on neurologically intact subjects,where an increased muscle activation was observed with active upper limb effort than with passive upper limb effort. [2]Greater amplitude MUAP's with more distinct bursts were recorded prominently with active than with passive upper limb movements. Also in this study, increased activity was observed for all the upper limb movements with 2 Kg load than with 1 kg load, where only in three out of five muscles, all the upper limb movements elicited activity. This is in accordance with the results of a study done on quadriceps muscles after SCI, where significantly greater improvements in force, type 1 fiber composition, fiber cross-sectional area, capillary-to-fiber ratio, oxygenation, and citrate synthase activity were observed in muscles trained with high load than muscles trained with minimal load. [9]

Active arm movements increased leg muscle recruitment during recumbent stepping in intact individuals and this could be attributed due to spill over and adaptations in the control system for the untrained lower limb muscles.[10,4]In another study, Hand-walking elicited significant locomotor-like activity in EMG recording in the legs of 58% of the participants, when the subjects were involved in mental arithmetic.[11] Vice versa ,rhythmical activity was recorded in arms and shoulder muscles during walking. In the current study, sensory information from stretch- and load-sensitive mechanoreceptors located in the muscles and skin of upper extremities could have stimulated the CPG'S which also controls the locomotor pattern in lower limbs.

Only patients with injury duration around one year were selected for this study as previous studies had shown that within six weeks after SCI, the size of lower-limb muscles was 45 percent smaller than normal subjects.[12] Though a case study on a single patient has reported a late neurologic motor recovery after 5 years of injury, most of the previous studies had found that rapid motor recovery occurs maximum within first 6 months post injury(greatest change within 3 months).Motor recovery in second year was found to be slower and at a smaller degree. [13] Neurologic level of injury, the initial motor strength, and neurologically complete or incomplete injury also determines recovery rate. In a pilot study done by the authors of the present study on 2 patients of 4 & 5 years duration of injury, no EMG activity was recorded for passive as well as active upper limb movements. The patients were under routine drug therapy for medical treatment of SCI during the study period and not under physiotherapy as we included only the patients who came to physiotherapy department for the first visit.

Supraspinal control does have a role in modifying CPG activity. During locomotion, along with CPG 'S, there is also activation of medial sensory motor cortex and supplementary motor areas.[14] Spontaneous reorganization occurred in cortex, cerebellum and brainstem over a period of one year indicating functional locomotor recovery after injury. This neuronal plasticity could also be further induced by functional training initiated within one year of injury.[15] Hence Regular task specific training with upper limbs could also increase the motor area for lower limb activity in the cortex.

Resistance exercises using dumb bells to strengthen the muscles of the upper extremity in paretic patients not only could improve activity in lowerlimb muscles paretic muscles but also provides sufficient strength for day to day activities like independent transfer from bed.

**Conclusion**

In acute lower limb paralysis patients, coordinated upper limb movements elicited EMG activity in 5specific lower limb muscle. The effect was more and complete for active than passive upper limb movements. In that the electrical activity was greater with 2kg than with 1kg load. These findings suggest that rhythmic arm movements could be effective in the rehabilitation of lower limb paresis. This would be an additional strategy to increase the excitability of spinal neuronal locomotor circuitries and this could also help in gait rehabilitation in Parkinson disease, stroke, cerebral palsy and other neurological injuries which disrupt interlimb coordination.

**Limitations**

1. This could have been done on a larger number of subjects to provide better result
2. Patients were not separated based on the etiology of injury
3. Familiarity with the testing procedures might influence the result

**Acknowledgement :** Nil

**Conflict of Interest :** Nil

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