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## INFLUENCE OF REHABILITATION TIMING ON FUNCTIONAL RECOVERY AFTER SPINAL CORD INJURY: A SCIM SCORE COMPARISON

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### ABSTRACT

**Background:** Spinal cord injury (SCI) frequently leads to permanent disability. Early initiation of rehabilitation may enhance functional independence and reduce secondary complications, especially in low-resource environments.

**Objective:** To compare functional recovery between SCI patients receiving early ( $\leq 4$  weeks) versus delayed ( $> 4$  weeks) rehabilitation, using the Spinal Cord Independence Measure-III (SCIM-III).

**Methods:** In this comparative cohort study at Jaya Rehabilitation Institute, Gujarat, 30 SCI patients were assigned to Early ( $n=15$ ) or Delayed ( $n=15$ ) Rehabilitation Groups. Both groups underwent identical 8-week standardized rehabilitation. SCIM-III scores were recorded at baseline and post-intervention. Statistical analysis included paired and independent t-tests and ANCOVA.

**Results:** Both groups improved significantly ( $p < 0.001$ ). The mean SCIM improvement in the early group was  $32.2 \pm 2.5$  vs.  $21.1 \pm 1.6$  in the delayed group ( $p < 0.001$ ). ANCOVA controlling for baseline confirmed timing as a significant factor ( $p < 0.01$ ).

**Conclusion:** Rehabilitation initiated within four weeks post-SCI leads to significantly greater functional gains than delayed initiation. Prioritizing early rehabilitation is essential for optimal recovery in SCI patients.

**Keywords:** spinal cord injury, rehabilitation timing, SCIM-III, functional recovery, early intervention

## INTRODUCTION

Spinal cord injury (SCI) is a life-altering condition that often results in permanent neurological deficits, leading to significant physical, psychological, and social challenges [1]. Characterized by partial or complete loss of motor, sensory, and autonomic functions below the level of injury, SCI can result from traumatic or non-traumatic events [1-5]. The complex and multifaceted nature of this disorder necessitates comprehensive rehabilitation to maximize recovery and improve quality of life [6].

Rehabilitation plays a pivotal role in SCI management, aiming to restore functional independence, prevent secondary complications, and support reintegration into the community [2, 6]. Among various factors influencing outcomes, the timing of rehabilitation has emerged as a critical determinant [2, 4]. Early initiation of structured institutional rehabilitation—typically within the first few weeks' post-injury—has been associated with enhanced neuroplasticity, preservation of musculoskeletal health, and improved functional outcomes [2, 4]. Moreover, it allows for early management of complications such as pressure ulcers, respiratory infections, and thromboembolic events, which can otherwise hinder recovery [6].

Conversely, delayed rehabilitation, often caused by systemic limitations, financial constraints, or logistical barriers, may reduce the optimal window for neurological and functional recovery<sup>8</sup>. Prolonged inactivity may result in complications such as muscle atrophy, joint contractures, and psychological distress [6, 7], thereby compromising overall rehabilitation potential. Despite these known effects, there is still no global consensus on the ideal timing for SCI rehabilitation, particularly in resource-limited environments [5, 8].

To objectively measure rehabilitation outcomes, standardized tools have been developed. The Spinal Cord Independence Measure (SCIM), specifically designed for the SCI population, is considered both reliable and valid for assessing functional independence across key domains such as self-care, respiration and sphincter control, and mobility [3].

This study aims to compare early versus delayed institutional rehabilitation in individuals with SCI, using SCIM-III scores as the primary outcome measure. By examining functional recovery in both groups, this research seeks to provide evidence-based insights to guide clinical decision-making, influence policy development, and enhance rehabilitation protocols for SCI patients.

## METHODOLOGY

### Study Design

This study adopts a comparative observational cohort design to evaluate the effect of rehabilitation timing on functional recovery among individuals with spinal cord injury (SCI). Participants will be categorized into two distinct cohorts based on the timing of their admission to institutional rehabilitation:

- Early Rehabilitation Group (ERG): Rehabilitation initiated within  $\leq 4$  weeks' post-injury.
- Delayed Rehabilitation Group (DRG): Rehabilitation initiated after  $>4$  weeks' post-injury.

### Study Setting

The study will be conducted at *Jaya Rehabilitation Institute*, Bidada, Gujarat, a tertiary care centre equipped with a specialized spinal cord injury rehabilitation unit.

### Study Population

The study population will consist of patients diagnosed with either traumatic or non-traumatic SCI who are referred for inpatient rehabilitation.

### Inclusion Criteria

- Age between 18 and 65 years
- Diagnosed with complete or incomplete SCI
- Medically stable and able to participate in an active rehabilitation program

- Willingness to provide informed consent
- Admission to rehabilitation within defined timelines ( $\leq 4$  weeks or  $>4$  weeks post-injury)

### Exclusion Criteria

- Pre-existing neurological conditions
- Severe cognitive impairments or psychiatric illnesses interfering with participation
- Progressive spinal pathologies (e.g., tumors, infections)
- Patients lost to follow-up prior to post-intervention assessment

### Sample Size and Sampling Technique

A minimum of 30 participants will be recruited, with 15 individuals in each group (ERG and DRG). The sample size is determined based on prior studies indicating a moderate effect size, with 80% power and a 5% level of significance. Consecutive sampling will be used to recruit eligible participants during the study period.

### Intervention Protocol

All participants will undergo a standardized institutional rehabilitation program, which includes:

- Upper and lower limb strengthening exercises
- Core strengthening exercises
- Cardiopulmonary conditioning
- Functional training for activities of daily living

The only variable differing between groups will be the timing of rehabilitation initiation.

### Outcome Measure

Functional outcomes will be assessed using the Spinal Cord Independence Measure, Version III (SCIM-III). This validated tool evaluates the following three domains:

- Self-care: Feeding, grooming, bathing, and dressing
- Respiration and sphincter management
- Mobility: Room and toilet mobility, indoor and outdoor movement

### Data Collection Timeline

- Baseline Assessment: SCIM score recorded at the time of rehabilitation admission
- Post-Intervention Assessment: SCIM score recorded after completion of an 8-week rehabilitation program

### Statistical Analysis

- Descriptive statistics will be used to summarize baseline demographic and clinical characteristics.
- Paired t-tests (or Wilcoxon signed-rank tests for non-parametric data) will assess within-group changes in SCIM scores.
- Independent t-tests (or Mann–Whitney U tests) will compare between-group differences.
- Analysis of Covariance (ANCOVA) will be employed to adjust for baseline score differences.

- A p-value of  $<0.05$  will be considered statistically significant.

### RESULTS

A total of 30 individuals diagnosed with spinal cord injury (SCI) were enrolled in this study and completed the 8-week institutional rehabilitation program. Participants were divided into two groups based on the timing of rehabilitation initiation: The Early Rehabilitation Group (ERG,  $n = 15$ ) and the Delayed Rehabilitation Group (DRG,  $n = 15$ ).

#### Demographic Characteristics

- Participants ranged in age from 18 to 65 years.
- Both traumatic and non-traumatic SCI cases were represented.
- All participants completed the full duration of the rehabilitation protocol without dropouts.

#### Functional Outcomes Assessed by SCIM-III

##### Early Rehabilitation Group (ERG)

| Metric               | Value      |
|----------------------|------------|
| Mean Pre-SCIM Score  | 41.5 ± 3.4 |
| Mean Post-SCIM Score | 73.7 ± 4.4 |
| Mean Improvement     | 32.2 ± 2.5 |

Participants in the ERG demonstrated substantial functional improvement, with SCIM score increases ranging from 28 to 38 points over the 8-week rehabilitation period.

##### Delayed Rehabilitation Group (DRG)

| Metric               | Value      |
|----------------------|------------|
| Mean Pre-SCIM Score  | 32.7 ± 1.8 |
| Mean Post-SCIM Score | 53.8 ± 2.8 |
| Mean Improvement     | 21.1 ± 1.6 |

While DRG participants also exhibited functional gains, the overall improvement

was significantly lower, with SCIM score increases ranging from 20 to 24 points.

#### Statistical Analysis

- **Within-Group Analysis:**

Paired *t*-tests revealed statistically significant improvements in SCIM scores pre- and post-rehabilitation for both ERG and DRG ( $p < 0.001$ ).

- **Between-Group Comparison:**

An independent *t*-test comparing SCIM score improvements between ERG and DRG showed a statistically significant difference favouring early rehabilitation ( $p < 0.001$ ).

- **ANCOVA:**

After adjusting for baseline SCIM score differences, ANCOVA confirmed that the timing of rehabilitation was a significant predictor of functional improvement ( $p < 0.01$ ).

## DISCUSSION

This study evaluated the impact of rehabilitation timing on functional outcomes in individuals with spinal cord injury (SCI), using the Spinal Cord Independence Measure (SCIM-III) as the primary outcome metric. The findings clearly demonstrate that although both early and delayed rehabilitation groups exhibited statistically significant improvements following an 8-week structured rehabilitation program, the Early Rehabilitation Group (ERG), which commenced intervention within four weeks

of injury, achieved significantly greater functional gains compared to the Delayed Rehabilitation Group (DRG).

The mean SCIM score improvement in the ERG ( $32.2 \pm 2.5$ ) significantly exceeded that observed in the DRG ( $21.1 \pm 1.6$ ), with a *p*-value of  $< 0.001$ . These results corroborate those of Lertrakarnsakul *et al.* and align with prior systematic reviews that emphasize the benefits of initiating rehabilitation during the early subacute phase to optimize neuroplastic potential and functional outcomes [2, 4]. The subacute post-injury phase is widely recognized as a period of heightened neuroplasticity, during which the central nervous system is particularly receptive to rehabilitation-driven reorganization and task-specific motor learning.

Early rehabilitation also plays a crucial role in mitigating common secondary complications such as pressure ulcers, respiratory tract infections, muscle deconditioning, and joint contractures [6]. These complications not only impede recovery but also increase healthcare utilization and burden. In contrast, delayed initiation may miss this optimal neurophysiological window, resulting in diminished rehabilitation efficiency—a trend observed by several researchers including Gordon *et al.*, and further supported by global epidemiological trends [5].

Furthermore, Yue *et al.* [9] emphasized the critical importance of early rehabilitation in SCI patients. Their study highlighted that early inpatient rehabilitation led not only to significantly better functional independence scores but also to shorter hospital stays and a lower incidence of complications. These outcomes closely mirror the current study's findings and reinforce the position that timely rehabilitation access is not merely beneficial but essential for improving both individual and system-level outcomes.

A notable strength of this study is the use of the SCIM-III, a validated, SCI-specific instrument designed to detect clinically relevant changes in domains such as self-care, mobility, and sphincter management [3]. The consistency of our findings with international recommendations, such as those from the WHO [8], further underlines the value of early intervention, particularly in resource-constrained environments.

Despite its valuable insights, this study has limitations. The relatively small sample size ( $n = 30$ ) limits the generalizability of the findings, and the observational cohort design cannot establish causality. Additionally, long-term follow-up was not conducted, so the durability of functional improvements remains unknown.

Future studies should include larger sample sizes, multicenter collaboration, and longitudinal follow-up to explore not only functional recovery but also quality of life,

return to work, and social reintegration. There is also a critical need to investigate systemic and logistical barriers to early rehabilitation in low- and middle-income countries, where such delays are more prevalent.

## CONCLUSION

The present study demonstrates that the timing of rehabilitation initiation significantly influences functional recovery in individuals with spinal cord injury (SCI). Patients who commenced rehabilitation within four weeks' post-injury exhibited markedly greater improvements in SCIM scores compared to those who began after the subacute phase. These findings support the hypothesis that early rehabilitation enhances neuroplastic adaptation, facilitates functional independence, and reduces secondary complications.

While delayed rehabilitation still yields functional benefits, the magnitude of improvement is comparatively limited. This underscores the critical importance of minimizing barriers to early rehabilitation access, particularly in resource-constrained settings. The results advocate for the integration of timely rehabilitation into standard SCI management protocols to optimize clinical outcomes.

Further research involving larger, diverse cohorts and extended follow-up periods is recommended to validate these findings and explore strategies to overcome systemic

challenges that delay early rehabilitation intervention.

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