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(EN) Effectiveness of Home-Based Telerehabilitation Versus Standard Physiotherapy for Balance Disorders in Stroke and MS: A Pilot Study

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SUMMARY/ABSTRACT

Starting point: Balance impairments and reduced mobility are common consequences of neurological disorders such as stroke and multiple sclerosis. Effective rehabilitation strategies are essential to improve patients' functional outcomes and quality of life.
Group: A total of 33 participants were enrolled and divided into an experimental group (n = 18) and a control group (n = 15).
Methods: The experimental group underwent a structured 4-week balance training program via the Homebalance telerehabilitation platform. Both groups were assessed at baseline and follow-up using the Berg Balance Scale (BBS), EQ-5D utility score, Visual Analogue Scale (VAS), and the EQ-5D mobility domain. Paired and independent t-tests were used for statistical comparisons.
Results: Significant within-group improvements in BBS and VAS scores were observed in both groups ($p < 0.01$). The experimental group showed greater, although not statistically significant, improvement in EQ-5D mobility (–0.412 vs. –0.133; $p = 0.079$). Changes in utility scores were minimal.
Conclusions: The Homebalance telerehabilitation system demonstrated clinical effectiveness comparable to standard therapy in improving balance and subjective health status. These findings suggest that telerehabilitation may serve as a viable, scalable alternative to conventional therapy for patients with balance deficits.

KEYWORDS

Telerehabilitation, Homebalance, Balance Disorders, Stroke, Multiple Sclerosis, Stability.

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1 INTRODUCTION

Balance disorders are common consequences of central nervous system damage, often resulting from neurodegenerative, demyelinating, or oncological diseases, cerebrovascular accidents, or traumatic events. These conditions frequently have a chronic nature, necessitating long-term rehabilitation care. However, despite the well-documented benefits of regular rehabilitation sessions, numerous barriers hinder patient participation, including transportation challenges, rising fuel costs, and long waiting times for therapy. These factors may ultimately reduce adherence to rehabilitation or even prevent access to necessary therapeutic interventions [8].

In the era of digital healthcare transformation, telerehabilitation presents an innovative solution that overcomes the limitations of conventional rehabilitation approaches. By leveraging advanced technologies, patients with balance disorders can engage in therapeutic exercises from the comfort of their homes

while remaining under the supervision of healthcare professionals. Virtual therapy, sensor-based monitoring systems, and interactive rehabilitation platforms enable precise tracking of patient progress, real-time feedback from therapists, and individualized exercise protocols tailored to specific patient needs [1, 2, 3, 4].

The increasing adoption of eHealth and telemedicine is driving a paradigm shift in rehabilitation, enhancing accessibility and treatment efficacy. The future of rehabilitation lies in intelligent, remote healthcare solutions that seamlessly connect patients with therapists, providing high-quality care without the necessity of frequent visits to healthcare facilities [1,4].

This article focuses on telerehabilitation for balance disorders resulting from the following neurological conditions: cerebrovascular accident (CVA) and multiple sclerosis (MS).

Cerebrovascular accidents (CVA), commonly referred to as strokes, remain a leading cause of severe disability. As such, they represent a significant medical, social, and economic burden. The incidence of stroke in the Czech Republic is approximately 350 cases per 100,000 inhabitants per year, translating to roughly 35,000 affected individuals annually. Approximately two-thirds of these patients survive, with half of them suffering from severe disabilities as a consequence of stroke. These individuals often require long-term family or institutional care, with rehabilitation playing a central role in their management [8].

Ischemic stroke accounts for up to 80% of all strokes and occurs due to a critical reduction in cerebral perfusion in a specific brain region or the entire brain. Neuronal damage and clinical symptoms manifest when cerebral blood flow drops below 20 mL/100 g of brain tissue. The causes of cerebral ischemia may be either local or systemic [8].

Hemorrhagic stroke, resulting from intracerebral hemorrhage, constitutes approximately 20% of all strokes and is associated with higher mortality rates compared to ischemic stroke. It typically occurs due to the rupture of a cerebral artery wall, most commonly caused by hypertension. The hemorrhage can be either fragmented (diffuse) or localized (globular). Additionally, around 5% of all strokes are attributed to subarachnoid hemorrhage [8].

Balance disorders as a consequence of cerebrovascular accidents (CVA) are recognized as a major clinical concern, primarily due to their high prevalence among neurological patients, including stroke survivors. These impairments lead to a range of negative consequences, such as reduced functional independence, impaired mobility, and an increased risk of falls. These limitations significantly affect activities of daily living and hinder full social reintegration, thereby reducing overall quality of life [8].

Similar to cerebrovascular accidents (CVA), the clinical presentation of multiple sclerosis (MS) depends on the localization of central nervous system (CNS) lesions. However, the early symptoms of MS commonly include retrobulbar neuritis and various types of sensory disturbances. As the disease progresses, patients frequently experience motor dysfunction, including central spastic paresis and cerebellar symptoms, often in combination with vestibular dysfunction, which can contribute to balance impairments. Additional manifestations include sphincter dysfunction and excessive fatigue, the latter affecting 80–90% of MS patients [8].

The severity of MS-related disability is assessed using the Kurtzke Expanded Disability Status Scale (EDSS), which ranges from 0 (normal neurological status) to 10 (death due to MS complications). This scale provides an estimate of disease severity and helps determine the level of care required for each patient [8].

In MS, balance disorders primarily result from cerebellar involvement, central sensory pathway lesions, dysfunction of the eighth cranial nerve, central motor pathway damage, or a combination of these factors. Other contributing causes include impaired vestibular response, leading to abnormal motor reactions to changes in head position or body weight distribution. Additionally, proprioceptive deficits, muscle weakness, and impaired muscle coordination further exacerbate balance instability [7, 12].

As a consequence of sensory and vestibular deficits, hip and ankle strategies for postural control may be compromised, causing patients to rely more heavily on their upper limbs for balance. Spatial orientation may also be impaired, and in rare cases, visual dependence occurs—where patients excessively rely on visual input, despite its unreliability for maintaining balance.

These stability impairments manifest as fear of falling and difficulty adapting to rapid positional changes, significantly restricting mobility and reducing overall quality of life for individuals with MS.

A common therapeutic approach to enhancing balance includes individually tailored balance training programs, vestibular rehabilitation programs, resistance and aerobic training, gait training, and interactive

video games. Research has demonstrated that individualized therapy programs targeting both motor and sensory functions under the supervision of a physiotherapist are more effective in improving performance and reducing fall incidence compared to therapies focusing solely on motor functions [8].

Among modern technologies used for balance training, systems such as Nintendo Wii and Xbox Kinect have gained popularity. These platforms rely on shifts in the center of gravity for control, effectively training postural stability through visual feedback mechanisms. These technologies are well-suited for home-based rehabilitation, where—after proper training by a therapist—they have been shown to yield comparable results to conventional therapy [12].

An additional advantage of these interactive systems is their engaging and gamified nature, which enhances patient motivation for regular exercise. Consistent home-based training increases the overall volume of physical activity, helping to maintain or extend the therapeutic effects achieved through structured physiotherapy sessions.

For many years, biofeedback therapy has been used in the rehabilitation of balance disorders, integrating both motor and sensory functions. It is hypothesized that biofeedback facilitates multisensory stimulation, including visual, vestibular, and proprioceptive inputs, thereby accelerating the compensatory process through the reorganization of neural circuits involved in balance control [8,13].

Currently, various biofeedback-based systems are utilized in clinical practice. One widely implemented approach is visual biofeedback, which employs interactive video games. These can be used either under the supervision of a therapist or in a home-based setting. The Homebalance medical device is an example of such a system, offering customizable training parameters tailored to the patient's individual rehabilitation needs. Stabilometric platforms exist in various forms, ranging from flat plates, mats, carpets, and belts to in-shoe inserts. The pressure applied to these platforms is converted into electrical signals, and most systems are capable of measuring the patient's total body weight. Several other visual biofeedback technologies are suitable for home-based rehabilitation, providing interactive balance training and postural control enhancement. These include: BoBo Pro Plus, Riablo Home, Equio, Doctor Kinetic, Tymo [5, 16, 17, 18, 20].

2 GROUP AND METHODS

Study Settings

This pilot study was conducted in the Czech Republic. Therapy sessions took place between January 2022 and April 2023. Baseline and final measurements were conducted in person in an outpatient setting at a healthcare facility.

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of General University Hospital in Prague under reference number 1597/19 S-IV.

Study design

The study is designed as a quantitative comparative analysis with prospective data collection, in which the clinical effectiveness of the new technology in the form of the Homebalance telerehabilitation set is compared to standard outpatient physiotherapy for balance disorders in patients after a stroke (CVA) and with multiple sclerosis (MS).

The technology used is a Class I medical device (hereafter referred to as MD) Homebalance and the associated telemedicine software. Patients who meet the inclusion criteria for the study are randomly assigned to two groups. The experimental group undergoes a four-week intervention in the home environment using the Homebalance MD with regular supervision by a therapist twice a week. The control group performs conventional therapy for balance and walking disorders without technical devices for four weeks.

Participants

Participants included in the study are adults with acquired brain damage and a subjective feeling of balance disorder who meet the indication criteria listed below. Participants were recruited for the ongoing study at the Department of Rehabilitation Medicine, 1st Faculty of Medicine, Charles University, General Teaching Hospital in Prague. All participants signed an informed consent form for the examination and subsequent therapy.

Indication criteria:

1. stability disorder diagnosed by the standardized Berg Balance Scale test,
2. minimum age of 18 years,
3. ability to stand independently without support,
4. ability to understand all instructions.

Exclusion criteria:

1. significant spasticity in the lower limbs,
2. severe cognitive deficit (inability to understand the task, perform exercises),
3. Montreal Cognitive Assessment score of 20 points or less,
4. Barthel Index score of 40 points or less,
5. significant stability disorder (inability to stand without support),
6. inability to stand upright independently,
7. severe sensory disorder preventing use of the Homebalance MD system,
8. severe visual impairment preventing viewing of therapeutic scenes on the tablet,
9. decompensated epilepsy,
10. severe psychological disorder (e.g. severe organic psychosyndrome),
11. non-cooperation of the patient or, possibly, his/her family members.

Outcome measures

Clinical effects are evaluated based on the BBS score, while quality of life is assessed using the EQ-5D-5L questionnaire.

Berg Balance Scale

The primary clinical marker monitored is the Berg Balance Scale (BBS). Originally developed to assess stability in older patients, BBS is now commonly used to evaluate balance and fall risk in patients post-stroke. It is used to objectively determine a patient's ability or inability to safely maintain balance during 14 specific tasks. These tasks are designed to assess the patient's ability to maintain balance in both static positions and dynamic movements. Each task is scored on a scale from 0 to 4, where 0 represents the lowest level of function (inability to perform the task) and 4 represents the highest level of function (flawless performance of the task independently). The BBS results are divided into three categories: 0–20 points indicate a high fall risk, 21–40 points indicate a moderate fall risk, and 41–56 points indicate a low fall risk.

EQ-5D-5L questionnaire

This is a tool for describing and assessing health. The EQ-5D-5L is the five-level version of the EQ-5D-3L questionnaire. By expanding the evaluation of each dimension from three to five levels, the sensitivity of the tool was increased, and the ceiling effect was reduced.
The questionnaire consists of two parts: the descriptive system EQ-5D and the visual analog scale EQ VAS.

The descriptive system includes five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension can be rated on one of five levels: no problems, slight problems, moderate problems, severe problems, and extreme problems. The patient selects one level for each dimension that best describes their current condition. The selected level is then converted to a numerical value from 1 to 5, where no problems represent 1 and extreme problems represent 5. The individual dimension values are then used to form a five-digit code that describes the patient's health status. Based on this five-digit code and using value sets, the final utility value is determined. These value sets are created for different countries. In the Czech Republic, based on the recommendation of SÚKL (State Institute for Drug Control), value sets for the United Kingdom are used for evaluation.

The EQ VAS endpoints represent, on one side, the best health state imaginable (100) and, on the other side, the worst health state imaginable (0). The patient subjectively marks their current health status on the visual analog scale. VAS can be used as a quantitative measure of health status, reflecting the patient's own judgment.

Intervention protocol

Experimental Group: Followed a specific exercise plan using the Homebalance, including exercises such as foot sole facilitation with a massage ball, semiflexion of knee joints, and balance games (Balance Desk, Balance Pong, Balance Rings, and Balance Route). Sessions lasted 20–25 minutes, 2–4 times per week for 4 weeks. Patient adherence was monitored automatically through the Homebalance software, which

recorded exercise frequency, duration, and completion rates. These data allowed therapists to verify compliance and adjust training intensity when necessary.

Control Group: Participants engaged in classical kinesiotherapy exercises at an outpatient rehabilitation facility, twice a week for 4 weeks, focusing on stability improvement.

Homebalance platform

The Homebalance MD consists of a patient unit comprising a stabilometric platform and a tablet with a program featuring new therapeutic games. The presented modules

are implemented as functionalities of the control software, enabling the execution of an exercise

plan. The telemedicine extension allows for remote configuration of the therapeutic exercise plan, remote recording of therapy progress and outcomes, a web-based environment for managing remote therapy, and evaluating health improvements.

The therapy principle is based on telemetry transmission, therapy with audiovisual feedback,

and monitoring of the patient's physical activity. The system also integrates specialized tools

for tracking the number of exercises performed, elements for assessing the quality of

rehabilitation, and monitoring adherence to the therapeutic plan. This module monitors physical activity parameters, specifically focusing on stability. Advanced functionalities support fall prevention and prevent subsequent complications. The BalanceDesk module displays the patient's current center of gravity as a ball and, by transferring the weight, aims to get the ball to the target point and stay there for two seconds. Another module, BalanceRings, concentrates on balance and memory training. In this module, patients engage in a game where they must memorize the order of the displayed rings and guide the ball to the marked location in the correct sequence. The BalanceRoute module features a game where patients attempt to navigate a marked route with a ball in the fastest time possible. The last module, Balance Pong, trains stability and reactions. Patients control the board by deflecting their lateral center of gravity, with the task of keeping the ball in play for as long as possible without missing it.

Conventional therapy

The exercise unit for the group of participants with conventional kinesiotherapy includes 18 exercises aimed at increasing stability, which are performed in several positions. In the first phase, when exercising lying on the back, the participant focuses on dorsal and plantar flexion in the ankle joints, circular movements in the ankle joints, flexion and extension of the lower limbs and abduction and adduction in the hip joints. This is followed by sitting exercises, where the facilitation of the sole of the foot using a massage ball is performed, exercises for the little foot, flexion and extension in the knee joints and increasing flexion in the hip joints. In the last phase, exercises in standing, the participant performs walking in place, weight transfer to the toes, heels, left and right lower limbs, standing on one leg, flexion and extension in the hip and knee joints, abduction in the hip joint and squatting. Exercises 7-16 are then performed on a balance pad, increasing the difficulty and effectiveness of the stability training. Each exercise is performed 10 times.

Data analysis

The obtained clinical data were subjected to subsequent statistical processing. First, classical descriptive methods were used, including graphical representations, and the estimation of the mean, standard deviation, median, interquartile range, minimum, and maximum. Subsequently, parametric tests, two-sample t-test and paired t-test were applied, which were used to test hypotheses.

To assess the clinical effectiveness of both therapies, the following hypotheses were formulated:

- The null hypothesis (H_0) states that there is no statistically significant difference between the initial and final examination.
- The alternative hypothesis 1 (H_1) assumes that there is a statistically significant difference between the initial and final examination.
- The alternative hypothesis 2 (H_2) assumes that the final examination score achieved was statistically higher compared to the initial examination.

To compare the effectiveness of the two different therapeutic approaches, another set of hypotheses was formulated. The comparison was based on the score gain between the initial and final examination in each group:

- The null hypothesis (H_0) states that there is no statistically significant difference in improvement between the two groups.
- The alternative hypothesis 1 (H_1) assumes that there is a statistically significant difference in improvement between the two groups.
- The alternative hypothesis 2 (H_2) assumes that the Homebalance group achieved a statistically greater improvement compared to the standard therapy group.

Statistical processing of data was performed using the RStudio program.

3 STARTING POINT, OBJECTIVE, TASKS

Patients with neurological diseases frequently suffer from balance disorders, which increase the risk of falls and reduce independence in daily life. Standard physiotherapy is effective but limited by accessibility, costs, and the need for in-person attendance. With the increasing availability of telemedicine and digital health solutions, telerehabilitation has emerged as a promising approach to overcome these barriers.

The main objective of this pilot analysis was to assess the clinical effectiveness of the Homebalance medical device in telerehabilitation for patients with balance disorders caused by selected neurological diseases, compared to standard physiotherapy. Data were collected as part of a pilot randomized controlled trial evaluating the effect of telerehabilitation using audiovisual feedback, wearable sensors, and accompanying electronic services.

The specific tasks of this pilot study were: (i) to compare the clinical outcomes of telerehabilitation using the Homebalance device with those of standard physiotherapy, (ii) to assess patient adherence and feasibility of remote supervision, and (iii) to explore the added value of audiovisual feedback and wearable sensors in improving balance performance.

4 RESULTS

Participants

A total of 33 patients participated in the study. Their basic characteristics are described in Table 3.1. In terms of gender distribution, women predominated in the cohort, with 21 (64%) of the 33 participants being female. The average age of the cohort was 52 years (SD = 15), and the median age with the lower quartile at 43 years and the upper quartile at 65 years. Within the studied sample, patients who had suffered a stroke (CVA) outnumbered those with multiple sclerosis (MS), with 28 (85%) patients post-stroke. The experimental group included 18 participants. Table 3.1 presents the baseline characteristics of the cohort.

Table 3.1: Basic Characteristics of the Cohort

Characteristic	N = 33
Sex, n (%)	
Male	12 (36%)
Female	21 (64%)
Age	
Median (IQR)	52 (43, 65)
Mean (SD)	52 (15)
Diagnosis[1], n (%)	
Stroke (CVA)	28 (85%)
Multiple Sclerosis	5 (15%)
Group, n (%)	

Characteristic	N = 33
Experimental group	18 (55%)
Control group	15 (45%)

IQR = Interquartile Range, SD = Standard Deviation
[1] Primary diagnosis for inclusion in the study

Table 3.2 describes the basic characteristics within each group. In the experimental group, 14 women were included out of a total of 18 participants. In the control group, there were 7 women out of 15 participants. Based on the Chi-square test and Fisher's exact test, no statistically significant difference in gender distribution was found between the two groups (p = 0.064). The average age in the experimental group was 50 years (SD = 16), with a median of 51 years, whereas in the control group, the average age was 54 years (SD = 14) and the median was 52 years. Based on the Wilcoxon rank sum test, it can be stated that there is no statistically significant difference in age between the groups (p = 0.5). The diagnosis of stroke (CVA) was more common in both groups. In the experimental group, it occurred 15 times, and in the control group, 13 times. No statistically significant difference was found here either (p > 0.9) in the distribution of diagnoses between the groups. These results indicate that the two groups were homogeneous in terms of gender, age, and diagnosis distribution, allowing for a fair comparison of outcomes.

Table 3.2: Basic Characteristics by Group

Characteristic	Experimental Group N = 18	Control Group N = 15	p-value
Sex, n (%)			0.064[1]
Male	4 (22%)	8 (53%)	
Female	14 (78%)	7 (47%)	
Age			0.52[2]
Median (IQR)	51 (41, 64)	52 (44, 66)	
Mean (SD)	50 (16)	54 (14)	
Diagnosis[3], n (%)			>0.91[1]
Stroke (CVA)	15 (83%)	13 (87%)	
Multiple Sclerosis	3 (17%)	2 (13%)	

IQR = Interquartile Range; SD = Standard Deviation
[1] Pearson's Chi-squared test or Fisher's exact test
[2] Wilcoxon rank sum test
[3] Primary diagnosis for inclusion in the study

Results of monitored parameters BBS a EQ-5D

Table 3.3 presents the average results of the baseline and follow-up assessments of the monitored parameters with their standard deviations. The table also includes p-values determined using the paired t-test, which was used to assess the effectiveness of the therapy. The primary clinical marker monitored was the standardized BBS. The average score measured during the baseline assessment was 47 for the experimental group and 48 for the control group. The average score during the follow-up assessment was 50 for both groups. Additionally, the participants filled out the generic EQ-5D-5L questionnaire. The average utility at the baseline assessment for the experimental group was 0.68, and it increased to 0.70 at follow-up. The average utility for the control group was 0.66 at baseline and 0.67 at follow-up. The EQ-5D-5L questionnaire also assessed the results of the visual analog scale (VAS). The average result of the baseline assessment for both groups was the same, at 67. The experimental group reached a score of 76 at the follow-up assessment, while the control group reached a score of 71. Furthermore, individual dimensions of

the EQ-5D-5L questionnaire were subjected to statistical evaluation. The table shows the results for only the mobility dimension, where statistically significant results were recorded.

A statistically significant result in the mobility dimension was recorded only for the experimental group (p = 0.004). No statistically significant improvement in overall utility was demonstrated in either group.

Table 3.3: Results of Monitored Parameters

Variable	Mean at Baseline (SD)	Mean at Follow-up (SD)	p-value[1]
Group I – BBS	47 (11)	50 (9.9)	<0.001
Group II – BBS	48 (4.7)	50 (3.5)	0.003
Group I – Utility[2]	0.68 (0.15)	0.70 (0.13)	0.720
Group II – Utility[2]	0.66 (0.13)	0.67 (0.13)	0.669
Group I – VAS	67 (16)	75 (15)	0.009
Group II – VAS	67 (17)	71 (16)	0.005
Group I – Mobility	2.6 (1.0)	2.2 (0.75)	0.004
Group II – Mobility	2.8 (0.68)	2.7 (0.62)	0.164

SD = Standard Deviation
[1] *Paired t-test*
[2] *EQ-5D utility*

Figure 3.1 presents the baseline and follow-up results of the Berg Balance Scale (BBS) assessments in both study groups. Statistical comparison was conducted using a paired t-test, with corresponding p-values displayed in the figure. Data are visualized using box plots, where the lower and upper bounds of the box represent the first and third quartiles, respectively, and the internal line denotes the median. Mean values are indicated by red crosses.

The distribution of the data is further illustrated using violin plots, providing additional insight into the density of measurements. In the experimental group, several outliers are visible as individual data points, corresponding to participants with substantially impaired balance compared to the cohort average. Despite this, even these participants exhibited observable improvement over time, as indicated by the graphical trends.

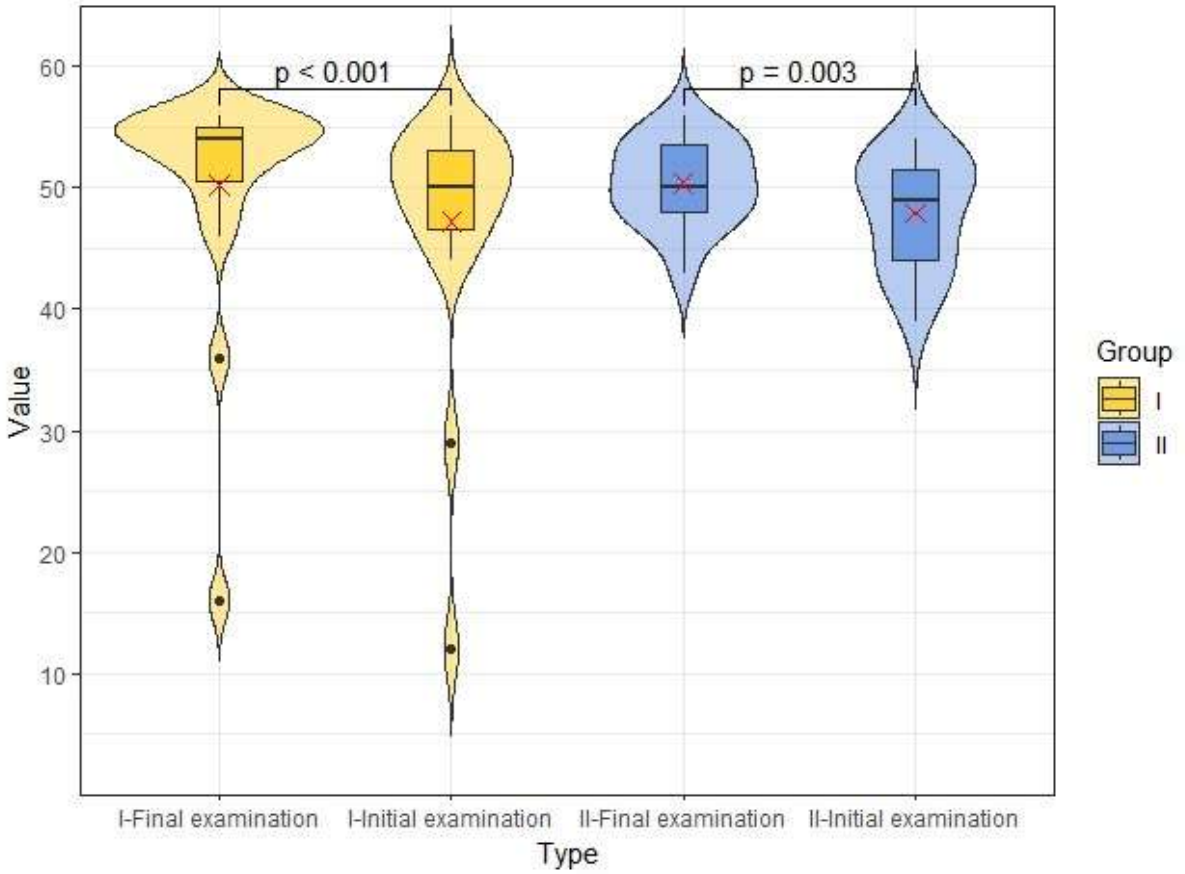

Figure 3.1: Baseline and Follow-up Results of the Berg Balance Scale (BBS) Assessment
Note: p-value determined using a paired t-test

Figure 3.2 displays the baseline and follow-up results of the Visual Analogue Scale (VAS) assessments in both groups, with p-values derived from paired t-tests. As in the previous figure, results are presented using box plots, supplemented by distribution density plots and red crosses indicating mean values.

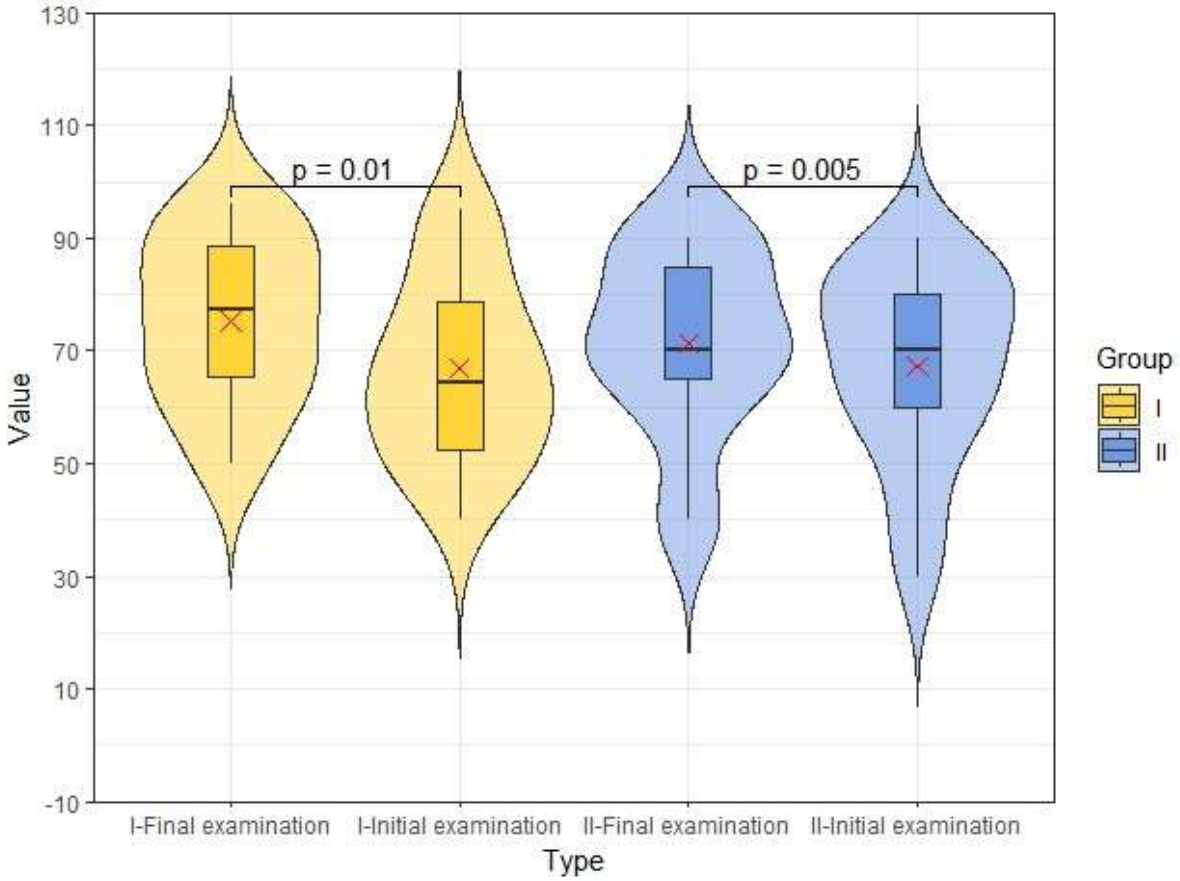

Figure 3.2: Baseline and Follow-up Results of the Visual Analogue Scale (VAS) Assessment
Note: p-values were determined using a paired t-test

Table 3.4 presents the average effect gains after completion of therapy in both groups. The table also includes p-values obtained using a two-sample t-test, which was used to compare the gains between the two groups for each observed parameter. For none of the observed parameters was a statistically significant difference between the effect gains of the groups demonstrated (based on the significance level of $p < 0.05$).

Table 3.4: Gains in Monitored Outcomes

Variable	Mean Change (SD) – Experimental Group	Mean Change (SD) – Control Group	p-value[1]
BBS	3.0 (1.97)	2.5 (2.61)	0.517
Utility	0.011 (0.13)	0.025 (0.02)	0.789
VAS	8.5 (12.5)	4.0 (4.71)	0.178
EQ-5D Mobility	–0.412 (0.51)	–0.133 (0.35)	0.079

SD = Standard Deviation
[1] p-values based on comparison between groups (e.g., independent t-test or equivalent method)

Therapy with the Homebalance system was found to be clinically effective. However, when comparing the effectiveness of the Homebalance intervention and standard therapy, no statistically significant difference in score gains was observed—supporting the null hypothesis that both therapies were similarly effective. A notable exception was observed in the mobility dimension of the EQ-5D-5L, where the Homebalance group showed a statistically significant improvement.

5 DISCUSSION

Karasu, Hung, Bracala, Kelly J. Bower, Shin, and Brunelli [17, 19, 21, 24, 26, 28] in their studies focused exclusively on the clinical effectiveness of medical devices operating on a similar principle as the Homebalance system. As in this thesis, the target group consisted of patients post-stroke (CVA) or with multiple sclerosis (MS), and the effect of the experimental therapy was compared with standard rehabilitation methods. All these studies demonstrated statistically significant improvements.

An inspiring example is the study by Brunelli et al. (2020) [28], in which a statistically significant difference between the effects of experimental intervention and standard rehabilitation was observed, favoring the experimental intervention. Another such example is the study by Karasu et al. (2016) [26], which also investigated the maintenance of therapy effects 4 weeks after its completion. In this case, statistically significant improvements were observed in both groups, but the experimental intervention showed a more significant increase and stability of the effect. Hung (2019) [19], also focused on studying the retention of therapy effects. Participants in the study were tested three months after the intervention ended, and it was shown that the effect of therapy fades over time in both cases, although more slowly in the case of standard therapy.

From the aforementioned studies, it is evident that long-term therapy is suitable for patients with these diagnoses, leading to the maintenance of their current health status. However, in everyday practice, rehabilitation is often irregularly administered, and its effect is often insufficient. Another issue in standard rehabilitation is the lack of therapist supervision when the patient is relying on practicing prescribed exercises at home. The use of telerehabilitation in combination with traditional rehabilitation could be an appropriate solution to this problem. In this mode, patients would have the opportunity for daily exercise and be motivated by regular feedback from the therapist. Additionally, telerehabilitation should be complemented by regular in-person therapy, during which home therapy could be monitored and evaluated. This approach could also lead to greater efficiency, with more patients served and reduced costs for in-person therapy.

Another reason for the implementation of telerehabilitation into routine practice is the well-known fact that healthcare in this area, as in many other specializations, faces longer waiting times and problems with accessibility. In many cases, the waiting time can be several weeks to months, leading to a deterioration of the existing health condition and the emergence of associated complications, such as: prolonged overall treatment process, reduced therapy effectiveness in chronically ill patients, or diminished effect of surgical interventions. This problem is caused by several factors, including a shortage of specialists in the field of physiotherapy, underfunding in this area, and a mismatch between supply and demand. As a result, many patients remain without adequate treatment, which can negatively impact their health, productivity, and overall quality of life. Telerehabilitation is one possible solution to improve the availability of rehabilitation care.

The Homebalance MD system was specifically developed to provide remote rehabilitation for patients with balance disorders. It is suitable for a wide range of diagnoses, from geriatric patients, where it serves the purpose of fall prevention, to patients with acquired brain injuries, helping them improve both static and dynamic balance. Homebalance may be an appropriate solution to fill the therapeutic gap, understood as the period when a patient is discharged from inpatient care but has not yet begun outpatient care. It is also used to maintain the effect of outpatient or inpatient therapy, or to extend it. Throughout the therapy, regular evaluations are conducted by a therapist, who monitors its progress through a cloud storage system where data from the device is sent. The clinical effectiveness of Homebalance has been extensively tested in studies under clinical and laboratory conditions for a wide range of diagnoses in both outpatient care and home settings. The system was also tested as part of a clinical study by Dr. Novotná, who tested it in a home setting for patients with multiple sclerosis. This study demonstrated the effectiveness of the telerehabilitation intervention. The study also monitored the retention of the therapy's effect. It was shown that the therapy effect slightly diminished 4 weeks after its completion. Dr. Novotná's study had a very similar design to this thesis, with the key difference being that the comparator was the absence of any therapy. The results from the experimental group were statistically compared with the results from this study, and no statistically significant difference was found between them.

The Homebalance system offers numerous advantages, including the creation of personalized therapeutic plans tailored to the individual needs of the participant. Another benefit is its ability to motivate users to achieve better results, as they can see whether they have improved compared to the previous therapy session.

Limitations

One of the limitations of this study was the collection of clinical data, which took place from January 2022 to April 2023. The interest in participating in this study was lower than expected, and as a result, the study involved 33 patients, with 18 patients in the experimental group and 15 in the control group. To achieve a higher level of statistical significance for the study's outcomes, it would have been necessary to: increase the total number of participants to at least 50 and create matching research and control groups with an equal number of participants. The study was designed as a pilot trial to test feasibility and clinical effectiveness within a mixed neurological cohort. The inclusion criteria allowed both post-stroke and MS patients to participate. However, due to the recruitment process, the number of MS participants was very limited. Consequently, the groups had borderline sample sizes, which restricts the statistical power and the possibility to draw diagnosis-specific conclusions. Future studies should increase the total sample size and focus on a single diagnostic category.

This pilot study serves as an essential step in understanding the potential of the Homebalance system, helping to refine methodologies and providing insights for the design of a larger, full-scale study in the future.

6 CONCLUSIONS

The aim of this pilot study was to evaluate the clinical effectiveness of telerehabilitation using the Homebalance MD system compared to standard therapy in patients with balance disorders after acquired brain injury. The clinical effectiveness analysis shows that telerehabilitation using the Homebalance platform is clinically effective, and its effectiveness is comparable to the effects of standard therapy.

Overall, integrating telerehabilitation into healthcare represents a promising approach to improving physical health in patients with balance disorders. This pilot study shows that a 4-week intervention using the Homebalance platform, which includes stability-focused exercises, demonstrates initial efficacy. However, further research with larger sample sizes and extended intervention durations is needed to fully evaluate long-term benefits and optimize therapeutic strategies. These additional studies will help validate the findings and refine telerehabilitation protocols for broader clinical use.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the pilot study.

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REFERENCES

[1] JANATOVÁ, M., M. Šollová, and O. Švestková. Telerehabilitace u pacienta s poruchou rovnováhy po cévní mozkové příhodě. Rehabilitation & Physical Medicine/Rehabilitace a Fyzikalni Lekarstvi

[online]. 2018, 28–33 [vid. 2022-06- 01]. Dostupné z: https://www.artak.cz/wp-content/uploads/2019/08/ Telerehabilitace/RehabFyzLek.pdf

[2] BRIENZA, David M. a Michael MCCUE. Introduction to Telerehabilitation.

In: [online]. 2013, s. 1–11. Dostupné z: doi:10.1007/978-1-4471-4198-3_1

[3] HAMOUZOVÁ D., Srbová J., Navrátil v. Využití telerehabilitace jako doplněk k běžné rehabilitační péči. Praktický lékař. 2018, 266–269.

[4] PĚTIOKÝ J., HOIDEKROVÁ K. a GRÜNEROVÁ LIPPERTOVÁ M.

Digitisation and telehealth - Telemedicine in rehabilitation in the Czech environment. Vnitřní lékařství [online]. 2022, 68(3), 166–171. ISSN 0042773X.

Dostupné z: doi:10.36290/vnl.2022.033

[5] MANUÁL HB. Homebalance Stability návod. 15. červen 2021

[6] BOHATÝ P. Poruchy rovnováhy. https://fyzioterapie.utvs.cvut.cz /document/show/id/77/ [online]. 2016 [vid. 2022-06-17]. Dostupné z: https: //fyzioterapie.utvs.cvut.cz/document/show/id/77/

[7] ŘASOVÁ K. Hodnocení klinických projevů u roztroušené sklerózy. Rehabilitation & Physical Medicine / Rehabilitace a Fyzikalni Lekarstvi. 2017, 50–54.

[8] KOLÁŘ P. Rehabilitace v klinické praxi. Praha: Galén, 2009. ISBN 978-80-7262- 657-1.

[9] SVATOŠ K. Trénink posturální stability u pacientů po cévní mozkové příhodě. Kladno, 2017. CTU.

[10] BULÁNOVÁ K. Vyšetření a terapie stability u pacientů po cévní mozkové příhodě. Prague, 2014. Charles University.

[11] BULÁNOVÁ K. Vyšetření a terapie stability u pacientů po cévní mozkové příhodě. Prague, 2014. Charles University of Prague.

[12] M. KÖVÁRI, K. NOVOTNÁ, M. HAVLÍČKOVÁ, L. ROUBÍČKOVÁ, R.

KONVALINKOVÁ, L. KADRNOŽKOVÁ a L. SUCHÁ. Léčba roztroušené sklerózy z pohledu rehabilitace. 2018, 25(1), 3–10.

[13] NOVOTNA K., JANATOVA M., HANA K., SVESTKOVA O., PREININGEROVA LIZROVA J. a KUBALA HAVRDOVA E. Biofeedback

Based Home Balance Training can Improve Balance but Not Gait in People with Multiple Sclerosis. Multiple Sclerosis International [online]. 2019, 2019, 1–9.

ISSN 2090-2654. Dostupné z: doi:10.1155/2019/2854130

[14] KUTÍLEK, P. a A. ŽIŽKA. Vybrané kapitoly z experimentální biomechaniky. Prague: Czech Technical University, 2012. ISBN 978-80-01-04993-8.

[15] NETOPIL O. Frekvenční analýza stabilometrických signálů. Brno, 2016. Brno University of Technology.

[16] KOŘÍNKOVÁ M. Pilotní studie využití stabilometrické plošiny Nintendo Wii v rehabilitaci. Prague, 2009. Charles University.

[17] BARCALA, Luciana, Luanda ANDRÉ COLLANGE GRECCO, Fernanda COLELLA, Paulo ROBERTO GARCIA LUCARELI, Shiguemi INOUE SALGADO a Santos OLIVEIRA. Visual Biofeedback Balance Training Using Wii Fit after Stroke: A Randomized Controlled Trial. 2013.

[18] PROSPERINI, Luca, Deborah FORTUNA, Costanza GIANNÌ, Laura LEONARDI, Maria Rita MARCHETTI a Carlo POZZILLI. Home-based balance training using the wii balance board: A randomized, crossover pilot study in multiple sclerosis. Neurorehabilitation and Neural Repair [online]. 2013, 27(6), 516–525. ISSN 15459683. Dostupné z: doi:10.1177/1545968313478484

[19] HUNG, Jen Wen, Chiung Xia CHOU, Yen Wei HSIEH, Wen Chi WU, Min Yuan YU, Po Chih CHEN, Hsueh Fen CHANG a Shan Er DING. Randomized comparison trial of balance training by using exergaming and conventional weight- shift therapy in patients with chronic stroke. Archives of Physical Medicine and Rehabilitation [online]. 2014, 95(9), 1629–1637. ISSN 1532821X. Dostupné z: doi:10.1016/j.apmr.2014.04.029

[20] BOWER, Kelly J., Ross A. CLARK, Jennifer L. MCGINLEY, Clarissa L. MARTIN a Kimberly J. MILLER. Clinical feasibility of the Nintendo WiiTM for balance training post-stroke: A phase II randomized controlled trial in an inpatient setting. Clinical Rehabilitation [online]. 2014, 28(9), 912–923. ISSN 14770873.

Dostupné z: doi:10.1177/0269215514527597

[21] BOWER, Kelly J., Julie LOUIE, Yoseph LANDESROCHA, Paul SEEDY,
Alexandra GORELIK a Julie BERNHARDT. Clinical feasibility of interactive motion-controlled games for stroke rehabilitation. Journal of NeuroEngineering and Rehabilitation [online]. 2015, 12(1), 63. ISSN 1743-0003. Dostupné z: doi:10.1186/s12984-015-0057-x

[22] PAU, Massimiliano, Giancarlo COGHE, Federica CORONA, Bruno LEBAN, Maria Giovanna MARROSU a Eleonora COCCO. Effectiveness and Limitations of Unsupervised Home-Based Balance Rehabilitation with Nintendo Wii in People with Multiple Sclerosis. BioMed Research International [online]. 2015, 2015, 1–8. ISSN 2314-6133. Dostupné z: doi:10.1155/2015/916478

[23] LLORÉNS, Roberto, Enrique NOÉ, Carolina COLOMER a Mariano ALCAÑIZ. Effectiveness, usability, and cost-benefit of a virtual reality-based telerehabilitation program for balance recovery after stroke: A randomized controlled trial. Archives of Physical Medicine and Rehabilitation [online]. 2015, 96(3), 418-425.e2. ISSN 1532821X. Dostupné z: doi:10.1016/j.apmr.2014.10.019

[24] SHIN, Doo Chul a Chang Ho SONG. Smartphone-Based Visual Feedback Trunk Control Training Using a Gyroscope and Mirroring Technology for Stroke Patients. American Journal of Physical Medicine & Rehabilitation [online]. 2016, 95(5), 319–329. ISSN 0894-9115. Dostupné z: doi:10.1097/PHM.0000000000000447

[25] THOMAS, Sarah, Louise FAZAKARLEY, Peter W. THOMAS, Sarah COLLYER, Sarah BRENTON, Steve PERRING, Rebecca SCOTT, Fern THOMAS, Charlotte THOMAS, Kelly JONES, Jo HICKSON a Charles HILLIER. Mii-vitaliSe: A pilot randomised controlled trial of a home gaming system (Nintendo Wii) to increase activity levels, vitality and well-being in people with multiple sclerosis. BMJ Open [online]. 2017, 7(9). ISSN 20446055. Dostupné z: doi:10.1136/bmjopen-2017-016966

[26] KARASU, A, E BATUR a G KARATAŞ. Effectiveness of Wii-based rehabilitation in stroke: A randomized controlled study. Journal of Rehabilitation Medicine [online]. 2018, 50(5), 406–412. ISSN 1650-1977. Dostupné z: doi:10.2340/16501977-2331

[27] YAZGAN, Yonca Zenginler, Ela TARAKCI, Devrim TARAKCI, Arzu Razak OZDINCLER a Murat KURTUNCU. Comparison of the effects of two different exergaming systems on balance, functionality, fatigue, and quality of life in people with multiple sclerosis: A randomized controlled trial. Multiple Sclerosis and Related Disorders [online]. 2020, 39. ISSN 22110356. Dostupné z: doi:10.1016/j.msard.2019.101902

[28] BRUNELLI, Stefano, Noemi GENTILESCHI, Marco IOSA, Francesca Romana FUSCO, Valerio GROSSI, Silvia DURI, Calogero FOTI a Marco TRABALLESI. Early balance training with a computerized stabilometric platform in persons with mild hemiparesis in subacute stroke phase: A randomized controlled pilot study. Restorative Neurology and Neuroscience [online]. 2020, 38(6), 467–475. ISSN 18783627. Dostupné z: doi:10.3233/RNN-201055

[29] CHANPIMOL, Shane, Kimberly BENSON, Heidi MALONI, Susan CONROY a Mitchell WALLIN. Acceptability and outcomes of an individualized exergaming telePT program for veterans with multiple sclerosis: a pilot study. Archives of Physiotherapy [online]. 2020, 10(1), 18. ISSN 2057-0082. Dostupné z: doi:10.1186/s40945-020-00089-5

[30] STANMORE, Emma K., Alexandra MAVROEIDI, Lex D. DE JONG, Dawn A. SKELTON, Chris J. SUTTON, Valerio BENEDETTO, Luke A. MUNFORD, Wytske MEEKES, Vicky BELL a Chris TODD. The effectiveness and cost- effectiveness of strength and balance Exergames to reduce falls risk for people aged 55 years and older in UK assisted living facilities: a multi-centre, cluster randomised controlled trial. BMC Medicine [online]. 2019, 17(1), 49. ISSN 1741- 7015. Dostupné z: doi:10.1186/s12916-019-1278-9

[31] LOWE R. Berg Balance Scale [online]. 2022 [vid. 2022-10-23]. Dostupné z: https://www.physiopedia.com/Berg_Balance_Scale

[32] SRALAB.ORG. Berg Balance Scale. Academy od neurologic physical therapy [online]. 2018 [vid. 2022-11-22]. Dostupné z: https://www.sralab.org /sites/default/files/downloads/2020-08/Berg%20Balance%20Scale%20Pocket% 20Guide.pdf

[33] EQ-5D. EQ-5D-5L | About [online]. 2021 [vid. 2022-10-23]. Dostupné z: https://euroqol.org/eq-5d-instruments/eq-5d-5l-about/