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Immersive Virtual Reality Therapy for Elderly Female Patients Undergoing Rehabilitation After Hip Arthroplasty: A Randomized Controlled Pilot Trial

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Background: Osteoarthritis often leads to total hip arthroplasty (THA), and effective postoperative rehabilitation is critical to recovery. This study tested whether adding virtual reality (VR) to standard inpatient rehabilitation improves psychological well-being and functional performance in women after THA.

Material/Methods: This pilot randomized controlled trial was conducted with 24 female patients aged 60 and older. Participants were randomized into two groups: a control group receiving 4-week standard rehabilitation and an experimental group receiving standard rehabilitation plus VR therapy. Psychological and functional statuses were assessed using the Hospital Anxiety and Depression Scale (HADS), Perception of Stress Questionnaire (PSQ), and various functional tests before and after the intervention.

Results: The experimental group showed significant improvements in psychological outcomes, with a 53% reduction in overall HADS scores and a 43% reduction in PSQ scores. Functional improvements were also observed, with significant increases in Tinetti Test, Barthel Index, and Rivermead Motor Assessment scores. In contrast, the control group showed no significant changes in psychological parameters and less pronounced functional improvements.

Conclusions: Adjunctive VR during post-THA rehabilitation improved psychological well-being and functional performance in women aged 65 years and older compared with usual care, and improvements in these domains were positively correlated. These preliminary results support VR as a promising adjunct to target both psychological and functional recovery, but confirmation in larger, multicenter trials with longer follow-up and economic evaluation is required.

Keywords: **Arthroplasty, Replacement, Hip • Depression • Rehabilitation • Relaxation Therapy • Virtual Reality • Virtual Reality Exposure Therapy**

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Introduction

The demand for total hip arthroplasty (THA) is rising. Across OECD countries, hip replacement rates averaged about 172 per 100,000 population in 2021 and are expected to grow further with population ageing [1]. In 2022, a total of 64,694 hip replacement surgeries were performed across Poland under agreements with the Polish National Health Fund (NFZ). According to NFZ data, the leading indications for primary THA were primary coxarthrosis, femoral neck fracture, and other primary coxarthroses, while mechanical complications of internal joint prostheses were the most common indication for revision surgery [2]. These national trends mirror international patterns of increasing procedure volume and underscore the need to optimize post-THA recovery pathways [1].

Osteoarthritis (OA), the most common form of arthritis worldwide [3], is characterized by cartilage degeneration, osteophyte formation, subchondral sclerosis, and weakening of periarticular muscles [4]. In 2020, an estimated 595 million people were living with OA, roughly 7.6% of the global population, with hip OA cases projected to increase by about 79% by 2050 [3]. These pathological changes result in pain, functional limitations, and disability, placing a substantial burden on individuals and society. Typical symptoms include joint pain, stiffness, and reduced range of motion, and multiple joints can be affected, particularly the hips, knees, hands, feet, and spine [5].

Persistent pain is the hallmark of OA and a major contributor to healthcare use, functional limitation, and reduced quality of life. Lower-extremity OA is a leading cause of mobility impairment in older adults [6] and contributes substantially to years lived with disability worldwide [3]. Pain persisting beyond 6 months, especially in the presence of comorbid mental health conditions or multisite pain, is associated with poorer psychological well-being and overall health status. This highlights the need to evaluate the psychological well-being in people living with persistent pain and chronic conditions and to develop clinical strategies that support both domains [7]. Notably, preoperative psychological distress, including anxiety and depression, is linked to worse postoperative pain and function and a higher complication risk after THA, which supports integrating psychological assessment and support into rehabilitation [8]. Despite this evidence, psychological evaluation and intervention are not yet standard practice in orthopedic rehabilitation in Europe.

Standard care for adults who have undergone THA for end-stage OA includes postoperative rehabilitation to optimize function, reduce pain, and restore activities of daily living. Although no disease-modifying treatments currently exist for OA, rehabilitation, particularly structured exercise therapy, remains a cornerstone of symptom management, with evidence for benefits in pain, physical function, and quality of life. Advances in protocols,

including individualized exercise, weight management, and digital health supports, can further improve outcomes. An expert consensus recommends therapeutic exercise for 4 to 8 weeks, 3 to 5 sessions per week, following THA [9]. Programs typically include resistance exercises and gait training and can be delivered at different postoperative stages, intensities, and settings, tailored to individual, social, and financial circumstances. However, uncertainty remains regarding which specific components should be standardized to maximize clinical outcomes and reduce avoidable complications or implant failure [10].

After THA, physiotherapy commonly includes cryotherapy, passive and active mobilizations initiated soon after surgery, and exercises aimed at improving hip function and strength [11]. Traditional approaches that rely heavily on passive and analytical exercises can be perceived as monotonous and insufficiently engaging, which can undermine motivation and adherence. Moreover, high socio-economic costs can limit continuity of care [12].

Virtual reality (VR) provides an immersive, multimodal simulated environment that can increase engagement and the sense of presence during therapy [13]. Use of VR-based rehabilitation in orthopedics, including THA and total knee arthroplasty, has expanded in recent years [14], and multiple VR-based postoperative protocols have been proposed [15]. Randomized trials indicate that, after THA, VR-based rehabilitation is comparable or superior to conventional therapy for early functional recovery, and after total knee arthroplasty it reduces early postoperative pain and anxiety, with mixed longer-term effects [16,17]. Nevertheless, evidence on VR's effectiveness for alleviating stress, anxiety, or depressive symptoms after THA or total knee arthroplasty remains limited. Therefore, the primary aim of the present study was to determine the impact of VR therapy on the psychological and functional state of patients participating in rehabilitation after total hip arthroplasty. We hypothesize that VR therapy significantly enhances both the psychological and functional states of patients, with a positive correlation between improvements in these 2 parameters.

Material and Methods

Study Design, Setting, and Participants

This study was designed as a single-blinded, randomized pilot clinical trial with blinded outcome assessors and was conducted at St. Hedwig Hospital in Trzebnica, Poland. Due to the nature of the intervention involving VR therapy, it was not possible to blind the patients or the intervention providers. In accordance with participant recruitment guidelines for pilot randomized trials outlined by Julious (2005) and Whitehead et al (2015) [18,19], we consecutively enrolled 24 female patients

between March and August 2023. The main inclusion criteria were female sex, age of 60 years or older, and having undergone THA. The primary exclusion criteria were contraindications to using VR therapy (eg, dizziness, epilepsy, significant visual impairments), inability to independently complete questionnaires, and refusal to participate in the study.

Participants were allocated into 2 groups by block randomization with computer-generated permuted blocks of size 4 at Randomizer.org, without stratification. Allocation concealment was ensured with sequentially numbered, opaque, and sealed envelopes prepared off-site. Outcome assessors remained blinded throughout data collection through separation of roles, no access to the randomization list, allocation records, or envelopes, and scheduling that prevented contact with treating therapists. To minimize bias, the intervention providers were not involved in the assessment process. Specifically, the individuals administering the intervention did not participate in evaluating its outcomes, ensuring an independent assessment by blinded evaluators

The study protocol was approved by the Bioethics Committee at the Wrocław Medical University, Poland (119/KB/2023), and registered in the ClinicalTrials.gov database (NCT06506760). All participants provided written informed consent prior to any study procedures.

Interventions

Patients from both groups participated in a standard rehabilitation program following THA, lasting 4 weeks as an inpatient regimen. The program included kinesiotherapy, with 2-h daily gait training sessions, occupational therapy for 30 min each day, and physiotherapy treatments, such as laser therapy, cryotherapy, magnetic field therapy, and electrotherapy, which were individually tailored to meet each patient's specific needs.

Additionally, patients in the experimental group participated in 8 VR therapy sessions (2 times per week), supplementing the standard rehabilitation. Each VR session lasted up to 20 min. The VR therapy was conducted using the VRTierOne medical device by Stolgraf (Stanowice, Poland). This device was equipped with HTC VIVE VR goggles and an HTC VIVE controller that tracked the movements of the dominant wrist. The use of VRTierOne was aimed to transport patients into a calm, virtual world, enabling relaxation and helping to soothe emotions. Each therapeutic session began at a gate through which patients entered a garden. With each session, the garden dynamically developed, becoming increasingly vibrant. In the middle of each therapeutic session, a mandala appeared in the garden, which the patients were tasked with coloring. The VR therapy was based on the principles of Ericksonian psychotherapy, making use of metaphors, hypnosis, and symbolism.

Additionally, the background of the VR therapy consisted of relaxation music, which changed as the therapy progressed. A detailed description of the VR therapy principles has been described in previous works [13,20,21]. Adverse events were monitored at each session by the treating therapist using a standardized checklist, and their onset, severity, and relatedness to the intervention were recorded in the case report forms.

Participants and intervention providers were aware of group assignments. Protocol adherence was ensured via automatic VR system logs and post-session therapist fidelity checklists, which were audited weekly against predefined deviation criteria by a supervising investigator. No protocol deviations were recorded.

Outcome Measures

Participants completed a custom questionnaire to collect basic sociodemographic data, including age, weight, height, body mass index (BMI), education level, and marital status. The study assessed both psychological and functional status through evaluations conducted at 2 time points: prior to the intervention (week 0) and upon its completion (week 4).

The primary outcome measure was the Polish version of the Hospital Anxiety and Depression Scale (HADS), which detects depressive and anxiety states [22]. It consists of 14 questions, with 7 each related to anxiety and depression. Higher scores on the HADS indicate higher levels of anxiety and/or depression, with cut-off scores of 8 and above on each subscale suggesting elevated anxiety or depression, and scores above 10 indicating a pathological state.

Secondary outcome measures included assessments of psychological status using the Polish versions of the Perception of Stress Questionnaire (PSQ), Generalized Self-Efficacy Scale (GSES), and visual analog scale (VAS) for pain. The PSQ measures generalized stress levels through 3 components: emotional tension, external stress, and intrapsychic stress, with overall scores ranging from 21 to 105 points [23]. A subscale cut-off score of 20 points suggests a borderline average result, with higher scores indicating greater tension or stress. The GSES assesses the general sense of self-efficacy, evaluating whether patients can anticipate coping strategies for daily problems and adapt to stressful situations [24]. Scores below 25 suggest low self-efficacy, while scores above 30 indicate high self-efficacy. The VAS for pain assessment ranges from 0 to 10, where 0 indicates no pain and 10 indicates the greatest possible pain [25].

Functional evaluations included the Tinetti test, Barthel Index of Activities of Daily Living, Rivermead Motor Assessment Gross Function Subscale (RMA-GF), and Short Physical Performance Battery (SPPB). The Tinetti Short Scale, a simplified version of the Tinetti Performance-Oriented Mobility Assessment, evaluates a

patient's gait and balance through tasks such as sitting to standing, standing still for 5 s, walking 3 m, turning 180 degrees, and maintaining a sitting position [26]. Each task is rated on a 3-point Likert scale, with total scores ranging from 0 to 15, where higher scores indicate better functional mobility. The Barthel Index analyzes patients' ability to perform daily living activities, awarding points on a scale from 0 to 10 for each activity, with a maximum score of 100 points [27]. Higher scores indicate better functional status, while lower scores indicate greater limitations in daily activities. The RMA-GF was used to assess patient mobility, modified to exclude the 10-m run and jumping tasks, due to THA contraindications [28]. The test included 11 tasks, with each correctly performed task earning 1 point, ranging from sitting independently to walking 40 m and climbing stairs. Higher scores, up to a maximum of 11, indicated greater functional capabilities and lower disability. The SPPB assesses the physical fitness of older adults and consists of 3 different types of physical activities: balance maintenance, gait speed, and chair rising [29]. A maximum score of 12 points can be achieved, and a low score can suggest potential mobility issues in the near future, possibly leading to the need for hospitalization or long-term care.

Data Analysis

Statistical analysis was conducted using JASP software, version 0.18.3 (University of Amsterdam, Netherlands). Descriptive data for categorical variables are presented as frequencies and percentages. For continuous variables, the mean and standard deviation (SD) were calculated. Group characteristics were compared using the chi-square test and the unpaired *t* test. The Shapiro-Wilk test was used to confirm that the distribution of the obtained results was close to normal. The effects of the intervention between groups were evaluated using analysis of variance (ANOVA) supplemented by unpaired *t* tests for independent groups (between-group effects) and dependent groups (within-group effects). Eta squared (η^2) values were interpreted based on Cohen's guidelines, with 0.01 indicating a small effect, 0.06 a medium effect, and 0.14 or greater indicating a large effect. Effect sizes for *t* tests were assessed using Cohen's *d*, with absolute values reported. A Cohen's *d* of 0.2 indicates a small effect, 0.5 indicates a medium effect, and 0.8 or greater indicates a large effect [30]. The relationship between changes in psychological and functional parameters was examined using Spearman's rank correlation coefficient. Values of $P < 0.05$ were considered statistically significant.

Results

Participant Characteristics

As illustrated in **Figure 1**, following an initial eligibility assessment, 24 women were randomly allocated to 1 of 2 treatment

groups. One patient from the experimental group did not finish the intervention due to eyesight problems in VR.

The average age of patients in the experimental group was 71.91 years, which was 0.26 years lower than that in the control group (**Table 1**). The average height in the experimental group was 0.35 cm higher than in the control group (experimental 161.27 cm and control 160.92 cm). The average weight of patients in the VR therapy group was 0.65 kg lower (experimental 74.18 kg and control 74.83 kg), and the average BMI was 0.38 lower than in the control group (experimental 28.69 kg/m² and control 29.07 kg/m²). Among all patients, 5 had a normal BMI, 10 had overweight, and 8 had obesity. Regarding education, 11 patients had vocational education, 9 had secondary education, and 3 had higher education. In terms of marital status, 15 patients were married, 7 were widows, and 1 was divorced. There were no statistically significant differences between the groups in the various variables.

Psychological State

As shown in **Table 2**, in the context of psychological state, statistically significant changes with medium to large effect size were observed in all measured parameters between measurement points in the experimental group, except for HADS-D ($P=0.16$). The overall HADS score significantly decreased by 53% (from 12.55 to 5.91; $P=0.03$, $d=0.79$), while the anxiety component (HADS-A) significantly decreased by 58% (from 7.00 to 2.91; $P=0.01$, $d=0.92$). The overall PSQ score significantly decreased by 43% (from 64.82 to 37.00; $P < 0.001$, $d=1.70$). Analysis of the individual stress components measured by the PSQ showed significant decreases: a 52% reduction in emotional tension (from 24.18 to 11.55; $P < 0.001$, $d=1.58$), a 31% reduction in external stress (from 19.73 to 13.55; $P=0.01$, $d=0.99$), and a 43% reduction in intrapsychic stress (from 20.91 to 11.91; $P < 0.01$, $d=2.10$). The GSES questionnaire results indicated a significant increase in self-efficacy after the intervention by 45% (from 26.73 to 38.82; $P < 0.001$, $d=1.81$). The analysis of the VAS scale results showed a significant reduction in pain experienced by patients by 84% (from 4.55 to 0.73; $P < 0.001$, $d=1.68$).

In contrast to the experimental group, the control group showed no significant changes between measurements in psychological state variables ($P > 0.05$), except for the VAS scale, which showed a small but significant improvement ($P=0.02$, $d=0.25$). Additionally, significant differences in intervention efficacy with large effect size ($d > 0.8$) were observed between the groups in all measured psychological parameters, except for HADS-D ($P=0.12$, $d=0.69$, **Table 2**), favoring the intervention used in the experimental group. Furthermore, the ANOVA results indicating significant group-by-time interactions with a large effect size ($\eta^2 P > 0.14$; **Table 3**) confirmed the observed differences in the effectiveness of interventions between the groups in terms of psychological parameters.

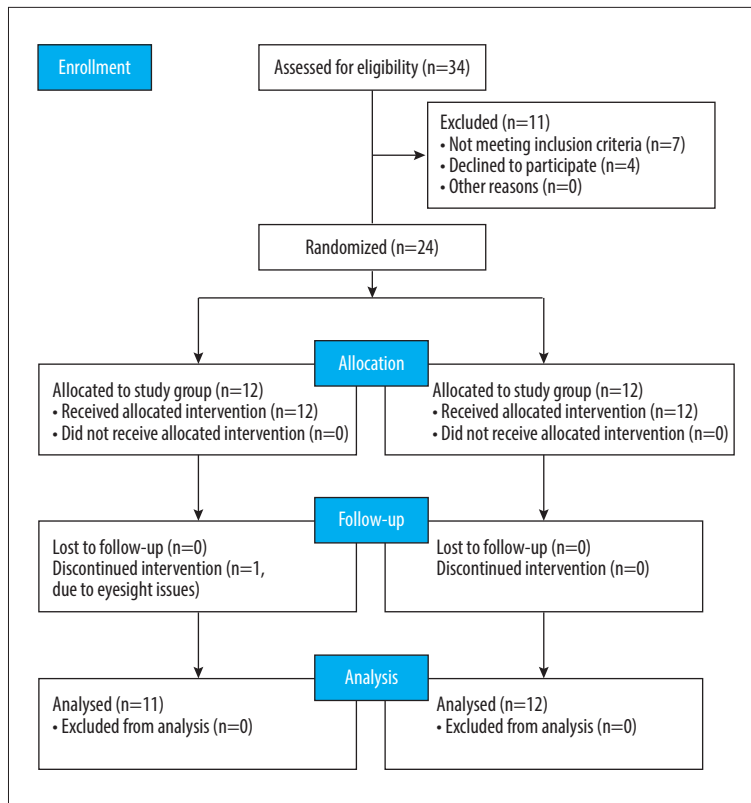


Figure 1. CONSORT flow diagram.

Table 1. Baseline characteristics of participants.

Variable	Total	Experimental group	Control group	p value
n	23	11	12	–
Age, years	72.04 (8.63)	71.91 (10.18)	72.17 (7.40)	0.95 ^a
Body height, cm	161.09 (7.40)	161.27 (5.64)	160.92 (8.98)	0.91 ^a
Body mass, kg	74.52 (11.44)	74.18 (8.57)	74.83 (13.95)	0.90 ^a
Body mass index, kg/m ²	28.88 (5.02)	28.69 (4.38)	29.07 (5.73)	0.86 ^a
Normal (BMI 18.5-24.9), n (%)	5 (21.74)	2 (18.18)	3 (25.00)	0.59 ^b
Overweight (BMI 25-29.9), n (%)	10 (43.48)	6 (54.55)	4 (33.33)	
Obese (BMI >30), n (%)	8 (34.78)	3 (27.27)	5 (41.67)	
Education, n (%)				0.17 ^b
Primary/vocational	11 (47.83)	3 (27.27)	8 (66.67)	
Secondary	9 (39.13)	6 (54.55)	3 (25.00)	
Higher	3 (13.04)	2 (18.18)	1 (8.33)	
Marital status, n (%)				0.14 ^b
Married	15 (65.22)	5 (45.46)	10 (83.33)	
Divorced	1 (4.35)	1 (9.09)	0 (0.00)	
Widowed	7 (30.44)	5 (45.46)	2 (16.67)	

^a Unpaired t test; ^b chi-square test. Continuous variables are expressed as mean (standard deviation). BMI – body mass index.

Table 2. Results of psychological tests, including the statistical significance of differences between the experimental and control groups.

	Experimental group (n=11)	Control group (n=12)	Effect size	p value ^a
HADS				
Before	12.55 (5.87)	15.25 (8.49)		
After	5.10 (4.74)	15.33 (6.67)		
Change	-6.64; -52.90% (-12.28; -1.00)	0.08; 0.54% (-2.51; 2.67)	1.03	0.02
p value ^b	0.03	0.95		
Effect size	0.79	0.14		
HADS-A				
Before	7.00 (2.65)	7.75 (8.49)		
After	2.91 (2.84)	7.50 (3.92)		
Change	-4.09; -58.44% (-7.07; -1.11)	-0.25; -3.23% (-1.88; 1.38)	1.07	0.01
p value ^b	0.01	0.74		
Effect size	0.92	0.17		
HADS-D				
Before	5.55 (4.06)	7.50 (4.52)		
After	3.00 (3.19)	7.83 (3.86)		
Change	-2.55; -45.90% (-6.33; 1.24)	0.33; 4.44% (-1.08; 1.75)	0.69	0.12
p value ^b	0.16	0.62		
Effect size	0.45	0.15		
PSQ				
Before	64.82 (17.60)	58.92 (21.37)		
After	37.00 (5.68)	57.08 (17.12)		
Change	-27.82; -42.92% (-38.83; -16.81)	-1.83; -3.11% (-9.09; 5.42)	1.86	<0.001
p value ^b	<0.001	0.59		
Effect size	1.70	0.16		
PSQ emotional tension				
Before	24.18 (7.52)	20.00 (7.91)		
After	11.55 (2.84)	20.08 (5.73)		
Change	-12.64; -52.26% (-18.02; -7.25)	0.08; 0.41% (-2.84; 3.01)	1.97	<0.01
p value ^b	<0.001	0.95		
Effect size	1.58	0.17		

Table 2 continued. Results of psychological tests, including the statistical significance of differences between the experimental and control groups.

	Experimental group (n=11)	Control group (n=12)	Effect size	p value ^a
PSQ external stress				
Before	19.73 (5.69)	18.17 (6.90)		
After	13.55 (2.02)	18.50 (5.81)		
Change	-6.18; -31.34% (-10.37; -2.00)	0.33; 1.83% (-1.43; 2.10)	1.37	<0.01
p value ^b	0.01	0.69		
Effect size	0.99	0.12		
PSQ intrapsychic stress				
Before	20.91 (6.69)	20.75 (7.46)		
After	11.91 (3.62)	18.50 (6.46)		
Change	-9.00; -43.04% (-11.88; -6.12)	-2.25; -10.84% (-5.41; 0.91)	1.45	<0.01
p value ^b	<0.001	0.15		
Effect size	2.10	0.21		
GSES				
Before	26.73 (7.24)	28.75 (6.59)		
After	38.82 (1.33)	30.00 (6.37)		
Change	12.09; 45.24% (7.61; 16.57)	1.25; 4.35% (-2.36; 4.86)	1.76	<0.001
p value ^b	<0.001	0.46		
Effect size	1.81	0.26		
VAS				
Before	4.55 (2.70)	4.00 (2.22)		
After	0.73 (1.27)	2.67 (2.02)		
Change	-3.82; -84.00% (-5.35; -2.29)	-1.33; -33.33% (-2.36; -0.31)	1.27	0.01
p value ^b	<0.001	0.02		
Effect size	1.68	0.25		

^a Significance of the unpaired *t* test; ^b significance of the paired *t* test. Values before and after are presented as mean values (standard deviation). The change is expressed as the mean difference and percentage change, along with 95% confidence intervals. The effect size values are the absolute values of Cohen's *d*. HADS – Hospital Anxiety (A) and Depression (D) Scale; PSQ – Perception of Stress Questionnaire; GSES – General Self-Efficacy Scale; VAS – visual analog scale for pain assessment.

Functional State

Statistical changes with large effect size ($d > 0.8$) were observed in all measured parameters between the measurement points in the experimental group (Table 4). After the intervention, the Tinetti test score significantly increased by 200% (from 3.27 to 9.82; $P < 0.001$, $d = 2.43$). The same trend was observed in other functional tests: the Barthel Index score increased by 66.7% (from 55.91 to 93.18; $P < 0.001$, $d = 2.84$), the RMA-GF test score

increased by 131.9% (from 4.27 to 9.91; $P < 0.001$, $d = 2.95$), and the SPPB test score increased by 143.2% (from 3.36 to 8.18; $P < 0.01$, $d = 1.18$). Similarly, in the control group, a significant increase with a small effect size ($0.2 \leq d < 0.5$) in functional parameter outcomes was observed after the intervention ($P < 0.001$ for Tinetti, Barthel, RMA-GF tests, and $P < 0.01$ for the SPPB test). Additionally, significant differences in intervention efficacy with large effect size ($d > 0.8$) between the groups were observed across all measured functional parameters, except

Table 3. Results of repeated measures analysis of variance (group-by-time interaction).

Variables	Mean square	F value	p value	η^2_p
Psychological parameters				
HADS	129.57	6.13	0.02	0.23
HADS-A	42.33	6.61	0.02	0.24
HADS-D	23.78	2.69	0.12	0.11
PSQ	1937.57	19.75	<0.001	0.49
ET	464.27	22.27	<0.001	0.52
ES	121.81	10.83	<0.01	0.34
IS	130.75	12.04	<0.01	0.36
GSES	337.25	17.72	<0.001	0.46
VAS	17.72	9.27	0.01	0.31
Functional parameters				
TT	29.61	13.61	0.001	0.39
BI	662.06	9.79	0.01	0.32
RMA-GF	12.10	9.50	0.01	0.31
SPPB	12.10	9.50	0.01	0.31

HADS – Hospital Anxiety and Depression Scale (A for anxiety, D for depression); PSQ – Perception of Stress Questionnaire; ET – emotional tension; ES – external stress; IS – intrapsychic stress; GSES – Generalized Self-Efficacy Scale; VAS – visual analog scale for pain assessment; TT – Tinetti Test; BI – Barthel Index; RMA-GF – Rivermead Motor Assessment Gross Function Subscale; SPPB – Short Physical Performance Battery.

for SPPB ($P=0.10$, $d=0.73$, **Table 4**), favoring the intervention applied in the experimental group.

Furthermore, the results of ANOVA indicating significant interactions between group and measurement point with large effect size ($\eta^2_p > 0.14$; **Table 3**) confirm the observed difference in the efficacy of the interventions applied between the groups in terms of functional parameters.

Correlations

Figure 2 shows the correlation between changes in psychological parameters and changes in functional parameters. Significant correlations were observed between the differences in psychological parameters and the following test results: SPPB (ranging from 0.43 to 0.74), Barthel Index (ranging from 0.42 to 0.60), and Tinetti test (ranging from 0.54 to 0.59). For the change in RMA-GF scores, a significant correlation of 0.43 was observed only with the change in GSES scores. All significant correlations were positive, suggesting that larger differences between measurements in psychological parameters correlated with greater differences in functional parameters, and vice versa.

Discussion

This study evaluated whether adjunctive VR therapy improves psychological well-being and functional status in women aged 65 years and older undergoing rehabilitation after THA. We hypothesized that VR would enhance both domains, and that improvements would be positively correlated. The findings aligned with this expectation: the VR group showed significant gains across all psychological measures and larger improvements in functional status relative to controls, while the control group exhibited no significant psychological change and smaller functional gains. Moreover, greater psychological improvement was associated with greater functional recovery.

The observed changes in psychological parameters aligned with findings from our previous studies on VR therapy across different areas of rehabilitation [13,31]. Psychological well-being plays a crucial role in rehabilitation success, as mental health challenges such as low mood, depressive symptoms, and anxiety are closely linked to poorer healthcare outcomes [32], including increased pain and reduced physical health [33-36]. These findings underscore the value of incorporating psychologically informed interventions into standard rehabilitation programs.

Table 4. Functional test results, including the statistical significance of differences between the experimental and control groups.

	Experimental group (n=11)	Control group (n=12)	p value ^a	Effect size
TT				
Before	3.27 (2.72)	3.00 (2.49)		
After	9.82 (0.41)	6.33 (2.35)		
Change	6.55; 199.97% (od 4.73; 8.36)	3.33; 111.10% (2.51; 4.16)	0.001	1.54
p value ^b	<0.001	<0.001		
Effect size	2.43	0.32		
BI				
Before	55.91 (19.34)	53.33 (19.23)		
After	93.18 (7.51)	75.42 (17.38)		
Change	37.27; 66.67% (28.47; 46.08)	22.08; 41.41% (15.66; 28.5)	0.01	1.31
p value ^b	<0.001	<0.001		
Effect size	2.84	0.29		
RMA-GF				
Before	4.27 (2.76)	4.17 (2.66)		
After	9.91 (1.04)	7.75 (2.22)		
Change	5.64; 131.9% (4.35; 6.92)	3.58; 85.99% (2.8; 4.37)	0.01	1.29
p value ^b	<0.001	<0.001		
Effect size	2.95	0.31		
SPPB				
Before	3.36 (3,17)	2.25 (2.09)		
After	8.18 (3.46)	4.75 (2.90)		
Change	4.82; 143.22% (2.08; 7.55)	2.50; 111.11% (1.19; 3.81)	0.10	0.73
p value ^b	<0.01	<0.01		
Effect size	1.18	0.29		

Values before and after are presented as means (standard deviation). The change is expressed as the mean difference and percent change, along with 95% confidence intervals. The effect size values are the absolute values of Cohen's *d*. TT – Tinetti Test; BI – Barthel Index; RMA-GF – Rivermead Motor Assessment Gross Function Subscale; SPPB – Short Physical Performance Battery.

An additional finding was that of significant functional improvement in both groups. Between-group comparisons showed a larger effect in the VR group than in the control group. Prior orthopedic studies report mixed functional effects of VR, with some reporting advantages over usual care and some reporting equivalence [17,37]. Our larger between-group difference may reflect the use of therapeutically scripted content (Ericksonian metaphors rather than distraction), greater session dose, timing of exposure within inpatient rehabilitation, and the older age of our cohort, factors that differ from those of several earlier trials.

Vincent et al and Crofford reported that psychological disorders, including depression, anxiety, and stress, can affect various

aspects of the recovery process for patients, such as reduced efficacy, prolonged recovery, and decreased overall quality of life [38,39]. Consistent with these reports, we observed that larger improvements in psychological outcomes were associated with greater functional gains, in line with prior work by Leo et al recognizing psychological disorders as potential impediments to rehabilitation effectiveness [40]. This association is plausibly mediated by symptoms such as low mood, anxiety, or negative appraisals, which can slow progress [41]. Patients with elevated psychological symptoms may therefore benefit from more individualized plans that integrate psychological treatment with physical therapy.

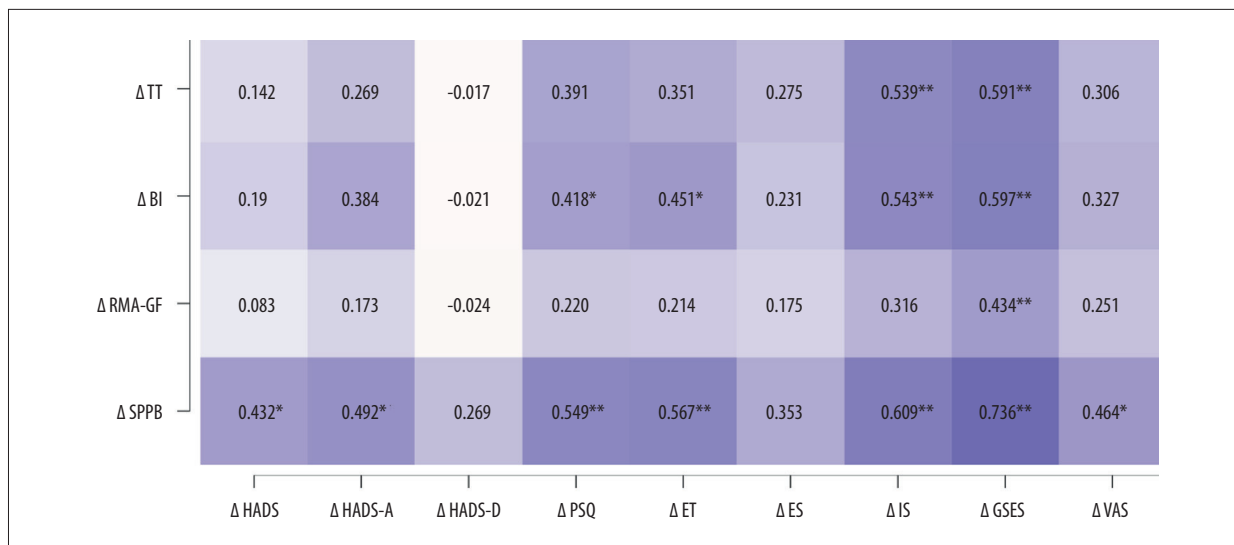


Figure 2. Correlation heatmap. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. HADS – Hospital Anxiety and Depression Scale (A for anxiety, D for depression); PSQ – Perception of Stress Questionnaire; ET – emotional tension; ES – external stress; IS – intrapsychic stress; GSES – Generalized Self-Efficacy Scale; VAS – visual analog scale for pain assessment; TT – Tinetti Test; BI – Barthel Index; RMA-GF – Rivermead Motor Assessment Gross Function Subscale; SPPB – Short Physical Performance Battery.

Clinical Implications

Adjunctive VR can be used as a targeted addition to post-THA rehabilitation, addressing both the psychological well-being and functional recovery of patients. Its immersive format can enhance motivation and engagement, and therapeutically scripted content can help manage anxiety and depressive symptoms that often hinder participation. In practice, services could introduce brief psychological screening at intake to identify candidates, schedule VR alongside physiotherapy with content mapped to rehabilitation goals, and monitor adherence via system logs, supported by therapist training, fidelity checklists, and standard adverse-event reporting. At the service and policy level, the adoption of VR should be paired with prospective evaluation of feasibility, acceptability, fidelity, cost, and equity, with clear procedures for procurement, data security, and documentation. Economic evaluations and multicenter studies can then inform guideline recommendations, reimbursement pathways, and criteria for integrating VR-based psychological components into routine post-THA care.

Limitations

Given the pilot design of the study, several limitations should be considered when interpreting these findings. This study enrolled a small, single-center sample of 24 women, which limits generalizability and yields imprecise effect estimates. The intervention spanned 4 weeks, with no extended follow-up; therefore, the durability of effects cannot be determined. Psychological outcomes were based on self-report scales, introducing potential response and expectancy bias despite

assessor blinding. As a pilot study, it was not powered for definitive between-group efficacy conclusions. Future research should include a larger, more diverse, and multicenter cohort, extend follow-up to the medium and long term, incorporate objective and clinician-rated outcomes alongside patient-reported measures, and be prospectively powered. Mediation analyses could test whether psychological change underpins functional gains.

Conclusions

In this randomized pilot study, we evaluated whether adjunctive VR therapy improves psychological well-being and functional status in women aged 65 years and older undergoing post-THA rehabilitation, and whether improvements in these domains are correlated. The VR group showed significant gains across psychological measures and larger improvements in functional tests relative to the control group, and greater psychological improvement was associated with greater functional recovery. These findings suggest that VR can be a useful adjunct to conventional rehabilitation for targeting psychological and functional outcomes. Given the small, single-center sample, short intervention period, and reliance on self-reported psychological measures, the results should be considered preliminary. Confirmation in larger, more diverse multicenter trials with longer follow-up and economic evaluation is needed before recommending routine implementation. Pending such evidence, rehabilitation services can consider exploring VR as a targeted option for patients with elevated psychological distress or low engagement within structured and monitored programs.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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