

Effect of Early Nursing-Led Sensory-Motor Activation on Functional Recovery among Patients with Severe Traumatic Brain Injury

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Abstract

Background: Severe traumatic brain injury (TBI) is a major cause of mortality, disability, and prolonged intensive care unit (ICU) stay. Sensory deprivation and prolonged immobilization may adversely affect neurological recovery and functional outcomes among critically ill patients.

Aim: To evaluate the effect of early nursing-led sensory-motor activation on functional recovery among patients with severe traumatic brain injury. **Design:** A quasi-experimental pretest-posttest control group design was utilized. **Setting:** The study was conducted at the Surgical Intensive Care Units, Mansoura Hospital. **Sample:** A purposive sample of 76 adult patients with severe traumatic brain injury was recruited and assigned into an intervention group (n = 38) and a control group (n = 38).

Tools: I- Patient Assessment Sheet, II-Full Outline of Unresponsiveness (FOUR) Score, III-Sensory Modality Assessment and Rehabilitation Technique (SMART), IV-Disability Rating Scale (DRS), and V-Functional Recovery and Clinical Outcomes Assessment Sheet. **Results:** Patients who received early nursing-led sensory-motor activation demonstrated significantly better neurological responsiveness, sensory responsiveness, and functional recovery than those receiving routine care. The intervention group achieved significantly higher FOUR and SMART scores, significantly lower DRS scores, and greater improvements across all SMART domains. Furthermore, patients in the intervention group demonstrated greater physiological stability, Shorter ICU length of stay (7.53 ± 2.35 vs. 16.18 ± 5.70 days) and a higher extubation success rate (78.9% vs. 15%), lower reintubation rates, and better discharge outcomes compared with the control group.

Conclusion: Early nursing-led sensory-motor activation effectively enhanced neurological responsiveness, sensory processing, functional recovery, physiological stability, and clinical outcomes among patients with severe traumatic brain injury. **Recommendations:** Incorporating structured sensory stimulation and graded motor activation into routine neurocritical care nursing practice may improve recovery trajectories and reduce disability in this patient population.

Keywords: Functional Recovery, Sensory-Motor Activation; and Severe Traumatic Brain Injury

Introduction

Traumatic brain injury (TBI) remains one of the leading causes of mortality and long-term disability worldwide, accounting for substantial healthcare expenditures and societal burden. Optimal management of TBI within intensive care units requires continuous monitoring of neurological status and systemic physiological parameters to minimize secondary brain injury and improve patient outcomes. Advances in neuromonitoring modalities, predictive models, and biomarker-based assessments have significantly expanded current understanding of TBI pathophysiology and

facilitated more individualized approaches to patient care (Slot et al., 2025).

Among patients with moderate to severe TBI, impaired consciousness often disrupts the ability to process and respond to sensory information, resulting in varying degrees of sensory deprivation. Alterations in the reticular activating system may further diminish arousal mechanisms and limit responsiveness to external stimuli. Such deficits can hinder neurological recovery and contribute to prolonged functional impairment. Consequently, sensory-motor stimulation has emerged as a promising rehabilitative strategy aimed at activating neural networks, enhancing

cortical responsiveness, and promoting neuroplastic adaptation. Evidence indicates that structured sensory and motor stimulation programs may improve neural organization and support functional recovery following severe brain injury (Alam et al., 2016).

The ICU environment may further exacerbate sensory disturbance through factors such as prolonged immobilization, mechanical ventilation, environmental isolation, and inadequate exposure to meaningful sensory experiences. Therefore, implementing targeted sensory-motor interventions during the acute phase of care may help mitigate the detrimental effects of sensory deprivation, facilitate neurological recovery, and improve clinical outcomes for patients with severe TBI. Early integration of such evidence-based interventions is increasingly recognized as an important component of comprehensive neurocritical care (Wen et al. 2025).

Early and effective management of patients with traumatic brain injury is crucial for reducing the risk of secondary complications and preventing long-term neurological and functional impairments. Within critical care settings, maintaining an optimal sensory environment constitutes an important aspect of comprehensive nursing care. Both sensory deprivation and sensory overload have been associated with unfavorable neurological outcomes, including suppression of the reticular activating system, disruption of cortical activity, impaired neuroplastic adaptation, and persistent cognitive dysfunction after ICU discharge (Adineh et al., 2022).

Sensory receptors serve as essential components of neurological assessment and clinical decision-making in critically ill patients. Neurological responses such as pupillary reflexes, reaction to painful stimuli, and other sensory-mediated reflexes provide valuable indicators of cerebral function and patient stability. In ventilated patients who are unable to communicate verbally, sensory responses and associated physiological changes become particularly important sources of clinical information. Variations in vital signs may reflect pain perception, neurological deterioration, or changes in overall clinical

status, thereby assisting healthcare providers in early detection of complications and timely intervention (Jackson, 2026).

Early mobilization has become a fundamental component of contemporary critical care practice, emphasizing the early initiation of physical activity among critically ill patients in the ICU. Historically, prolonged sedation and immobilization were commonly utilized to facilitate medical management and reduce physiological stress. Nevertheless, growing research evidence has highlighted the detrimental consequences of extended bed rest, including muscle atrophy, ICU-acquired weakness, ventilator-related complications, and adverse psychological outcomes. As a result, early mobilization interventions have gained increasing attention as effective strategies for preserving physical function, preventing complications associated with immobility, and promoting recovery through a gradual and individualized progression of movement activities tailored to patients' clinical conditions and tolerance levels (Singam, 2024).

Early multimodal sensory stimulation can facilitate brain organization and reorganization by using tactile, kinesthetic, visual, gustatory, vestibular, auditory, and olfactory stimulations in multiple combinations(Rajarajeswari et al., 2022). So, this study aims to evaluate the effect of early nursing-led sensory-motor activation on functional recovery among patients with severe traumatic brain injury

Significance of the study

Traumatic brain injury (TBI) remains one of the leading causes of death and long-term disability worldwide. Recent estimates indicate that approximately 27 million new cases of TBI occur annually, resulting in substantial mortality and long-term neurological deficits, including sensory-motor impairments, cognitive dysfunction, and reduced quality of life (Zhang et al., 2025).

A critical complication in ICU-admitted TBI patients is sensory deprivation, exacerbated by brain injury, prolonged immobility, social isolation, and ICU conditions. Reduced sensory

input elevates the activation threshold of the reticular activating system, impairing normal brain activity, prolonging coma and hospitalization. ICU admission induces significant stress, contributing to anxiety, environmental fear, and hemodynamic instability (e.g., elevated blood pressure, heart rate, and respiratory rate (**Moshtaghi et al., 2026**).

The actual burden of traumatic brain injury (TBI) in Egypt is likely underestimated due to the limited availability of comprehensive epidemiological data. Among the various consequences of head trauma, skull base fractures (SBFs) represent a significant clinical concern, occurring in an estimated 4% to 30% of patients with head injuries. These injuries may arise from either direct impact to the skull base or the propagation of high-energy traumatic forces across the cranial vault. The challenge of managing such cases is further compounded by the considerable pressure placed on the Egyptian healthcare system, which is required to provide care for a large volume of trauma patients despite the ongoing limitations in healthcare workforce capacity and medical resources characteristic of many developing countries (**Saad et al., 2024**).

A review of Mansoura Main University Hospital Statistical Records has recorded that 3300 patients with head injury were admitted to Mansoura Emergency Hospital from January to December 2025 (**Mansoura trauma hospital records, 2026**).

Aim of the Study

The aim of this study was to evaluate the effect of early nursing-led sensory-motor activation on functional recovery among patients with severe traumatic brain injury

Research hypotheses:

H1: Patients with severe traumatic brain injury who receive early nursing-led sensory-motor activation will demonstrate better functional recovery than those receiving routine care.

H2: Patients with severe traumatic brain injury who receive early nursing-led sensory-motor activation will achieve significantly higher neurological responsiveness scores (FOUR score and SMART score) than patients receiving routine care.

H3: Patients with severe traumatic brain injury who receive early nursing-led sensory-motor activation will demonstrate significantly lower disability levels as measured by the Disability Rating Scale (DRS) than patients receiving routine care.

H4: Patients with severe traumatic brain injury who receive early nursing-led sensory-motor activation will exhibit greater physiological stabilization than patients receiving routine care.

H5: Patients with severe traumatic brain injury who receive early nursing-led sensory-motor activation will have shorter ICU length of stay and higher extubation success rates than patients receiving routine care.

Methods

Design

A quasi-experimental pretest-posttest control group design was utilized to evaluate the effect of early nursing-led sensory-motor activation on functional recovery among patients with severe traumatic brain injury. Random assignment of participants was not feasible because of the critical condition of the patients, the emergency nature of ICU admissions, and ethical and practical considerations related to providing timely care. Therefore, eligible patients were consecutively recruited and alternately allocated to the intervention and control groups according to the study protocol, making a quasi-experimental design the most appropriate approach for the current study.

Setting

The present study was carried out in the surgical intensive care units (ICUs) of

Mansoura Hospital. The hospital comprises three surgical ICUs (Surgical ICU 1, Surgical ICU 2, and Surgical ICU 3), each containing 10 beds. These units provide specialized care for patients with surgical and neurological conditions as well as those suffering from multiple traumatic injuries. All ICUs are equipped with advanced medical technology and staffed with qualified healthcare personnel to ensure optimal patient care. The nurse-to-patient ratio in these units is approximately 1:2.

Sample:

A purposive sample of 76 adult patients diagnosed with severe traumatic brain injury (TBI) and admitted to the Surgical Intensive Care Unit (SICU) was recruited to participate in the study. Patients were eligible for inclusion if they were aged 18–65 years, diagnosed with severe traumatic brain injury, medically stable to receive the study intervention, and met the predetermined inclusion criteria. **Inclusion criteria:** participants were aged 18–65 years, had a confirmed diagnosis of severe traumatic brain injury, were medically stable to receive the intervention, and fulfilled all study eligibility requirements. **Exclusion criteria:** patients were excluded if they had spinal cord injuries, pre-existing neurological disorders, severe musculoskeletal deformities limiting movement, hemodynamic instability preventing participation in sensory-motor activation activities, or documented hearing or visual impairments that could interfere with sensory stimulation procedures.

Calculation of sample size:

Sample size estimation was performed a priori using G*Power software (Version 3.1) for the comparison of two independent groups. Assuming a medium effect size ($d = 0.65$), an alpha value of 0.05, and a power level of 0.80, the required sample size was determined to be 66 participants. To minimize the impact of potential dropouts and incomplete follow-up among critically ill patients, an additional 10 participants were recruited. As a result, the final study sample comprised 76 patients, equally distributed between the intervention ($n = 38$) and control ($n = 38$) groups.

Tools:

Five tools were used to collect the required data. The first and fifth tools were developed by the researchers after reviewing the relevant literature, whereas the second, third and fourth tools were adapted from an established evidence-based source.

Tool I: Patient assessment sheet

Following a comprehensive review of the pertinent literature, the researcher designed a structured assessment tool to gather baseline demographic and clinical information of the study participants. The tool encompassed demographic variables (age and sex) as well as clinical characteristics, including medical diagnosis, history of chronic illnesses, and the Acute Physiology and Chronic Health Evaluation II (APACHE II) score (Knaus et al., 1985). Additionally, physiological and laboratory measurements were recorded, comprising arterial blood gas values (pH, PaO₂, PaCO₂, and FiO₂) and vital signs, namely body temperature, heart rate, blood pressure, and respiratory rate. (Moshtaghi et al., 2026)

Tool II: Full Outline of Unresponsiveness (FOUR score)

This tool was adopted from (Jain et al., 2025). It was used to assess the level of consciousness among patients with severe traumatic brain injury. It is a 16-point clinical scale used by medical professionals to assess patients with impaired consciousness. Unlike the Glasgow Coma Scale (GCS), it excludes verbal testing, making it ideal for intubated patients.

Domains

The FOUR score evaluates four specific neurological domains; each scored from 0 to 4. Eye Response: Measures eye tracking, blinking, or opening to commands/pain. Motor Response: Tests for complex movements like a thumbs-up or fist, localizing to pain, or extensor posturing. Brainstem Reflexes: Evaluates pupillary, corneal, and cough reflexes. Respiration Pattern: Assesses breathing, ranging from

regular non-intubated patterns to ventilator-controlled breaths.

Scoring system

The total FOUR score ranges from **0 to 16**, with higher scores indicating better neurological responsiveness and level of consciousness, whereas lower scores indicate severe neurological impairment.

- **16:** Fully awake and neurologically intact.
- **13–15:** Mild to moderate impairment of consciousness.
- **9–12:** Severe impairment of consciousness.
- **≤ 8:** Deep coma with a high likelihood of requiring endotracheal intubation.
- **≤ 4:** Highly predictive of in-hospital mortality.

Tool III: Sensory Modality Assessment and Rehabilitation Technique (SMART)

The Sensory Modality Assessment and Rehabilitation Technique (SMART). It was adopted from Gill-Thwaites and Munday (2004) and was used to evaluate patients' responses to sensory stimulation. SMART provides a hierarchical assessment of sensory responsiveness, motor function, and arousal level in patients with disorders of consciousness.

Domains

It consists of eight assessment domains: visual response, auditory response, tactile response, olfactory response, gustatory response, motor function, communication, and arousal. Each domain was assessed according to five hierarchical response levels: Level 1 (No Response), Level 2 (Reflexive Response), Level 3 (Withdrawal Response), Level 4 (Localizing Response), and Level 5 (Discriminative Response).

Scoring System

The total SMART score ranges from 8 to 40, with higher scores indicating better sensory responsiveness, motor performance, communication ability, and arousal status.

Score of 8–15: Profound unresponsiveness (vegetative state), 16–24: Severe impairment, 25–32: Moderate impairment / Minimally Conscious State (MCS), 33–40: Mild impairment / Emerging from MCS.

Tool IV: Disability Rating Scale (DRS)

The Disability Rating Scale (DRS) was adopted from Rappaport et al. (1982) and was used to assess the level of disability among patients with severe traumatic brain injury. The DRS is an 8-item clinician-rated scale designed to evaluate functional disability across the continuum of recovery from coma to community reintegration.

Domains

The DRS evaluates four major domains: Arousal and awareness, Cognitive ability for self-care, Dependence on others and Employability

Scoring System

The Disability Rating Scale (DRS) yields a total score ranging from 0 to 29, with lower scores signifying better functional outcomes and reduced disability levels, while higher scores reflect increased functional impairment and dependency. The severity of disability is categorized as follows: 0 indicates no disability; 1 indicates mild disability; 2–3 represent partial disability; 4–6 indicate moderate disability; 7–11 denote moderately severe disability; 12–16 correspond to severe disability; 17–21 reflect extremely severe disability; 22–24 indicate a vegetative state; and 25–29 represent an extreme vegetative state.

Tool V: Patients' Functional Recovery and Clinical Outcomes Assessment Sheet

This tool was developed by the researcher after reviewing the relevant literature and patients' medical records. It was used to assess the clinical outcomes of patients with severe traumatic brain injury throughout the study period.

Part I: Extubation Outcome

This part was used to assess the extubation outcome of the studied patients. Extubation outcome was categorized as successful extubation or failed extubation requiring reintubation during the observation period.

Part II: Length of ICU Stay

This part was used to determine the length of stay in the intensive care unit. ICU length of stay was recorded as the total number of days from ICU admission until discharge, transfer, or death.

Part III: Discharge Outcome

This part was used to assess patients' discharge status. Discharge outcome was recorded as discharge from the ICU, transfer to another hospital unit, or death.

Scoring System

The variables included in this tool were recorded as objective clinical outcomes obtained from patients' medical records and ICU documentation.

Tools Development and Validation:

The study tools were selected and developed after an extensive review of the relevant national and international literature related to severe traumatic brain injury, sensory-motor activation, neurological assessment, and functional recovery. Tool I (Patient Assessment Sheet) and tool V (functional recovery and outcomes assessment sheet) were developed by researcher to collect demographic and clinical data relevant to the study objectives. Tools II, III, and IV were adopted from previously validated instruments, including the Full Outline of Unresponsiveness (FOUR) Score, the

Sensory Modality Assessment and Rehabilitation Technique (SMART), and the Disability Rating Scale (DRS).

The content **validity** of Tool I & V were assessed by a panel of five experts in critical care nursing and neurocritical care. The experts evaluated the tool for relevance, clarity, comprehensiveness, and appropriateness. The necessary modifications were made according to their recommendations. The adopted instruments (FOUR, SMART, and DRS) have demonstrated satisfactory validity and reliability in previous studies and have been widely used in patients with severe traumatic brain injury and disorders of consciousness.

Reliability:

The psychometric properties of the adopted instruments were verified through previously published studies. The FOUR Score demonstrated good inter-rater reliability and validity (Amirtharaj et al., 2022). The SMART showed excellent intra-observer and inter-observer reliability, with intraclass correlation coefficients of 0.97 and 0.96, respectively (Gill-Thwaites & Munday, 2004). The Disability Rating Scale demonstrated good inter-rater reliability ($r = 0.91$) and acceptable validity in patients with severe traumatic brain injury (Gouvier et al., 1987).

Ethical Considerations:

Ethical approval for conducting the study was obtained from the Faculty of Nursing, Mansoura University, and the Research Ethics Committee (Approval No.260828). The study was conducted in accordance with established ethical principles governing clinical research.

Prior to participation, written informed consent was obtained from all eligible participants. For patients who were unable to provide consent because of their critical condition, written informed consent was obtained from their legally authorized representatives. Participants and/or their representatives were informed about the aim of the study, study procedures, potential benefits and risks, and their right to refuse participation

or withdraw from the study at any stage without any consequences for the care provided.

Confidentiality and anonymity were maintained throughout the study. All collected data were coded and stored securely, and access was restricted to the research team only. Patients' privacy and dignity were respected during data collection, assessment procedures, and implementation of the study intervention.

The sensory-motor activation intervention was implemented only after ensuring patients' hemodynamic stability and medical eligibility, and all procedures were performed in accordance with standard safety precautions and institutional guidelines. Any signs of intolerance or physiological instability during the intervention resulted in immediate discontinuation of the session and appropriate medical management.

Pilot study

A pilot study was conducted on 10% of the total study sample (eight patients) to assess the clarity, feasibility, applicability, and sequence of the study tools and intervention procedures. The pilot study also helped identify potential practical problems that might arise during data collection and implementation of the sensory-motor activation program. No necessary modifications were made accordingly. Patients included in the pilot study were excluded from the main study sample.

Operational definitions

Sever traumatic Brain Injury:

Patients diagnosed with traumatic brain injury who required admission to the Surgical Intensive Care Unit and met the predetermined study eligibility criteria.

Sensory-Motor Activation

A structured nursing-led intervention consisting of multimodal sensory stimulation (visual, auditory, tactile, olfactory, and gustatory stimulation) combined with graded motor activation activities implemented according to the study protocol.

Functional Recovery

Progressive improvement in neurological responsiveness, sensory processing, communication ability, arousal level, and disability status over the study period, measured using the FOUR Score, SMART, and DRS.

Extubation Success

Successful removal of the endotracheal tube without the need for reintubation during the follow-up period.

ICU Length of Stay

The total number of days from admission to the Surgical Intensive Care Unit until discharge, transfer, or death.

Data Collection Process

The study was carried out over six months, Data collection and intervention implementation were organized into three sequential phases: the preparatory phase, implementation phase, and evaluation phase.

I. Preparatory phase

Prior to data collection, official approval was obtained from the responsible authorities of the Faculty of Nursing and the Surgical Intensive Care Unit (SICU). The study purpose and procedures were explained to the ICU medical and nursing staff to facilitate data collection and implementation of the intervention. The study tools were reviewed and finalized after validation by a panel of experts. Required materials and equipment for sensory-motor activation were prepared, including visual, auditory, tactile, olfactory, and gustatory stimulation materials. Standardized procedures for implementing the sensory-motor activation protocol and the application of the study tools were established to ensure consistency throughout the study period.

Step 1: Patient Screening, Recruitment, and Group Assignment

Upon admission to the Surgical Intensive Care Unit (SICU), potentially eligible patients

were screened by the researcher according to the predetermined inclusion and exclusion criteria. Patients' medical records were reviewed, and consultation with the attending physician was undertaken when necessary to verify eligibility for participation in the study. Patients who met the study eligibility criteria were approached through their legally authorized representatives because of the impaired level of consciousness associated with severe traumatic brain injury. The purpose, procedures, benefits, and potential risks of the study were explained, and written informed consent was obtained prior to participation. A total of 76 eligible patients were recruited. Because random assignment was not feasible due to the critical condition of patients with severe traumatic brain injury, a quasi-experimental approach was adopted. Participants were assigned into two equal groups according to the study protocol: an intervention group (n = 38) and a control group (n = 38).

Step 2: Baseline Assessment

Following enrollment, baseline data were collected for all patients using Tools I, II, III, IV and V. Demographic and clinical information, including age, sex, medical diagnosis, APACHE II score, medical history, arterial blood gas parameters, type of ICU admission, and vital signs, were obtained and documented.

Baseline neurological responsiveness was assessed using the Full Outline of UnResponsiveness (FOUR) Score. Baseline sensory responsiveness, motor responsiveness, communication ability, and arousal level were assessed using SMART. Functional disability was evaluated using the Disability Rating Scale (DRS).

All baseline assessments were completed before implementation of the intervention to ensure comparability between the intervention and control groups.

Step 3: Implementation of the Early Nursing-Led Sensory-Motor Activation Program

Following completion of the baseline assessment, patients in the intervention group received the early nursing-led sensory-motor activation program in addition to routine care. **The intervention protocol was developed based on previous evidence regarding sensory stimulation and early mobilization among patients with traumatic brain injury (Alam et al., 2016; Adineh et al., 2022; Yen et al., 2024).** The intervention was initiated within 24-48 hours of ICU admission after confirmation of hemodynamic stability and medical eligibility. The program was administered twice daily for three consecutive weeks. Each sensory stimulation session lasted approximately 30 minutes and was subsequently followed by motor activation activities. All intervention sessions were delivered by the researcher according to a standardized protocol under continuous monitoring to ensure patient safety and tolerance.

Environmental Preparation

Before each intervention session, the researcher assessed the patient's hemodynamic stability and ensured that the patient was medically suitable to undergo the intervention. A quiet, safe, and comfortable environment was maintained within the ICU to minimize unnecessary distractions and maximize patients' responsiveness. The researcher approached the patient using a calm voice tone and provided reassurance throughout the intervention session.

Sensory Stimulation Phase

Patients underwent structured daily sensory stimulation involving all five sensory modalities in a consecutive sequence.

Auditory Stimulation

Auditory stimulation was delivered by speaking to the patient in a calm, clear voice while repeatedly addressing the patient by name and providing simple orientation cues regarding time, place, and situation. Whenever possible, a close family member was encouraged to communicate with the patient directly; otherwise, a recorded message from a familiar relative was used.

Visual Stimulation

Visual stimulation was initiated by presenting a flashlight approximately 10 cm from each eye to encourage eye opening and visual attention. When eye opening occurred, brightly colored objects were slowly moved within the visual field to encourage fixation and visual tracking.

Tactile Stimulation

Tactile stimulation consisted of the gentle application of alternating warm and cool stimuli to the upper extremities, allowing sufficient time between stimuli for observation of behavioral and physiological responses.

Olfactory Stimulation

Olfactory stimulation was provided through familiar scents such as perfumes and coffee. The selected odor was held close to the patient's nostrils for a few seconds while the patient's mouth remained closed.

Gustatory Stimulation

Following oral care and tongue moistening, a small amount of freshly squeezed lemon juice was applied to the tongue to provide gustatory stimulation, and responses were observed and documented.

A rest period of approximately one to two minutes was provided between each sensory stimulus to avoid overstimulation and allow adequate response time.

Motor Activation Phase

Following completion of the sensory stimulation session, motor activation was initiated. Passive range-of-motion exercises for both upper and lower extremities were performed twice daily for approximately 10 minutes over three consecutive weeks. Motor activation was conducted only after ensuring patients' tolerance and physiological stability.

Monitoring and Documentation

Throughout all intervention sessions, patients were continuously observed for any signs of physiological instability or intolerance to the intervention. Observed responses, physiological changes, and patient tolerance were documented immediately after each session using the study assessment tools

Step 4: Control Group

Patients in the control group received standard neurocritical care throughout the study period according to the existing unit protocol. Routine care included continuous physiological monitoring, airway management, positioning, medication administration, nutritional support, and other standard nursing and medical interventions routinely provided for patients with severe traumatic brain injury. No structured sensory-motor activation program was administered to this group.

Step 5: Follow-Up and Outcome Assessment

All participants were followed throughout the study period by the researcher. Neurological responsiveness, sensory-motor responsiveness, and disability status were reassessed weekly using the FOUR Score, SMART, and DRS.

Follow-up assessments were conducted at baseline, at the end of the first week, the second week, and the third week of the study period.

Vital signs were monitored continuously and documented according to the unit protocol. Clinical outcomes, including extubation outcome, ICU length of stay, and discharge status, were assessed using Tool V and recorded throughout the follow-up period.

All assessments were conducted using the same standardized evaluation procedures to maintain consistency between the intervention and control groups.

III-Evaluation phase

All participants were followed throughout the study period by the researcher.

Neurological responsiveness, sensory responsiveness, motor performance, communication ability, arousal level, and disability status were evaluated using the FOUR Score, SMART, and Disability Rating Scale (DRS). Assessments were conducted at baseline and repeated at the end of the first, second, and third weeks following implementation of the intervention. Vital signs were monitored and documented according to the unit protocol. Clinical outcomes, including extubation outcome, ICU length of stay, and discharge status, were assessed using Tool V and recorded throughout the study period. All assessments were conducted using the same standardized evaluation procedures to maintain consistency between the intervention and control groups

Results

Table (1) Shows that 68.4% of patients in the intervention group and 44.7% of patients in the control group were aged from 18 to 35 years. The mean age was 35.66 ± 14.39 years in the intervention group and 40.37 ± 15.66 years in the control group. No statistically significant difference was observed between both groups regarding age ($p = 0.10$). Male patients constituted the majority of both groups, with no significant difference regarding sex distribution ($p = 0.51$). Similarly, no statistically significant difference was found regarding past medical history ($p = 0.70$). Furthermore, the mean APACHE II score was 9.76 ± 5.4 among the intervention group and 9.91 ± 7.3 among the control group, with no statistically significant difference ($p = 0.98$)

Table (2) shows that no statistically significant difference was observed between the study and control groups at baseline regarding the mean FOUR score (7.21 ± 3.42 vs. 8.13 ± 2.71 , $p = 0.197$). The mean FOUR scores were significantly higher in the study group at the end of the first week (8.37 ± 2.84 vs. 6.13 ± 3.16 , $p = 0.002$), the second week (8.29 ± 2.87 vs. 6.74 ± 3.18 , $p = 0.02$), and the third week (11.84 ± 3.58 vs. 8.13 ± 4.01 , $p = 0.001$), with statistically significant differences between both groups.

Table (3) shows that no statistically significant difference was observed between the

study and control groups at baseline regarding total SMART scores (29.92 ± 4.05 vs. 30.57 ± 2.61 , $p = 0.41$), patients in the study group achieved significantly higher SMART scores than those in the control group throughout the follow-up period. Significant differences were observed at the end of the first week (23.97 ± 3.34 vs. 20.07 ± 3.13 , $p < 0.001$), the second week (30.0 ± 2.6 vs. 24.9 ± 0.4 , $p < 0.001$), and the third week (34.15 ± 4.79 vs. 29.55 ± 4.17 , $p < 0.001$).

Table (4) indicates that both groups exhibited a gradual reduction in DRS scores over the follow-up period. No significant difference was detected at baseline ($p = 0.80$). However, statistically significant differences emerged after the intervention, with the study group achieving lower DRS scores than the control group. The lowest mean DRS score in the study group was observed during the third week (7.32 ± 1.45 vs. 9.74 ± 1.50 , $p < 0.001$).

Table (5) illustrates that the study group achieved significantly higher scores across all SMART domains at the end of the third week compared with the control group. Significant differences were observed in visual responses (3.77 ± 0.72 vs. 3.44 ± 0.65 , $p = 0.039$), auditory responses (3.76 ± 0.52 vs. 2.49 ± 0.64 , $p < 0.001$), olfactory responses (3.80 ± 0.62 vs. 2.57 ± 0.70 , $p < 0.001$), tactile responses (3.97 ± 0.73 vs. 1.99 ± 0.67 , $p < 0.001$), gustatory responses (3.73 ± 0.71 vs. 2.97 ± 0.49 , $p < 0.001$), motor function (3.67 ± 0.71 vs. 2.43 ± 0.57 , $p < 0.001$), and arousal level (2.72 ± 0.38 vs. 2.10 ± 0.20 , $p < 0.001$).

Table (6) Baseline assessment during Week 1 revealed no statistically significant differences were observed between the study and control groups in terms of heart rate and mean arterial pressure, respiratory rate, oxygen saturation, or body temperature ($p > 0.05$). However, after intervention, the study group showed significantly lower mean arterial pressure, heart rate, and respiratory rate, together with significantly higher oxygen saturation compared with the control group ($p < 0.001$). Similar significant difference was observed throughout Weeks 2 and 3, whereas body temperature remained comparable between both groups during all assessment periods ($p > 0.05$).

Table (7) Shows that patients in the study group experienced a significantly shorter ICU length of stay than those in the control group (7.53 ± 2.35 vs. 16.18 ± 5.70 days, $t = -8.65$, $p < 0.001$). Extubation success was markedly higher among the study group (78.9%) compared with the control group (15.0%), whereas reintubation occurred less frequently in the study group (21.1%) than in the control group (84.2%), with a statistically significant difference between both groups ($\chi^2 = 30.40$, $p < 0.001$).

Figure (1) shows that the study group demonstrated a markedly higher improvement

rate and a lower mortality rate compared with the control group.

Figure (2) Presents the progression of SMART, Disability Rating Scale (DRS), and FOUR scores among the study and control groups throughout the follow-up period. The intervention group demonstrated greater improvement over time compared with the control group, as evidenced by higher SMART and FOUR scores and lower DRS scores during follow-up assessments. By the end of third week, the intervention group achieved better neurological and functional outcomes than the control group.

Table 1. Demographic and Clinical Characteristics of Patients at Baseline (N = 76)

	Intervention (N=38)		Control (N=38)		X2	P. Value
	No	%	No	%		
Age group						
18-35 years	26	68.4	17	44.7	4.4	0.1
35-50 years	7	18.4	11	28.9		
51-65 years	5	13.1	10	26.3		
Mean $\pm$SD (range)	35.66 $\pm$ 14.39		40.37 $\pm$ 15.66			
Sex						
Male	30		27		0.63	0.51
Female	8		11			
Past medical history						
None	21		16		2.4	0.7
HTN	4		6			
DM	7		4			
COPD	5		10			
HTN&DM	1		2			
APACHE II score	9.76 $\pm$ 5.4		9.91 $\pm$ 7.3			0.98

Chi-square test was used for comparison of categorical variables between groups, while the independent-samples t-test was applied for continuous variables. $P < 0.05$ indicates statistical significance; $P < 0.01$ indicates high statistical significance.

Table(2) Comparison of mean FOUR score between the study and control groups throughout the follow-up period (N=76)

Time of assessment	Study group M±SD	Control group M±SD	P-value
Baseline (Pretest)	7.2105± 3.41822	8.1316± 2.71304	0.197
End of Week 1 (post test1)	8.3684± 2.84197	6.1316± 3.16374	0.002*
End of Week 2 (post test 2)	8.2895± 2.87494	6.7368± 3.17664	0.02*
End of Week 3 (post test 3)	11.8421± 3.58319	8.1316± 4.00790	0.001**

Mean ± SD = Mean and Standard Deviation.

- Independent T-test quantitative data between the two groups

*Significant level at P value < 0.05, **Significant level at P value < 0.01

Table (3) Comparison of Total SMART Scores Between the Study and Control Groups Throughout the Follow-up Period (N=76)

Time of assessment	Study group M±SD	Control group M±SD	P-value
Baseline (Pretest)	29.92± 4.05	30.57± 2.61	0.41
End of Week 1 (post test1)	23.97± 3.34	20.07± 3.13	<0.001**
End of Week 2 (post test 2)	30 ±2.6	24.9 ±0.4	<0.001**
End of Week 3 (post test 3)	34.15± 4.79	29.55± 4.17	<0.001**

Mean ± SD = Mean and Standard Deviation.

▪ Independent samples t-test was used to compare quantitative variables between the study and control groups.

▪ Statistical significance was considered at $p < 0.05$ (*), $p < 0.01$ (), and $p < 0.001$ (*).

Table (4). Mean Disability Rating Scale (DRS) Scores Among Study and Control Groups During the Study Period (N=76)

Time of assessment	Study group M±SD	Control group M±SD	P-value
Baseline (Pretest)	15.50 ± 0.43	15.97 ± 0.54	0.8
End of Week 1 (post test1)	12.82 ± 1.45	13.58 ± 1.62	0.03*
End of Week 2 (post test 2)	12.58 ± 0.86	13.05 ± 1.31	0.05*
End of Week 3 (post test 3)	7.32 ± 1.45	9.74 ± 1.50	<0.001**

-Mean ± SD = Mean and Standard Deviation.

- Independent-samples t-test was used to compare quantitative variables between the study and control groups. $P < 0.05$ was considered statistically significant (*), and $P < 0.01$ was considered highly statistically significant (). **, *** Significant level at P value < 0.001

Table (5). Comparison of SMART Domains Between Study and Control Groups at the end of the Third Week (N=76)

SMART Domain	Study group N=38 M±SD	Control group N=38 M±SD	P-value
Visual	3.77±0.72	3.44±0.65	0.039*
Auditory	3.76 ± 0.52	2.49 ±0.64	<0.001**
Olfactory	3.80±0.62	2.57±0.7	<0.001**
Tactile	3.97±0.73	1.99±0.67	<0.001**
Gustatory	3.73±0.71	2.97±0.49	<0.001**
Motor function	3.67±0.71	2.43±0.57	<0.001**
Arousal	2.72±0.379	2.1±0.2	<0.001**

Mean ± SD = Mean and Standard Deviation.

- The independent-samples t-test was used to compare quantitative variables between the study and control groups. Statistical significance was defined as P < 0.05 (*), highly significant as P < 0.01 (), and very highly significant as P < 0.001 (*).

Table (6): Comparison of Vital Signs Between the Control and Study Groups Across Three Consecutive Weeks (Weekly Averages) (N=76)

Week	Vital Sign	Control Before	Study Before	p- value	Control After	Study After	p- value
Week 1	Heart Rate (bpm)	89.2 ± 6.8	89.5 ± 6.4	0.81	88.7 ± 6.9	82.1 ± 4.8	<0.001*
	MAP (mmHg)	94.1 ± 7.2	94.5 ± 7.0	0.74	93.9 ± 7.0	89.1 ± 5.2	<0.001*
	Respiratory Rate (breaths/min)	22.4 ± 3.1	22.6 ± 3.0	0.81	22.2 ± 3.0	19.2 ± 2.2	<0.001*
	Oxygen Saturation (SpO ₂ %)	95.1 ± 2.2	95.0 ± 2.1	0.86	95.3 ± 2.1	97.1 ± 1.4	<0.001*
	Body Temperature (°C)	37.2 ± 0.4	37.2 ± 0.4	0.91	37.2 ± 0.4	37.2 ± 0.4	0.940
Week 2	Heart Rate (bpm)	88.5 ± 6.4	83.2 ± 5.1	0.002*	88.1 ± 6.2	78.4 ± 4.1	<0.001*
	MAP (mmHg)	93.8 ± 6.9	89.0 ± 5.5	0.004*	93.5 ± 6.8	84.2 ± 4.1	<0.001*
	Respiratory Rate (breaths/min)	22.1 ± 2.9	19.5 ± 2.4	<0.001*	21.9 ± 2.8	17.3 ± 1.9	<0.001*
	Oxygen Saturation (SpO ₂ %)	95.3 ± 2.0	96.8 ± 1.5	<0.001*	95.5 ± 1.9	98.2 ± 1.1	<0.001*
	Body Temperature (°C)	37.1 ± 0.3	37.1 ± 0.3	0.85	37.1 ± 0.3	37.1 ± 0.3	0.820
Week 3	Heart Rate (bpm)	87.9 ± 6.1	77.8 ± 4.2	<0.001*	87.4 ± 5.9	74.5 ± 3.2	<0.001*
	MAP (mmHg)	93.2 ± 6.5	84.1 ± 4.3	<0.001*	93.0 ± 6.4	81.5 ± 3.1	<0.001*
	Respiratory Rate (breaths/min)	21.8 ± 2.7	17.1 ± 1.8	<0.001*	21.6 ± 2.6	15.8 ± 1.4	<0.001*
	Oxygen Saturation (SpO ₂ %)	95.4 ± 1.9	97.9 ± 1.1	<0.001*	95.6 ± 1.8	99.0 ± 0.8	<0.001*
	Body Temperature (°C)	37.0 ± 0.3	37.0 ± 0.3	0.78	37.0 ± 0.3	37.0 ± 0.3	0.800

-Mean ± SD = Mean and Standard Deviation. - MAP: mean arterial pressure

-Independent-samples t-test was utilized to assess differences in quantitative variables between the two groups. Statistical significance was considered at $P < 0.05$, highly significant at $P < 0.01$, and very highly significant at $P < 0.001$.

Table (7) Comparison of Clinical Outcomes Between the Study and Control Groups (N=76)

Outcome Variables	Study Group (n=38) Mean $\pm$ SD	Control Group (n=38) Mean $\pm$ SD	X ²	p-value
Length of Stay (days)	7.53 $\pm$ 2.35	16.18 $\pm$ 5.70	-8.65	<0.001*
Extubation outcomes				<0.001*
Reintubation	8(21.1%)	32(84.2%)	30.40	
Extubation success	30(78.9%)	6(15%)		

Chi-square analysis was used to compare categorical variables between the two groups, whereas the independent-samples t-test was employed to compare continuous variables. Statistical significance was established at $P < 0.05$ (*), $P < 0.01$ (), and $P < 0.001$ (*).

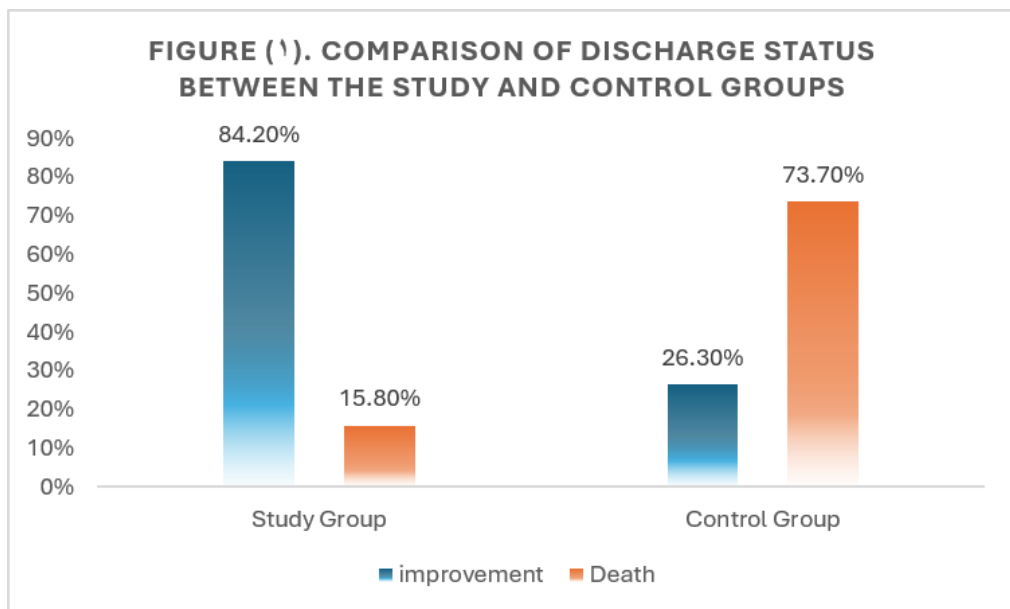


Figure (1) Comparison of Discharge Status Between the Study and Control Groups

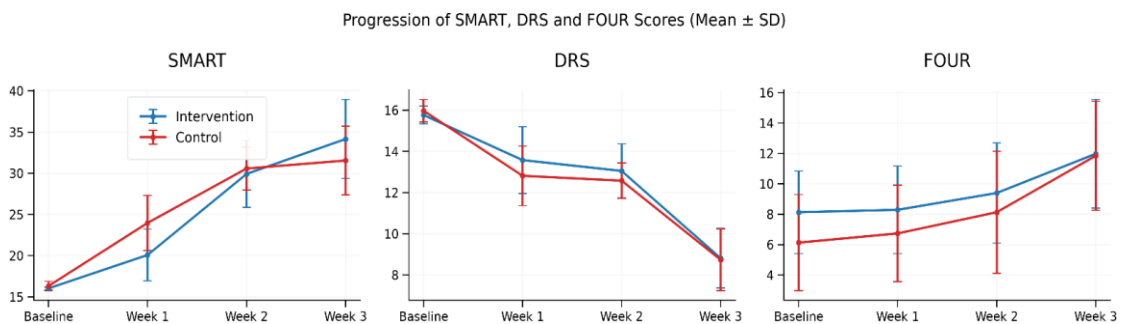


Figure (2). Changes in FOUR, SMART, and Disability Rating Scale (DRS) Scores Among the Study and Control Groups Throughout the Follow-up Period

Discussion

Patients with severe traumatic brain injury frequently experience impaired

consciousness, altered sensory responsiveness, and varying degrees of sensory deprivation, all of which may negatively affect neurological recovery. Consequently, sensory stimulation and early motor activation have been proposed

as therapeutic strategies to enhance cortical activation, facilitate neuroplasticity, and promote functional recovery. Therefore, the present study was conducted to evaluate the effect of early nursing-led sensory-motor activation on functional recovery among patients with severe traumatic brain injury. The findings demonstrated significant improvements in neurological responsiveness, sensory responsiveness, functional recovery, physiological stability, and clinical outcomes among patients who received the intervention.

Regarding demographic and clinical characteristics, the present study demonstrated that no statistically significant differences were identified between the intervention and control groups with respect to demographic characteristics and clinical characteristics. This comparability indicates that both groups were homogeneous before implementation of the intervention and supports that the observed differences in outcomes were likely related to the intervention rather than baseline differences between groups. The majority of patients in both groups were young adult males. This finding reflects the recognized epidemiological pattern of traumatic brain injury, which occurs more frequently among young males because of greater exposure to road traffic accidents, occupational injuries, and other high-risk activities. Similar findings were reported by Adineh et al. (2022) and Alam et al. (2016), who found that most participants receiving sensory stimulation interventions were young adults and predominantly male.

As regards the level of consciousness, the mean FOUR scores varied between the study and control groups throughout the study period. Progressive improvements in neurological responsiveness became evident during follow-up assessments, with patients receiving the intervention demonstrating superior recovery of consciousness compared with those receiving routine care. These findings indicate a favorable neurological effect of sensory-motor activation among patients with severe traumatic brain injury. This improvement may be explained by the ability of sensory and motor stimulation to enhance neuronal organization, increase dendritic connectivity, stimulate the reticular activating system, and

promote recovery of neurological function (Harrison, 2015).

This findings match with several studies which assessed the patients' level of consciousness (Adineh et al., 2022; Alam et al., 2016; Chuaykarn & Jitpanya, 2017; Singh et al., 2019). These studies illustrated significant improvements in the study group's consciousness throughout the study phases compared to the control group.

Regarding sensory responsiveness and SMART outcomes, patients who received early nursing-led sensory-motor activation demonstrated significantly higher SMART scores throughout the follow-up period compared with those receiving routine care. These findings suggest that the intervention enhanced patients' responsiveness to environmental stimuli and promoted recovery across multiple sensory modalities. The observed improvement may be attributed to increased sensory input, stimulation of neural pathways, and activation of cortical networks involved in awareness and behavioral responsiveness. These findings are consistent with Alam et al. (2016), who reported significant improvements in cognitive and sensory responsiveness following implementation of a structured sensory stimulation program. Similarly, Cheng et al. (2018) suggested that sensory stimulation programs may facilitate recovery of consciousness by enhancing neural responsiveness and behavioral performance.

Additionally, Adineh et al. (2022) reported that sensory stimulation programs delivered by family members were associated with improved levels of consciousness and reduced pain among critically ill patients.

Chuaykarn and Jitpanya (2017) investigated the effectiveness of two sensory stimulation approaches in promoting recovery among adults with severe traumatic brain injury. Their findings demonstrated beneficial effects of sensory stimulation therapy on patient recovery.

The present study revealed significantly higher SMART scores across all assessed

domains among patients in the study group at the end of the third week, indicating superior neurological recovery compared with the control group. A plausible explanation for this finding is that the sensory-motor stimulation program facilitated neural activation and promoted cortical reorganization through enhanced sensory input and stimulation of the reticular activating system, thereby improving patients' responsiveness and functional recovery Abu Jebbeh et al. (2025). This interpretation is supported by Alam et al. (2016), who reported significant improvements in sensory modality assessment and rehabilitation outcomes following the implementation of a structured sensory-motor stimulation protocol. However, these findings differ from those of Lombardi et al. (2002), whose systematic review found insufficient evidence to support the effectiveness of sensory stimulation in improving sensory function among patients in a coma or vegetative state. The discrepancy between studies may be related to variations in intervention characteristics, timing of implementation, intensity of stimulation, patient characteristics, and outcome measures used to evaluate recovery.

Regarding specific SMART domains, patients in the intervention group achieved significantly higher scores in visual, auditory, olfactory, tactile, gustatory, motor, and arousal domains by the end of the third week compared with the control group. These findings suggest that early sensory-motor activation may enhance multisensory integration and facilitate recovery of neural networks responsible for sensory processing and behavioral responsiveness. Repeated exposure to structured sensory stimuli may strengthen residual neural pathways and promote adaptive neuroplastic changes, resulting in improved responsiveness across different sensory modalities. Similar findings were reported by Alam et al. (2016), who demonstrated significant improvements in sensory modality assessment scores following implementation of a structured sensory stimulation program. Furthermore Abu Jebbeh et al., (2025), concluded that integrated sensory stimulation contributes positively to consciousness, sensory responsiveness, and cognitive recovery among critically ill patients.

Regarding functional recovery, patients in the intervention group demonstrated significantly lower Disability Rating Scale (DRS) scores throughout the follow-up period compared with the control group, with progressively greater reductions in disability observed across the follow-up period. Since lower DRS scores indicate reduced disability and better functional status, these findings suggest that early nursing-led sensory-motor activation contributed positively to functional recovery among patients with severe traumatic brain injury. This improvement may be attributed to the combined effects of repeated sensory stimulation and early motor activation, which promote neural reorganization, facilitate motor responsiveness, and enhance patients' ability to interact with their environment. Furthermore, early rehabilitation interventions may reduce the adverse consequences of prolonged immobilization and support restoration of functional capacity during the acute recovery phase. These findings are consistent with those reported by Zou et al. (2026), who found that early rehabilitation nursing significantly improved neurological outcomes, motor performance, functional independence, and quality of life among patients with severe traumatic brain injury. Similarly, Yen et al. (2024) demonstrated that early mobilization was associated with superior functional outcomes and enhanced recovery trajectories among critically ill traumatic brain injury patients.

Regarding hemodynamic stability, the current study demonstrated significant improvements in heart rate, mean arterial pressure, respiratory rate, and oxygen saturation among patients in the intervention group throughout the follow-up period, while body temperature remained comparable between both groups. These findings suggest that early sensory-motor activation may contribute to improved physiological regulation, enhanced respiratory efficiency, and better cardiopulmonary function. Improved physiological stability may provide a more favorable environment for neurological recovery and overall patient improvement. Similar findings have been reported by Yen et al. (2024) and Zou et al. (2026), who highlighted the positive effects of early

rehabilitation and mobilization on physiological and clinical recovery among patients with severe traumatic brain injury.

Regarding clinical outcomes, patients who received early nursing-led sensory-motor activation experienced significantly shorter ICU length of stay, higher extubation success rates, lower reintubation rates, and better discharge outcomes compared with the control group. These findings suggest that the intervention facilitated earlier clinical stabilization and accelerated recovery among critically ill patients with severe traumatic brain injury.

Successful extubation is an important indicator of recovery because extubation failure and subsequent reintubation are associated with prolonged mechanical ventilation, increased complications, and longer hospitalization. Therefore, the lower reintubation rate observed in the intervention group may partially explain the shorter ICU stay and more favorable discharge outcomes. Improved consciousness, enhanced functional recovery, and greater physiological stability may also have contributed to patients' readiness for ventilator liberation and successful discharge.

These findings are supported by Yen et al. (2024), who demonstrated that early progressive mobilization improved mobility, functional recovery, and overall clinical outcomes among patients with moderate-to-severe traumatic brain injury. Similarly, Zou et al. (2026) reported superior neurological and functional outcomes among patients receiving early rehabilitation nursing compared with routine care. Conversely, Xia et al. (2025) found that although early mobilization significantly improved neurological recovery, motor function, and quality of life, it did not significantly affect mortality or some measures of functional independence. This discrepancy suggests that the effectiveness of early activation may vary according to the outcome assessed and intervention characteristics.

Furthermore, Howroyd et al. (2026) highlighted several barriers to early mobilization among patients with severe traumatic brain injury, including neurological instability, sedation, mechanical ventilation, and

hemodynamic concerns. These findings do not contradict the effectiveness of early activation but rather emphasize the practical challenges associated with implementing such interventions in critical care settings.

Overall, the findings of the current study provide strong evidence supporting the effectiveness of early nursing-led sensory-motor activation among patients with severe traumatic brain injury. The intervention was associated with significant improvements in consciousness level, sensory responsiveness, functional recovery, physiological stability, extubation outcomes, discharge status, and length of hospital stay. These findings highlight the important role of early nursing rehabilitation interventions in promoting neurological recovery and improving clinical outcomes among critically ill patients with severe traumatic brain injury. The favorable outcomes observed in the present study may be explained by the synergistic effect of combining sensory stimulation with motor activation. While sensory stimulation enhances cortical activation and awareness, motor activation promotes neuromuscular function and physical recovery. Together, these interventions may provide an integrated rehabilitation approach that supports recovery across multiple neurological and functional domains.

Therefore, incorporating structured sensory-motor activation into routine neurocritical care practice may represent a valuable strategy for enhancing recovery and reducing the burden of disability among this patient population.

Limitation of the study:

The findings of this study should be interpreted in light of several limitations. First, the study employed a quasi-experimental design without randomization, which may limit causal inference and introduce selection bias. Second, the study was conducted in a single center, which may reduce the generalizability of the findings. Third, the sample size was relatively limited. Finally, long-term neurological and functional outcomes after hospital discharge were not assessed. Future multicenter

randomized studies with extended follow-up periods are recommended.

Conclusion

The findings of the present study demonstrated that early nursing-led sensory-motor activation significantly improved functional recovery among patients with severe traumatic brain injury. Patients who received the intervention exhibited better neurological responsiveness, higher sensory responsiveness and arousal levels, lower disability scores, improved physiological stability, higher extubation success rates, shorter ICU length of stay, and better discharge outcomes compared with patients receiving routine care. These findings support the effectiveness of integrating structured sensory stimulation and early motor activation into routine intensive care nursing practice to enhance recovery and improve clinical outcomes among patients with severe traumatic brain injury.

Recommendations

- **Integrate early nursing-led sensory-motor activation into routine ICU care** for patients with severe traumatic brain injury, initiating the intervention once hemodynamic stability is achieved and following standardized evidence-based protocols.

- **Implement continuous assessment of neurological responsiveness and functional recovery** using validated tools such as the FOUR Score, SMART, and DRS to monitor patient progress and guide clinical decision-making.

- **Strengthen institutional support for sensory-motor activation programs** by providing adequate resources, equipment, and ongoing education and training for critical care nurses.

- **Conduct larger multicenter and longitudinal studies** to verify the effectiveness of sensory-motor activation, future studies should examine additional outcomes such as functional independence, cognitive recovery, and quality of life.

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