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ORIGINAL ARTICLE

The effect of visual feedback-based clinical monitoring application in patients with chronic low back pain: a randomized controlled trial

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Abstract

Purpose No study has addressed the effect of patient-reported outcomes as a visual feedback tool during telerehabilitation. This study aimed to investigate the effect of a visual feedback-based monitoring application *PhysioAnalyst* on pain, pain catastrophizing, physical functions, quality of life, usability, satisfaction, and exercise adherence in individuals with chronic low back pain (CLBP).

Methods A single-blind, randomized controlled trial was conducted with 44 CLBP patients. Participants were randomized into two groups: the tele-assessment feedback group (TAFG) ($n=22$) and the control group (CG) ($n=22$). Participants were assessed before the intervention, at the 4th week and after the intervention. Individuals were assessed using the Visual Analog Scale (VAS), Nottingham Health Profile (NHP), Pain Catastrophizing Scale (PCS), Oswestry Disability Index (ODI), Telehealth Usability Questionnaire (TUQ), Telemedicine Satisfaction Questionnaire (TSQ), and Exercise Adaptation Rating Scale (EARS) via *PhysioAnalyst*. Individuals in the TAFG group received graph-based visual feedback on assessment data in week 4.

Results The improvement in VAS, NHP, ODI, TUQ, TSQ, and EARS of individuals in TAFG was statistically significant ($p<0.05$). Only ODI and PCS scores in CG showed significant improvement ($p<0.05$). After the graphics-based visual feedback presented to the TAFG, the VAS, NHP-Emotional, NHP-Sleep, NHP-Total, PCS, TUQ, TSQ, ODI, and EARS scores gained more than CG ($p<0.05$).

Conclusion The results confirmed the additional contribution of telerehabilitation's graphics-based visual feedback in pain, pain catastrophizing, disability, quality of life, and exercise participation. Since the importance of continuity in long-term rehabilitation in patients with CLBP is comprehended, feedback to increase patient motivation can be added to telerehabilitation applications.

Keywords Low back pain · Rehabilitation · Telerehabilitation · Visual feedback

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Introduction

Telerehabilitation has been frequently used in physiotherapy and rehabilitation clinical practice in recent years. Remote rehabilitation of musculoskeletal system problems provides clinicians practicality in-home exercises, patient monitoring, and management process [1, 2]. Since rehabilitation in individuals with chronic pain should be long-term, physiotherapists specifically consider telehealth applications [3].

Chronic low back pain, a frequent musculoskeletal problem in the last decades, is practically managed by telehealth applications [4, 5]. Recent randomized controlled trials have demonstrated the effectiveness of remote physiotherapy and rehabilitation interventions in individuals with chronic low back pain. Evidence-based practical implications have

shown that telerehabilitation provides efficient clinical outcomes in improving pain, function, and quality of life [6, 7].

Telerehabilitation is usually presented to individuals through mobile applications or platforms [8]. In recent years, studies have also demonstrated that remote patient assessment is as practical as face-to-face assessment. In addition, some studies indicated the agreement between tele- and face-to-face assessment methods [9, 10]. Current psychometric studies also have emphasized the inter-rater and intra-rater reliability of tele-assessment protocols regarding the range of motion and clinical/physical performance tests [11, 12].

A development study has reported that remote monitoring of patients' clinical outcomes and feedback on their performance can positively impact physiotherapy and rehabilitation outcome [13]. Current mobile applications process individuals' sensor-based movement assessment result data and generate graphical outputs, aiming to increase the efficiency of rehabilitation by providing visual feedback to patients [13–16]. In addition, video-conferencing-based assessment methods have been addressed in some studies within the scope of telerehabilitation applications, indicating promising results in terms of practical use [17].

During remote exercise sessions, data on inertial or infrared sensors (e.g., Kinect) provides visual feedback to patients, improving their physical performance, and clinical outcomes [13]. In addition, the graphical presentation of the sensor data for evaluation by the therapist is also crucial for regulating the rehabilitation progression and adjusting the exercise prescription [15, 16].

Tele-assessment studies have generally addressed the assessment results of objective tools. Although motion analysis, sensor-based data, performance tests, or device-based data may provide precise clinical measurements, the ease of use and accessibility issues restrict the effective use of these technologies in clinical practice. Practical assessment tools based on subjective patient data can be used more efficiently, particularly during telerehabilitation [18]. A recent study emphasized that tele-assessment is a valid and reliable method in a patient-reported outcome measure (PROM)-based analysis [19]. However, to our knowledge, no study has addressed the effect of patient assessment outcomes on PROMs as a visual feedback tool during rehabilitation.

Patients' self-monitorization of their clinical progress on PROMs can provide additional motivation and adherence to the rehabilitation. The patient's rehabilitation satisfaction and related outcomes may also be enhanced if they can practically follow their clinical progress through a tele-assessment mobile application. This study aimed to examine the effect of a visual feedback-based clinical monitoring application on pain, pain catastrophizing, physical functions, quality of life, usability, satisfaction, and exercise adherence in individuals with chronic low back pain. Based on the fact that individuals who observe their pain, function, and participation with a table or chart of the change in the clinical situation will adopt their rehabilitation more concretely. Therefore, the present study was focused on the purpose that individuals can adopt the awareness of good or bad clinical courses.

Materials and methods

Study design and recruitment

The randomized controlled study was conducted with chronic low back pain patients in Department of Orthopaedics and Traumatology, Muğla Sıtkı Koçman University between April to July 2023. The study was carried out following the consolidated standards of reporting trials (CONSORT) and taking into account the recommendations of standard protocol items: SPIRIT (Statement of Recommendations for Interventional Trials) [20]. A total of 52 patients were invited to participate in the study. Participants were informed about the research, and their consent was obtained. Inclusion criteria were as follows: (1) individuals with low back pain for at least three months, (2) patients diagnosed with chronic low back pain by an orthopedics and traumatology physician regarding the American Pain Society AAPT Diagnostic Criteria for chronic low back pain, (3) patients between the ages of 18 and 65, (4) patients with no radicular symptoms, (5) individuals who do not have communication problems, (6) individuals with no comorbid diseases, and (7) patients with available telerehabilitation equipment. Exclusion criteria were: (1) spine surgery, (2) malignancy, and (3) pregnancy. Eight individuals were excluded due to various criteria (Fig. 1). As a result, a total of 44 individuals were randomized to the tele-assessment feedback group (TAFG) ($n=22$) and the control group (CG) ($n=22$).

Sample size

The sample size was calculated with G-Power 3 [21]. A preliminary calculation with reference values from a recent randomized controlled trial focusing on the efficacy of telerehabilitation for chronic low back pain showed that an effect size of 0.79 could be assumed [7]. A total of 44 individuals were determined to be required with 80% power and 95% confidence level.

Ethical consideration

The study was carried out in accordance with the ethical principles and the Helsinki Declaration. Informed consents of the patients were obtained. The study protocol was approved by the ethics committee of Muğla Sıtkı Koçman University (No: 220139/155, Approval Date: 29.12.2022).

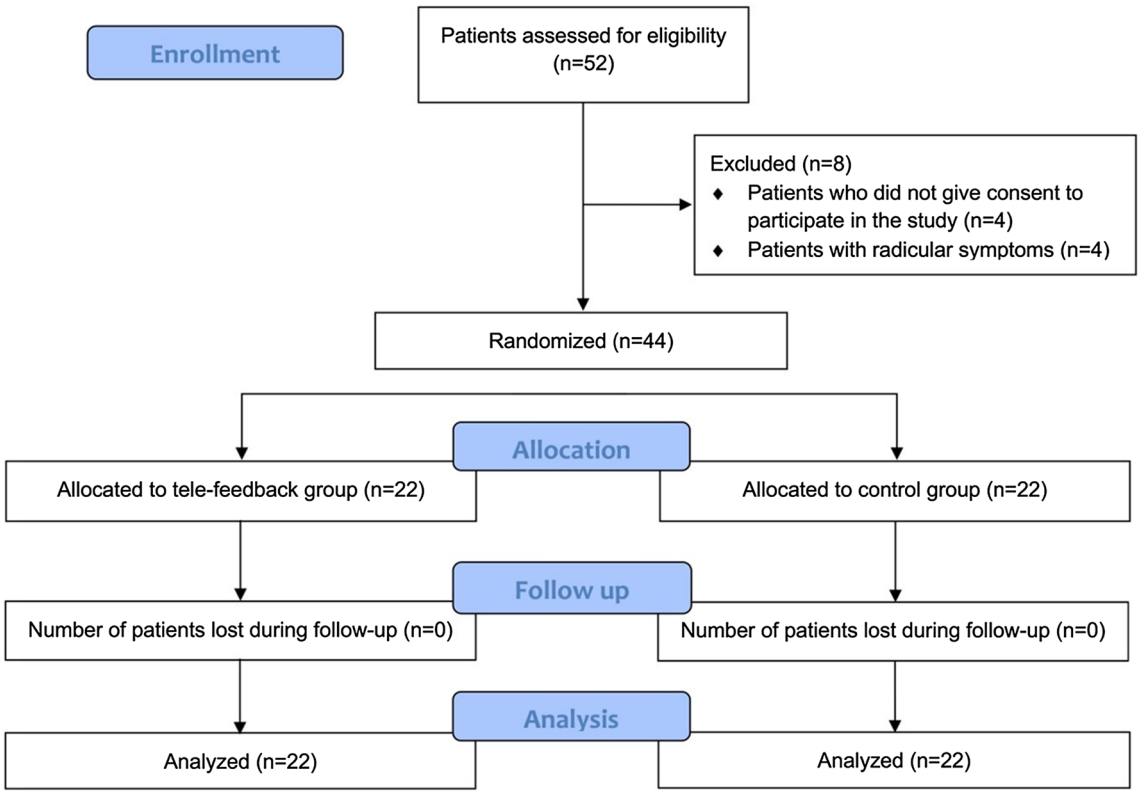

Fig. 1 CONSORT flow chart of the study

The study protocol was prospectively registered (ClinicalTrials.gov Identifier: NCT05816824).

Randomization and blinding

A single blinded physiotherapist carried out three assessment sessions of the study. The "National Institutes of Health National Cancer Institute Clinical Trial Randomization Tool" was used to randomize the participants to the groups. The randomization method included an allocation scheme using the asymptotic maximal procedure [22]. Participants identifying information was kept confidential.

Interventions

The *PhysioAnalyst* application was used for tele-assessment (Fig. 2). PhysioAnalyst is a mobile application that provides tele-assessment with PROMs, developed exclusively for this academic research. The web application has three main parts: (1) a physiotherapist interface, (2) a patient interface, and (3) admin panel. The administrator registers the patient. The physiotherapist sends the electronic PROMs to the patient. The patient completes the assessments and receives graphical (table, chart) feedback on the PROM's output. Physiotherapists can observe the progress of their patients on the same graphs.

Tele-assessment feedback group (TAFG)

Individuals in TAFG received a video exercise-based home exercise program after an initial assessment on *PhysioAnalyst*. Current clinical guidelines were used to determine the exercises. Exercise protocols (stretching exercises, strengthening exercises, core stabilization exercises, Williams' flexion exercises, and McKenzie extension exercises) were determined according to the needs of the patients within the framework of ethical principles [23]. Each individual performed two sets of 10 repetitions every day of the week. At the end of the 4th week, the patients were re-evaluated with *PhysioAnalyst*. Patients monitored their clinical score development based on graphical feedback via *PhysioAnalyst* at this stage. After the second 4-week exercise period, patients completed the questionnaires with *PhysioAnalyst* for the third time.

Control group (CG)

Individuals in CG were followed up for 4 weeks with the same video exercise protocol as TAFG after the first

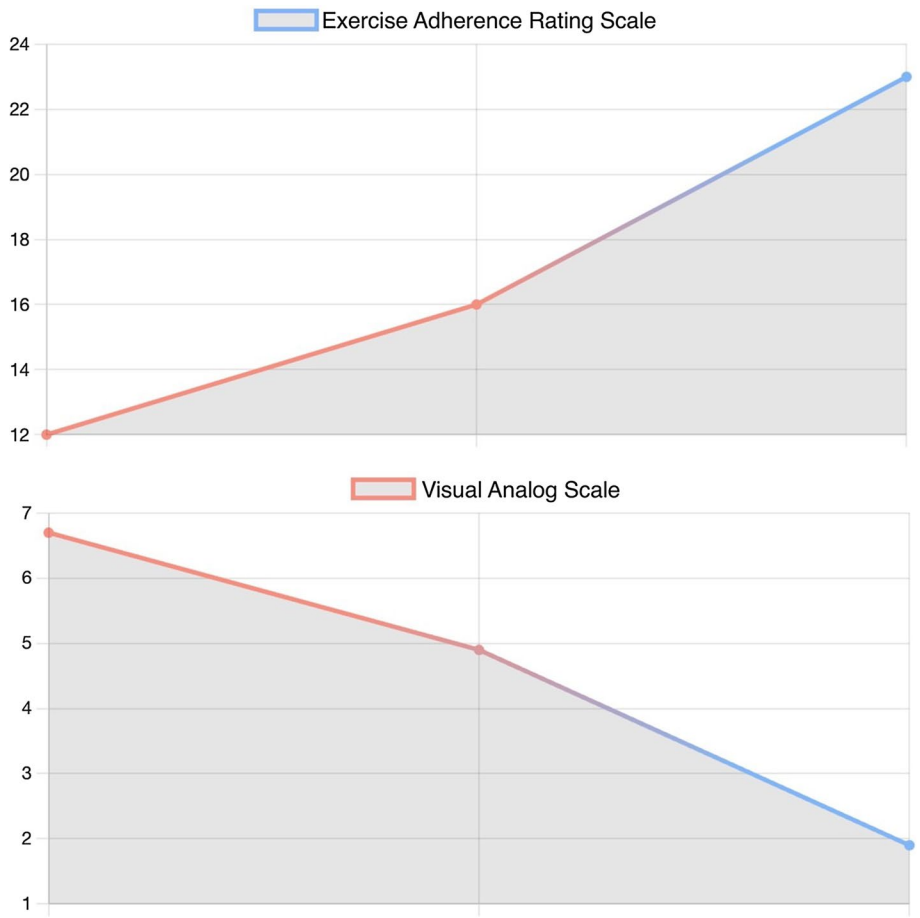

Fig. 2 *PhysioAnalyst* application: graph-based visual feedback samples

evaluation with *PhysioAnalyst*. After the second evaluation, the patients were included in the second 4-week exercise without visual feedback. At the end of 8 weeks, the final evaluation of the individuals was completed again on *PhysioAnalyst*, and the intervention program was terminated.

Data collection

Participants were evaluated before, during the 4th week of rehabilitation and after the intervention (end of the 8 week). During the initial registration process, the age, gender, height, and weight of the participants were taken by the administrator. Individuals were assessed using the visual analog scale, Nottingham Health Profile, Pain Catastrophizing Scale, Oswestry disability index, Telehealth usability questionnaire, Telemedicine satisfaction questionnaire, and Exercise adherence rating scale via PhysioAnalyst.

Visual analog scale (VAS)

The patient is asked to mark their pain on a 10 cm straight line or numeric scale (0: no pain, 10: unbearable pain). Numeric VAS was used in our study. A VAS value of 3.4 and lower indicates mild pain, 3.5–7.4 indicates moderate pain and 7.5 and higher indicates severe pain [24].

Nottingham health profile (NHP)

The Turkish version of the 38-item measure was validated by Küçükdeveci et al. The measure comprises six subcategories testing physical activity, energy, pain, social isolation, sleep, and emotional reactions. The scores for each subcategory and total scores are calculated to assess quality of life. Scores range from 0 to 100 for each subcategory. Low scores indicate a low impact of the complaint/incident, and high scores indicate a high impact of the complaint/incident [25].

Telehealth usability questionnaire (TUQ)

The questionnaire consists of 21 items assessing the remote rehabilitation service. The questionnaire addresses usability, ease of use and learnability, interface quality, interaction quality, reliability, and satisfaction. The TKA uses a 7-point Likert-type scale (1 = disagree, 7 = agree). The total score is calculated by summing the 21 items. The validity and

reliability of the Turkish version was performed by Özden et al. [26].

Pain catastrophizing scale (PCS)

The Turkish version was validated by Süren et al. [26]. PCS assesses the patient's feelings and thoughts about pain and disaster. It is a self-administered questionnaire consisting of 13 items and three subscales. A 5-point Likert design is used for each item, with higher values representing greater catastrophizing. The subscales are determined by summing the scores of each item, and a total score is calculated by summing all items. The total score ranges from 0 to 52 points [27].

Oswestry disability index (ODI)

The Turkish version was validated by Yakut et al. (2001). The Oswestry Disability Index consists of 10 questions measuring functional status. Each question is evaluated between 0 and 5 points, and the maximum score is 50. A higher score indicates more disability [28].

Telemedicine satisfaction questionnaire (TSQ)

This questionnaire consists of 14 items. It assesses patients' level of satisfaction with the software or system through which they receive treatment or other remote rehabilitation services. The questionnaire uses a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The total score ranges from 14 to 70 for 14 questions, with a maximum score of 5. The Turkish validity and reliability of the questionnaire were performed by Özden et al. [26].

Exercise adaptation rating scale (EARS)

A Turkish version was conducted by Korkmaz et al. It assesses the adherence level of the patients to the exercise program. EARS was performed on the first day and after 8 weeks [29].

Statistical analysis

All analysis was conducted by SPSS (Statistical Package for Social Sciences) for Windows v25.0 (SPSS Inc, IBM Corp, Armonk, New York). The mean and standard deviation (SD) for quantitative variables were reported. For qualitative variables, percentages (%) were presented. The statistical significance level was set at $p < 0.05$. In the statistical analysis test decision, the conformity of all the data to the normal distribution was examined by conducting the one-sample Kolmogorov–Smirnov test and drawing a histogram. Parametric and non-parametric tests were used according to the homogeneity of the data. Independent sample *t* test was used for comparison of independent group differences when parametric test assumptions are met; when parametric test assumptions were not met, the Mann–Whitney *U* test was used to compare independent group differences. In addition, chi-square analysis was used for categorical variables in independent group comparisons. In dependent group comparisons, when parametric test assumptions are provided, paired *t* test was used; when parametric test assumptions were not met, Wilcoxon signed-rank test was used.

Results

Patient characteristics

The study was conducted with 44 individuals (44.86 ± 12.41 years, 25 women, and 19 men) in total. The demographic characteristics of the participants were similar ($p > 0.05$). The results showing the demographic characteristics of the participants are given in Table 1.

Pain

There was a significant difference in VAS score between the groups with TAFG being better at all time points ($p < 0.05$). There was a significant difference in VAS scores between the three measurement points in the TAFG group ($p < 0.05$). There was no significant difference between the measurement points in the CG group ($p > 0.05$). Statistical results of VAS are presented in Tables 2 and 3.

Nottingham health profile

In the difference in change between the first and second time point, TAFG was significantly better in the NHP-Social Isolation subscore ($p < 0.05$). TAFG was significantly better in the difference in change between the second and third time point, NHP-Emotional, Sleep subscore, and first and second section total scores ($p < 0.05$). TAFG was significantly better in the difference in change between the first and third time point, NHP-Pain, Emotional, Sleep, subscore, and first section total scores ($p < 0.05$). There was no significant difference between the groups in other parameters ($p > 0.05$). There was a significant difference in all NHP scores between the three assessment points in the TAFG group ($p < 0.05$). There was no significant difference between measurement points in any parameter in the CG group ($p > 0.05$). Statistical results of NHP are presented in Tables 2 and 3.

Table 1 Baseline characteristics of the participants

	TAFG ($n=22$)	CG ($n=22$)	p
Gender (female/male, %)	68.2/31.8	45.5/54.5	0.128[a]
Age (years, mean ± SD)	43.5 ± 12.58	46.22 ± 12.38	0.473[b]
Height (m, mean ± SD)	1.66 ± 0.08	1.69 ± 0.08	0.311[c]
Weight (kg, mean ± SD)	69.04 ± 11.74	75.68 ± 13.13	**0.08**[c]
BMI (kg/m^2, mean ± SD)	24.79 ± 3.94	26.34 ± 4.02	0.113[c]
VAS	5.6 ± 1.88	4.28 ± 1.73	**0.035**[c]
NHP-Pain	46.23 ± 28.62	30.92 ± 19.29	0.070[c]
NHP-Emotional	34.91 ± 34.6	17.41 ± 22.05	0.086[c]
NHP-Sleep	32.89 ± 29.27	15.88 ± 26.3	**0.012**[c]
NHP-Social Isolation	19 ± 32.6	7.91 ± 23.26	0.095[c]
NHP-Physical	32.73 ± 22.49	30.85 ± 16.86	0.768[c]
NHP-Energy	34.4 ± 39.9	26.98 ± 36.73	0.496[c]
NHP-First Section Total	200.19 ± 115.15	129.98 ± 103.97	**0.024**[c]
NHP-Second Section Total	2.81 ± 2.3	2.36 ± 1.73	0.527[c]
PCS	20.00 ± 11.19	19 ± 9.8	0.796[c]
TUQ	102.59 ± 30.66	119.18 ± 29.72	0.054[c]
TSQ	55.18 ± 10.56	57.86 ± 12.46	0.305[c]
ODI	33.23 ± 15.59	23.09 ± 13.85	**0.044**[c]
EARS	15.31 ± 3.95	13.13 ± 4.49	**0.040**[c]

n the number of participants; *TAFG* tele-assessment feedback group; *CG* control group; *BMI* body mass index; *SD* standard deviation; *kg* kilogram; *m* meter

Bold mark indicates a statistical significant difference

[a]Pearson Chi-Square test

[b]Independent sample *t* test

[c]Mann–Whitney *U* test

Pain catastrophizing scale

In the difference of change between the second and third time point and the first and third time point, TAFG was significantly better in PCS score ($p<0.05$). There was no significant difference between the groups in PCS between the first and second time point change score ($p>0.05$). There was a significant difference in PCS score between the first, second, and third evaluation times in the TAFG and CG groups ($p<0.05$). Statistical results of PCS are presented in Tables 2 and 3.

Telehealth usability questionnaire and telemedicine satisfaction questionnaire

TAFG was significantly better in the change scores between the second and third measurement points and between the first and third measurement points, TUQ and TSQ scores ($p<0.05$). There was no significant difference between the groups in the change scores between the first and second measurement points, TUQ and TSQ scores ($p>0.05$). There was a significant difference in TUQ and TSQ scores between the three different measurement points in the TAFG group ($p<0.05$) but not in the CG group ($p>0.05$). Statistical results of TUQ and TSQ are presented in Tables 2 and 3.

Oswestry disability index

In the change scores between the second and third assessment points and between the first and third assessment points, TAFG was significantly better in the ODI score ($p<0.05$). There was no difference between the groups in the change scores between the first and second assessment points and in the ODI score ($p>0.05$). There was a significant difference in ODI score between the measurement times in both groups ($p<0.05$). Statistical results of ODI are presented in Tables 2 and 3.

Exercise adherence rating scale

In the change scores between the second and third evaluations and between the first and third evaluations, TAFG was significantly better in the EARS score ($p<0.05$). There was no significant difference between the groups in EARS in the change score between the first and second evaluations ($p>0.05$). There was a significant difference in EARS score between different assessment times within the TAFG group ($p<0.05$). By contrast, the EARS score in CG was not significantly different between the assessment times ($p>0.05$). Statistical results of EARS are presented in Tables 2 and 3.

Discussion

This study investigated the effect of graphic-based visual feedback in individuals with chronic low back pain. In addition to video exercises, we investigated the hypothesis that this effect would increase motivation and activation with visual feedback graphics provided to patients through the same web-based mobile application. The study's results confirmed the additional contribution of graphic-based visual feedback provided by telerehabilitation in pain, pain catastrophizing, disability, quality of life, and exercise participation. Since the importance of continuity in long-term rehabilitation in patients with chronic low back pain is comprehended, feedback applications that increase patient motivation can be added to telerehabilitation applications.

The study sample included the identical individual characteristics of the two groups in terms of age, gender, and body mass index. This outcome confirmed that the two groups were homogeneous regarding their physical characteristics. The essence of homogeneity between groups in randomized controlled trials is also underlined in CONSORT guidelines [30]. Since the possible influence of physical

Table 2 Outcome measures between groups

		TAFG ($n=22$)	CG ($n=22$)	p (between group)
VAS*	Δ_{1-2} (mean change, 95% CI)	−1.7 ± 2.0 (−2.65 to −0.87)	−0.49 ± 1.1 (−0.98 to −0.00)	**0.012**[a]
	Δ_{2-3} (mean change, 95% CI)	−2.8 ± 1.87 (−3.63 to −1.96)	−0.38 ± 1.3 (−0.95 to 0.19)	**0.001**[a]
	Δ_{1-3} (mean change, 95% CI)	−4.5 ± 1.3 (−5.16 to −3.97)	−0.8 ± 1.6 (−1.59 to −0.16)	**0.001**[a]
NHP-Pain*	Δ_{1-2} (mean change, 95% CI)	−13.01 ± 33.77 (−27.99 to 1.95)	−1.93 ± 19.24 (−10.46 to 6.59)	0.209[a]
	Δ_{2-3} (mean change, 95% CI)	−16.02 ± 24.53 (−26.90 to −5.15)	−3.47 ± 20.55 (−12.58 to 5.63)	0.09[a]
	Δ_{1-3} (mean change, 95% CI)	−29.04 ± 27 (−41.01 to −17.07)	−5.4 ± 19.98 (−14.26 to 3.45)	**0.001**[a]
NHP-Emotional*	Δ_{1-2} (mean change, 95% CI)	−16.11 ± 44.87 (−36.00 to 3.78)	−4.31 ± 24.18 (−15.03 to 6.41)	0.271[a]
	Δ_{2-3} (mean change, 95% CI)	−10.82 ± 33.31 (−25.59 to 3.95)	2.93 ± 19.63 (−5.76 to 11.64)	**0.014**[a]
	Δ_{1-3} (mean change, 95% CI)	−26.93 ± 33.06 (−41.59 to −12.27)	−1.37 ± 24.3 (−12.14 to 9.40)	**0.011**[a]
NHP-Sleep*	Δ_{1-2} (mean change, 95% CI)	−7.47 ± 19.63 (−16.18 to 1.22)	1.56 ± 16.06 (−5.56 to 8.68)	0.059[a]
	Δ_{2-3} (mean change, 95% CI)	−16.14 ± 22.9 (−26.30 to −5.98)	−0.51 ± 17.12 (−8.10 to 7.07)	**0.041**[a]
	Δ_{1-3} (mean change, 95% CI)	−23.62 ± 29.39 (−36.65 to −10.58)	1.04 ± 19.47 (−7.58 to 9.68)	**0.001**[a]
NHP-Social Isolation*	Δ_{1-2} (mean change, 95% CI)	−13.4 ± 31.56 (−27.39 to 0.59)	−0.25 ± 25.49 (−11.55 to 11.04)	**0.046**[a]
	Δ_{2-3} (mean change, 95% CI)	−3.08 ± 18.23 (−11.16 to 5.00)	−3.65 ± 18.35 (−11.79 to 4.48)	0.507[a]
	Δ_{1-3} (mean change, 95% CI)	−16.48 ± 36.09 (−32.48 to −0.47)	−3.91 ± 24.56 (−14.80 to 6.98)	0.067[a]
NHP-Physical*	Δ_{1-2} (mean change, 95% CI)	−9.04 ± 26.42 (−20.75 to 2.67)	−1.35 ± 15.75 (−8.34 to 5.62)	0.196[a]
	Δ_{2-3} (mean change, 95% CI)	−9.1 ± 19.31 (−17.67 to −0.54)	−7.96 ± 14.47 (−14.38 to −1.54)	0.548[a]
	Δ_{1-3} (mean change, 95% CI)	−18.15 ± 26.37 (−29.84 to −6.45)	−9.32 ± 20.54 (−18.42 to −0.21)	0.168[a]
NHP-Energy*	Δ_{1-2} (mean change, 95% CI)	−1.67 ± 43.51 (−20.96 to 17.62)	−10.21 ± 33.15 (−24.91 to 4.48)	0.737[a]
	Δ_{2-3} (mean change, 95% CI)	−24.21 ± 41.89 (−42.79 to −5.64)	−2.72 ± 30.83 (−16.39 to 10.94)	0.053[a]
	Δ_{1-3} (mean change, 95% CI)	−25.89 ± 36.1 (−41.90 to −9.88)	−12.94 ± 31.31 (−26.83 to 0.94)	0.091[a]
NHP-First Section Total*	Δ_{1-2} (mean change, 95% CI)	−60.72 ± 118.87 (−113.42 to −8.01)	−16.51 ± 75.03 (−49.78 to 16.74)	0.1[a]
	Δ_{2-3} (mean change, 95% CI)	−79.4 ± 111.11 (−128.67 to −30.13)	−15.39 ± 69.4 (−46.16 to 15.38)	**0.006**[a]
	Δ_{1-3} (mean change, 95% CI)	−140.12 ± 121.86 (−194.15 to −86.09)	−31.9 ± 73.62 (−64.55 to 0.73)	**0.001**[a]
NHP-Second Section Total*	Δ_{1-2} (mean change, 95% CI)	−0.31 ± 2.86 (−1.58 to 0.95)	−0.45 ± 1.65 (−1.18 to 0.27)	0.68[a]
	Δ_{2-3} (mean change, 95% CI)	−1.31 ± 2.55 (−2.44 to −0.18)	−0.36 ± 0.95 (−0.78 to 0.05)	**0.029**[a]
	Δ_{1-3} (mean change, 95% CI)	−1.63 ± 1.98 (−2.51 to −0.75)	−0.81 ± 1.68 (−1.56 to −0.07)	0.241[a]
PCS*	Δ_{1-2} (mean change, 95% CI)	−7.4 ± 10.81 (−12.20 to −2.61)	−6.86 ± 8.69 (−10.71 to −3.00)	0.647[a]
	Δ_{2-3} (mean change, 95% CI)	−7.09 ± 8.83 (−11.00 to −3.17)	2.9 ± 6.61 (−0.02 to 5.84)	**0.001**[a]
	Δ_{1-3} (mean change, 95% CI)	−14.5 ± 8.42 (−18.23 to −10.76)	−3.95 ± 9.45 (−8.14 to 0.23)	**0.002**[a]
TUQ**	Δ_{1-2} (mean change, 95% CI)	12.54 ± 29.57 (−0.56 to 25.65)	−0.4 ± 27.04 (−12.39 to 11.58)	0.127[a]
	Δ_{2-3} (mean change, 95% CI)	21.81 ± 26.95 (9.86 to 33.76)	−7 ± 25.46 (−18.29 to 4.29)	**0.001**[a]
	Δ_{1-3} (mean change, 95% CI)	34.36 ± 36.1 (18.35 to 50.36)	−7.4 ± 39.39 (−24.87 to 10.05)	**0.001**[a]

Table 2 (continued)

		TAFG ($n=22$)	CG ($n=22$)	p (between group)
TSQ**	Δ_{1-2} (mean change, 95% CI)	3.09 ± 11.16 (−1.85 to 8.04)	−3.18 ± 12.7 (−8.81 to 2.44)	0.054[a]
	Δ_{2-3} (mean change, 95% CI)	7 ± 12.79 (1.32 to 12.67)	−3.54 ± 11.3 (−8.55 to 1.46)	**0.028**[a]
	Δ_{1-3} (mean change, 95% CI)	10.09 ± 13.76 (3.98 to 16.19)	−6.72 ± 16.98 (−14.25 to 16.19)	**0.001**[a]
ODI*	Δ_{1-2} (mean change, 95% CI)	−8.77 ± 17.35 (−16.47 to −1.08)	−5.72 ± 8.95 (−9.69 to −1.75)	0.417[a]
	Δ_{2-3} (mean change, 95% CI)	−14.09 ± 17.19 (−21.71 to −6.46)	2.11 ± 7.66 (−1.28 to 5.51)	**0.001**[a]
	Δ_{1-3} (mean change, 95% CI)	−22.86 ± 12.48 (−28.40 to −17.33)	−3.61 ± 9.39 (−7.77 to 0.55)	**0.001**[a]
EARS**	Δ_{1-2} (mean change, 95% CI)	0.31 ± 5.9 (−2.30 to 2.93)	1.59 ± 5.17 (−0.70 to 3.88)	0.509[a]
	Δ_{2-3} (mean change, 95% CI)	4.72 ± 5.65 (2.21 to 7.23)	−0.63 ± 4.69 (−2.71 to 1.44)	**0.001**[a]
	Δ_{1-3} (mean change, 95% CI)	5.04 ± 5.25 (2.71 to 7.37)	0.95 ± 6.07 (−1.73 to 3.64)	**0.016**[a]

TAFG tele-assessment feedback group; *CG* control group; *n* the number of participants; *SD* standard deviation; *VAS* Visual Analog Scale; *NHP* Nottingham Health Profile; *PCS* Pain Catastrophizing Scale; *TUQ* Telehealth Usability Questionnaire; *TSQ* Telemedicine Satisfaction Questionnaire; *ODI* Oswestry Disability Index; *EARS* Exercise Adherence Rating Scale; Δ_{1-2} change scores between first and second assessment; Δ_{2-3} change scores between second and third assessment; Δ_{1-3} change scores between first and third assessment; *CI* confidence interval

Bold mark indicates a statistical significant difference

*Lower values = Better

**Higher values = Better

[a]Mann–Whitney *U* test

parameters on chronic low back pain is comprehended [31], the fact that the groups had similar physical characteristics was valuable data.

Although the pain level of the participants decreased in both groups, the reduction in pain score was statistically significant only in the TAFG group. Similar to this result, improvement in quality of life, disability, and pain catastrophizing levels were similarly improved only in the TAFG group. Improvement was also observed in exercise participation, satisfaction, and telerehabilitation usability parameters of individuals in TAFG. Only the improvement in ODI and PCS scores was significant in the CG group. Although improvement was noticed in the scores of the CG who were only offered an exercise program with telerehabilitation without feedback, significant improvements were only noticed in terms of disability and pain catastrophizing. The more visible improvement in the progress of the individuals who received visual feedback may have resulted in a statistically significant improvement in the outcomes.

Another critical issue that may confirm the hypothesis of this study is the improvement of the participants between the 4th and 8th week after the visual feedback intervention. The graphic-based visual feedback provided to the individuals in TAFG would construct a difference between the groups. According to our results, the improvement of the individuals in TAFG in terms of pain between weeks 4–8 was significant. The motivation provided by visual feedback improves the level of exercise participation [7]. More participation in rehabilitation may have led to more improvement in clinical parameters, especially pain [32]. In this way, individuals' quality of life, disability levels and pain catastrophizing improved. This outcome may be because individuals followed their exercises more comprehensively with self-motivation to increase their scores in the graph [33].

Our study showed improvements in both the physical and mental dimensions of pain. In addition to improving pain, improvements in pain catastrophizing more effectively confirm the improvements in the psychological state reflections with increased motivation and participation of individuals [34]. After 8 weeks of rehabilitation, positive reflections were also observed in the quality of life of the individuals. Although physical function, energy, and social isolation sub-parameters of quality-of-life dimensions did not improve more specifically with visual feedback, the total quality of life score was enough to reveal that clinical improvement was also influential in the quality-of-life dimension.

When the groups are compared in terms of usability and satisfaction level with the telerehabilitation intervention, it is noticed that individuals in the TAFG are more satisfied with the rehabilitation platform. Although the individuals in both groups were evaluated through the same web application, providing additional graphics and visuals and additional information and motivation about their development in the 4th week may have improved their clinical conditions and thus increased their satisfaction with the telerehabilitation software. In this context, ideas that could increase the

Table 3 Outcome measures within groups

		TAFG ($n=22$)	CG ($n=22$)
VAS*	1. Assessment (mean ± SD)	5.6 ± 1.88	4.28 ± 1.73
	2. Assessment (mean ± SD)	3.83 ± 2.29	3.79 ± 1.89
	3. Assessment (mean ± SD)	1.03 ± 1.03	3.4 ± 1.95
	p (within group)	**0.001**[a]	0.154[a]
NHP-Pain*	1. Assessment (mean ± SD)	46.23 ± 28.62	30.92 ± 19.29
	2. Assessment (mean ± SD)	33.21 ± 26.07	28.99 ± 16.58
	3. Assessment (mean ± SD)	17.19 ± 22.75	25.51 ± 13.28
	p (within group)	**0.001**[a]	0.682[a]
NHP-Emotional*	1. Assessment (mean ± SD)	34.91 ± 34.6	17.41 ± 22.05
	2. Assessment (mean ± SD)	18.8 ± 26.02	13.1 ± 17.37
	3. Assessment (mean ± SD)	7.98 ± 21.91	16.04 ± 14.2
	p (within group)	**0.001**[a]	0.727[a]
NHP-Sleep*	1. Assessment (mean ± SD)	32.89 ± 29.27	15.88 ± 26.3
	2. Assessment (mean ± SD)	25.42 ± 23.91	17.45 ± 23.12
	3. Assessment (mean ± SD)	9.27 ± 15.49	16.93 ± 22.14
	p (within group)	**0.001**[a]	0.872[a]
NHP-Social Isolation*	1. Assessment (mean ± SD)	19 ± 32.6	7.91 ± 23.26
	2. Assessment (mean ± SD)	5.6 ± 12.76	7.65 ± 18.32
	3. Assessment (mean ± SD)	2.52 ± 11.82	4 ± 8.68
	p (within group)	**0.016**[a]	0.727[a]
NHP-Physical*	1. Assessment (mean ± SD)	32.73 ± 22.49	30.85 ± 16.86
	2. Assessment (mean ± SD)	23.69 ± 16.51	29.49 ± 14.34
	3. Assessment (mean ± SD)	14.58 ± 17.31	21.53 ± 12.64
	p (within group)	**0.001**[a]	0.107[a]
NHP-Energy*	1. Assessment (mean ± SD)	34.4 ± 39.9	26.98 ± 36.73
	2. Assessment (mean ± SD)	32.72 ± 37.24	16.76 ± 26.6
	3. Assessment (mean ± SD)	8.5 ± 21.07	14.03 ± 27.48
	p (within group)	**0.003**[a]	0.349[a]
NHP-First Section Total*	1. Assessment (mean ± SD)	200.19 ± 115.15	129.98 ± 103.97
	2. Assessment (mean ± SD)	139.47 ± 101.96	113.46 ± 76.37
	3. Assessment (mean ± SD)	60.06 ± 96.71	98.07 ± 70.77
	p (within group)	**0.001**[a]	0.956[a]
NHP-Second Section Total*	1. Assessment (mean ± SD)	2.81 ± 2.3	2.36 ± 1.73
	2. Assessment (mean ± SD)	2.5 ± 2.19	1.9 ± 1.19
	3. Assessment (mean ± SD)	1.18 ± 1.73	1.54 ± 1.14
	p (within group)	**0.001**[a]	0.062[a]
PCS*	1. Assessment (mean ± SD)	20.00 ± 11.19	19 ± 9.8
	2. Assessment (mean ± SD)	12.59 ± 11.56	12.13 ± 7.17
	3. Assessment (mean ± SD)	5.5 ± 6.54	15.04 ± 7.69
	p (within group)	**0.001**[a]	**0.027**[a]
TUQ**	1. Assessment (mean ± SD)	102.59 ± 30.66	119.18 ± 29.72
	2. Assessment (mean ± SD)	115.13 ± 29.26	118.77 ± 19.08
	3. Assessment (mean ± SD)	136.95 ± 16.83	111.77 ± 19.24
	p (within group)	**0.001**[a]	0.414[a]
TSQ**	1. Assessment (mean ± SD)	55.18 ± 10.56	57.86 ± 12.46
	2. Assessment (mean ± SD)	58.27 ± 12.02	54.68 ± 9.65
	3. Assessment (mean ± SD)	65.27 ± 7.77	51.13 ± 9.44
	p (within group)	**0.001**[a]	0.159[a]

Table 3 (continued)

		TAFG ($n=22$)	CG ($n=22$)
ODI*	1. Assessment (mean ± SD)	33.23 ± 15.59	23.09 ± 13.85
	2. Assessment (mean ± SD)	24.45 ± 17.05	17.36 ± 12.41
	3. Assessment (mean ± SD)	10.36 ± 11.72	19.47 ± 10.99
	p (within group)	**0.001**[a]	**0.018**[a]
EARS**	1. Assessment (mean ± SD)	15.31 ± 3.95	13.13 ± 4.49
	2. Assessment (mean ± SD)	15.63 ± 5.87	14.72 ± 5.16
	3. Assessment (mean ± SD)	20.36 ± 4.19	14.09 ± 4.67
	p (within group)	**0.001**[a]	0.765[a]

TAFG tele-assessment feedback group; *CG* control group; *n* the number of participants; *SD* standard deviation; *VAS* Visual Analog Scale; *NHP* Nottingham Health Profile; *PCS* Pain Catastrophizing Scale; *TUQ* Telehealth Usability Questionnaire; *TSQ* Telemedicine Satisfaction Questionnaire; *ODI* Oswestry Disability Index; *EARS* Exercise Adherence Rating Scale

Bold mark indicates a statistical significant difference

*Lower values = Better

**Higher values = Better

[a]Friedman test

participation of may be more effective on satisfaction and usability [35]. As a result, increasing the motivational elements in the app to be developed may lead to more improvement in clinical parameters with increased participation and, thus, increased satisfaction with telerehabilitation.

While there are no studies in the literature with our study's design, various technological rehabilitation studies provide visual feedback. The effect of cysteamine providing feedback on ROM development in individuals with stroke has been confirmed [13]. The positive effect of rehabilitation with visual feedback on pain relief in individuals with chronic low back pain has been confirmed [15]. In addition, the positive effects of a training program with visual feedback on postural control in individuals with chronic low back pain have been reported [16]. However, a graphics-based visual feedback assessment like the one in our study has been addressed for the first time. The results of our study are unique in this respect.

Limitations

Some limitations of the study should be recognized. First of all, only the evaluator was blinded in the study. Unblinding treatment providers may bring up bias in motivational issues. Second, with longer follow-ups and frequent evaluations, the sustainability of the visual feedback provided to the patients could have provided a more motivating environment. However, due to the difficulty of efficiently reaching patients and collecting data in long-term follow-ups, it may be more efficient to address patient pain, disability, and other parameters only on VAS in future studies. Third, although we tried to create homogenous groups with eligibility criteria, some parameters (Six out of 18, please see in Table 1) are significantly different between groups. Therefore, to rule out this situation, we presented statistical significance tests on change scores and 95% CI to address the possibility of potential overlap. Finally, the treatment programs of the individuals were made specific according to individual needs. Although more precise results could be obtained with a standardized exercise program, the participants' requirements were considered within ethical considerations.

Conclusions

The study results confirmed the additional contribution of telerehabilitation's graphics-based visual feedback in pain, pain catastrophizing, disability, quality of life, and exercise participation. Since the importance of continuity in long-term rehabilitation in patients with chronic low back pain is known, motivational feedback applications can be added to telerehabilitation software. Self-monitoring of individuals with graphical visual feedback can be valuable regarding motivation and participation. Individuals can progress more with the same logic on exergaming platforms in a constructive competitive environment.

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Declarations

Conflict of interest We have no conflict of interest to declare.

Ethical approval The study was carried out in accordance with the ethical principles and the Helsinki Declaration. Informed consents of the patients were obtained. The study protocol was approved by the ethics committee of Muğla Sıtkı Koçman University (No: 220139/155, Approval Date: 29.12.2022). The study protocol was prospectively registered (ClinicalTrials.gov Identifier: NCT05816824).

Consent to participate Informed consent of the patients was obtained.

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