Case report

Effects on postural control in quadriplegia with Galvanic Vestibular Stimulation: case report

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ABSTRACT | INTRODUCTION: Spinal cord injury leads to sensorimotor sequelae with functional impairment, which may affect postural control. Galvanic vestibular stimulation (GVS) stimulates the postural muscles that support vertical posture. The present study was registered as a clinical trial in the Brazilian Registry of Clinical Trials under numbers UTN U1111-1295-1127 and Rebec RBR-8w55n2g on 14-08-2023. **AIM:** To evaluate the effects of postural control in a quadriplegic patient obtained through exposure to GVS. **METHOD:** This is a case study; the participant was clinically assessed using the Functional Independence Measurement and the American Spinal Injury Association Scales. The computerized photographic postural assessment was conducted, and then a force platform assessment using Clinical Posturography was conducted. The patient underwent a therapeutic test to establish GVS dosimetry. Ten treatment sessions were conducted using GVS, vestibular rehabilitation, and neurofunctional physiotherapy exercises. The assessment procedures were repeated at the end. **RESULTS:** The patient showed gains in ASIA in sensory level scores, and FIM showed gains in independence. There were gains in Computerized Postural Assessment and Clinical Posturography Evaluation (increase in the sway area and speed variables in the x axes, and a decrease in the y axis velocity). A change in condition to sitting without support was achieved and recorded. **CONCLUSION:** GVS is a novel resource in the recovery of postural control by stimulating physiological circuits in quadriplegic patients after spinal cord trauma. This case report helped us to evaluate a novel clinical and functional tool, as the features of this proposal to studied with more participants.

KEYWORDS: Spinal Cord Injuries. Postural Balance. Quadriplegia. Transcranial Direct Current Stimulation. Case Report.

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1. Introduction

Postural control requires interaction between sensory systems, integrating neural centers, descending control pathways, and the musculoskeletal system. Postural control correlates with orientation, which is the ability to properly maintain the relationship between body segments and between the body and the environment, and balance, or postural stability, defined as the ability to keep the center of mass within the limits of the base of support.[1,2]

Galvanic Vestibular Stimulation (GVS) polarizes the vestibular nerves, which means that GVS separates and accumulates positive and negative electrical charges in two distinct regions of the nerves triggering two reflexes in particular: the vestibular-ocular reflex, which is directed toward the extrinsic muscles of the eyes, and the vestibulospinal reflex, which is directed towards the muscles of the body. The vestibulospinal reflex mainly recruits the antigravity and postural muscles, causing its neural demand to reach the gamma motoneuron. This process activates the semicircular canals, the otolithic organs, and the adjacent vestibular nerves. Thus, the GVS modulates posture, balance, oculomotor responses, and spatial orientation.[3]

Spinal cord injury (SCI) is a lesion to the spinal cord resulting from a traumatic injury, causing neurological changes and compromising spinal cord activity to varying degrees. One of the many possible functional deficits caused by SCI is quadriplegia, which most often leads to sensory-motor sequelae, which can be complete or incomplete due to the impairment of the neural elements within the spinal canal.[4,5]

Spinal cord injury affects the integrity of the somatosensory system, as it impairs the functionality of the main postural muscles, expected postural synergies, and the sensorimotor integration of the lower limbs and trunk. Also, it damages motor tracts, impairing postural and motor control.[6]

In a previous clinical case study, we observed that the use of vestibular stimulation through galvanic vestibular stimulation apparatus can modulate the postural control of patients with chronic spinal cord trauma, for example, which is observed through a reduction in the sway of the center of pressure and an improvement in anticipatory postural adjustment, in addition to reflecting clinical and functional improvement.[7]

GVS is a resource that has shown promise in physiological, functional, and clinical assessments. Galvanic Vestibular Stimulation can recruit vestibular sensory cells, hair cells, neural cells of the vestibular nerve, and second and third-order cells that go to different levels of the central nervous system. The vestibulo-ocular and vestibulospinal reflexes are recruited through their activity, leading even individuals without lesions to improve their postural stability. This stimulus can also increase neurotransmitter levels within the central nervous system pathways.[8-14] The GVS needs head movement to enhance its response[8], like vestibular rehabilitation exercises as adaptation exercises (with head movement and eye fixation on a target), neurofunctional exercises (as target reach with hands or head, and play the ball exercises within the patient condition) and stability exercises to maintain posture with no support but allowing neural mechanisms to support the patients postural control.

This is a unique case about the GVS use as a postural and motor control resource in a patient where these neural mechanisms are damaged. We had a previous study, but the neural mechanisms, limitations, and security still need to be investigated.

2. Objective

This study aimed to evaluate the clinical and functional effects on postural control (trunk and limbs) regarding posture and postural balance obtained through exposure to galvanic vestibular stimulation, vestibular rehabilitation exercises, and neurofunctional physiotherapy in one patient with spinal cord trauma.

3. Methods

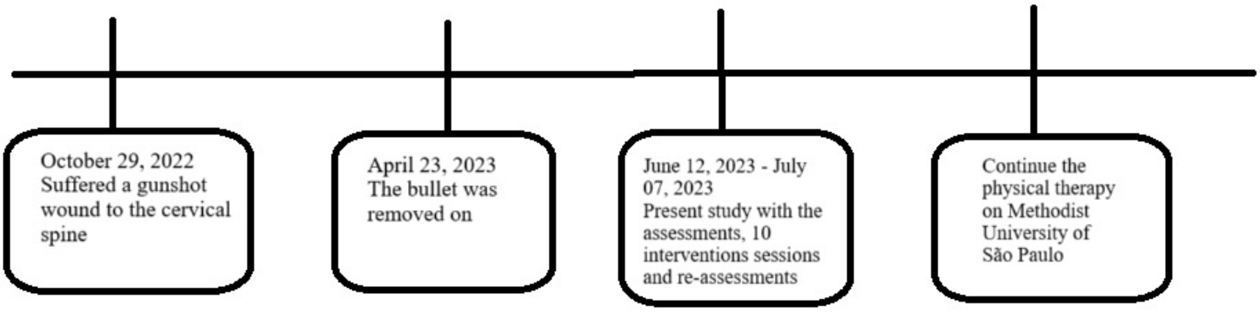
3.1 Case study

The study was submitted to the Ethics and Research Committee of the Methodist University of São Paulo in accordance with resolution 466/12.

It was approved, with CAAE number 67942323.3.0000.5508, following the Declaration of Helsinki, and could be started. This study was registered as a clinical trial in the Brazilian Clinical Trials Registry under numbers UTN U1111-1295-1127 and Rebec RBR-8w55n2g on 14-08-2023. The patient accepted and signed the Informed Consent Form before the start of the study.

Patient, 24 years old male, with sequelae of spinal cord trauma; the motor sequelae were characterized as quadriplegia. The patient suffered a gunshot wound to the cervical spine on October 29, 2022, and has been under continuous medical care and rehabilitation programs ever since. He participated in programs to readapt the activities of daily living and functional rehabilitation, stimulating arm movement and trunk control, and the hygiene could be performed by the caregivers more easily, support for the arm with injury of luxation, and more functionality in sitting posture. The bullet was removed on April 23, 2023. The timeline for this case is shown in Figure 1 (Figure 1).

Figure 1. Timeline indicating the events of the case report, the time of the lesion and the period of the intervention with Galvanic vestibular stimulation, vestibular rehabilitation and neurofunctional physical therapy



Source: the authors (2025).

3.1.1 Clinical findings

This case report describes the findings in a patient with spinal cord injury due to a traumatic lesion resulting in quadriplegia. We had no access to image exams. The physical examination before evaluating the selected instruments showed muscle spasms in the flexors and extensors of the lower limbs and elastic hypertonia in those, as well as hyporeflexia in deep reflexes in the lower and upper limbs (triceps, radial, and patellar) and hyperreflexia in biceps, ankle, and adductor. It was observed that there was little mobility and strength in the upper limbs and no mobility and muscle strength in the lower limbs, and low postural tone in the trunk in the sitting position (most muscles showing strength between degrees one and zero). There was a lower range of motion in the arm due to orthopedic disease associated with the poor neural motor control in this segment (hypertonia and low strength in these muscles).

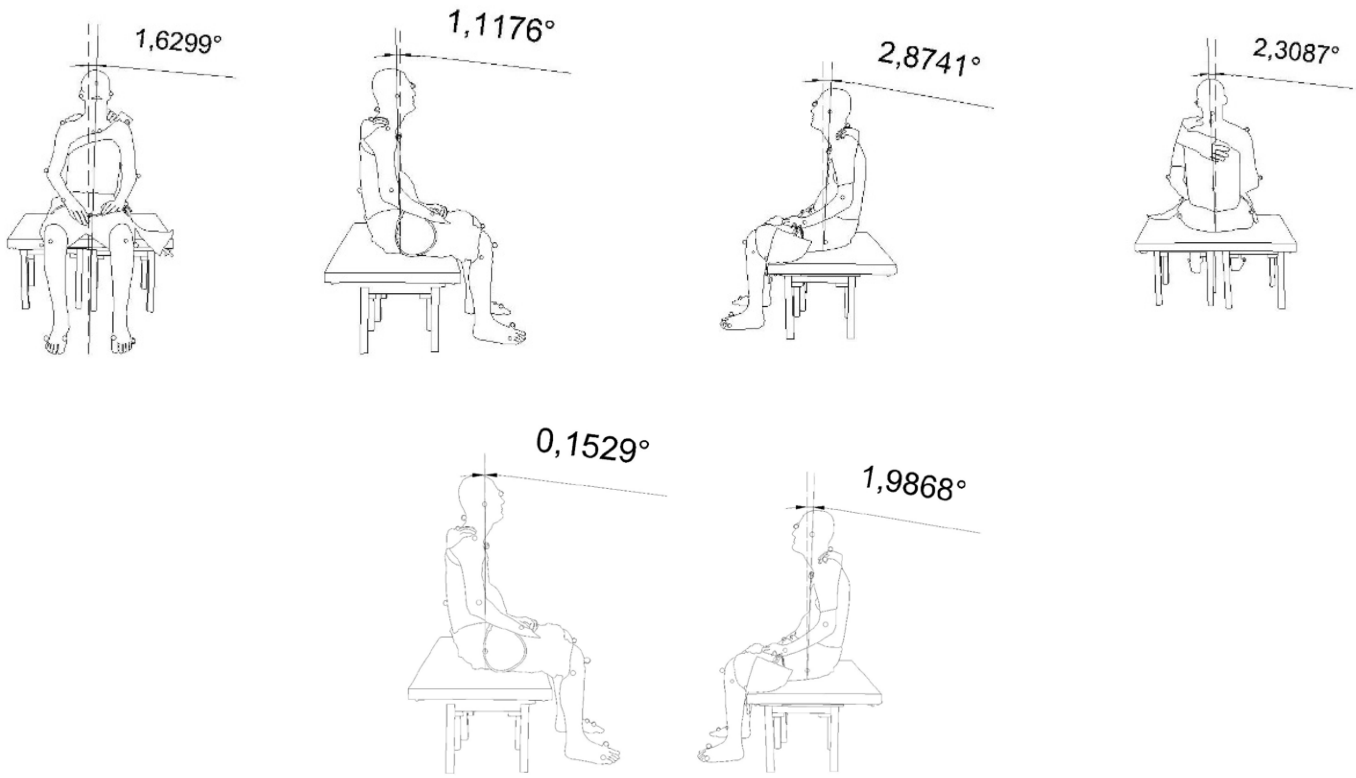
3.1.2 Diagnostic assessments

The pre-treatment Functional Independence Measure (FIM)[15] scored 42, showing the need for assistance in self-care, sphincter control, mobility, and locomotion. The pre-treatment American Spinal Injury Association (ASIA) assessment[16] showed a C6 motor level on the right, a C4 motor level on the left, and a C4 sensory level on the right and left. The degree of disability showed a complete lesion (A) (Table 1).

The initial assessments to analyze this patient's postural control were carried out sitting, supported by a second individual. He could not maintain a still sitting posture without support because he had lost his balance. Postural alignment, sensorimotor postural stability, and functional reach were assessed in this posture.

The computerized graphic postural assessment was carried out using a photographic evaluation of the sitting posture in the anterior, right lateral, left lateral, and posterior views. A vectorization of these photographs was processed using the AutoCAD® program. Then the silhouettes were scaled and orthogonalized, and the analysis of deviation angles was made, drawing the ideal gravity line and the segmental gravity line for reference. The deviation angle was then calculated (to deviations of relative gravity and body segmental deviation). The pre-treatment assessment showed a deviation from the ideal gravity line (small dashed line) in the coronal plane to the left and the sagittal plane with a backward deviation. The deviation from the segmental line (extensive dashed line) indicated a posterior deviation (Figure 2).

Figure 2. Data from the computerized graphic postural assessment of the pre-treatment moment. The pre-treatment moment is represented by the figures following the order in the anterior view, right lateral view, left lateral view, and posterior view, concerning, on the top, the gravity line reference, and, above, the segmental line reference



Source: the authors (2025).

The Clinical Posturography assessment used the Wii Balance Board® force platform to assess the center of pressure variables (area and velocity in x, laterolateral, and y, anteroposterior axes). It was coupled to a computer, Windows®, with the Brain Blox® Program installed to capture the platform's data and the Ellipse® Program from the Lucy Montoro Network to process the platform's signal. The Sensory Organization Test (SOT) was carried out using four sensory conditions: Condition 1: eyes open-fixed platform, condition 2: eyes closed-fixed platform, condition 3: eyes open-movable platform (on the cushion), and condition 4: eyes closed-movable platform (on the cushion), which showed a sway area, corresponding to the area of the ellipse, of less than 1 cm² in the conditions in the sitting posture with support (Table 1) (each condition was recorded in 60 seconds). The Functional Reach Test was also carried out on the force platform in a seated position, collecting the data by the maximum distance obtained in the anterior displacement of the center of pressure and the measurement of the maximum distance from the initial and final position of the index finger that marks the performance in the test. This task showed a sway area of 9.11 cm² in 30 seconds, with a performance of 1 cm on the first attempt and 6 cm on the second of the anterior displacement, showing the difficulty in performing the anterior displacement while keeping the arms in 90° flexion. All the clinical posturography assessments were done in the sitting position.

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3.2 Therapeutic intervention

The patient underwent a therapeutic proof to choose the Galvanic Vestibular Stimulation (GVS) parameter, carried out using NKL® Non-Invasive Brain Stimulation equipment, model MicroEstim Tes®, with random noise stimulation (RNS) current, following a stochastic phenomenon. The current was applied through silicone electrodes placed on a sponge cover soaked in 0.9% saline solution. The electrodes were each placed on a mastoid and connected to the equipment via the equipment's cables, without the positive and negative pole sides being relevant due to the characteristics of the RNS current, which alternates these poles during stimulation, stimulating both internal ears. The current parameters were frequency one of 1 Hz and frequency two of 100 Hz, ramp up of 20 seconds, and ramp down of 20 seconds. According to the patient's report, a dosage of 1.3 mA was found; he noticed more strength in his trunk balance, felt his vertebrae "wobble," and found it easier to speak without discomfort in a sitting position in this dosage. The therapeutic proof is a proposal to achieve the best dosage of galvanic vestibular stimulation, giving different doses (0.3 mA; 0.5 mA; 0.7 mA; 0.9 mA; 1.1 mA; and 1.3 mA) for short periods (2 minutes) of stimulation, and calculating the postural and clinical effects clinically promoted for each dosage and with the clinical posturography in the condition eyes open – fixed platform been recorded for post analyses.

The therapeutic time was done in ten sessions conducted three times a week, of GVS (1.3 mA) care associated with customized Neurofunctional Physiotherapy (reach exercises, play a ball and postural balance exercises in sitting position) and Vestibular Rehabilitation (adaptation exercises of head movement in horizontal and vertical planes fixing the eyes in a static and a dynamic target). Maintaining this proposal, the exercises were increased to maintain more patient autonomy while doing them with less support.

3.3 Post-intervention and outcomes

The Neurofunctional Exam, Postural Assessment, Sensory Organization and Functional Reach tests, as well as the FIM and ASIA assessments, were reassessed after completing the intervention.

During the sessions, we observed an increase in the time the patient remained unsupported. He maintained control of the trunk and posture and gradually even performed the proposed exercises without needing an individual (therapist) to support him in maintaining postural alignment and stability. Each session lasted around 1 hour (all with the GVS being active), with the patient intermittently remaining unsupported for 40 minutes, performing the proposed exercises while under GVS.

The post-treatment moment assessment showed that the muscular spasms diminished. It was a modulation of hypertonia (summed with more mobility of the joints in the upper and lower limbs). The profound reflexes were generally more excellent (except for the ankles reflexes, which were low). The passive mobility increases for the upper and lower limbs, and the motor index for muscle strength remains the same. The FIM assessment showed a total score of 44, with gains in independence in eating and social interaction. In the ASIA assessment, there was a gain in the right sensory level, and going from a degree of disability of complete lesion (A) to incomplete lesion (C) (Table 1).

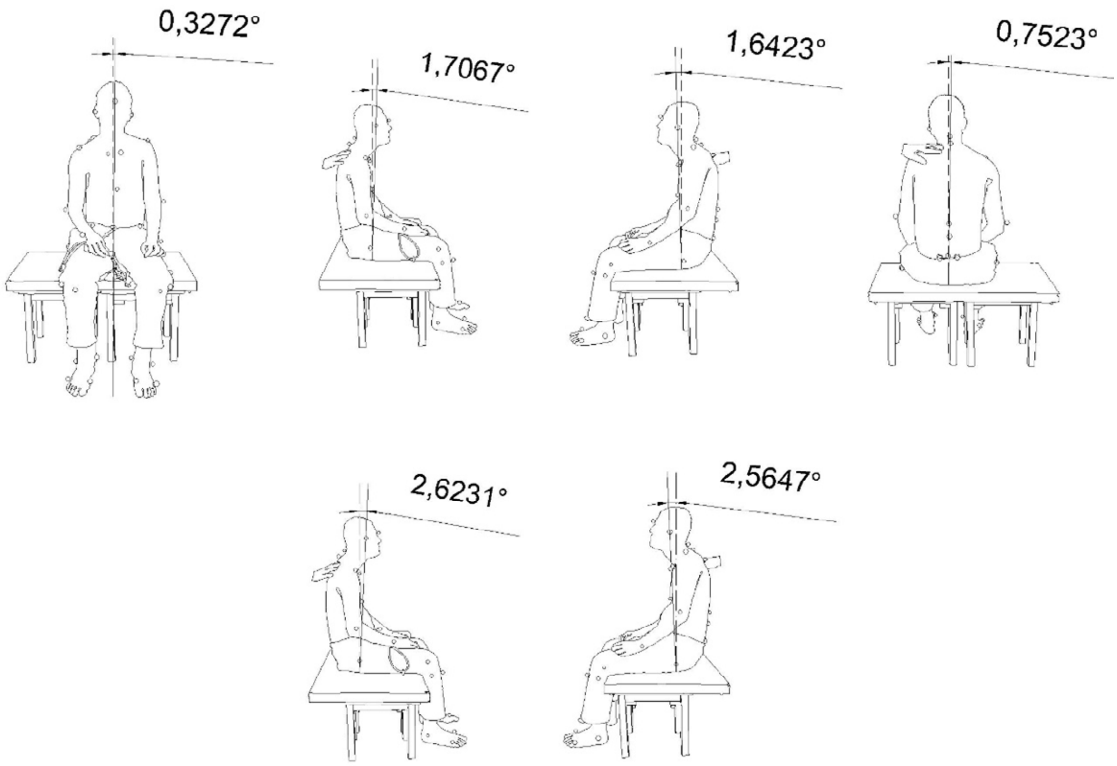
Table 1. Pre- and post-treatment results of the American Spinal Injury Association (ASIA) Assessment Scale. Right (R) and left (L) motor level, pre and post-treatment; right (R) and left (L) sensory level, pre and post-treatment with Galvanic Vestibular Stimulation

	Motor level R		Motor level L	
	Pre	Post	Pre	Post
ASIA	C 6	C 6	C 4	C 4
	Sensory level R		Sensory level L	
	Pre	Post	Pre	Post
	C 4	C 5	C 4	C 4

Source: the authors (2025).

The post-treatment computerized graphic postural assessment showed a minor deviation concerning the gravity line (small dashed line) in the coronal plane and an anterior deviation in the sagittal plane (Figure 3). Concerning the segmental reference, patient deviation was great in the anterior direction. The difference in the sagittal plane (right and left views) between the two views pre and post-intervention moments with the gravity and segmental references tended to diminished (from 1,75 degrees in the gravity reference pre-intervention to 0,06 degrees post-intervention comparing right and left views; and for the segmental line from 1,83 degrees to 0,058 degrees comparing right and left views). After treatment, the computerized graphic postural assessment was carried out in the same initial condition, with the patient being supported by an individual. However, at this point, the patient could remain unsupported.

Figure 3. Data from the computerized graphic postural assessment of the post-treatment moment. The post-treatment moment is represented by the figures following the order in the anterior view, right lateral view, left lateral view, and posterior view, concerning, on the top, the gravity line reference, and, above, the segmental line reference



Source: the authors (2025).

The post-treatment Clinical Posturography Evaluation showed an increase in the sway area (ellipse) and speed variables in x (latero-lateral), in general, and a decrease in the y (antero-posterior) axis velocity (Table 2). A change in condition to sitting without support post-treatment was achieved and recorded. In the sitting posture without support, this test showed a sway area greater than 5 cm² in condition 1, and better scores in all variables during the maintenance of the sitting posture with no support compared to the supported maintenance sitting posture (Table 3). The Functional Reach Test with support showed a sway area of 1.76 cm² (smaller than in the pre-intervention moment), performed in 30 seconds with a performance of 29 cm on the first and 31 cm on the second attempts for the anterior displacement. Similarly, it was performed without support, showing an oscillation area of 13.39 cm² over 30 seconds with a performance of 17 cm in forward movement.

Table 2. Scores of center of pressure kinetic variables from the posturographic assessment at pre- and post-treatment in the Sensory Organization Test in the sitting position with support. Condition 1: eyes open-fixed platform (EO-FP), condition 2: eyes closed-fixed platform (EC-FP), condition 3: eyes open-movable platform (EO-MP), condition 4: eyes closed-movable platform (EC-MP). x = laterolateral axis, y = anteroposterior axis. Pre- and post-treatment moments

	Condition 1 (EO-FP)		Condition 2 (EC-FP)		Condition 3 (EO-MP)		Condition 4 (EC-MP)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ellipse area (cm 2)	0.55	1.17	0.6	0.67	0.44	0.43	0.25	2.1
Velocity x (cm/s)	0.75	0.74	0.71	0.75	0.78	0.75	0.76	0.88
Velocity y (cm/s)	0.53	0.47	0.49	0.47	0.72	0.58	0.62	0.62

Source: the authors (2025).

Table 3. Scores of the center of pressure kinetic variables from the posturographic assessment at the post-treatment moment with and without support in the sitting position. Condition 1: eyes open-fixed platform (EO-FP), condition 2: eyes closed-fixed platform (EC-FP), condition 3: eyes open-movable platform (EO-MP), condition 4: eyes closed-movable platform (EC-MP). x = laterolateral axis, y = anteroposterior axis. A post-treatment moment with support and without support

	Condition 1 (EO-FP)		Condition 2 (EC-FP)		Condition 3 (EO-MP)		Condition 4 (EC-MP)	
	Post with support	Post without support	Post with support	Post without support	Post with support	Post without support	Post with support	Post without support
Ellipse area (cm 2)	1.17	5.53	0.67	9.58	0.43	13.82	2.1	38.32
Velocity x (cm/s)	0.74	1.15	0.75	1.29	0.75	1.8	0.88	1.65
Velocity y (cm/s)	**0.47**	**0.7**	**0.47**	**0.79**	**0.58**	**1.19**	**0.62**	**1.2**

Source: the authors (2025).

4. Discussion

This study evaluated the clinical and functional effects on postural control (trunk and limbs) regarding posture and postural balance obtained through exposure to galvanic vestibular stimulation, vestibular rehabilitation exercises, and neurofunctional physiotherapy in a patient with spinal cord injury. This objective was fully achieved.

The clinical evaluations of this case report showed gains in the FIM scale[15] and in the ASIA assessment[16] compared to before and after treatment with Galvanic Vestibular Stimulation. Due to the sensorimotor dysfunctions in quadriplegia, which generate difficulties in activities of daily living (ADLs), the pre-treatment assessment shows assistance in self-care, sphincter control, mobility, and locomotion. The post-treatment assessment showed gains in independence in the eating and social interaction subscales. The ASIA assessment showed a change in the degree of disability from A (complete) to C (incomplete); even though the lesion was initially complete, there were responses below the neurological level with a degree of strength of less than 3 to key-muscles (lower the skeletal level and previous neurological levels) after the GVS intervention sessions.[16] The motor level remained the same, but the sensory level on the right side changed after treatment with Galvanic Vestibular Stimulation (GVS) from C4 to C5, increasing the area of preserved sensitivity in the upper limb.

The pre-treatment computerized graphic postural assessment showed a deviation from the line of gravity in the coronal plane to the left and the sagittal plane with a posterior deviation. Post-treatment showed the opposite, with less deviation in the coronal plane to the left and in the sagittal plane with an anterior deviation within the base of support. The differences between the angles of right and left deviations (gravity and segmental lines) decrease in the post-intervention moment (sagittal plane or y, anteroposterior direction). This reflects postural control increases, which is defined as the ability to maintain or assume a position during a static or dynamic activity.[1,2,17] In this case report, the patient had a wheelchair as a support base in his daily activities, on which postural control occurs in a sitting posture to perform his ADLs.[6] The strategy that could be seen was that this individual used a deviation in relation to the line of gravity to the anterior, as segmental line references, and balanced his center of mass on the support base to be able to remain in the sitting posture without the need to have some support, so as not to leave his axis.

The evaluation of the ideal line of gravity and its deviation, as the segmental line references, has not been attempted before concerning vestibular function. However, it is known that one of the main characteristics of the vestibular system's role is the stimulation of this system, of postural control, in the face of the perception of the force of gravity. The utricle and saccule provide information on body position concerning the perception of the force of gravity[1], resulting in an effect on posture by stimulating the antigravity muscles. More studies must be done in order to enhance this discussion.

Day, Guerraz, and Cole (2002)[18] conducted a study with a patient in different conditions with a rare disease, a neuropathy affecting large fibers. His main symptom was the loss of sensation below the neck; he did not know where his limbs and body were in space. However, he learned to live independently, using visual feedback. The patient couldn't stand with her eyes closed safely, so they studied the responses in the sitting posture using GVS. With eyes closed, the size of the response was more significant than with eyes open, thus presumably representing a gain in the influence of the vestibular system on balance. This shows that the vestibular system greatly influences postural control, activating the tonic antigravity muscles and allowing for more excellent postural stability.

Postural stability or balance, defined by the ability to maintain the projected center of mass within the limits of stability, and this automated process, is compromised in patients with spinal cord injury, thus developing new patterns of postural control[19], which can be observed in the evaluation of clinical posturography. Post-treatment, there was an increase in sway under conditions of less sensory input, and there is no data in the literature to explain whether greater sway would be a loss or gain of postural stability, especially in this patient's reference posture, the sitting posture. Only y (antero-posterior) velocity scores decrease in the post-intervention moment. A previous case report showed that the patient achieved less sway in the sitting posture[7] as a pre- and post-treatment comparison. Still, this patient already stands with no support of a second individual in the pre-treatment moment, and remains that in the post-treatment moment with less sway of the center of pressure.[7] Still, in the present case report and under different conditions, where the patient could not maintain himself in a sitting posture without support, he achieved such an independent posture. Therefore, we cannot say that a more significant sway means less postural stability because the patient could reach a stability limit to remain balanced in the sitting posture without support. Also, we could not determine whether this rehabilitation support could diminish the measured parameters with more time. To maintain control of upright posture, postural control selects appropriate strategies activated through vestibulospinal reflexes, adapting to changes in the responses of the sensory and motor systems to the demands of the task and the environment[19], and these mechanics may be altered when there is an absence or failure of vestibular information.[17] In this clinical case, we could observe these mechanisms in the upright sitting posture.

In the functional reach test, we can assess anticipatory postural adjustment. This test assesses the individual's ability to move anteriorly while maintaining a fixed base[19] in the sitting posture. The individual evaluated in this study had difficulty keeping himself in the sitting posture without support. Still, it was notable that he achieved independence in this posture, having a lower functional range of motion in the base of support and higher in anterior displacement (third finger). He also performed anterior displacement with greater sway when without support, outperforming the pre-treatment with support. The stimuli received by the vestibular nucleus from the utricle, saccule, semicircular canals, cerebellum, and spinal cord contribute to the vestibulo-ocular and vestibulospinal reflexes, which activate the antigravity muscles of the neck, trunk, and limbs, used to support upright posture.[1,20] Takakusaki (2017)[20] concludes that the cortico-reticular tract and the reticulospinal tract can generate anticipatory postural adjustment.

Galvanic vestibular stimulation is helpful as a therapeutic resource in diseases that affect the nervous system. It is a method that stimulates and inhibits vestibular afferents, activating the semicircular canals, otolithic organs, and vestibular nerves, thus modulating posture and balance, oculomotor responses, and spatial orientation. The stimulus reaches the vestibulospinal and reticulospinal tracts, producing a postural response that excites tonic muscles and contributes to maintaining posture. Therefore, improving postural stability and balance in rehabilitation[21,22] is an option.

The limitations of this case report were that there was not enough data in the literature to compare what was found as a response, and the small number of patients with quadriplegia-type injuries at the university clinic for the study. The variations in the variables can also be due to variations in the tools used, following differences not only derived from functional or clinical improvements when this kind of proposal is novel, and we didn't have this data in the scientific literature. The case report is a study that looks for new resources and can help answer a scientific question that must be addressed with further studies. Also, it is important to know potential variables that must be studied in this case, as well as the security parameters for this technique.

The main lesson our study can teach us is about the vital contribution vestibular system can done in postural control, even in the subject with no lesion on it, but with poor postural control regarding posture (alignment, orientation) and postural balance (stability) deficits, and the applicability of this feature on quadriplegic patient after spinal cord injury. More than that, we believe that all of this was achieved due to the fact that this patient has an incomplete lesion with a probable preservation of the vestibular and reticular tracts (in an anterior position on the spinal cord).

5. Conclusion

Galvanic Vestibular Stimulation is a novel adjunct in recovering postural control in postural alignment, stability, stability limits, postural adjustment, and risk of falls in rehabilitation. Together with neurofunctional physiotherapy and vestibular rehabilitation exercises, it could stimulate physiological circuits, especially the vestibular system, in a quadriplegic patient after spinal cord trauma.

5.1 Patient perspective

The patient described his final account: "Well, I don't even know where to start. I really enjoyed being part of this experiment; it helped me a lot and motivated me more. It was carried out by excellent people; I'm sure it can help other people, too, because it gave me more hope. And I'm very grateful for all the smiles and jokes we had. It's an experience I'll carry with me for the rest of my life. If I had the chance, I'd do it again, because in this short time it's already helped me a lot. I don't even have the words to express this feeling because every day I do the exercises I used to do, I feel better. Thank you for everything."

5.2 Data availability statement

The data will be available when contacting the authors and after 1 year from the publication of this paper.

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Authors contributions

The authors declared that they have made substancial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsability for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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