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Case Report

FUNCTIONAL RECOVERY FOLLOWING ONE-YEAR REHABILITATION IN A CHILD WITH POST-TRAUMATIC CERVICAL INSTABILITY: A CASE REPORT

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Keywords

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ABSTRACT

Purpose: Post-traumatic cervical instability may be associated with persistent functional impairments even after radiological healing has been achieved. Post-traumatic cervical instability may affect movement control, postural regulation, and sensorimotor integration, potentially leading to limitations in head-eye coordination and daily functional activities. Although rigid immobilization and cervical traction are commonly applied during the acute management phase, clinical reports describing rehabilitation approaches targeting sensorimotor recovery following orthotic treatment in pediatric populations remain limited.

Methods: This case report describes a seven-year-old female patient with post-traumatic cervical instability managed conservatively. Orthotic management included full-time cervical traction for approximately two months, followed by use of a Philadelphia collar for approximately two and a half months. Over a one-year period, the patient participated in a structured rehabilitation program emphasizing active postural correction, task-oriented exercises, and cervical stabilization. Due to persistent deficits in head-eye coordination during dynamic activities, an additional eight-week proprioception-focused target-based exercise program was implemented.

Results: Cervical and trunk active range of motion, as well as cervical joint position sense, were assessed before and after the rehabilitation period. Following the intervention, cervical range of motion increased in most movement directions, whereas trunk range of motion demonstrated minimal change. Cervical joint position error values decreased in most directions after completion of the exercise program.

Conclusion: This case describes measurable improvements in cervical mobility and proprioceptive performance following a comprehensive rehabilitation program. The findings emphasize the importance of functional and sensorimotor assessments in monitoring recovery and guiding rehabilitation planning in pediatric patients with post-traumatic cervical instability, alongside conventional imaging findings.

INTRODUCTION

Cervical spine injuries in the pediatric population may result in complex clinical presentations, including post-traumatic loss of stability and impairments in sensorimotor control. Although cervical spine injuries are relatively rare in children, trauma-related

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pathologies such as fractures, subluxations, and ligamentous injuries may occur and can lead to long-term functional impairments (1). In addition, anatomical characteristics of the pediatric cervical spine—including ligamentous laxity, the relative absence of cervical lordosis, and an immature musculoskeletal system—are recognized factors that increase the risk of post-traumatic instability (2).

Traumatic cervical instability refers to a loss of normal segmental control of the cervical spine following injury, resulting in abnormal motion patterns and compromised mechanical support. In pediatric patients, such instability may manifest as altered cervical alignment, reduced postural control, and limitations in functional movement (2). These impairments may interfere with activities requiring head control, visual orientation, and coordinated upper extremity use, thereby affecting daily activities and participation. While structural healing of osseous injuries may be achieved, functional consequences related to movement control and stability can persist beyond the acute phase (3, 4). Therefore, management should not be limited to fracture healing alone but should also address musculoskeletal and sensorimotor aspects of recovery.

External cervical orthoses are commonly used to provide temporary stabilization by limiting cervical motion in patients with cervical instability (5, 6). Depending on the required level of motion control, a range of orthotic designs may be utilized, including soft or rigid cervical collars, such as the Philadelphia, Aspen, or Miami J collars, as well as more restrictive cervicothoracic systems like the Minerva orthosis or Sternal Occipital Mandibular Immobilizer (SOMI) (6). In cases requiring maximal immobilization, particularly in the presence of significant or upper cervical instability, halo-type immobilization may be considered (6, 7). In pediatric patients, custom-made cervical orthoses are frequently used to accommodate anatomical characteristics and growth-related considerations (7). However, evidence suggests that standard cervical collars alone may be insufficient to adequately immobilize an unstable cervical spine, underscoring the need for careful orthosis selection, close monitoring, and integration with comprehensive clinical management (6).

In children, prolonged immobilization, traction, or external cervical support may influence neuromuscular control and sensory feedback mechanisms, which are known to contribute to cervical stability and postural regulation (8). From the perspective of restoring cervical stability and refined movement control, management should not be limited to fracture healing alone but should also address musculoskeletal (including range of motion and muscle strength) and sensorimotor recovery (including postural control, neuromuscular coordination and proprioceptive sense). This broader approach includes components related to movement capacity and stabilization, as well as neuromuscular mechanisms that contribute to cervical and postural control, as described in models of clinical spinal instability that emphasize the role of active and neural subsystems beyond passive structural integrity (4, 9).

When the cervical region is affected following trauma, altered cervical proprioceptive input may disrupt cervico-ocular and vestibulo-ocular reflexes, leading to impaired gaze stability and reduced coordination of head and eye movements (10, 11). If these impairments are not adequately addressed through rehabilitation, symptom-related anxiety and avoidance of movement or daily activities may develop, potentially limiting functional participation (12).

Nevertheless, clinical reports specifically addressing sensorimotor rehabilitation following orthotic management—particularly those focusing on postural control, stabilization, and proprioceptive function—remain limited in the pediatric literature. Therefore, the aim of this case report is to describe a comprehensive evaluation and rehabilitation-based conservative treatment approach in a pediatric patient with post-traumatic cervical instability, with particular emphasis on functional recovery beyond radiological findings.

METHODS

Case History

A seven-year-old female patient sustained a clavicle fracture as a result of a fall at school. No medical intervention was administered immediately following the injury. Two days post-injury, the patient developed cervical deviation accompanied by mandibular protraction. Approximately three weeks after the injury, radiographic and magnetic resonance imaging evaluations confirmed radiological union of the clavicle fracture; however, abnormal cervical alignment persisted.

On clinical examination, the patient presented with a deviated head posture characterized by right lateral flexion and left rotation. She also demonstrated difficulty maintaining a corrected head position.

Interventions

The patient was initially assessed by an orthopedic surgeon and underwent full-time cervical traction therapy for one month during hospitalization (Figure 1), followed by an additional three weeks of home-based traction after discharge (Figure 2). Before being referred to our rehabilitation unit, this traction protocol was used as part of the initial orthopedic management. Throughout this seven-week period, pain-free traction was maintained on a full-time basis, with the traction load progressively increased according to a structured protocol. Traction was initiated with a load of 2 kg and subsequently increased by 2 kg each week until reaching a target load corresponding to approximately half of the patient's body weight (14 kg). In parallel, the daily duration of weighted traction was gradually increased, beginning at 10 minutes per day and progressing to a maximum of 30 minutes per day by the end of the protocol. The traction load was gradually increased under medical supervision and was well tolerated; no neurological, temporomandibular, or other negative effects were noted during the traction period, according to the medical records and caregiver reports.

Figure 1. Cervical Traction Therapy for One Month During Hospitalization

Figure 2. Home-Based Cervical Traction After Hospital Discharge

Following completion of traction therapy, a custom-made Philadelphia-type cervical orthosis (Figure 3), permitting controlled cervical rotation was prescribed and used for approximately two and a half months. During the first month, the orthosis was worn for 23 hours per day and removed for one hour daily for rest. In the second month, a structured weaning protocol was implemented, with daytime wear progressively reduced by three additional hours each week. During the final two weeks, the orthosis was worn only at night before being fully discontinued. Throughout this treatment period, a concurrent exercise program was also implemented.

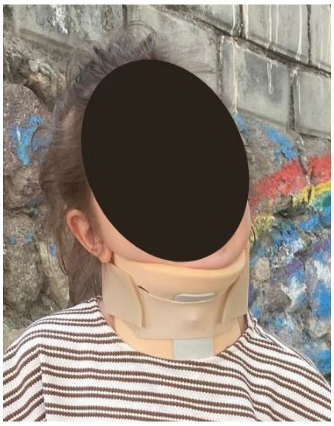

Figure 3. A Custom-Made Philadelphia-Type Cervical Orthosis Used During the Rehabilitation Period

Assessment Protocol

Outcome assessments were performed by an examiner who was not involved in the administration of the exercise program. The patient's medical history was reviewed, and radiographic and magnetic resonance imaging findings were documented. The findings were consistent with atlantoaxial joint subluxation and counterclockwise rotation of the C2 vertebral body.

Cervical active range of motion (AROM) was assessed using the GYKO inertial measurement unit (IMU) system (Microgate, Bolzano, Italy) (13) at three time points: at the initiation of exercise program (approximately 2 months post-injury), immediately prior to the commencement of the proprioceptive exercise program (approximately 10 months post-injury), and following completion of the proprioceptive intervention. Cervical flexion, extension, right and left lateral flexion, and right and left rotation ranges were recorded.

At the beginning of the proprioceptive exercise program, cervical joint position sense was assessed using an active head repositioning test (Figure 4). Cervical angular displacement was recorded using the GYKO IMU system, which was securely positioned on the participant's head according to the manufacturer's guidelines. Participant were guided to predefined target positions of 30° cervical flexion, 30° cervical extension, 30° cervical lateral flexion (right and left), and 30° cervical rotation (right and left). After reaching each target position, participant returned to the neutral starting position and were then instructed to actively reproduce the target angle with their eyes closed. The angular difference between the target position and reproduced position was calculated as the absolute reposition error (°). The selection of a 30° target angle across all movement planes was based on previously established cervical joint position sense assessment protocols reported in the literature (14-17). JPE is commonly reported as angular error and is considered a useful indicator of cervical proprioceptive dysfunction (16). Although precise, age-specific normative cutoff values have not been established for pediatric populations, reductions in joint position error are generally interpreted as clinically meaningful improvements in cervical proprioceptive and sensorimotor control (16, 17). Proprioceptive assessments were performed at the onset of the proprioceptive exercise program and repeated upon completion of the 8-week intervention period.

Figure 4. Active Head Repositioning Test Setup for Cervical Joint Position Sense Assessment Using using an inertial measurement unit (IMU) (A. Inertial Position of Neck B. Flexion of Neck)

Exercise Program

Active Postural Correction and Task-Oriented Exercises

Concurrently with the initiation of Philadelphia-type cervical orthosis use, the patient began a structured exercise program based on active self-correction and task-oriented principles. Initially, the patient was instructed to achieve a corrected head and trunk posture. Subsequently, stabilization of the corrected alignment was practiced during a variety of functional tasks. The exercise program was designed and implemented in accordance with the Scientific Exercise Approach to Scoliosis (SEAS) methodology (18). SEAS was initially developed for the treatment of spinal deformities in AIS, but its fundamental principles are not specific to any particular condition. SEAS emphasizes active self-correction, task- and goal-based motor control, and the integration of postural regulation into functional activities (18). In this case, the selected SEAS principles have been adapted to address cervical instability by focusing on active cervical stabilization, sensorimotor integration, and head-trunk coordination rather than correcting spinal alignment. This conceptual adaptation ensured that the rehabilitation program prioritized neuromuscular control and functional movement strategies in the context of pediatric cervical instability, without implying the direct transfer of scoliosis-specific treatment protocols.

The rehabilitation program was conducted over a 10-month period. Supervised clinical sessions lasting 45 minutes were scheduled once weekly during the first two months, biweekly during the subsequent three months, and once monthly during the final five months. On non-clinic days, the patient continued a 45-minute home-based exercise program. Each rehabilitation session consisted of 6–7 different exercises and included a variety of tasks tailored to the patient's individual needs, targeting cervical and trunk stability, mobility, head-eye coordination, postural control, and functional integration.

At the end of the 10-month exercise program, persistent deficits in head-eye coordination during dynamic activities were identified. Consequently, the patient was additionally enrolled in a proprioception-focused exercise program for a further two-month period.

Proprioceptive Exercise

Proprioceptive exercise was delivered using target-based exercises with the AOS PropPoint device with a laser apparatus, three days per week (19, 20). The program consisted of one supervised face-to-face session of approximately 45 minutes conducted in the clinic and two home-based sessions of approximately 30 minutes each. Exercise involved tracking a target map using head and trunk movements during various tasks, including exercises integrating upper extremity movements (Figure 5).

Figure 5. Target-Based Proprioceptive Exercise Tasks Performed Using a Laser-Guided Visual System

The exercise protocol was structured around goal-directed movements, joint position reproduction tasks, and controlled movement execution. The Target Platform system provided spatial reference and visual feedback during task performance. Exercises were performed under both eyes-open and eyes-closed conditions to progressively reduce visual reliance and enhance proprioceptive input. To further challenge sensorimotor control, tasks were executed on different surfaces, at varying heights, and across sitting, standing, and dynamic postural conditions.

Exercise content focused on head position control, controlled cervical flexion–extension and rotation movements, and maintenance of static head positions aligned with predefined targets. Task difficulty was progressively increased over the eight-week intervention period by modifying visual input, narrowing the base of support, increasing movement amplitude, and enhancing task complexity.

No adverse events were reported during the intervention, and the patient completed the program as planned.

RESULTS

Following completion of the one-year exercise program, changes were observed in cervical and trunk active range of motion. After the initial 10-month active postural correction and task-oriented exercise program, cervical active range of motion increased in movement across all planes (Table 1). Improvements included increases of 10° in flexion, 6° in extension, 21° in right rotation, 30° in left rotation, 19° in right lateral flexion, and 11° in left lateral flexion.

Following the subsequent two-month proprioceptive exercise program, additional increases in cervical range of motion were observed. Cervical flexion increased by 6°, extension by 10°, right rotation by 14°, left rotation by 3°, and left lateral flexion by 13°, while right lateral flexion remained unchanged (Table 1).

Trunk active range of motion showed minimal changes throughout the intervention period. Small variations were observed, including a 1° increase in trunk flexion, a 1° decrease in extension, a 2° decrease in right rotation, a 1° increase in left rotation, a 12° increase in right lateral flexion, and a 3° increase in left lateral flexion (Table 1).

Table 1. Range of Motion Before and After an 8-Week Proprioceptive Exercise Program

	Range of Motion		
Motion	**At the initiation of Task-Oriented Exercise Program** (2 months post-injury)	**Before Proprioceptive Exercise Program** (10 months post-injury)	**After Proprioceptive Exercise Program** (12 months post-injury)
Cervical (°)			
Flexion	26	36	42
Extension	28	34	44
Right Rotation	18	39	53
Left Rotation	14	44	47
Right Lateral Flexion	23	42	42
Left Lateral Flexion	19	30	43
Trunk (°)			
Flexion		89	90
Extension		22	21
Right Rotation	n/a	35	33
Left Rotation		29	30
Right Lateral Flexion		34	46
Left Lateral Flexion		41	44

Values represent single-subject measurements. Absolute change (Δ) indicates the numerical difference between pre- and post-intervention assessments. n/a: not available

Cervical joint position error values decreased after completion of the proprioceptive exercise program in most movement directions. Reductions were observed in cervical flexion (from 8° to 4°), extension (from 14° to 4°), left rotation (from 14° to 6°), right lateral flexion (from 28° to 22°), and left lateral flexion (from 12° to 10°). No change was observed in right rotation joint position error, which remained at 4° before and after the intervention (Table 2).

Table 2. Joint Position Error Before and After an 8-Week Proprioceptive Exercise Program

	Joint Position Error at 30°		
Motion	**Before Proprioceptive Exercise Program** (10 months post-injury)	**After Proprioceptive Exercise Program** (12 months post-injury)	**Change (Δ)**
Cervical (°)			
Flexion	8	4	−4
Extension	14	4	−10
Right Rotation	4	4	0
Left Rotation	14	6	−8
Right Lateral Flexion	28	22	−6
Left Lateral Flexion	12	10	−2

Joint position error values represent absolute angular error (°) during active head repositioning tasks at a target angle of 30°.

At the end of the treatment period, the patient achieved a neutral, vertically aligned head posture and was able to maintain an upright head position while looking straight ahead. No adverse events or symptom exacerbations were reported during the intervention period, and the patient completed the program as planned.

DISCUSSION

This case report describes the functional recovery of a child with post-traumatic cervical instability following a conservative treatment strategy consisting of cervical traction, orthotic management, and a structured rehabilitation program (SEAS and target-based exercises), with observed improvements in head posture, cervical mobility, and proprioceptive performance over the follow-up period.

In the present case, cervical range of motion demonstrated a gradual and plane-specific improvement over the follow-up period. Reduced cervical mobility is commonly reported following cervical trauma and prolonged immobilization (21). Notably, cervical range of motion increased across all movement planes following the initial 10-month exercise program emphasizing active postural correction and task-oriented exercises, with further, albeit smaller, gains observed after the subsequent proprioceptive training phase. These improvements occurred in the absence of aggressive mobilization or manual stretching techniques. This suggests that the observed changes likely reflect a progressive restoration of neuromuscular control and movement confidence rather than abrupt structural alterations.

Results from previous work suggest that improvements in cervical range of motion may be achieved through rehabilitation programs that focus on restoring sensorimotor control and segmental stability, rather than through passive mobilization alone. In this context, interventions that include head repositioning activities and carefully controlled movement tasks have been linked to concurrent improvements in cervical joint position sense and active cervical mobility in individuals with cervical dysfunction (3, 22). Comparable findings have also been reported in trauma-related neck conditions, such as whiplash-associated disorders, where exercise programs targeting deep cervical muscle activation and stabilization were associated with increased cervical mobility together with better movement control and functional performance (23).

In addition to improvements in cervical mobility, proprioceptive performance, assessed by cervical joint position sense measures, also improved over time. Cervical joint position error is widely used as a clinical indicator of proprioceptive accuracy in individuals with cervical dysfunction, and increased repositioning error has been reported following cervical injury (3, 14). In the present case, the observed reduction in repositioning error during follow-up suggests enhanced accuracy in reproducing cervical positions. As underlying neuromuscular or sensory mechanisms were not directly examined, these findings are interpreted descriptively as improvements in proprioceptive performance rather than evidence of specific physiological adaptations.

The additional improvements observed following the proprioceptive intervention, particularly in flexion, extension, and rotational movements, may indicate enhanced sensorimotor integration and improved precision of cervical movement. In contrast, trunk range of motion showed minimal change throughout the intervention period, supporting the notion that the observed cervical improvements were region-specific and related to targeted rehabilitation rather than generalized mobility gains. Clinical literature suggests that recovery processes following cervical instability extend beyond the restoration of joint excursion and also involves improvements in movement accuracy and neuromuscular control. In this context, reliance of radiological findings alone may be insufficient to identify residual functional deficits, particularly in cases characterized by subtle or low-grade instability (21). Functionally, the patient initially experienced difficulty maintaining head-eye coordination during sustained visual tasks such as reading and classroom activities that required prolonged visual attention, as well as during visual scanning while walking. After an 8-week proprioceptive exercise program, both the patient and caregiver reported improved tolerance for these tasks and greater fluidity in head-eye coordination during daily activities.

The restoration of a neutral, vertically aligned head posture with the ability to maintain forward gaze represents a clinically meaningful outcome in the context of cervical instability (21). This postural improvement occurred alongside gradual increases in cervical range of motion and reductions in joint position error, suggesting concurrent enhancements in mobility, movement control, and proprioceptive accuracy (3). Together, these findings suggest improved neuromuscular coordination of the head–neck complex, which is commonly compromised following cervical trauma and prolonged immobilization. The minimal changes observed in trunk range of motion further support the interpretation that these improvements were region-specific (4) and attributable to targeted cervical rehabilitation rather than generalized mobility gains.

In the present case, rehabilitation was implemented in a gradual and closely monitored manner, emphasizing the restoration of controlled cervical movement. This approach aligns with conservative strategies reported in the literature, in which progression is guided by symptom response and aggressive mobilization is avoided when cervical instability is a concern. Within this framework, the observed improvements over the one-year follow-up period are best interpreted as functional recovery outcomes reflecting enhanced movement stability and tolerance to activities of daily living, rather than as evidence of specific mechanistic adaptations (9, 21).

CONCLUSION

This case report describes the conservative rehabilitation course of a child with post-traumatic cervical instability. Over the follow-up period, measurable improvements were observed in cervical mobility and in the accuracy of cervical joint position sense, reflecting a functional recovery beyond radiological healing alone. Although the findings derived from a single case do not allow causal inferences, they underscore the clinical relevance of incorporating functional and sensorimotor assessments alongside imaging findings when monitoring recovery and planning rehabilitation in pediatric patients with cervical trauma. Future studies are warranted to further explore the role of structured rehabilitation and proprioceptive training in this population.

Ethics Committee Approval: Ethics committee approval was obtained from Hacettepe University Physical Therapy and Rehabilitation Department Research Ethics Committee (Approval No: FTREK25/71).

Informed Consent: Written informed consent was obtained from the patient’s legal guardian for participation in the study and for the publication of clinical data and images.

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Author Contributions: Kübra Nurdoğan-Çakır contributed to the conception and design of the study, data collection and processing, analysis and interpretation of data, literature review, and drafting of the manuscript. Gözde Yağcı contributed to the conception and design of the study, supervision, analysis and interpretation of data, and critical revision of the manuscript. Fatih Erbahçeci contributed to the conception of the study, supervision, and critical revision of the manuscript. All authors approved the final version of the manuscript.

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