Evaluation of the quality of life of patients with hereditary spastic paraplegia after intervention: a pilot study

Avaliação da qualidade de vida em pacientes com paraplegia espástica hereditária após intervenção: estudo piloto

Maria Izabel Rodrigues Severiano [1,2*]
Geslaine Janaina Bueno dos Santos [1,2]
Cristiano Miranda de Araujo [3]
Flávio Magno Gonçalves [3]
Bianca Simone Zeigelboim [3]
Hélio Afonso Ghizoni Teive [1]

[1] Universidade Federal do Paraná (UFPR), Curitiba, PR, Brazil
[2] Instituto Federal do Paraná (IFPR), Curitiba, PR, Brazil
[3] Universidade Tuiuti do Paraná (UTP),Curitiba, PR, Brazil

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***Correspondence:** maria.severiano@ufpr.br

Abstract

Introduction: Hereditary spastic paraplegia (HSP) encompasses a heterogeneous group of degenerative diseases that cause spastic paraparesis and progressive weakness in the lower limbs. **Objective:** To evaluate the quality of life (QoL) of patients with HSP using the World Health Organization Quality of Life Questionnaire (WHOQOL-bref) applied pre- and post-rehabilitation with virtual reality (VR). **Methods:** This is a pilot randomized controlled clinical trial, registered on the Rebec Platform, test RBR-3JMX67, involving 16 adult diagnosed with HPS, regardless of the type (pure or complicated), randomly allocated into two groups: balance group (BG) and strength group (SG). All were submitted to anamnesis, otorhinolaryngological and labyrinthine evaluation. Next, the WHOQOL-bref questionnaire was applied at three moments: T0 (before rehabilitation with VR), T1 (after 10 sessions) and T2 (after 20 sessions). **Results:** The application of the WHOQOL-bref questionnaire showed differences in the comparison of T0, T1 and T2 in SG for the physical, psychological, environmental, and general QoL domains ($p \leq 0.009$). When comparing T1 and T2, considering the VR game scores, both groups improved their performance ($p \leq 0.005$). **Conclusion:** There was an improvement in QoL, especially in SG, after VR with the Nintendo Wii®, suggesting that the integration of strength exercises + balance exercises can improve balance and QoL. VR is a low-cost tool that improves functional capacity and reduces the risk of falling, which is fundamental for the QoL of patients with HSP. The WHOOQL-Bref quantified the effects of the therapy. Performance in the games provided motivation and rapid feedback.

Keywords: Hereditary spastic paraplegia. Muscle spasticity. Quality of life. Rehabilitation. Virtual reality.

Resumo

Introdução: *A paraplegia espástica hereditária (PEH) abrange um grupo heterogêneo de doenças degenerativas que causam paraparesia espástica e fraqueza progressiva nos membros inferiores.* ***Objetivo:*** *Avaliar a qualidade de vida (QV) de pacientes com PEH por meio do Questionário de Qualidade de Vida da Organização Mundial da Saúde (WHOQOL-bref) aplicado pré e pós-reabilitação com realidade virtual (RV).* ***Métodos:*** *Trata-se de um ensaio clínico piloto randomizado controlado, registrado na Plataforma Rebec, teste RBR-3JMX67, envolvendo 16 adultos com diagnóstico de PEH, independentemente do tipo (pura ou complicada), alocados aleatoriamente em dois grupos: grupo equilíbrio (GE) e grupo força (GF). Todos foram submetidos à anamnese, avaliação otorrinolaringológica e labiríntica. A seguir, aplicou-se o questionário WHOQOL-bref em três momentos: T0 (antes da reabilitação com RV), T1 (após 10 sessões) e T2 (após 20 sessões).* ***Resultados:*** *A aplicação do questionário WHOQOL-bref mostrou diferenças na comparação de T0, T1 e T2 no GF para os domínios físico, psicológico, ambiental e QV geral (p ≤ 0,009). Ao comparar T1 e T2, considerando os escores do jogo RV, ambos os grupos melhoraram seu desempenho (p ≤ 0,005).* ***Conclusão:*** *Verificou-se melhoria na QV, especialmente no GF, após a RV com Nintendo Wii®, sugerindo que a integração de exercícios de força + exercícios de equilíbrio podem melhorar o equilíbrio e a QV. A RV é uma ferramenta de baixo custo que melhora a capacidade funcional e reduz o risco de queda, o que é fundamental para a QV dos pacientes com PEH. O WHOOQL-bref quantificou os efeitos da terapia. O desempenho nos jogos proporcionou motivação e feedback rápido.*

Palavras-chave: *Paraplegia espástica hereditária. Espasticidade muscular. Qualidade de vida. Reabilitação. Realidade virtual.*

Introduction

Hereditary spastic paraplegia (HSP) encompasses a heterogeneous group of degenerative diseases of hereditary nature, presenting disorders of a single gene, characterized by progressive and retrograde degeneration of the long axonal fibers of the corticospinal tracts of the spinal cord.[1-4] HSPs are a group of heterogeneous neurodegenerative diseases that cause spastic paraparesis and progressive weakness in the lower limbs.[5-8] Over 70 genetic subtypes described so far can be inherited in an autosomal dominant, autosomal recessive, X-linked, or mitochondrial manner.[4] HSPs are classified as pure or simple, complex or complicated. The pure form presents a family history, with a predominant clinical picture of progressive spastic paraparesis, with gait disturbance, often accompanied by urinary incontinence and sen-sory alteration in the lower limbs.[5-8] The complex form is associated with other signs such as cognitive im-pairment, ataxia, cerebellar signs, peripheral neuropa-thy, parkinsonism, epileptic seizures, deafness, optic atrophy, retinopathy, ichthyosis, among others.[2,4,9-11] The progression of this disease is usually slow; however, its evolution may differ for patients with the same genetic pattern. [11]

The pure forms of the disease are generally autosomal dominant (AD-HSPs), while the complex forms present other symptoms and are more common in autosomal recessive inheritance (AR-HSPs). The prevalence of HSP varies from 1.3 to 9.6 cases per 100,000 people, and it is estimated that it is as common as other known neurodegenerative diseases.[12] AD-HSPs are more frequent than AR-HSPs, with 80% of the cases in Europe and North America. Possibly due to the high number of consanguineous marriages in Brazil, recessively inherited HSP is as common as AD-HSP.[13,14]

Rehabilitation with virtual reality (VR) is a therapeutic resource for patients with neurological disorders to improve vestibule-visual interactions, stabilize their condition, and improve static and dynamic postural stability. The advantages of using VR games about traditional balance training stand out, as it physiologically acts on the vestibular system being considered a therapeutic resource due to their proposed action; based on the central mechanisms of neuroplasticity, the ability of the central nervous system (CNS) to modify some of its morphological and functional properties in response to environmental changes.[15-18]

VR platforms allow immersion in an illusory and artificial world that promotes perception of the environment and causes reflex changes related to the symptoms presented, and have been shown to be effective in individuals with neurodegenerative diseases.

Patients with neurodegenerative diseases have impaired gait that causes imbalance and falls, which hinders the performance of daily activities, especially those that require quick head movements, trunk flexion, and/or head, directly influencing the quality of life (QoL).[17]

The objective of the present study was to evaluate the QoL of HSP patients through the World Health Organization Questionnaire (WHOQOL-BREF) applied pre- and post-rehabilitation with VR.

Methods

This is a pilot randomized controlled clinical trial with adult patients with HSP from the Department of Neurology at the Hospital das Clínicas, in Curitiba, Paraná, Brazil. The research was approved by the Beneficent Evangelical Society ethics committee, under No. 3.580.973 (CAAE: 370.837.14.0.0000.0103). The protocol was registered and approved on the Rebec platform (RBR-3JMX67 trial), and was published by Zeigelboim et al.[18]

Patients were undergoing genetic investigation to determine the type of HSP. The diagnosis of HSP was established on the basis of personal and family medical history, along with neurological clinical examination findings. In addition, laboratory and imaging studies confirmed the presence of patterns compatible with the disease. A total of 16 male and female patients with HSP residing in the city of Curitiba and/or metropolitan region participated in the study. The selection was carried out consecutively from February to September 2022, ending on this date due to the period necessary to complete the rehabilitation. All patients and/or guardians authorized the procedures by signing the informed consent form.

The inclusion criteria were age ≥ 18 years (without restrictions imposed on the maximum age), diagnosis of HSP confirmed through clinical and/or laboratory tests, and individuals who can understand the explanations of the present study. The exclusion criteria were as follows: an otologic condition that can affect vestibular examination findings; dependency on a gait-assistance device; the inability to understand simple verbal commands; a significant musculoskeletal condition that could affect the assessment and VR outcomes; severe visual impairment or another abnormality that could impede the proposed intervention (Figure 1). The Consolidated Standards of Reporting Trials (CONSORT) checklist was used when writing the report.[19]

Before intervention, patients were randomly allocated to balance group (BG) or strength group (SG), each with eight patients. Randomization was performed by an independent researcher using a simple lottery system with sealed opaque envelopes immediately after the baseline assessment. The patients were considered participants in the study when the envelope was opened. The patients were randomized to receive the following distinct interventions: BG underwent rehabilitation with VR (balance games) using the Wii® console, Wii-Remote, or Wii Balance Board (Nintendo); and SG underwent rehabilitation with VR (balance games and muscle strength games) using the Wii® console, Wii-Remote, or Wii Balance Board (Nintendo). All patients initially underwent a medical history and otorhinolaryngological evaluation to exclude any middle ear impairment that could affect the vestibular examination assessing the presence of vestibular disorders.

Next, the WHOQOL-bref questionnaire was administered before and after VR rehabilitation in both groups at three different time points: before rehabilitation (T0), after 10 rehabilitation sessions (T1), and after 20 rehabilitation sessions (T2). The standardized WHOQOL-bref questionnaire (Portuguese version) was used to assess QoL, as described by Fleck et al.[20] This questionnaire evaluates four domains: physical, psychological, social relationships, and environmental, in addition to a self-assessment of QoL and the total score for a total of 24 questions. Descriptive statistics were used to analyze the scores, defining each domain of the questionnaire according to the criteria of Pedroso et al.,[21,22] as described: Domain I – Physical domain; Domain II - Psychological domain; Domain III - Social relations; Domain IV – Environment; Domain V - Self-assessment of QoL; Total score.

Rehabilitation with VR

The evolution of the disease impacts the ability to perform essential movements such as standing, sitting, and walking satisfactorily, which implies the need for efficient therapeutic approaches, which justifies this experimental study and the selection of VR games.

VR was performed using the Wii Fit Plus® system composed of the Wii® console, Nintendo brand, Wii-Remote, and Wii Balance Board (WBB). WBB is a platform whose biggest feature is the sensors that detect the gamer's position and where he is pointing on the screen. In other words, in some games, the player must perform the same movements as he would in a real game. The games were selected with strategies aiming at changes in balance and postural instability that involved saccadic and optokinetic stimuli; head and trunk move-

ment; static and dynamic balance; motor coordination; eye-foot coordination; circular pelvic movements; knee, ankle, and hip flexion-extension; and weight shifts (anteroposterior and lateral). Five balance games (Soccer heading, Table tilt, Tightrope walk, Penguin slide, and Perfect 10) were performed for the BG, while the same balance games described previously were performed for the SG, in addition to four muscle strength games (Single leg extension, Torso twist, Sideways leg lift, and Single leg twist).

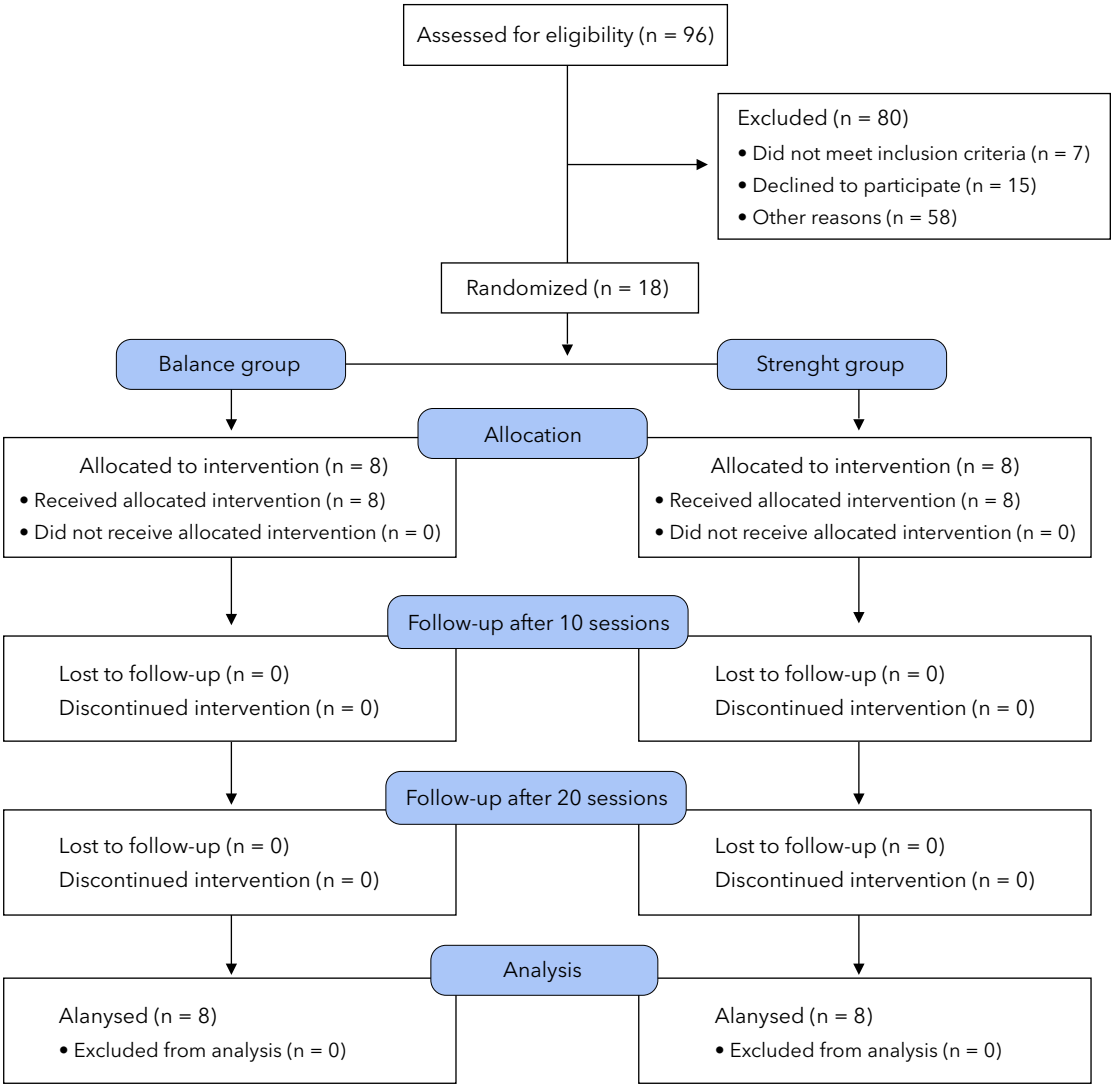

Figure 1 - Consolidated Standards of Reporting Trials (CONSORT) flow diagram (2010).

All patients underwent 20 sessions of VR rehabilitation lasting 50 minutes, twice a week, and completed the same assessment questionnaires at the time of the evaluation (T0), after 10 sessions (T1), and after 20 sessions (T2). All the sessions were held in the same place and were properly prepared to avoid possible falls. The Wii platform was installed on the floor, and a stretcher was placed in front of it for possible support. For safety reasons, the researcher remained close to the patient during all the sessions. After the beginning of the sessions, there were no dropouts.

For the studied sample, descriptive statistics (frequency, percentage, mean, and standard deviation) were calculated considering the analysis of sociodemographic

indicators and other characteristics. The assessment of data normality was conducted using the Shapiro-Wilk test, and variance homogeneity was verified through Levene's test. Comparisons between different time points (T0, T1, and T2) for each group were carried out using repeated-measures ANOVA. In cases where statistical significance was observed, the Holm post hoc test was employed for specific pairwise comparisons.

To analyze the difference between assessment times, two measurements were calculated, namely, the difference between the first and second timepoints (Δ1 = T0 – T1) and the difference between the first and third timepoints (Δ2 = T0 – T2), utilizing the Mann-Whitney U test. Additionally, comparisons between the BG and SG groups (Δ1 and Δ2) regarding games were performed using Student's t test. To ensure group similarity, comparisons between groups for the variables sex, age, and disease duration were conducted. The significance level was set at $p < 0.05$, with a 95% confidence interval. All the statistical analyses were conducted using JASP 2023 software (version 0.17.2).

Results

General demographic data, including patients' sex and age, and specific demographic data, including onset and duration of the disease and diagnosis of HSP, were collected, as shown in Table 1. There was a predominance of females (62.5%) in both groups of this sample. In the vestibular assessment, changes were observed in most patients. These changes influence the vestibular system, which is essential for maintaining balance and visual stability during head movements.

Table 1 - General characteristics of the sample

Characteristics	Balance group	Strenght group	p-value*
Sex (%)			
Male	37.5	37.5	1.00
Female	62.5	62.5	
Age (years)**	54 (17.0)	36 (28.5)	0.14
Time of illness (years)**	14 (9.0)	14 (9.5)	0.75
Vestibular evaluation (%)			
Normal	37.5	25.0	0.28
Bilateral deficient central vestibular dysfunction	50.0	25.0	
Bilateral deficiency peripheral vestibular dysfunction	0.0	37.5	
Left central irritant vestibular dysfunction	12.5	12.5	

The most frequently reported complaints during anamnesis by group were imbalance and fatigue (100% in both groups), muscle weakness, and a sensation of heaviness in the lower limbs (BG = 87.5%; SG =100%), directly impacting their gait and QoL. When comparing the two groups (BG and SG) at the different assessment times (T0 and T1) and (T0 and T2), considering the overall results of the WHOQOL-BREF questionnaire and each assessed domain, no significant differences were observed, as shown in Table 2.

Table 3 shows that T0, T1, and T2 had significantly different scores in the physical, psychological, and environmental domains, respectively, and overall, these findings indicate a greater level of QoL perception for patients who were part of the SG and who performed balance exercises and strength exercises. The differences were not confirmed between the groups only for social relationships and self-evaluations of QoL.

Regarding the results of the balance game intervention comparing T1 (after 10 sessions) and T2 (after 20 sessions) for the BG and SG, all the results were significant, indicating the effectiveness of rehabilitation with VR, as shown in Table 4. The positive results of the games demonstrate that this technology was able to overcome physical disabilities on many occasions, mainly due to the motivational factor; the patient perceives their difficulties and the motor gains, "plays", and due to the characteristics of the game itself, win the stages.

Table 2 - Comparison between the groups for differences between T1 and T0 (Δ1) and between T2 and T0 (Δ2) according to the WHOQOL-bref analysis and by domain

Domains	Balance group	Strength group	p-value*
Δ1	0.35 ± 1.70	1.44 ± 1.29	0.169
Δ2	2.08 ± 3.58	1.87 ± 1.48	0.879
Δ Domain I	1.50 ± 3.73	2.43 ± 2.28	0.557
Δ Domain II	1.50 ± 2.89	2.25 ± 1.95	0.553
Δ Domain III	3.00 ± 4.93	0.33 ± 3.17	0.219
Δ Domain IV	2.44 ± 4.31	1.88 ± 1.43	0.732
Δ Domain V	3.00 ± 4.00	1.00 ± 1.51	0.207

Note: WHOQOL-bref = World Health Organization Quality of Life Questionnaire; T0 = before rehabilitation with virtual reality; T1 = after 10 sessions; T2 = after 20 sessions; Domains: I = physical; II = psychological; III = social relations IV = environment V = self-assessment of quality of life. Data presented as mean ± standard deviation. *Student's t test ($p < 0.05$).

Discussion

The main complaints reported by patients were imbalance and fatigue for both groups (100%), followed by muscle weakness and a feeling of heaviness in the lower limbs (100% for the GF and 87.5% for the GE). This condition causes pain, decreases range of motion, and contractures that impair walking, one of the most disabling aspects of PEH.

The reported complaints directly relate to slow and progressive spastic paraparesis and altered muscle tone, predominantly in the lower limbs, which leads to progressive difficulties in motor control and gait.[4,12,23,24] This spasticity of skeletal muscles is one of the main health problems for these patients, as it leads to serious complications, limiting mobility and impacting their independence in activities of daily living (ADLs) and work, consequently affecting their QoL.[25,26]

The progression of the disease and symptoms, based on the speed and degree of functional disability increase, are variable, ranging from stability to increased disability. This variability is related to the interaction of multiple factors, such as neurodegeneration and neuroplasticity, which interfere with independence in ADLs, i.e., satisfactory performance in various movements such as getting up, bending, and walking.[27]

Individuals with spasticity need to have control over their posture. This control is directly related to the body balance necessary for the execution of these activities. Body balance, essential for maintaining posture, is related to a set of information provided by the visual, vestibular, and proprioceptive systems. Rehabilitation of balance disorders is essential to achieve safety and prevent instabilities, imbalances, falls, floating sensations, and dizziness, among others. Rehabilitation of body balance through VR is an action that promotes the individual's health with repercussions on the community.[27,28]

In the results found by WHOQOL-bref, for the physical, psychological, environmental, and general domains, there was a lot of significance for the SG, corroborating with studies on QoL and neurological diseases that demonstrated that the physical and mental aspects of QoL correlate significantly with the severity of the disease, especially with the ability to walk.[1,15,16] The motor and emotional aspects assessed by the WHOQOL-bref brought clinically significant outcomes in the HSP research.

Reduced mobility substantially negatively impacts an individual's QoL.[27] The proper management of spasticity depends on understanding its pathophysiological mechanisms, natural disease history, and its impact on patients, allowing for an appropriate approach to minimize complications such as pain and deformities and promoting improved functionality.[30,31]

Therapeutic interventions, including stretching, splinting, immobilization, neurectomy, intrathecal baclofen pump placement, botulinum toxin injections, and electrical muscle stimulation, have limited effects, and it is estimated that complications from muscle spasms cost millions of dollars, representing a significant medical challenge with a substantial economic impact.[32] Physical therapy facilitates functional recovery through techniques to adjust muscle tone, increasing range of motion, preventing contractures, and improving gait patterns.[33]

Bellofatto et al.,[34] in a systematic review of the management of patients with spasticity, found five studies that related spasticity and rehabilitation using conventional methods, hydrotherapy, electrical stimulation, and robotic gait training. However, the efficacy of rehabilitation in patients with spasticity documented in these studies does not provide clear indications and the most appropriate type of physical therapy for spasticity, lacking precise data on reported improvements. [34]

Table 3 - Comparisons between T0, T1, and T2 and each domain of the WHOQOL-BREF score separated by balance group and strength group

Domains	Groups	
	Balance	Strength
Domain I		
T0	12.71 ± 2.64[a]	12.93 ± 3.16[a]
T1	12.57 ± 2.77[a]	15.00 ± 2.15[b]
T2	14.21 ± 3.48[a]	15.36 ± 2.58[b]
p-value	0.225	0.008*
Domain II		
T0	15.33 ± 2.76[a]	12.50 ± 3.96[a]
T1	15.50 ± 2.33[a]	14.33 ± 2.55[a]
T2	16.83 ± 1.58[a]	14.75 ± 3.05[b]
p-value	0.186	0.009*
Domain III		
T0	13.00 ± 3.09[a]	14.17 ± 3.49[a]
T1	14.83 ± 3.38[a]	15.33 ± 2.47[a]
T2	16.00 ± 3.49[a]	14.50 ± 3.45[a]
p-value	0.115	0.541
Domain IV		
T0	13.56 ± 3.41[a]	13.81 ± 1.83[a]
T1	13.69 ± 2.65[a]	14.63 ± 1.77[a]
T2	16.00 ± 2.49[a]	15.69 ± 2.34[b]
p-value	0.091	0.015*
Domain V		
T0	13.00 ± 3.38[a]	14.00 ± 2.83[a]
T1	14.25 ± 2.92[a]	15.00 ± 2.14[a]
T2	16.00 ± 2.83[a]	15.00 ± 3.02[a]
p-value	0.064	0.279
General	**Both groups**	
T0	13.48 ± 2.55[a]	
T1	14.38 ±1.89[ab]	
T2	15.45 ± 2.29[b]	
p-value	0.003*	

Note: WHOQOL-bref = World Health Organization Quality of Life Questionnaire; T0 = before rehabilitation with virtual reality; T1 = after 10 sessions; T2 = after 20 sessions. Domains: I = physical; II = psychological; III = social relations IV = environment V = self-assessment of quality of life. Data presented as mean ± standard deviation. *ANOVA Repeated Measure test ($p < 0.05$). Different letters on the same line indicate statistically significant differences according to the post hoc test.

Table 4 - Comparison between T1 and T2 for virtual reality games, separated by the studied groups

Games	Groups	
	Balance	Strength
Table tilt		
T1	55.91 ± 23.51	52.75 ± 24.99
T2	71.69 ± 31.64	69.00 ± 21.72
p-value	0.002*	< 0.001*
Tightrope walk		
T1	28.59 ± 7.20	24.81 ± 7.81
T2	32.40 ± 4.45	29.15 ± 6.63
p-value	0.029*	0.016*
Penguin slide		
T1	51.81 ± 8.48	56.31 ± 14.27
T2	59.56 ± 15.06	63.03 ± 15.61
p-value	0.019*	0.029*
Perfect 10		
T1	13.40 ± 5.13	13.31 ± 4.18
T2	14.81 ± 4.28	15.53 ± 3.55
p-value	0.012*	0.001*
Soccer heading		
T1	57.56 ± 61.47	42.90 ± 24.42
T2	116.0 ± 132.3	89.18 ± 71.56
p-value	0.008**	0.034*
Single leg extension		
T1	-	92.18 ± 4.45
T2	-	95.75 ± 3.99
p-value	-	0.007*
Torso twist		
T1	-	73.40 ± 15.01
T2	-	78.46 ± 13.06
p-value	-	0.086
Sideways leg lift		
T1	-	90.15 ± 9.56
T2	-	95.50 ± 5.84
p-value	-	0.025*
Single leg twist		
T1	-	77.40 ± 15.71
T2	-	85.96 ± 15.07
p-value	-	0.025*

Note: T1 = after 10 sessions; T2 = after 20 sessions. Data presented as mean ± standard deviation. *Student's t test ($p < 0.05$). **Wilcoxon signed-rank test ($p < 0.05$). (-) group did not perform strength exercise.

In recent years, VR has been tested as a therapeutic tool in neurorehabilitation research for other neurodegenerative diseases, such as Parkinson's disease. Severiano et al.[15] found better results in final scores on the Dizziness Handicap Inventory, Berg Balance Scale, and Strength Test after rehabilitation. The SF-36 showed a significant change in functional capacity for the Tightrope Walk and Ski Slalom games ($p < 0.05$) and mental health for the Ski Slalom game ($p < 0.05$), resulting in evident clinical improvement in patients after virtual rehabilitation, especially in balance improvement, which had positive effects on patients' self-confidence, impacting their QoL.[15] In this study, the WHOOQL-bref results indicated VR rehabilitation as an excellent therapeutic alternative, especially for strength-focused exercises.[15]

The technology used has proven to be an important rehabilitation tool in neurological patients, overcoming the limitations of conventional interventions, mainly due to its motivational factor when patients perceive their motor gains in a playful way.[15,16] This corroborates the results from the excellent scores observed in all virtual games applied after rehabilitation, both for BG and SG.

Ali et al.[35] refers to VR as a safe and efficient tool in the rehabilitation of many diseases due to its potential to improve motor and functional skills through cortical reorganization and neuronal activation. In this review, the authors mention that VR therapies can improve anticipatory postural control and reaction mechanisms, consequently improving locomotor characteristics. This corroborates the present study, that demonstrated that improving balance and strength improved patients' perception in assessing their QoL and improving the execution of their daily tasks.

The benefits of rehabilitation through VR described in the literature include correction of balance and posture, improvement in locomotion, functionality of upper and lower limbs, as well as promoting greater motivation for patients to perform exercises, improving their motor coordination and relearning through modification of brain architecture, contributing to greater bodily independence.[36] What could be observed from the patients' reports, as demonstrated by the performance of game scores, was the stabilization of static and dynamic postural control and improvement in vestibule-visual interaction. The improvement in balance helped restore patients' confidence, reducing anxiety and improving social interaction. The significant results of VR rehabilitation and its low cost demonstrate that this therapy should be further studied and effectively implemented in other diseases.

Little is known about the psychosocial impact of the disease and health related QoL in patients with spasticity, which is why rehabilitation programs should focus on increasing the patient's independence in ADLs, primarily because individual perceptions of well-being are important factors in patients with chronic diseases and disabilities.[37] The positive impact of the rehabilitation program proposed in this study on the subjective health of patients and QoL, which is affected by disease progression, deserves recognition.

The use of VR as an intervention based on activities of daily living may be promising, but this approach is still hotly debated. VR has emerged as a potentially valuable tool in the field of motor and cognitive intervention, providing activities to stimulate neuroplasticity and improve regenerative processes. This brain capacity for change and adaptation in response to experiences and environmental stimuli is stimulated by VR, by the countless ways of playing and interacting with platforms and games.[38] Regarding QoL indicators, significant results were observed in patients with spasticity in the SG compared to the BG, indicating that it is important to emphasize exercise programs that prioritize muscle strength. Although there are challenges and limitations associated with VR, its use in this intervention can significantly improve the QoL of affected individuals.

This study has a limitation regarding its sample size, although the primary outcome had high statistical power. Additionally, the COVID-19 pandemic affected patient recruitment, with 17.70% of eligible patients not returning to the outpatient clinic. Another 39.58% resided in other cities and did not participate due to the need for attendance at 20 rehabilitation sessions, twice a week, and the requirement for assistance from others for transportation, making it challenging to achieve a larger sample size.

Conclusion

There was an improvement in the perception of QoL in patients with PEH, especially in the SG, after VR using the Nintendo Wii® video game. These results indicate that the use of the platform can be a low-cost tool for improving functional capacity, reducing the risk of falls, one of the main factors that impact the QoL of these patients. SG patients obtained better results in the QoL questionnaire in all domains applied after rehabilitation with VR, indicating that the incorporation of strength

exercises concomitantly with balance exercises through VR needs to be further studied as a mechanism to improve body balance and, consequently, the QoL.

The WHOOQL-bref questionnaire to assess QoL, as well as the positive results in game performance, effectively contributed to quantifying the effect of the applied therapy and its impact on the daily life activities of patients with PEH. Future clinical trials with patients with PHS are needed to evaluate the effects of long-term training, with a larger sample size, encouraging the evaluation of other physical, psychological and social variables in this population.

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Authors´contributions

MIRS, GJBS, BSZ and HAGT designed the study protocol; MIRS and GJBS executed the study. MIRS, GJBS and BSZ analyzed and interpreted the findings, while CMA e FMG were responsible for the statistical analysis. HAGT and BSZ performed a critical revision of the manuscript, and all authors approved the final version.

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