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Case Study
Assessment and treatment of balance dysfunction using a pressure platform and visual biofeedback in a patient with chronic stroke sequelae.

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UNIDADE DE SAÚDE FAMILIAR FERNANDO NAMORA (USF FN)

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If you have some doubts about any information or need some advice about a Balance Sytem, feel free to book a quick meeting with me.

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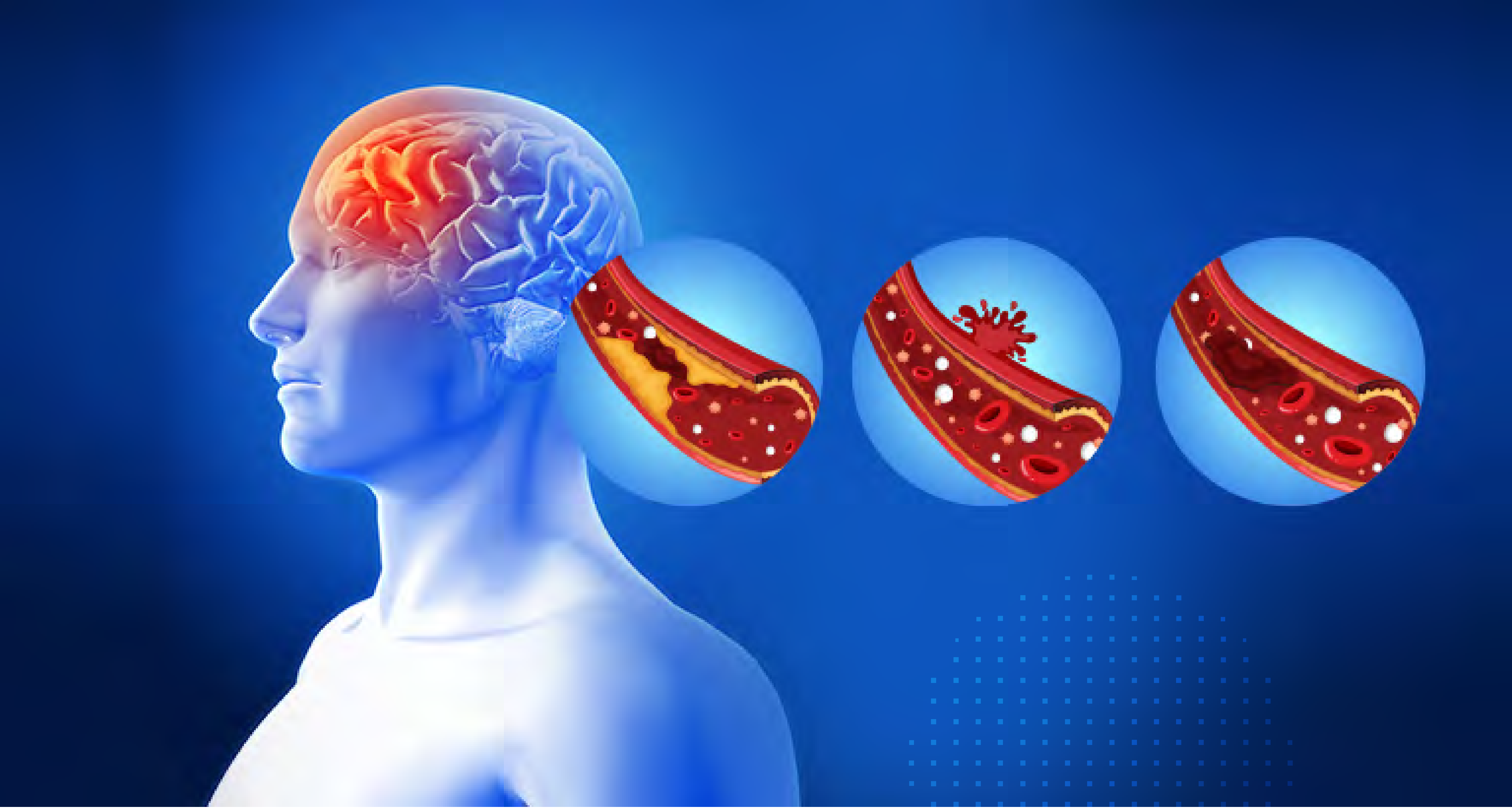


Abstract

Stroke is the third leading cause of mortality and morbidity globally, with a predicted rise in prevalence creating an increased demand for rehabilitation services. Balance dysfunction, a common sequela post-stroke, significantly impairs daily activities and heightens fall risk. This case study investigates the impact of a 15-session balance exercise program, incorporating a balance plate with visual biofeedback and interactive games, on improving postural control in a 67-year-old male stroke patient. The intervention targeted weight transfer, directional control, and stance symmetry, resulting in notable improvements in static and dynamic balance and behavioral domains. Despite being a case study and acknowledging its limitations, the findings suggest that integrating technology with rehabilitation practices can enhance recovery outcomes for stroke patients, offering a promising direction for future research and clinical applications.

Introduction

Stroke constitutes the third cause of mortality and morbidity worldwide. As for the future, the predictions showcase a reduction of 17% in mortality in Europe, accompanied by a 23% increase in prevalence, leading to an elevated burden for rehabilitation centers. For this reason, the European Stroke Organization prioritized research developments focused on rehabilitation for improving management, outcome, and quality of life after stroke [1], [2].

Approximately two-thirds of patients who suffered a stroke present neurological deficits that limit daily life activities performance, and 30% would benefit from prolonged access to rehabilitation services [3]. Balance dysfunction is one of the most frequent and impactful sequelae after a stroke, restricting patients from participating in community life and dramatically increasing the risk of fall [4]. The American Stroke Association states that 70% of stroke patients fall in the first 6 months after hospital/ rehabilitation release, suffering from serious injuries related to those falls [4], [5]. Therefore, it is fundamental to consider the need for continuing the rehabilitation process, particularly balance training, during the chronic phase of stroke recovery [6].

The impact of balance dysfunction in stroke patients led to an increase in research and development of new methods and technologies for assessing and treating balance dysfunctions. Regarding balance assessment, posturographic analysis from stroke patients with hemiparesis shows, in an objective way, a decrease in postural stability demonstrated by an increase in body sway, asymmetry in weight distribution on the lower limbs, a decrease in weight transfer capacity, a reduction of limits of stability and a higher reliance on the visual input for postural orientation [7], [8], [9], [10]. As for balance training, the use of balance plates with visual biofeedback that allow the execution of interactive games and activities has been shown to promote significant improvements in static and dynamic balance in stroke patients [7], [8], [11], [12], [13], [14], [15].

This case study investigates the impact of a balance exercise program, incorporating a balance plate with visual biofeedback activities and interactive games, on enhancing balance control and correcting weight-bearing asymmetry in a stroke patient. We hope that the results from this case study will enable us to replicate the intervention with a broader population of stroke patients.

Methods

Subjects from a Health Care Unit were screened out of the available list of subjects, only two met the following criteria for inclusion in the study: 1) Age ≥40 and ≤70 years, 2) Diagnosis of Stroke at least 6 months prior, and 3) Able to understand and follow simple verbal instructions. Subjects who met the following criteria were excluded from the study: 1) Presence of additional neurological disease and psychiatric disease, 2) Presence of aphasia, 3) Presence of neglect, 4) Presence of vestibular disease, 5) Presence of orthopedic disease that prevented the execution of the exercises and balance tests, and 6) Use of orthoses and/or prostheses. After interviewing both subjects, the selection of the participant was based on the availability for participating in the study.

The intervention consisted of 15 sessions of 30 minutes of balance training performed on a balance platform with visual biofeedback (PhysioSensing Pressure Plate, Balance Software). Clinical and posturographic assessments were carried out before the start of the program (T0) and at the end (T1).

The study was approved by the Ethical Committee from Administração Regional de Saúde do Centro (CES-ARS), the participant provided informed consent before participation.

Participant characterization

Our subject is a 67-year-old male with a history of ischemic stroke in the posterior circulation (left paramedian pontine lesion in November 2020) with multiple vascular risk factors. These include Type 1 diabetes mellitus (diagnosed 33 years ago), a smoking habit, and a cervical CT angiography showing a suspected asymptomatic carotid web on the left.
There have been no new vascular events or complications since the stroke. The patient continues to experience difficulty using the right upper limb. Gait is possible without support. Blood pressure is controlled with medication.

For a complete characterization of different domains of daily life – physical, functional, social, and emotional, the following scales were used: Geriatric Depression Scale, Katz Index of Independence in Activities of Daily Living, Brody Instrumental Activities of Daily Living Scale (IADL), and Functional Ambulation Categories (FAC).

Measurements

Posturography Assessment

The static and dynamic balance were assessed using the PhysioSensing platform (Sensing Future Technologies, Lda) that measures pressure distribution data, running at a frequency of 100 Hz. The platform contains 1600 pressure sensors (10 mm by 10 mm) with a maximum load capacity value of 100 N/sensor. Voltage data are converted with an 8-bit A/D converter and are transmitted via Universal Serial Bus to the main computer. Data was stored and analyzed with commercial software (PhysioSensing v.22.0.0.3).

Figure 1 - PhysioSensing Pressure Platform Set-up

Click here to know more about PhysioSensing

Sit-to-Stand Protocol

PhysioSensing Balance Software, using the pressure plate, has a different version of the Sit-to-Stand, with three commanded repetitions, based on the research from Chang Gung Memorial Hospital and Chang Gung University [14].

This protocol measures the Sit-to-Stand performance on three 15-seconds trials:1) Lift from a sitting position, without using the hands, to a standing position, as quickly as possible after indication in the interface, 2) Stand still until the end of the trial, 3) Sit and repeat for the second and third trial. The patient must be seated on an armless chair, about 43 cm high. The knees and hips should be at an angle of 90°, and the feet must always be on the platform during the protocol.

Measures calculated:

- **Weight time transfer:** The time between the indication to get up and the arrival of the center of pressure over the feet, in seconds.
- **Rising Index:** The force exerted during the rising phase, from the lift-off moment until the end of the extension, expressed as a percentage of body weight.
- **Sway velocity:** The displacement of the center of pressure during the rising phase and the following 5 seconds (during the stabilization phase), divided by the time (°/s).
- **Left/right symmetry:** The percentage of weight difference between the right and left leg during the rising phase and the following 5 seconds (during the stabilization phase).

Limits of Stability Protocol

Limits of Stability (LOS) is a commonly used protocol for evaluating stability and voluntary motor control in dynamic states. The goal of this assessment is to determine the maximum distance that the patient can displace his/her center of pressure from the primary vertical position in 8 different directions, without losing balance. LOS assessment provides valuable bio-mechanic information by tracking the instantaneous changes in the center of pressure velocity and position [15], [16].

Measures calculated:

• **Reaction time (RT):** The time between the indication to move and the initiation of the movement, in seconds.

• **Endpoint excursion (EPE):** The distance from the first attempt to reach the orange target, expressed as a percentage of LOS. The end of the first attempt is considered the point at which the initial movement towards the goal ceases.

• **Maximum excursion (MXE):** The maximum distance reached during the 8-second trial, expressed as a percentage of LOS.

• **Movement velocity (MVL):** The distance traveled by the center of pressure, between 5% and 95% of the first attempt, divided by the elapsed time (°/s).

• **Directional control (DCL):** The percentage of movement in the intended direction minus off-axis movement during the first attempt.

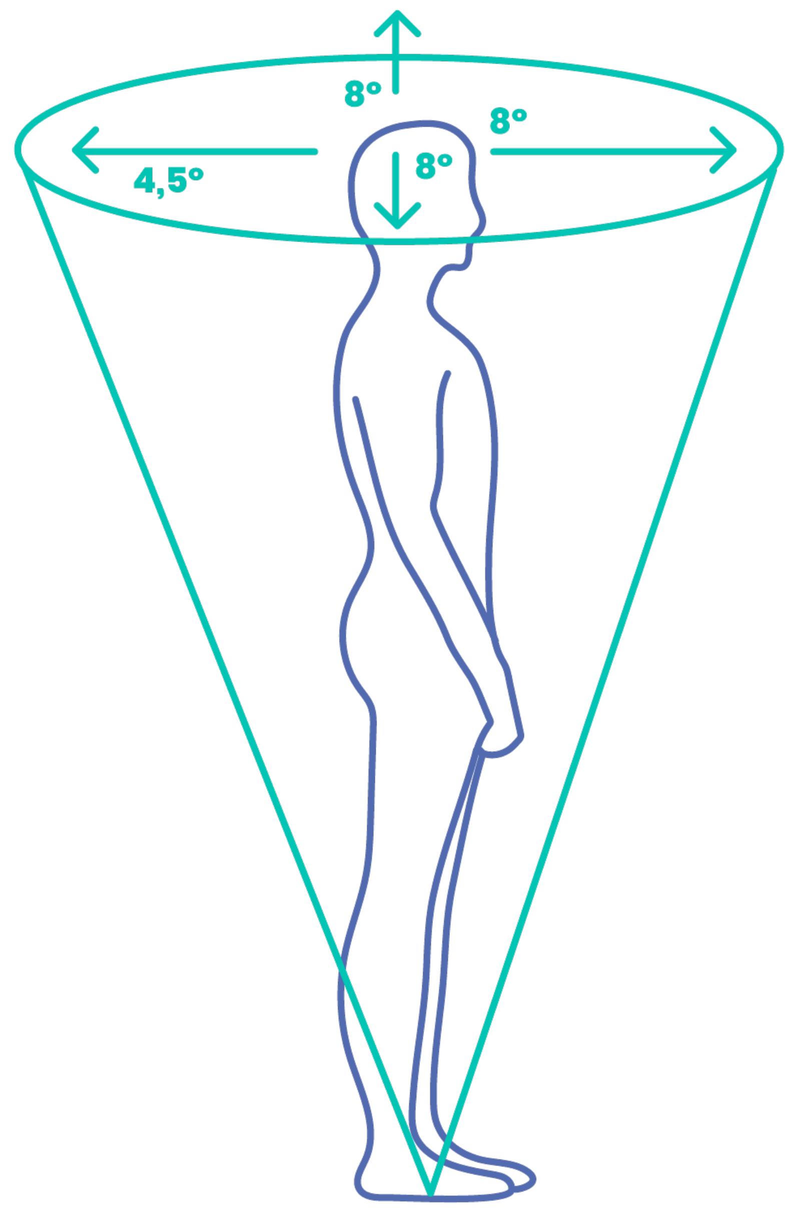


Figure 2 - Limits of stability

Fall Risk Protocol

The Fall Risk test protocol is based on research from the University of Dayton [16] and the University of Jyväskylä in Finland [17].

This protocol measures static balance in four conditions: 1) Comfortable stance with eyes open, 2) Comfortable stance with eyes closed, 3) Narrow stance with eyes open, 4) Narrow stance with eyes closed.

Measures calculated:

• **Sway velocity index (SVI):** Based on the mediolateral velocity divided by the height of the patient, and then normalized by the natural logarithm function. High values are suggestive of postural control deficits.

For a clinical evaluation of balance, the Berg Balance Scale was used [18].

Intervention

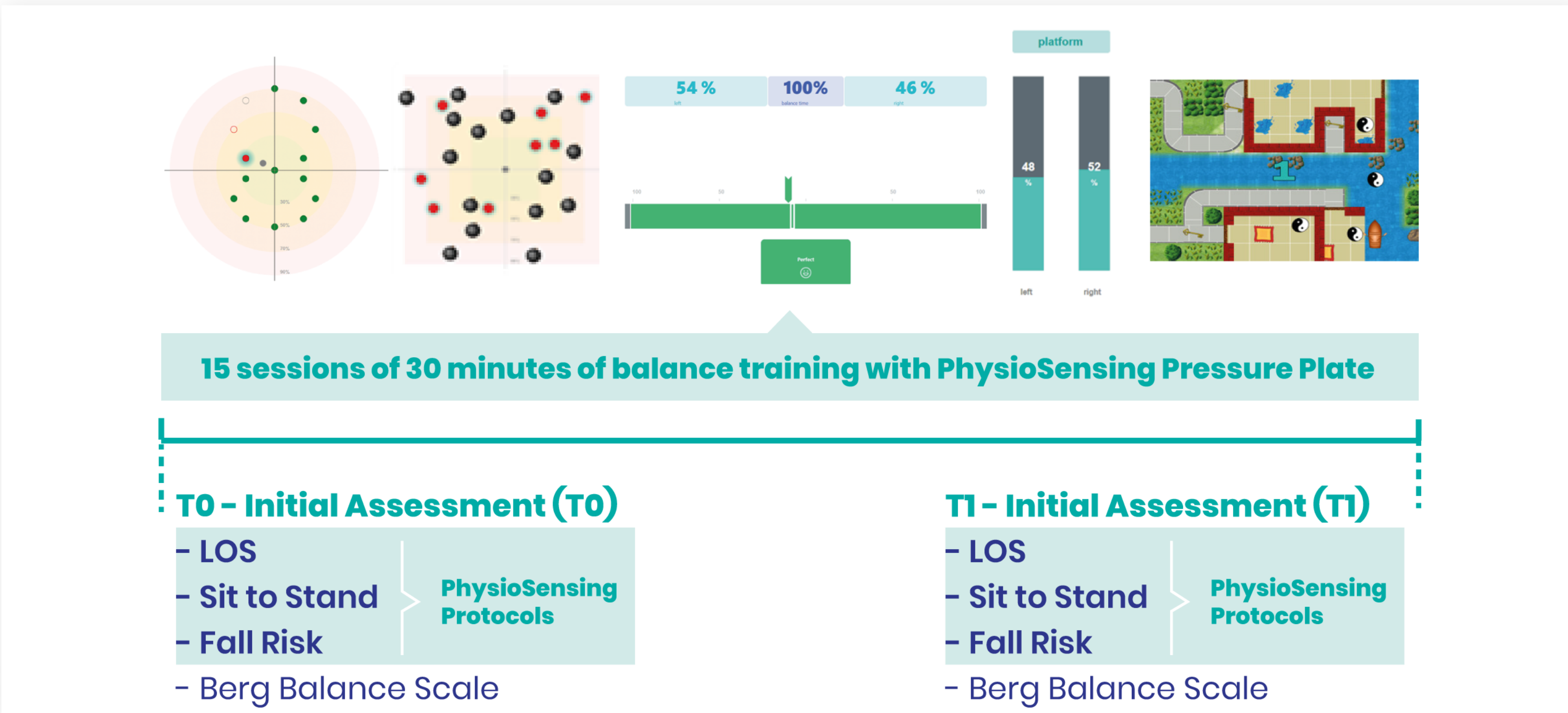
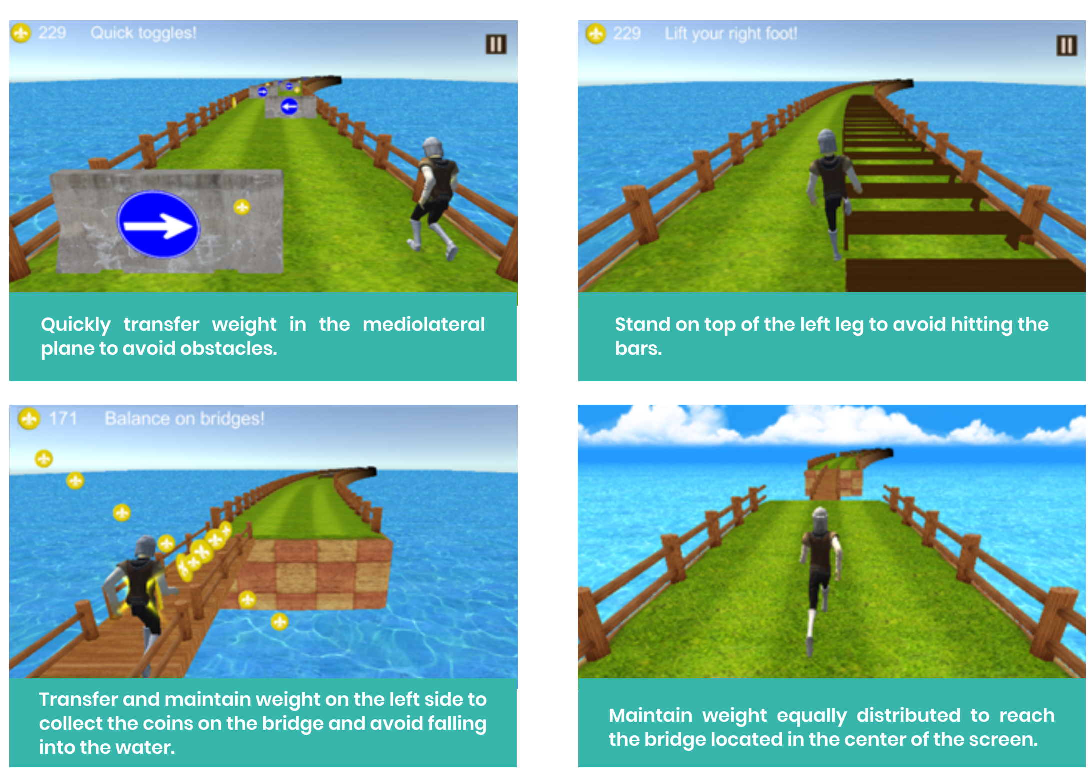


Figure 3 - Intervention

Participant performed 15 sessions of balance exercises on a balance plate in conjunction with real-time visual biofeedback, to improve static and dynamic balance and achieve a more symmetrical stance. The exercises chosen allowed the training of 1) Weight transfers in every direction, including diagonal weight shifts, as strong correlations have been discovered between the reduced ability to voluntarily displace the center of pressure in diagonal directions and measures of balance and gait speed [19], [20], [21], 2) Direction control and the correct activation of anticipatory movement strategies for each task [22], and 3) Symmetry of stance during sit to stand [8], [23]

Figure 4 - Participant playing Bart game



Results and Discussion

Clinical Scales Applied

Scale	Score in T0	Score in T1
Berg Balance Scale	37 points	45 points*
Katz Index of Independence in Activities of Daily Living	6 points	6 points
Brody Instrumental Activities of Daily Living Scale	4 points	4 points
Functional Ambulation Categories	4 points	4 points
Geriatric Depression Scale	6 points	4 points*

Table 1 - Results from Berg Balance Scale, Katz Index of Independence in Activities of Daily Living; Brody Instrumental Activities of Daily Living Scale; Functional Ambulation Categories; Geriatric Depression Scale. Scores obtained in T0 and T1

At the beginning of the intervention, the Katz Index of Independence in Activities of Daily Living Scale and the Brody Instrumental Activities of Daily Living Scale results indicated good function. The Functional Ambulation Categories also showed us that our participant could ambulate independently on level surfaces but required supervision to navigate obstacles (e.g. stairs, inclined surfaces, unstable surfaces). However, the Berg Balance score obtained at the beginning was 37 points, suggesting just an acceptable balance level. The Geriatric Depression Scale also suggested the presence of mild depression.

Interestingly, after 15 sessions of balance training, the scores from the Berg Balance Scale and the Geriatric Depression Scale improved. An improvement in the score from the Berg Balance Scale was expected since the exercises were chosen to target different dominions of Balance. The results obtained from the Geriatric Depression Scale are indeed curious and lead us to the topic of gamification in physical therapy. Joep Janssen et al. [24] stated that the attractiveness, motivation, and engagement associated with games are involved in reward-related dopaminergic systems in the brain that facilitate learning through long-term neural connections that trigger physical and cognitive patterns fundamental to neurological recovery.

Results from posturography analysis

Sit-to-Stand Protocol

We chose to use the Sit to Stand protocol for assessing dynamic stability, as it constitutes a fundamental ability from daily life that significantly correlates with autonomous living. The measurement of sit-to-stand with a balance plate enables an objective analysis of the entire movement: 1) The transfer of the center of pressure from the buttocks to the center of the feet, 2) the raising phase, and 3) the stabilization phase, where the person achieves a stable position to initiate a second task, such as walking [25], [26].
Available research shows that stroke patients frequently show asymmetrical limb loading during sit-to-stand, probably explained by muscle weakness and impaired postural control [23]. This was very clear on the first assessment (Figure 6 - Weight Variation Over Time, graphic A). Importantly, the asymmetrical weight bearing has been associated with increased fall risk [27], [28].

Having an objective view of how such an important movement was performed at the beginning of the intervention allowed us to identify specific problems and decide on the correct course for the intervention. During the intervention, we used exercises with visual biofeedback to stimulate a more symmetric stance during quiet stance and sit-to-stand (Figure 7).

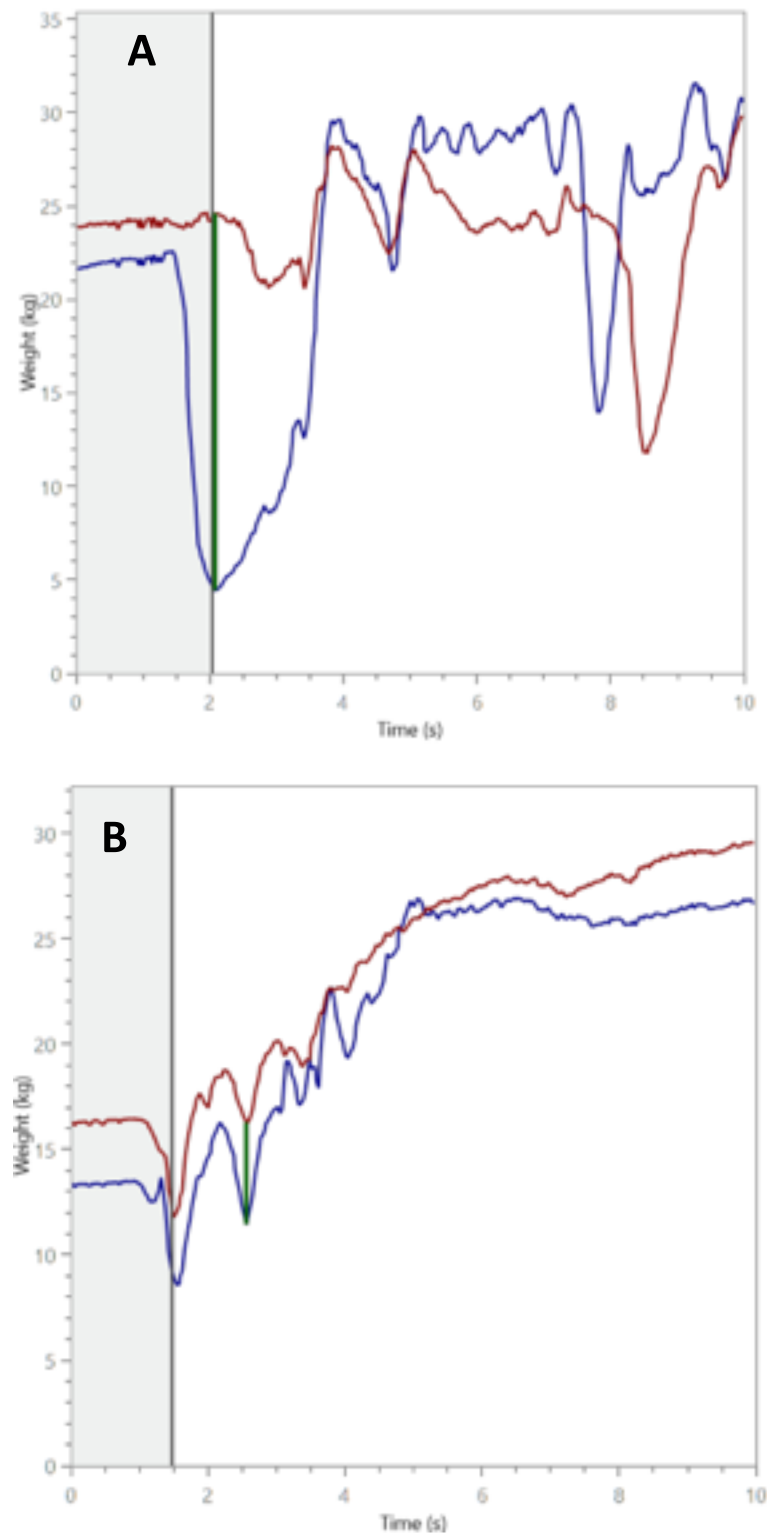


Figure 6 -Sit to Stand - Weight Variation Over Time. A: T0; B: T1. Left leg: Blue. Right Leg: Red. Maximum Differential: Green

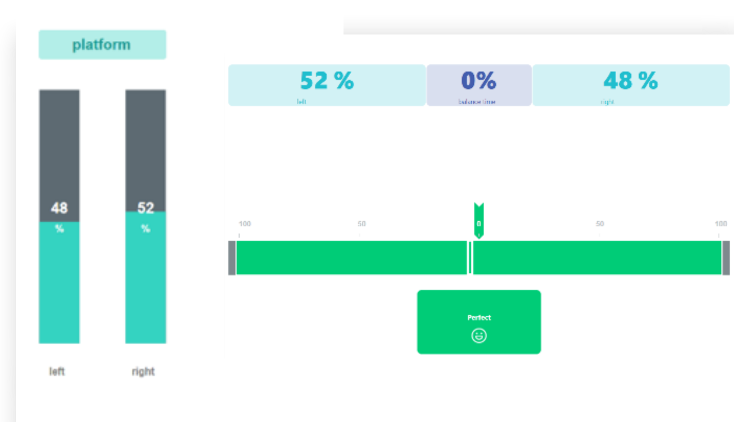


Figure 7 - Exercise for symmetric stance during quiet stance and while performing sit-to-stand.

Figure 8- Sit-to-Stand - Weight time transfer (s); Rising Index (% body weight); Mean COP sway velocity (º/s); Left/Right symmetry (%) in T0 (green) and in T1 (blue).

The results show clear improvements in weight distribution during the entire movement, as shown on the Weight Variation Over Time graphic (Figure 6), and on the Left/Right Symmetry where a 50% improvement can be seen (Figure 8 – Left/Right symmetry %). In addition, there is a marked 60% improvement on the Rising Index, meaning that the participant exerted 60% more force during the rising phase when compared with T0. Not in the same scale as the above-referenced improvements, the results seen in Weight Time Transfer (Fig 6 – Weight time transfer) inform us that the patient was able to transfer the weight from the sited position to the beginning of the rising phase (arrival of the center of pressure over the feet) 20% faster. Unexpectedly, the mean COP sway velocity increased by 20%. Although it is not possible to be certain of what has caused this, we believe that the explanation may be the calculation of the parameter itself, since the COP velocity is measured during the rising phase and the following 5 seconds (stabilization phase). We believe that the calculation of this parameter should be reconsidered to only measure sway velocity during the stabilization phase. However, we also can consider that as compensation for starting the rising phase earlier, exerting more force, and displacing more weight on the hemiparetic side, the participant struggled more in the stabilization phase.

Our results seem to follow the available research. In a single-center, single-blinded randomized controlled trial [8], the authors concluded that an audio-visual biofeedback rehabilitation program significantly improved weight-bearing distribution during quiet standing. In addition, a review of the mechanisms underlying balance recovery conducted by A.C.H. Geurts et al. showed that biofeedback training during sit-to-stand transfers seemed to be an efficient strategy for improving dynamic balance and weight symmetry in stroke patients, even during chronic phase [29].

Limits of Stability Protocol

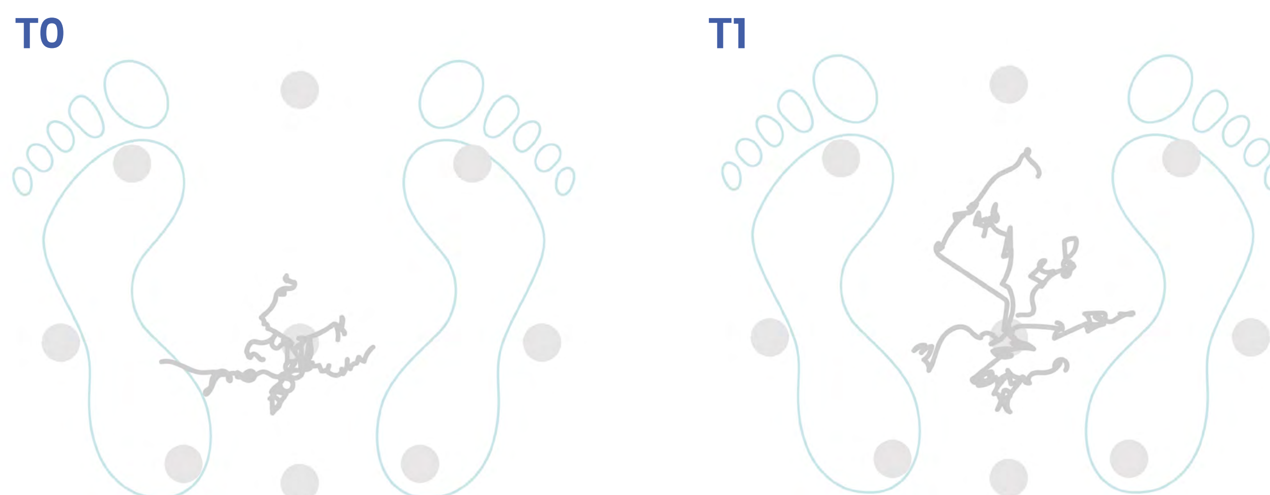


Figure 9 - Limits of Stability - COP displacement towards targets in T0 and T1

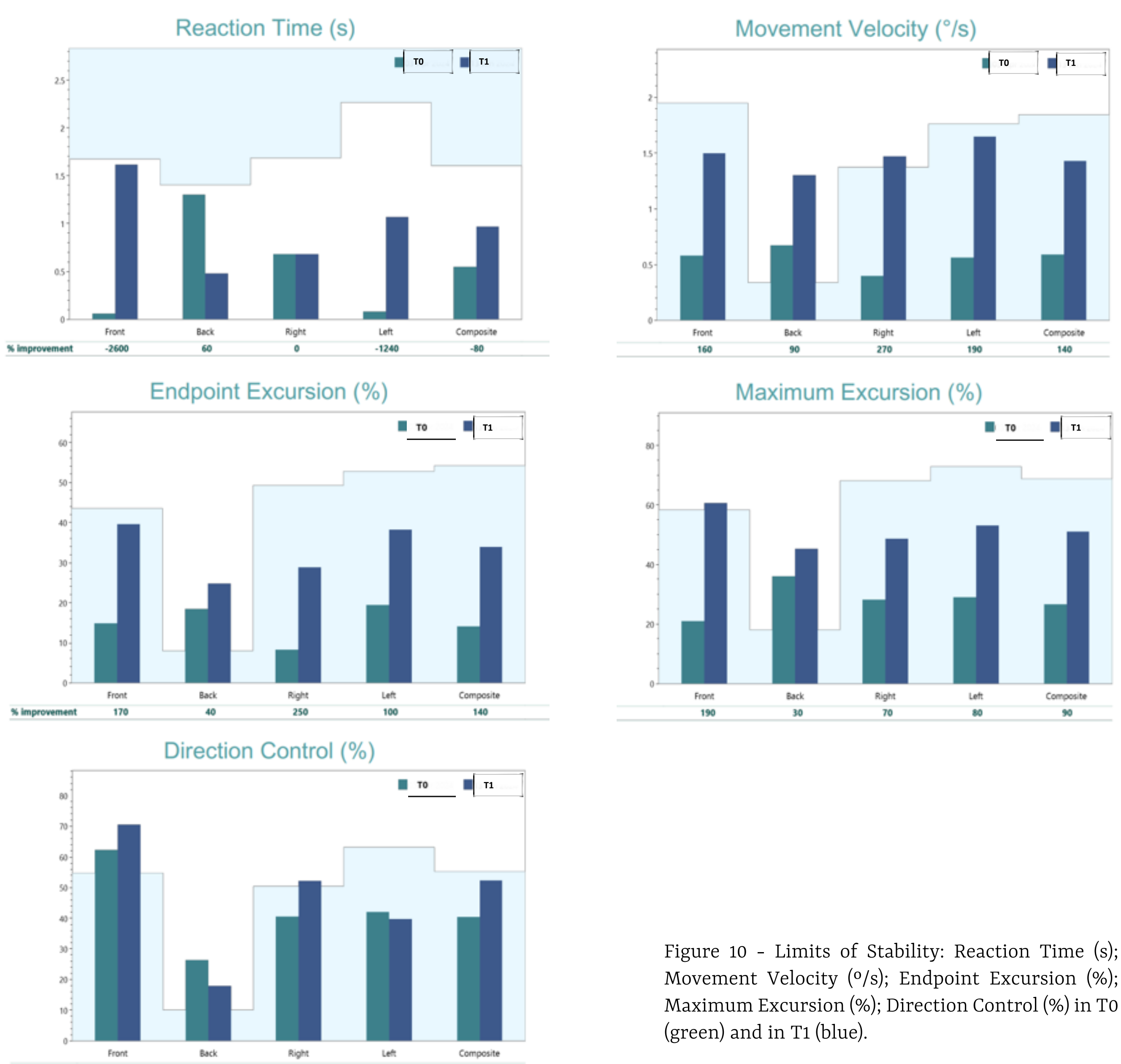


Figure 10 - Limits of Stability: Reaction Time (s); Movement Velocity (°/s); Endpoint Excursion (%); Maximum Excursion (%); Direction Control (%) in T0 (green) and in T1 (blue).

Parameter	T0	T1
Composite reaction time (s)	0.55	0.97
Composite movement velocity (°/s)	0.59	1.43
Composite endpoint excursion (%)	14.15	33.84
Composite maximum excursion (%)	26.64	51.1
Composite directional control time (%)	40.42	52.37

Table 2 - Limits of Stability resultant parameter in T0 and T1

Limits of Stability is a concept defined as the maximum distance a person can displace the center of pressure by leaning the body within the base of support without losing balance. Assessing the Limits of Stability allows for the evaluation of stability and voluntary motor control in a dynamic state, serving as an effective screening tool for fall risk, particularly among the elderly. Research indicates that a decreased ability to control the center of pressure displacement within the base of support boundaries can increase the risk of falling. This is especially true during daily activities that push the limits of stability, such as leaning to reach an object [30]. This assessment is particularly significant for stroke patients considering that postural dysfunction commonly present in these patients frequently involves motor weakness, asymmetrical muscular tone, sensory loss, perceptual deficits, and altered spatial cognition concerning the postural body scheme, which will be reflected in smaller limits of stability [22], [28].

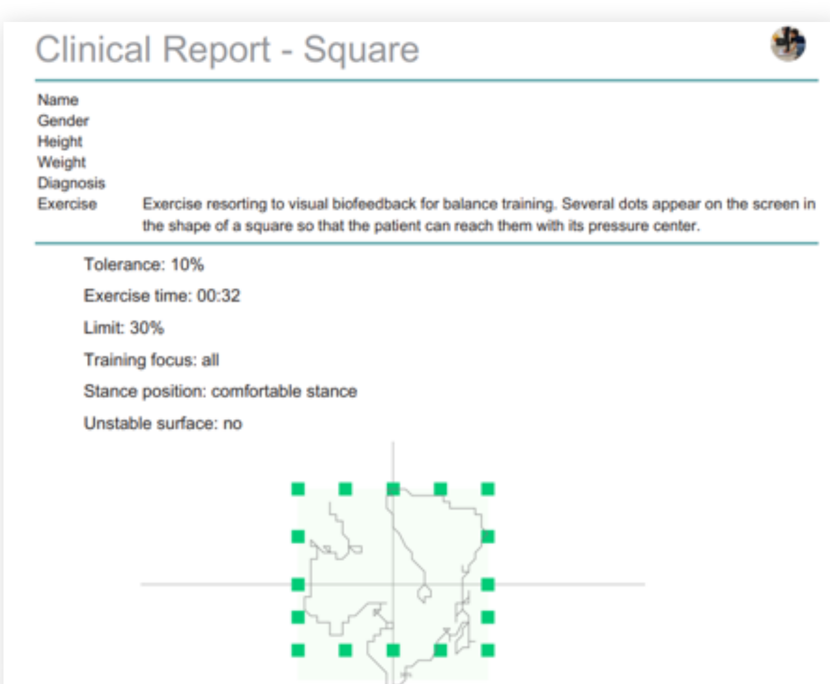


Figure 11 - Weight transfer exercise.

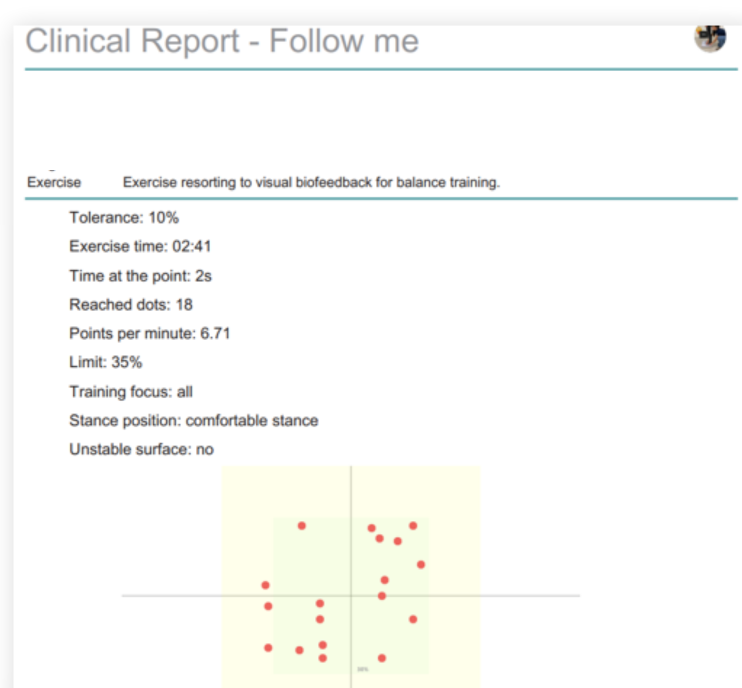


Figure 12 - Weight transfer exercise.

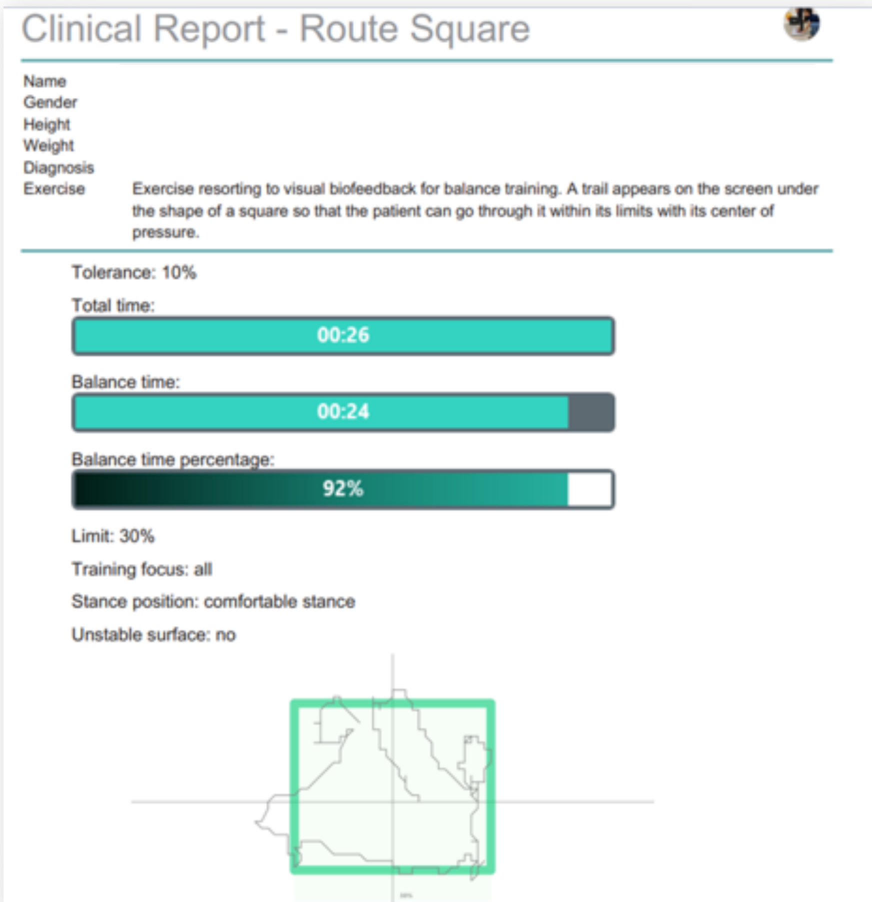


Figure 13 - Exercise for weight transfer and direction control.

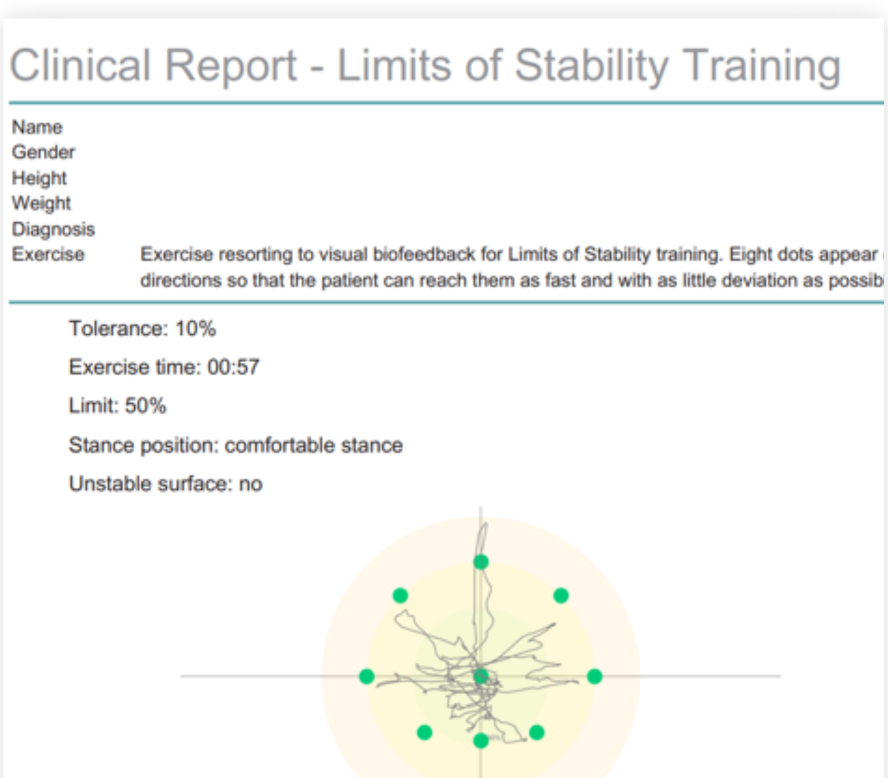


Figure 14 - Limits of Stability training exercise.

On the initial assessment, we found significantly reduced COP excursion, more pronounced towards the affected side (right side) and during the first try (endpoint excursion). Moreover, we observed reduced movement velocity towards each direction, except for the backward direction, and reduced directional control, specifically toward the right and left targets. These alterations are in accordance with the evidence available that suggests a decrease in lateral and diagonal-forward maximum weight shift towards the affected side in stroke patients [19]. Daily life activities involving reaching, transfer, turning, and even gait, encompass diagonal weight shifting [19], [20]. Considering all this, we decided to use exercises that worked on maximum weight displacements and direction control for every direction. The parameters of each exercise were adjusted to fit the participant's abilities. For viewing examples of exercise used during the intervention consult the Appendix (Figures 11, 12,13, and 14).

Re-assessment at the end of intervention (T1) shows a relevant increase in limits of stability, demonstrated by the increase of endpoint excursion and maximum excursion parameters, for all directions (Figure - 15). The magnitude of the results can be seen in the percentage of improvement from T0 to T1. We can assume that the exercises chosen had a very positive impact on the participants' limits of stability.

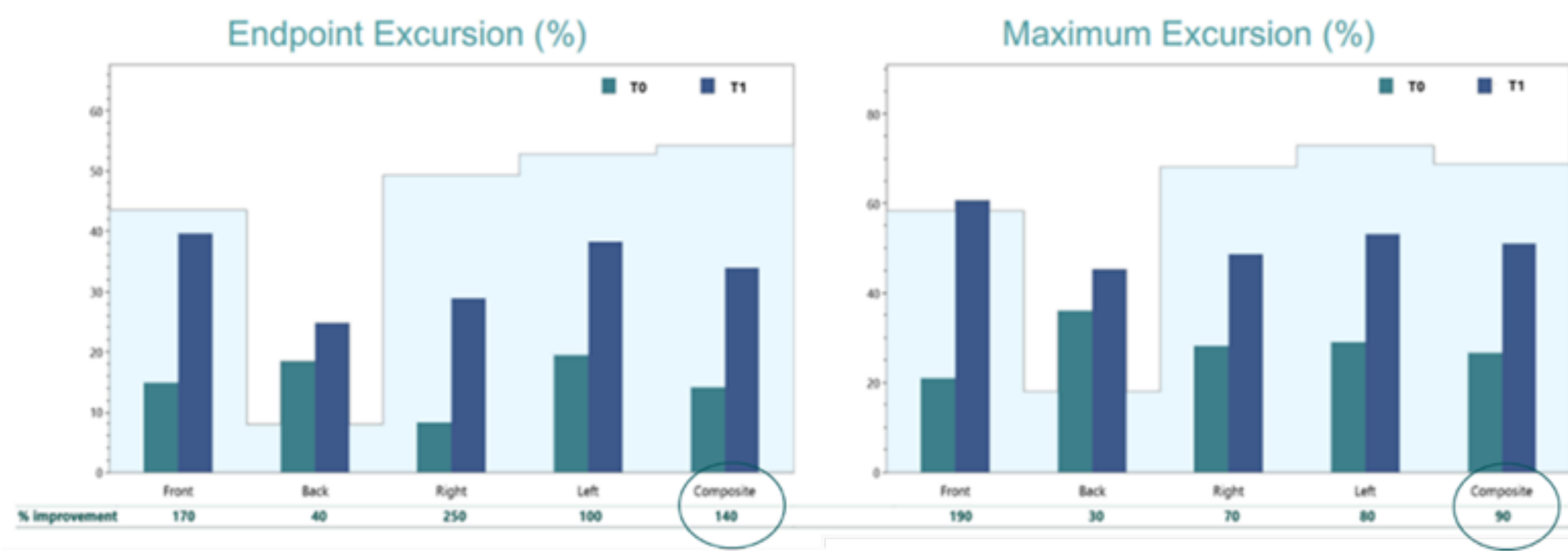


Figure 15 - Endpoint Excursion and Maximum Excursion Results

Moreover, the results also show a clear improvement in the movement velocity, accompanied by an improvement in direction control. This tells us that our intervention also impacted motor control. The participant was able to displace his center of pressure further away in all directions, significantly faster and without losing the quality of movement (Figure 16).

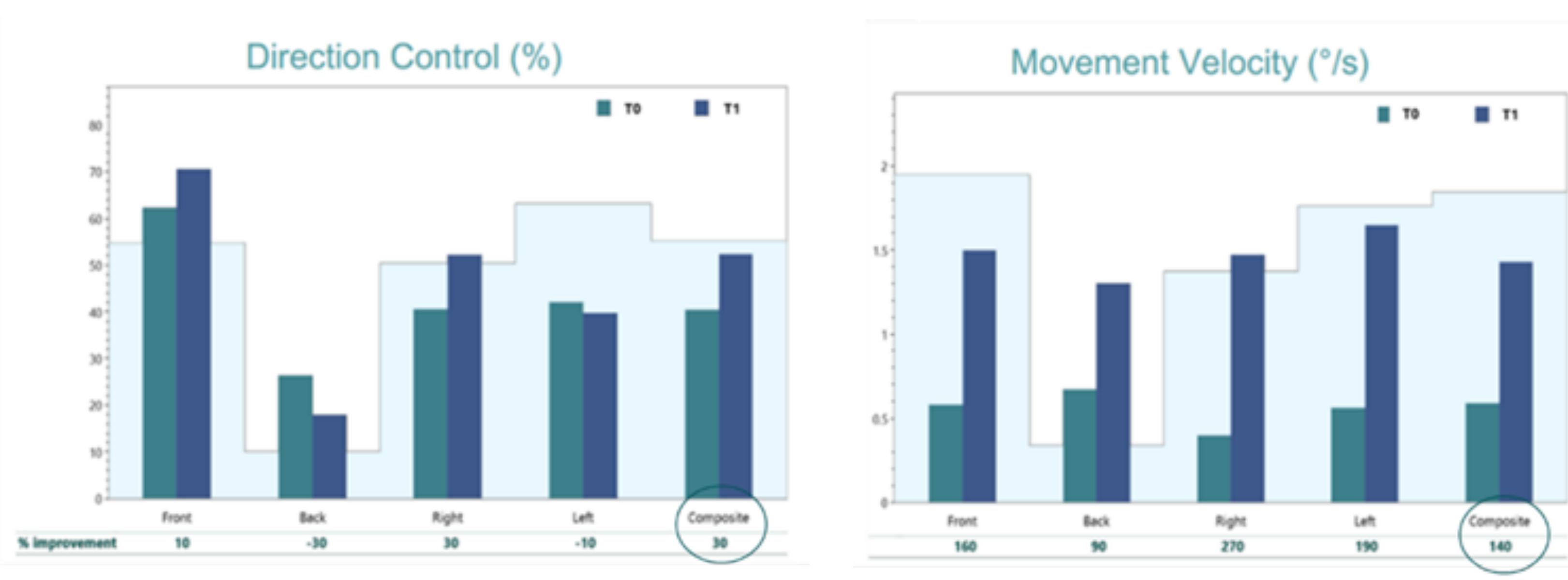


Figure 16 - Movement Velocity and Direction Control Results

Fall Risk Assessment Protocol

Parameter	T0	T1
Composite Sway velocity index	8.95	7.79

Table 3 - Fall Risk Assessment - Sway velocity index in T0 and T1

Static posturography is a useful tool for assessing balance, particularly in the most vulnerable elderly populations, since it allows for the objective measurement of balance control. Through COP measurement it is possible to quantify the small corrections that are performed to oppose the destabilizing effect of gravity, meaning that we can quantify and characterize postural stability. Higher levels of COP displacement and velocity suggest difficulties in postural control.

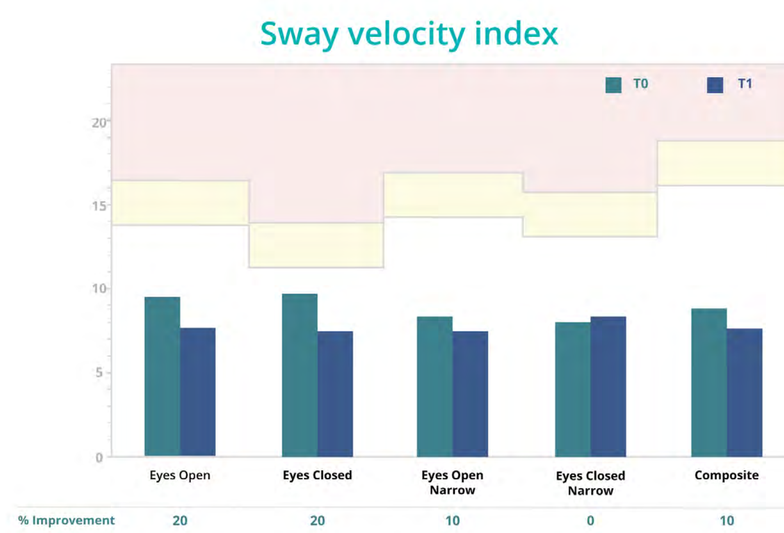


Figure 17 - Fall risk Assessment: Sway velocity index in T0 (green) and T1 (blue)

The study conducted by Kimberly Bigelow and Necip Berm [16] aimed to identify the test conditions and postural sway measures that most effectively distinguish recurrent fallers from non-recurrent fallers. The results indicated that the "eyes closed, comfortable" test condition, along with medial-lateral sway velocity, were the most reliable indicators for this differentiation.

The results from the Fall Risk Assessment show a 20% improvement in the "eyes closed, comfortable stance" condition. As already mentioned in the methodology, the sway velocity index is based on the mediolateral velocity divided by the height of the patient, and then normalized by the natural logarithm function. Compared with the results from the Sit-to-Stand Protocol and Limits of Stability, the improvement in this static assessment is more subtle, this was expected. We chose to add two dynamic balance assessments so we could have a more rigorous view of postural control, considering the complex interaction of all sensorimotor processes, and all the resources required.

Conclusion

Even though this is a case study and considering all the limitations attached, the study showed promising results. The use of the pressure plate alongside the exercises and games chosen did target fundamental aspects related to postural control, such as direction control, the ability to transfer weight to the affected side, limits of stability, and the achievement of a more symmetric stance during functional activities. Our intervention had a very positive effect on balance control, both static and dynamic. Moreover, we also saw an improvement in the cognitive and behavioral aspects, measured with the Geriatric Depression Scale.

The study allowed the testing of a physiotherapy intervention based on balance exercises, performed on a balance platform and using visual biofeedback, to improve the balance and postural control of a patient from a Family Health Unit with chronic stroke sequelae. We hope that this will be the beginning of more ambitious projects that allow the integration of technology and rehabilitation in the community.

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