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The effect of exercises done with virtual reality glasses on pain, daily life activities, and quality of life of individuals with lumbar disc hernia: a randomized controlled trial

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Abstract

Background Lumbar disc herniation is a prevalent condition that leads to pain, disability, and a reduction in quality of life. While conventional treatments are widely utilized, virtual reality-based exercise programs present a promising alternative. However, the effectiveness of these exercises in the rehabilitation of lumbar disc herniation remains unclear.

The aim of this study was to evaluate the effects of virtual reality-based exercises on pain, daily activities, quality of life, and fall risk in individuals with lumbar disc herniation.

Materials and methods This randomized controlled trial included 68 patients meeting the study criteria. Inclusion criteria: No other physical disabilities, no surgery in the last 6 months, no uncontrolled diseases, no vertigo, knee or joint issues, moderate/low balance impairment, and body mass ındex below 40. Exclusion criteria: Uncontrolled diseases, vertigo, knee/joint issues, cognitive impairments, pregnancy, inability to complete fall risk measurement, or attend follow-ups**.** Participants were divided into a virtual reality group ($n=34$, Mean age ± Standard Deviation = 51.05 ± 13.39, 41.2% male, 58.8% female) and a control group ($n=34$, Mean age ± Standard Deviation = 53.55 ± 12.25, 29.4% male, 70.6% female). The virtual reality group performed 28 sessions of virtual reality -based exercises, while the control group received routine hospital treatment. The study was conducted in a single hospital due to equipment limitations in the region. Data were collected using the Patient Information Form, Visual Analog Scale, Oswestry Disability Index, Short Form-36 Quality of Life Scale, and Fall Risk Device. Statistical analyses were performed using Statistical Package for the Social Sciences 20, including t-tests, chi-square tests, effect size analysis, and skewness/kurtosis assessments for homogeneity.

Results The virtual reality group showed a significant reduction in pain (Visual Analog Scale: 3.38 ± 1.48, CI: -2.49, -0.86, $p<0.05$) and disability (Oswestry Disability Index: 21.59 ± 6.00, CI: -19.92, -7.38, $p<0.05$), along with significant improvements in all Short Form-36 Quality Of Life sub-dimensions ($p<0.05$).Fall risk scores also decreased significantly

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in the virtual reality group (CI: -26.57, -7.26, $p < 0.05$). There were no significant baseline differences between the groups, confirming their comparability before the intervention.

Conclusion Virtual reality -based exercises effectively reduced pain, improved daily activities and quality of life, and decreased fall risk in lumbar disc herniation patients, suggesting their potential as a complementary rehabilitation approach. Blinding was not applied due to the nature of the interventions, which may introduce a potential risk of bias.

Trial registration This study was registered at ClinicalTrials.gov (Clinical trial number: NCT05463588; Registration date: 08/07/2022). The study was retrospectively registered.

Keywords Pain, Health, Lumbar disc hernia, Virtual reality, Quality of life

Introduction

Lumbar disc herniation (LDH) is a spinal condition characterized by the protrusion of intervertebral disc material beyond its physiological boundaries, affecting a large segment of the population, especially individuals aged 30–50 years [1–4]. Its clinical presentation typically includes low back pain radiating to the leg, sensory disturbances, and muscular weakness. In severe cases, cauda equina syndrome may arise, causing urinary, fecal, and sexual dysfunction [2, 5, 6]. Bed rest is commonly used in acute LDH for symptom relief [7–9]. Chronic LDH is managed conservatively with pharmacologic treatments, physical therapy (e.g., heat/cold, traction, electrotherapy), orthotics, education, and exercise. Regular structured exercise is crucial for musculoskeletal conditions, enhancing spinal mobility, strengthening lumbar and abdominal muscles, reducing pain, and speeding recovery in LDH [10–12]. Numerous studies confirm exercise reduces pain and improves function [13–18]. A proposed mechanism contributing to these therapeutic effects is exercise-induced hypoalgesia (EIH), which involves activation of endogenous pain modulation systems, increasing pain thresholds and reducing pain perception [19].

However, although lumbar disc herniation (LDH) is a common cause of low back pain (LBP), it is not the only one [20]. This study focuses on LDH-related LBP, examining its impact on daily life, treatment, and rehabilitation. LBP is a major global health issue causing frequent hospital visits and reduced productivity [21, 22]. While cost estimates generally cover chronic LBP, LDH-related LBP incurs higher costs due to prolonged treatment and work absenteeism [23, 24].

Identifying LDH-specific pain is challenging due to diagnostic complexities. This study examines LDH-related pain and treatment response. In 5–15% of cases, low back pain becomes chronic, impairing function and quality of life [25]. Chronic cases are often accompanied by kinesiophobia (fear of movement), leading to inactivity, muscle weakening, and a cycle of pain and disability [26, 27]. Chronic low back pain due to LDH often limits patients' ability to perform daily tasks and fulfill social roles [26–28]. Studies have shown a direct link between pain severity, functional limitations, and poor sleep quality [28, 29].

These impairments contribute to reduced physical activity, emotional well-being, and overall quality of life [30, 31].

Therapeutic exercise during the chronic phase of LDH strengthens lumbar muscles, reduces pain, and improves functional capacity [32–34]. Structured exercise programs have been shown to significantly enhance health outcomes and quality of life, including in elderly populations [32, 34].

Balance and postural impairments in LDH elevate fall risk and pain perception, highlighting the need for postural management [35]. Correcting posture strengthens lumbar muscles, reduces pain, and supports independence in daily activities [36, 37]. Orthotic corsets and posture training are commonly used to lower fall risk. Evaluating fall risk is vital to understand how LDH-related balance deficits affect functional capacity and quality of life [35, 38].

Technological advances, especially virtual reality (VR), are increasingly used in healthcare. VR offers interactive 3D simulations through specialized devices and affordable headsets, enabling use across clinical settings [15, 16, 18, 39, 40]. It effectively enhances motor learning, proprioception, and postural control in neurological and orthopedic rehabilitation—benefits applicable to LDH patients with balance deficits [35, 38]. VR provides real-time sensory feedback and creates a cognitive distraction effect, reducing pain perception and addressing maladaptive behaviors. Its immersive nature may also help alleviate kinesiophobia by promoting active participation in rehabilitation [39].

VR exercise programs have gained attention for their motivational and functional benefits in healthcare. Maynard et al. [41] combined endurance and strength training with VR headsets in hemodialysis patients, while McEwen et al. [42] applied VR-based balance and gait training in post-stroke patients. Despite promising results, VR lumbar exercise studies for LDH patients are limited. Given its capacity to combine physical training with psychological engagement, VR may represent a

cost-effective and motivationally enriched rehabilitation approach for patients with chronic LDH [41, 42].

This study was designed to evaluate the effectiveness of a virtual reality (VR) headset-based exercise intervention on pain, daily living activities, quality of life, and fall risk in individuals with LDH. Potential mechanisms involve cognitive distraction, enhanced motor learning, and proprioceptive feedback. By providing an immersive and interactive environment, VR may reduce pain perception, improve postural control and core stability, and facilitate rehabilitation by alleviating fear of movement, thereby promoting active participation.

Hypotheses:

- H0: VR-based exercise has no effect on pain, daily living activities, quality of life, or fall risk.
- H1a: VR-based exercise reduces pain levels.
- H1b: VR-based exercise improves daily living activities.
- H1c: VR-based exercise enhances quality of life.
- H1d: VR-based exercise reduces fall risk scores.

This study is based on the following theoretical framework. The efficacy of VR-based exercises for patients with LDH can be attributed to multiple mechanisms. VR offers cognitive distraction that may diminish pain perception by diverting attention from discomfort. It also facilitates motor learning and proprioceptive feedback, enhancing postural control and core stability. Furthermore, the immersive experience of VR may reduce kinesiophobia and increase rehabilitation adherence, leading to improvements in daily function, quality of life, and fall risk reduction.

Materials and methods

Study design

This study was registered as a randomized controlled trial (RCT) under the number NCT05463588 on 08/07/2022 at ClinicalTrials.gov and was retrospectively registered. It was conducted and reported in accordance with the CONSORT guidelines.

Participants

Inclusion criteria

Participants had no recent surgery (6 months), uncontrolled diseases, vertigo, joint/knee issues, or severe balance problems; Body Mass Index (BMI) < 40; and no regular pain medication use during the study.

Exclusion criteria

Excluded if uncontrolled diseases, vertigo, balance/joint disorders, recent surgery, cognitive issues, pregnancy, incomplete fall risk tests, missed follow-ups, or lack of consent.

Sample size calculation

Between September 2021 and March 2022, 230 patients were treated at the Physical Therapy and Rehabilitation Unit of Atatürk University Hospital. An a priori power analysis indicated that 64 participants would be sufficient to detect significant effects [41]. During the study, 68 eligible patients who consented were enrolled. Diagnoses were confirmed by a senior physical medicine and rehabilitation specialist with over ten years of experience in musculoskeletal rehabilitation. Sample size was determined using G*Power (v3.1.9.7) based on a clinically meaningful difference in primary outcomes, with an effect size of 0.99, power of 0.80, and alpha of 0.05. No interim analyses or stopping guidelines were organized or implemented throughout the trial. Initially, 73 patients were considered; 5 were excluded (2 COVID-19, 1 declined, 2 incomplete fall risk data), leaving 68 participants (34 VR group, 34 control). Post-hoc analysis confirmed a large effect size (1.00) and power (0.98) at 95% CI. Randomization was done via MedCalc 14, with allocation concealed by opaque envelopes. Power analysis focused on comparing post-test VAS pain scores between groups.

Randomization and allocation concealment

Randomization was performed using MedCalc 14 software, generating a computer-based sequence to ensure unbiased group assignment. Participants had equal chances of being allocated to VR or control groups. An independent researcher, uninvolved in intervention or assessment, managed group assignments. Allocation concealment was maintained using opaque envelopes, keeping assignments confidential until intervention, preventing team bias.

Blinding inability

Blinding was not feasible due to the visible nature of VR intervention, so participants and researchers were aware of group allocation, posing potential bias. To mitigate this, rigorous randomization and allocation concealment were applied. ata were analyzed using Statistical Package for the Social Sciences (SPSS) version 20. Descriptive statistics and normality tests were performed. Independent and paired t-tests, Chi-square tests, effect sizes, and Cronbach's alpha were used based on data type and research questions.

Control of confounding variables

Potential confounders (e.g., age, gender, BMI, baseline pain, functional scores) were controlled by strict inclusion/exclusion criteria. Homogeneity between groups

was verified using t-tests and chi-square tests, showing no significant baseline differences ($p > 0.05$). Intention-to-treat analysis was applied. Missing data were handled using multiple imputation.

Interventions

VR group

"The VR group received standard physiotherapy modalities, including electrotherapy and heat application, alongside lumbar exercise training. Exercises demonstrated during the initial session were later performed using the VR headset. A video with 13 different'Back School Exercises'was shown through the headset, with each exercise repeated at least five times. The first exercise was selected based on the patient's preference and condition. To ensure hygiene, hygienic head pads were used with the VR headset. The researcher was present to intervene in case of emergency.

Control group

The control group received standard physiotherapy modalities, including electrotherapy and heat application, along with lumbar exercise training aimed at improving flexibility, strength, and mobility of the lumbar spine. These exercises were performed in the exercise room during scheduled appointments, without the VR headset. After the study, interested control group patients were offered the opportunity to perform exercises using the VR headset.

Intervention details

Control group

Participants in the control group received a single, 30-min educational session. This session was delivered through a PowerPoint presentation, direct instruction, and a question-and-answer format. The education covered the anatomy of the lower back, causes of lumbar disc herniation, preventive measures, and recommended lumbar exercises. Following the session, participants independently performed the learned exercises over a total of 28 sessions without the use of virtual reality glasses.

Study Group (SG)

Participants underwent VR-based exercise therapy twice daily for 28 sessions. Sessions started at ~ 25 min, reducing to ~ 20 min from week two as strength and flexibility improved. Exercise intensity increased progressively with gains in joint mobility, muscle strength, and movement familiarity. VR videos recorded with a 360° GoPro Max showed four physical therapists demonstrating exercises simultaneously, guided verbally by an instructor. Each exercise was repeated five times per session, with two sessions daily throughout the intervention.

Adherence monitoring

Patient adherence was tracked via daily attendance records and researcher supervision. Participants reported any exercise completion barriers. Adherence rate was calculated as the percentage of completed sessions out of the planned 28.

Number and duration of exercise practices

The standard physical therapy for LDH lasts 3 weeks (15 weekdays). With the first day reserved for lumbar education, the VR group (SG) had 14 days for exercise therapy, completing two sessions daily, totaling 28 sessions. Patients wore comfortable clothing, and sessions were paused if needed, resuming from the last completed movement.

Intervention environment and materials

Exercise Room: A 5×4 m^2 room equipped with a mat and a VR headset for lumbar exercises. No other equipment was used; safety protocols were observed.

Lumbar health protection booklet

Prepared from back school programs, it details lumbar anatomy, posture, and protective exercises with text and illustrations. Reviewed by ten experts prior to use.

Virtual reality headset

Device specs included 64 GB storage, 2560×1440 resolution, and 470 g weight. Thirteen instructor-led lumbar exercise videos were preloaded.

Outcome measures

Questionnaire

A 20-item questionnaire developed based on the literature [2, 27, 28].

Visual Analog Scale (VAS)

Originally developed by Hayes and Patterson in 1921 to assess pain intensity [43]. Participants rate their pain on a 10 cm scale, where 1–4 indicates mild pain, 5–6 moderate pain, and 7–10 severe pain [44]. In this study, the VAS was specifically used to assess low back pain intensity in individuals with lumbar disc herniation.

Oswestry Disability Index (ODI)

Created by Fairbank et al. in 1980 to assess disability from low back pain [45]. Scores are between 0–100%, with higher scores indicating more severe disability. The Cronbach's α coefficient in this study was 0.92.

SF-36 quality of life scale

Developed by Ware in 1987 to assess the physical and mental health-related quality of life [46]. It consists of 36 questions across 8 sub-dimensions: Physical Function,

Social Function, Physical Role Function, Emotional Role Function, Mental Health, Energy and Fatigue, Pain, and General Health. The scores range from 0–100, with higher scores indicating better health. The Cronbach's α for this study ranged from 0.41 to 0.90. The Emotional Role Function sub-dimension was excluded due to low reliability.

Fall risk measurement

Calculated using the Tetrax FB posturography device (Model: Tetrax FB, Manufacturer: Sunlight Medical). The patient places their bare feet on designated pressure areas, and a computer program calculates the fall risk score. Scores are categorized as"Mild Fall Risk"(0–36%),"Medium Fall Risk"(36–58%), or"High Fall Risk"(58–100%) [47].

Variables of the study

Independent variable

Exercise performed using VR headsets.

Dependent variables

Visual Analog Scale (VAS), Oswestry Disability Index (ODI), quality of life scores, and fall risk scores.

Data collection

Conducted via face-to-face interviews using standardized tools, gathering demographic, clinical, pain, medication, and adherence data.

Ethical principles

Approved by Atatürk University Ethics Committee; participants provided informed consent and were informed of withdrawal rights. Study adhered to the Declaration of Helsinki and was registered (NCT05463588). Participants completed questionnaires as part of data collection; nevertheless, patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research. No adverse events or harms were recorded or reported during the intervention period. Participant safety was observed closely by the research team during the study. No important changes were made to the trial protocol after the onset of the study.

Statistical analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 20. Descriptive statistics and normality tests were performed. Independent and paired t-tests, Chi-square tests, effect sizes, and Cronbach's alpha were used based on data type and research questions. No additional analyses were completed.

CONSORT flow diagram

(Fig. 1 CONSORT diagram).

Results

The distribution and comparison of the demographic characteristics of the people who participated in the study are given in Table 1. Both groups were similar in terms of all variables, including mean age (VR group: 51.05 ± 13.39 years; Control group: 53.55 ± 12.25 years) (Table 1).

Although the VAS score difference between the VR and control groups was statistically insignificant in the pretest ($p > 0.05$), the VAS score of the VR group was lower in the posttest ($p < 0.05$). Also, a significant decrease was detected in post-test pain scales in paired measurements in both groups ($p < 0.05$). However, the rate of change was 2.15-fold higher in the VR group (according to the effect sizes) (Table 2).

Although the ODI Score difference between the VR and control groups was insignificant in the pretest ($p > 0.05$), the ODI Score of the VR group was lower in the posttest ($p < 0.05$). Also, a significant decrease was detected in post-test ODI Scores in intragroup measurements in both groups ($p < 0.05$). However, the rate of change was 2.55-fold higher in the VR group (according to the effect sizes) (Table 3).

The difference between the physical function, physical role function, pain, and energy/vitality sub-dimension mean scores of the SF-36 quality of life scale of the VR and control groups was insignificant in the pre-test ($p > 0.05$), the difference in the mean scores in social function, general health perception and mental health sub-dimensions were significant ($p < 0.05$), and the difference between all sub-dimension mean scores was higher in the posttest ($p < 0.05$). Also, a significant increase was detected in all post-test SF-36 quality of life sub-dimension scores in intragroup measurements in both groups ($p < 0.05$). The rate of change in the post-test was between 1.12–8.52 in the VR group (according to the effect sizes) (Table 4).

The fall risk score difference between the VR and control groups was insignificant in the pre-test ($p > 0.05$) and the fall risk score of the VR group was lower in the post-test ($p < 0.05$). Also, post-test fall risk scores of both groups increased at significant levels in the control group, but decreased significantly in the VR group. The rate of change was 4.20-fold higher in the VR group in the posttest (according to the effect sizes) (Table 5).

Discussion

In this section, the findings of the study are discussed by comparing them with similar studies in the literature.

The first hypothesis of the study was "The exercise applied with VR glasses is effective on pain levels". Intra- and intergroup comparisons were made by using VAS pain scale mean scores to verify this hypothesis. The VAS pain score difference between the VR and the control

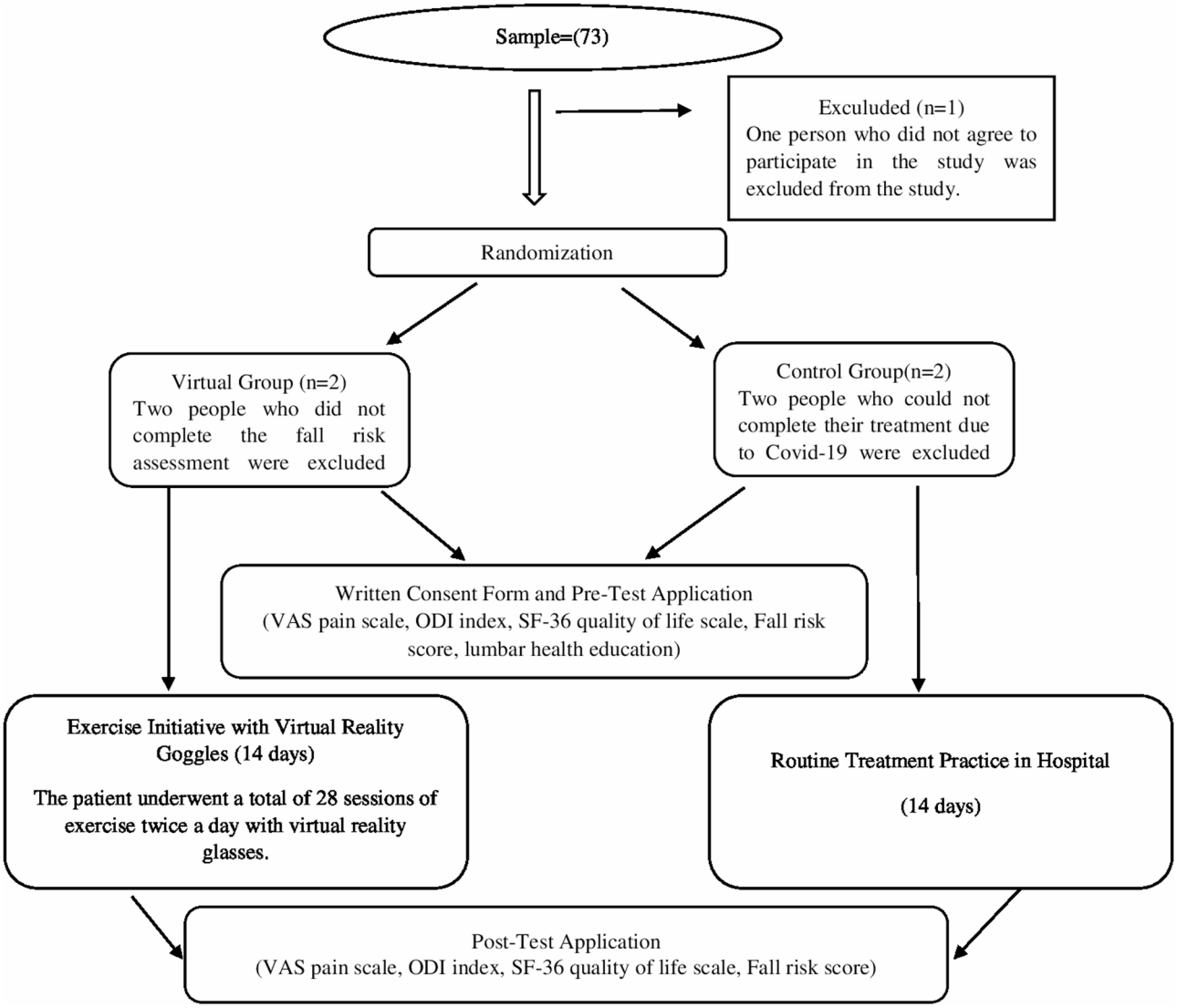

Fig. 1 CONSORT diagram

group was insignificant in the pretest and the VAS pain score difference decreased significantly in the post-test in the VR group. When the paired VAS pain scores were compared, the VR and the control group mean score decreased. When the studies in the literature were reviewed, findings supporting our first hypothesis were obtained. Yelvar et al. [48] reported that trekking exercises done with VR glasses with patients who had low back pain relieved acute pain significantly. Thomas [18] et al. treated 26 patients with chronic low back pain for 3 sessions and 3 weeks, they exercised by playing dodgeball game with virtual glasses and evaluated the pain levels of the patients. As a result of the study, there was no increase in the pain levels of the experimental group as a result of exercise with virtual glasses. found in a study. Alemanno et al. [13] performed virtual back pain monitoring in 20 patients with chronic low back pain in Italy. They applied exercise in a 12-session neurorehabilitation program with the reality system and found that there was a significant decrease in the pain values of the patients. Nambi et al. [16] found that athletes with low back pain exercising with virtual glasses had less pain. Abderaouf et al. [49] reported that exercise performed with VR glasses significantly improved the pain intensity in athletes with low back pain. Rezaei et al. [50] reported that the exercise method performed with VR glasses in patients who had neck pain reduced neck pain. In a study conducted in Turkey, the effect of exercises done with VR glasses in the treatment of a group of patients who had chronic neck pain was investigated and it was found that the improvement was higher in the VR group. [51].

When the present study and other study findings were evaluated, it was found that exercises performed with VR goggles were more effective. One reason for this may

Table 1 The distribution and comparison of the demographic characteristics of the participants

Demographic characteristics			VR group		Control group		Test and significance
			n	%	*n*	%	
Gender	Female		20	58.8	24	70.6	$x^2=1.030$
	Male		14	41.2	10	29.4	$p=0.310$
Marital status	Married		29	85.3	31	91.2	$p=0.709$*
	Single		5	14.7	3	8.8	
House type	Flat		24	70.6	29	85.3	$x^2=2.138$
	Private		10	29.4	5	14.7	$p=0.144$
Income level	Income less than expenses		8	23.5	7	20.6	$x^2=2.441$
	Income equal to expenses		14	41.2	20	58.8	$p=0.295$
	Income more than expenses		12	35.3	7	20.6	
Education level	Literate		7	20.6	10	29.4	$x^2=2.943$
	Primary education		7	20.6	8	23.5	$p=0.567$
	Secondary education		5	14.7	7	20.6	
	High school		9	26.5	4	11.8	
	University		6	17.6	5	14.7	
Profession	Housewife		15	44.1	20	58.8	$x^2=5.466$
	Retired		4	11.8	7	20.6	$p=0.141$
	Officer		7	20.6	5	14.7	
	Self-employment		8	23.4	2	5.9	
BMI	Slim		3	8.8	-	-	$x^2=5.305$
	Normal		4	11.8	2	5.9	$p=0.151$
	Light-weight		14	41.2	12	35.3	
	Obese		13	38.2	20	58.8	
Chronic Disease Status	Yes	Hypertension**	11	32.4	6	17.6	$x^2=0.971$
		Diabetes**	7	20.6	12	35.3	$p=0.324$
		Thyroid**	5	14.7	6	17.6	
		Heart**	2	5.9	-	-	
		Prostate**	2	5.9	4	11.8	
	No		16	47.1	12	35.3	
Diagnosis Duration		0–5 years	9	26.5	6	17.6	$x^2=5.100$
		6–10 years	10	29.4	10	29.4	$p=0.277$
		11–15 years	9	26.5	15	44.1	
		16–20 years	3	8.8	3	8.8	
		21 years and above	3	8.8	-	-	
Vision Problem		Yes	14	41.2	18	52.9	$x^2=0.944$
		No	20	58.8	16	47.1	$p=0.331$
Use of Glasses		Using	14	41.2	18	52.9	$x^2=0.944$
		Not using	20	58.8	16	47.1	$p=0.331$
Duration of Pain Due to LDH		0–5 years	9	26.5	6	17.6	$x^2=4.735$
		6–10 years	10	29.4	11	32.4	$p=0.316$
		11–15 years	9	26.5	14	41.2	
		16–20 years	3	8.8	3	8.8	
		21 years and above	3	8.8	-	-	

*Fisher's Chi-Square Test

**Multiple markings were made

be that virtual reality technology has a stronger impact on the pain center. Additionally, VR exercises may have attracted the participants'attention and increased their motivation due to the novelty of the method. This could have helped them perform exercises more accurately and effectively, leading to a significant improvement in pain perception. Since the reduction in pain made a clinically significant difference, it can be concluded that patients gained more independence in their activities of daily living.

The second hypothesis of the study was "The exercise applied with VR glasses is effective on daily life activities". To check this hypothesis, the mean scores of the ODI were compared between the groups and within the

Table 2 The pre and post-test and intra-group comparison of VAS pain scores in virtual reality and control groups

		Pre-test			Post-test*				Effect size	Effect size difference	Effect size rate
		n	%	*Mean ± SD (Min–Max)*		*n*	%	*Mean ± SD (Min–Max)*			
VR Group*	Mild	-	-	8.32 ± 1.15 (6–10)	Mild	26	76.5	3.38 ± 1.48 (1–6)	d = 3.67	1.96	2.15
	Moderate	2	5.9		Moderate	8	23.5				
	Severe	32	94.1		Severe	-					
Control Group*	Mild	1	2.9	8.00 ± 1.54 (3–10)	Mild	12	35.3	5.06 ± 1.86 (2–8)	d = 1.71		
	Moderate	4	11.8		Moderate	13	38.2				
	Severe	29	85.3		Severe	9	26.5				
Test and Significance**		t = 0.983 (−0.33, 0.98), p = 0.329			t = −4. 118 (−2.49, −0.86), p = **0.000***				-	-	-

Effect Size Difference: determines the magnitude of the difference between two groups

Effect Size Rate: Shows the magnitude of the change rate between the groups

*$p < 0.001$

**The values in parentheses represent the lower and upper bounds of the 95% confidence interval

Table 3 The pre-post-test and intra-group comparison of the ODI index scores of virtual reality and control groups

	Pre-test				Post-test*				Effect size	Effect size difference	Effect size rate
	*ODI index score**	*n*	%	*Mean ± SD (Min–Max)*	*ODI index score**	*n*	%	*Mean ± SD (Min–Max)*			
Virtual Reality Group*	1	-	-	30.38 ± 7.42	1	-	-	14.76 ± 6.92	d = 2.17	1.32	2.55
	2	3	8.8		2	6	17.6				
	3	14	41.2		3	16	47.1				
	4	14	41.2		4	12	35.3				
	5	3	8.8		5	-	-				
Control Group*	1	10	29.4	27.06 ± 6.83	1	-	-	21.59 ± 6.00	d = 0.85		
	2	15	44.1		2	18	52.9				
	3	9	26.5		3	14	47.2				
	4	-	-		4	2	5.9				
	5	-	-		5	-	-				
Test and Significance**				t = 1.922 (−0.26, 13.55) *p* = 0.059	**Test and Significance****			t = 4.346 (−19.92, −7.38) *p* = **0.000*** -		-	-

Effect Size Difference: determines the magnitude of the difference between two groups

Effect Size Rate: Shows the magnitude of the change rate between the groups

1. Low back pain is not an important problem in the patient's life

2. Low back pain restricts the patient's daily life slightly

3. Low back pain limits the patient's daily life severely

4. The patient's daily life is completely restricted because of low back pain

5. The patient is bedridden because of low back pain

*$p < 0.001$

**The values in parentheses represent the lower and upper bounds of the 95% confidence interval

groups. The ODI score difference was insignificant in the pretest between the groups and the VR group ODI score difference decreased significantly in the posttest. When the paired ODI mean scores were compared, the VR and control groups mean score decreased. When the literature was reviewed, some studies measured the effect of using virtual glasses on individuals with LDH on activities of daily living with the ODI Index. In their study, Fotoye et al. [15] used exercises with VR glasses in LDH patients for 8 weeks and reported that activities of daily living decreased significantly ODI score. In a double-blind randomized study, Ecclestona et al. [52] had patients with LDH exercise with a game loaded into virtual reality goggles and evaluated the limitation effect on activities of daily living. The ODI index score of the group exercising with virtual glasses decreased significantly after the intervention. In the last two years. In their randomized controlled study, Afzal et al. [53] used exercises in a group of LDH patients who had VR glasses and found that their ODI score decreased. As a result of the literature review, different findings were found with the hypothesis of the research. For example, in the study

Table 4 The pre-post-test and intra-group comparison of SF-36 scale sub-dimensional scores of virtual reality and control groups

SF-36 scale sub-dimensions	Group	Pre-test score *Mean ± SD (Min–Max)*	Post-test score *Mean ± SD (Min–Max)*	Test and significance**	Effect size difference	Effect size rate
Physical Function	Virtual Reality Group ($n=34$)	45.29 ± 17.62	74.26 ± 16.38	t = −11.526 (−6.82, −4.77) $p=$ **0.000*** d = 1.70	1.04	2.57
	Control Group ($n=34$)	42.94 ± 22.33	57.21 ± 20.93	t = −7,456 (−3.63, −2.07) $p=$ **0.000*** d = 0.66		
	Test and Significance**	t = 0.482 (−1.48, 2.42) $p=0.631$	t = 3.742 (1.59, 5.23) $p=$ **0.000***			
Social Function	Virtual Reality Group ($n=34$)	25.16 ± 12.32	58.17 ± 15.49	t = −10.795 (−3.53, −2.41) $p=$ **0.000*** d = 2.33	1.42	2.56
	Control Group ($n=34$)	15.69 ± 13.15	27.12 ± 11.98	t = −6.406 (−1.36, −0.70) $p=$ **0.000*** d = 0.91		
	Test and Significance**	t = 3.066 (0.30, 1.41) $p=$ **0.003***	t = 9.244 (1.28, 2.25) $p=$ **0.000***			
Physical Role Function	Virtual Reality Group ($n=34$)	11.03 ± 20.58	75.00 ± 30.77	t = −11.843 (−3.00, −2.41) $p=$ **0.000*** d = 2.36	0.64	1.37
	Control Group ($n=34$)	4.41 ± 11.47	30.88 ± 17.47	t = −7.582 (−1.34, −0.84) $p=$ **0.000*** d = 1.72		
	Test and Significance**	t = 1.637 (−0.02, 0.60) $p=0.108$	t = 7.270 (2.19, 3.40) $p=$ **0.000***			
Mental Health	Virtual Reality Group ($n=34$)	37.65 ± 16.77	59.18 ± 7.09	t = −8.316 (−6.70, −4.07) $p=$ **0.000*** d = 1.48	0.16	1.12
	Control Group ($n=34$)	27.65 ± 12.12	42.35 ± 8.87	t = −10.909 (−4.36, −2.99) $p=$ **0.000*** d = 1.32		
	Test and Significance**	t = 2.818 (0.01, 0.52) $p=$ **0.006***	t = 8.641 (3.23, 5.18) $p=$ **0.000***			
Energy/Vitality	Virtual Reality Group ($n=34$)	30.29 ± 15.22	57.35 ± 13.50	t = −11.552 (−6.36, −4.46) $p=$ **0.000*** d = 1.87	1.32	3.40
	Control Group ($n=34$)	27.50 ± 10.75	33.53 ± 11.11	t = −4.317 (−1.77, −0.64) $p=$ **0.000*** d = 0.55		
	Test and Significance**	t = 0.874 (−0.72, 1.83) $p=0.385$	t = 7.945 (1.28, 2.25) $p=$ **0.000***			
Pain	Virtual Reality Group ($n=34$)	18.30 ± 12.79	54.25 ± 13.88	t = −12.588 (−3.76, −2.71) $p=$ **0.000*** d = 2.69	1.36	2.02
	Control Group ($n=34$)	14.71 ± 12.15	30.07 ± 10.78	t = −6.825 (−1.79, −0.97) $p=$ **0.000*** d = 1.33		
	Test and Significance**	t = 1.188 (−0.22, 0.87) $p=0.239$	t = 8.022 (1.63, 2.72) $p=$ **0.000***			

Table 4 (continued)

SF-36 scale sub-dimensions	Group	Pre-test score *Mean ± SD (Min–Max)*	Post-test score *Mean ± SD (Min–Max)*	Test and significance**	Effect size difference	Effect size rate
General Health Perception	Virtual Reality Group ($n=34$)	28.98 ± 18.45	57.06 ± 16.01	t = −9.528 (−6.82, −4.42) $p=$ **0.000*** d = 1.62	1.43	8.52
	Control Group ($n=34$)	19.71 ± 14.56	22.35 ± 12.75	t = −0.934 (−1.68, 0.62) $p=$ **0.000*** d = 0.19		
	Test and Significance	t = 2.298 (0.24, 3.46) $p=$ **0.025**	t = 9.890 (5.54, 8.34) $p=$ **0.000***			

Effect Size Difference: determines the magnitude of the difference between two groups

Effect Size Rate: Shows the magnitude of the change rate between the groups

*$p<0.001$

**The values in parentheses represent the lower and upper bounds of the 95% confidence interval

Table 5 The pre-post-test and intra-group comparison of fall risk scores of virtual reality and control groups

	Pre-test				Post-test*				Effect size	Effect size difference	Effect size rate
	Degree of Risk	*n*	*%*	*Mean ± SD (Min–Max)*	*Degree of Risk*	*n*	*%*	*Mean ± SD (Min–Max)*			
VR Group*	Mild	-	-	67.91 ± 20.88 (37–100)	Mild	7	10.3	50.56 ± 20.59 (12–92)	d = 0.84	6.40	4.20
	Moderate	11	32.4		Moderate	18	52.9				
	Severe	23	67.6		Severe	9	26.5				
Control Group*	Mild	-	-	63.56 ± 20.06 (37–100)	Mild	-	-	67.47 ± 19.27 (40–100)	d = 0.20		
	Moderate	15	44.1		Moderate	14	41.2				
	Severe	19	55.9		Severe	10	58.8				
Test and Significance**	t = 0.877 (−5.56, 14.27), $p=0.384$				t = −3.497 (−26.57, −7.26), $p=$ **0.001**				-	-	-

Effect Size Difference: determines the magnitude of the difference between two groups

Effect Size Rate: Shows the magnitude of the change rate between the groups

*$p<0.001$

**The values in parentheses represent the lower and upper bounds of the 95% confidence interval

of Li et al. [54, 55], exercises done with VR did not affect the activities of daily living.

Considering the results from the literature, we believe that the ODI (Oswestry Disability Index) score decreased more in the VR group in this study. The exercises performed with VR goggles showed an improvement that exceeded the MCID threshold by increasing the individuals'range of motion, supporting flexibility, enhancing muscle strength control, and fostering independence in daily life. This suggests that VR-based exercises made a clinically meaningful difference, and participants gained more independence in activities of daily living.

The third hypothesis of the study was "The exercise applied with VR glasses is effective on quality of life". The SF-36 quality of life scale was used to evaluate this hypothesis. Significant differences were found in the pre-test between the VR and control groups in the social function, mental health, and general health perception sub-dimension scores. VR and control group SF-36 scale mean scores increased in all sub-dimensions in the post-test, and the difference between the scores was statistically significant. Paired SF-36 scale sub-dimension mean scores increased in the VR and the control groups. When the results of the study were evaluated, a limited number of studies supporting the third hypothesis of the study were found. Yalfani et al. [34]. conducted a double-blind randomized study and found that exercise performed with VR glasses in elderly women with LDH significantly improved their quality of life. Alemanno et al. [13] had patients who had LDH exercise with VR for 6 weeks and found that the patient's quality of life improved. Mbada et al. [32] found that exercise given to individuals with LDH with VR glasses improved the energy and vitality dimensions of the quality of life.

In the literature, there are also studies examining the effect of exercise with virtual reality glasses on quality of life in different disease groups. García-Bravo et al. [56] on virtual heart patients exercise with reality improves the quality of life of the people in the experimental group has

been found. Again, patients with fibromyalgia were made to exercise with virtual reality glasses for 8 weeks and it was found that the mental health dimension of quality of life improved [57]. Virtualization applied on Parkinson's patients for 6 weeks reality exercise has been found to positively affect quality of life [58].

In this context, the study by Wójcik et al. [59] emphasizes that the quality of life in women during pregnancy is significantly affected by factors such as back and pelvic pain. Similarly, in our study, it is observed that exercises performed with VR glasses improved the quality of life of individuals with conditions such as back pain. These findings allow us to assess the potential of VR technology to improve quality of life from a broader perspective.

In line with these results, in the present study, we suggest that the reason for the improvement in the average quality of life score in the VR group was that exercises performed with VR goggles facilitated the participants'adaptation to the exercises, increased their motivation, reduced their fear and anxiety, and made the exercise experience more enjoyable and sustainable. Furthermore, these improvements likely exceeded the MCID threshold, indicating that the changes in quality of life were clinically meaningful. This suggests that VR-based exercises contributed to significant improvements in both the physical and psychological aspects of the participants'health, which were perceivable to the participants themselves.

The condition in which exercise increases the pain threshold is known as exercise-induced hypoalgesia. This mechanism is generally considered to be at play during exercise to some extent. A detailed discussion on this aspect is essential for a more comprehensive understanding of the study's implications. The final hypothesis of the study was "The exercise applied with VR glasses is effective on fall risk scores". A balancing device connected to a computer was used in the evaluation of this hypothesis. Although there were no significant differences between the VR and control group fall risk averages in the pre-test, the fall risk average of the VR group was lower in the post-test. When the mean fall risk scores within the group were compared, the scores decreased in the VR group but increased in the control group. A limited number of studies were found in the literature that had similar results to our results.In the study of Yalfani et al. [34], it was found that the risk scores of the LDH elderly women were reduced by exercising with VR glasses.

In the literature, there are also studies examining the effect of exercise with virtual reality glasses on fall risk scores in different disease groups. Zahedian-Nasab et al. [60], Phu et al. [61], Sadeghi and Shojaedin [62], had a group of elderly people exercise with virtual reality glasses and assessed their risk of falling. As a result of the studies, the risk of falls decreased in the last two years. Three patients who had suffered a stroke were given 25 sessions of exercise with virtual reality goggles and their fall risk scores were reduced [63].

As a result of the data from our study, it can be inferred that the visual and auditory feedback provided by the exercises perfor med with VR glasses had positive effects on the brain's balance center, contributing to a significant reduction in fall risk within the VR group. Moreover, the fact that the level of fall risk reduction exceeded the MCID (Minimum Clinically Important Difference) threshold suggests that this improvement is clinically meaningful. These exercises also helped patients gain greater independence in their daily activities, underscoring that VR-based exercises not only foster physical and functional recovery but also provide significant safety benefits.

The positive outcomes observed in the VR group regarding pain, quality of life, and fall risk can be explained by various biological and psychological mechanisms. The visual and auditory stimuli provided by VR technology may divert attention away from pain and activate central analgesic pathways, leading to exercise-induced hypoalgesia [64]. Additionally, the gamified and interactive nature of VR can enhance participants'motivation and improve adherence to exercise protocols. The reduction of kinesiophobia and anxiety may further support engagement. Feedback mechanisms may contribute to improved postural control and more effective functioning of the balance system. Collectively, these factors suggest that VR-based exercises offer benefits not only in physical rehabilitation but also in psychological well-being.

Clinical significance

This study highlights VR exercise benefits in lumbar disc herniation rehab, filling a literature gap on pain, function, quality of life, and fall risk. VR offers clinicians a cost-effective tool to enhance engagement and reduce workload, while providing patients a motivating, interactive rehab option that improves mobility and reduces pain.

Future research considerations

Future studies should assess VR exercise effectiveness in diverse populations, including varied ages, genders, body types, and health conditions, to enhance generalizability. Investigating individual factors and long-term effects on pain, balance, and quality of life will clarify the sustainability of benefits.

Conclusion

This study found that VR-based exercises significantly reduced pain, improved daily living independence, enhanced quality of life, and lowered fall risk in LDH patients. No adverse events were noted in either group.

Study limitations

This study was limited to a single hospital due to lack of fall risk devices in others. Blinding was not feasible since participants knew their VR group assignments.

Strengths of the study

Exercises used innovative VR technology, providing an immersive experience beyond traditional methods. The randomized controlled pre-post design enhanced reliability by directly comparing patient progress and intervention effects.

Abbreviations

LDH	Lumbar Disc Herniation
LBP	Low Back Pain
VR	Virtual Reality
VAS	Visual Analog Scale
ODI	Oswestry Disability Scale
SD	Standart Deviation
N	Number of Participants in the sample
x^2	Chi-sguare

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Authors' contributions

Author 1: Study design (equal), data collection (equal), manuscript preparation (equal). Author 2: Data analysis, manuscript preparation (equal).

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was performed in accordance with the Declaration of Helsinki and written informed consent was obtained from all participants. The study was approved by the local regional ethical board in Ataturk university Nursing faculty (Ethics Committee No: 2019–6/9).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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