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Effect of a Tele-Rehabilitation Exercise Protocol on Pain, Balance, and Function in Females with Patellofemoral Pain Syndrome: A Randomized Controlled Trial

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Authors

Fatemeh Livani [1*], MSc
Sahar Boozari [2], PhD

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[1] Department of Physiotherapy, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran.

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*** Correspondence**
Assistant Department of Physiotherapy, Faculty of Medical Sciences, Tarbiat Modares University, Gisha, Jalal St., Tehran, Iran
P.O.Box: 14117- 13116
Tel: 982182885053
Fax: 0098 828224555
E-mail s.boozari@modares.ac.ir

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ABSTRACT

Aims: Patellofemoral Pain Syndrome (PFPS) is a common musculoskeletal condition that limits physical activity due to pain and functional impairments. Tele-rehabilitation offers a promising alternative by providing remote exercise supervision with professional oversight. This study evaluated the effectiveness of a structured tele-rehabilitation exercise program on pain, balance, and function in females with PFPS.

Method and Materials: Twenty-eight females with PFPS were randomly assigned to a tele-rehabilitation exercise group or control group. The six-week program included targeted hip and knee strengthening and stretching exercises initially taught in person and subsequently supervised remotely via phone or video calls, with biweekly in-person evaluations. Pain intensity was assessed through the Visual Analog Scale (VAS), balance through the Y-balance test, and function through the Kujala score at baseline and post-intervention.

Findings: The tele-rehabilitation group showed significantly better outcomes than the control group ($p < 0.05$ for all measured variables). Pain intensity decreased by 80.31% versus 16.25% in the control group. Balance improved in all Y-balance test directions (anterior: 13.51%, posteromedial: 13.75%, posterolateral: 13.25%), and functional scores increased by 27.33%, both with negligible changes in the control group.

Conclusion: A tele-rehabilitation exercise program incorporating remote supervision and periodic in-person assessments is a practical and accessible approach for managing patellofemoral pain syndrome (PFPS) in females. This hybrid model combines the benefits of real-time monitoring with professional in-person evaluations. The findings support the clinical applicability of tele-rehabilitation in musculoskeletal rehabilitation, particularly for conditions requiring exercise-based management.

Keywords: Patellofemoral Pain Syndrome; Rehabilitation; Exercise Therapy; Physical Functional Performance

Introduction

Patellofemoral Pain Syndrome (PFPS) is a prevalent musculoskeletal condition leading to anterior knee pain, which is often exacerbated by activities such as squatting, running, and stair climbing. It predominantly affects physically active individuals, females being at a higher risk due to anatomical and biomechanical factors, including a greater quadriceps angle (Q-angle) and altered lower limb kinematics and kinetics during dynamic tasks. Despite its high prevalence, the exact etiology of PFPS remains incompletely understood, as multiple intrinsic and extrinsic factors contribute to its development [1-5].

Among the primary contributors to PFPS, neuromuscular dysfunction plays a critical role, with muscular weakness, tightness, and overall imbalance in the hip and knee musculature, which contribute to the onset and persistence of symptoms. These deficits result in impaired load distribution across the patellofemoral joint, increased joint stress, and inefficient movement patterns, which further exacerbate pain and functional limitations. Given these underlying mechanisms, exercise therapy, including strengthening exercises, flexibility training, and neuromuscular control exercises, has been widely recognized as a fundamental intervention for managing PFPS, as it addresses muscular imbalances, enhances neuromuscular control, and improves movement efficiency [6-12].

Despite the well-documented benefits of exercise therapy, many patients face barriers to,

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accessing rehabilitation services, including those with long travel distances, time constraints, and financial burdens. These challenges often resulted in poor adherence and suboptimal treatment outcomes. To address these limitations, tele-rehabilitation has emerged as a promising alternative to traditional in-person therapy, allowing patients to participate in guided exercise programs remotely while receiving professional supervision and feedback.

Tele-rehabilitation has demonstrated promising results in managing various musculoskeletal conditions by enhancing accessibility, improving patient engagement, and maintaining treatment continuity [13-17]. However, despite its growing adoption, evidence regarding the effectiveness of tele-rehabilitation specifically for PFPS remains limited [18, 19] with one study utilizing real-time video conferencing and another relying on an initial in-person education session followed by phone or email follow-ups.

While these approaches have shown effectiveness, each comes with its limitations. Solely relying on real-time video conferencing may be technologically demanding for some patients, while a model based only on phone or email communication may lack sufficient interaction and monitoring. To bridge this gap, the present study introduces a hybrid tele-rehabilitation approach designed to enhance accessibility while maintaining professional oversight. This program combines real-time video consultations with scheduled in-person therapist evaluations every two weeks, ensuring that patients receive personalized guidance while benefiting from the convenience of remote rehabilitation. By evaluating the impact of a structured tele-rehabilitation program that includes targeted hip and knee strengthening and stretching exercises, this study aims to assess its effectiveness in improving pain, balance, and functional performance in individuals with patellofemoral pain syndrome (PFPS). The primary outcomes include pain intensity, measured using the Visual Analog Scale (VAS), dynamic balance assessed via the Y-balance test, and functional performance evaluated by the Kujala Patellofemoral Score (an anterior knee pain scale). All these scales will provide valuable insights into the feasibility and clinical applicability of this tele-rehabilitation model for PFPS management.

Method and Materials

In this study, 28 females suffering from PFPS were assessed. Using G*Power software, the required sample size was determined based on pilot data and previous studies [20, 21], with an alpha level of 0.05 and a statistical power of 80%.

Participants were entered into the study if they were females aged 18 to 35 years, had a normal Body Mass Index (BMI) (18.5–24.9 kg/m^2), and were non-professional athletes diagnosed with PFPS. The diagnosis was confirmed based on a history of anterior, peripatellar, or retro-patellar knee pain lasting at least three months, with symptoms exacerbated by at least three activities, such as running, jumping, squatting, prolonged sitting with knee flexion, or stair ascent and descent. Additionally, participants had to present with a positive Clarke's test. Pain severity was required to be between 3 and 6 on the Visual Analog Scale (VAS), and functional impairment was assessed using the Kujala patellofemoral score, by which only individuals scoring below 85 were included. Participants also needed a Tegner activity scale score of 5 or 6, indicating moderate levels of physical activity [22-24].

Participants were excluded if they were pregnant, undergoing treatment for PFPS within the past six months, engaging in specialized exercise therapy, or presenting with a lower limb length discrepancy exceeding 1.5 cm. Additional exclusions included a history of permanent orthopedic, rheumatologic, or neurological conditions affecting lower limb function or spinal alignment, as well as severe visible lower limb deformities.

An independent researcher, not involved in data collection, performed block randomization to allocate participants into either the exercise therapy group or the control group. The study protocol was approved by the Ethics Committee of Tarbiat Modares University and registered with the Iranian Registry of Clinical Trials.

Following randomization, pain, balance, and functional ability were assessed in both groups before the intervention. Pain was measured using the Visual Analog Scale (VAS), a 10-cm scale ranging from 0 (no pain) to 10 (the worst pain imaginable). Functional ability was evaluated using the Kujala Score. This patient-reported measure assesses activities such as walking, running, stair climbing, squatting, and jumping, with scores ranging from 0 to 100, where higher scores indicate better function [25]. The Persian version of the Kujala Score, which has demonstrated reliability and validity, was used [26].

Dynamic balance was assessed using the Y-Balance Test. Participants stood on the affected leg at the center of a star-shaped grid. They were instructed to reach as far as possible in the anterior, posteromedial, and posterolateral directions with the opposite leg while maintaining balance. Reach distances were normalized to leg length, measured from the anterior superior iliac spine to the medial malleolus, to account for individual differences. This test is particularly relevant in patients with PFPS, as it evaluates postural control and neuromuscular function, which are often impaired in this population [27, 28].

The exercise therapy group participated in a structured six-week intervention, designed based on a review of prior research [6-12]. Participants were instructed to perform the exercises 4–5 days per week. The program targeted key muscle groups involved in PFPS, focusing on exercises that strengthen and stretch these areas. Initially, participants attended an in-person session where a therapist demonstrated all exercises to ensure correct technique. A detailed brochure outlining the exercises was provided, and adherence was monitored through weekly phone or video calls, tailored to meet the participants' needs. Additionally, an in-person check-up was conducted every two weeks to assess progress and make necessary adjustments. The protocol consisted of a combination of strengthening and stretching exercises. Strengthening exercises included as follows:

1- Quadriceps-setting exercise: Participants lie supine with a pillow placed under the affected knee. They pressed the knee down into the pillow, contracting the quadriceps muscle, and held the contraction. 2- Terminal knee extension: While lying supine with a pillow positioned under the thigh, participants extended the knee by lifting the lower leg (shank) while keeping the ankle in dorsiflexion.3- Supine straight leg raises: Participants lifted the affected leg to the height of the contralateral knee, which remained bent with the foot resting on the surface. During this movement, the lower extremity was externally rotated, and the ankle was kept in dorsiflexion. 4- Resisted hip abduction: While in a crooked-lying position (lying on the back with knees bent), participants performed hip abduction by moving the knees outward against resistance provided by a strap tied around them. 5. Side-lying hip abduction: Participants lie on their unaffected side and lift the affected leg upward, performing hip abduction.
6- Clamshell exercise: In a side-lying position with both knees bent, participants performed resisted hip abduction by opening the knees outward against a resistance band placed around them. 7- Quadruped hip abduction: From a quadruped position (on hands and knees), participants extended the affected leg and moved it outward (abducted) to the side while keeping the knee bent. 8- Glute bridge: In the crook-lying position (supine with knees bent), participants lifted their hips off the ground, actively engaging their gluteal muscles throughout the movement.

Stretching exercises included as follows:

1. Plantar Flexor Stretch: Participants sat with one leg extended in front and used a towel or strap looped around the foot to gently pull it toward themselves, stretching the calf muscles. 2- Hamstring stretch: While lying supine, participants lifted the affected leg straight upward, keeping the knee extended and the ankle dorsiflexed to enhance the stretch. 3- Quadriceps stretch: Participants performed a standing stretch by holding the ankle of the affected leg and pulling the foot toward the glutes. 4- Iliotibial band stretch: Standing sideways near a wall, participants positioned the unaffected side closer to the wall and leaned their trunk laterally away from it to stretch the opposite hip and IT

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band.

The progression of exercises was structured based on patient tolerance and the absence of significant pain. Strengthening exercises began with 10 repetitions and a 5-second hold, progressively increasing to 15-second holds and 15 repetitions per set. Stretching exercises started with a 10-second hold and were gradually increased to 30 seconds per repetition, with the number of repetitions progressing from 10 to 15.

The control group did not receive any therapeutic intervention during the study period. However, for ethical reasons, both groups, including the control group, received general lifestyle recommendations to minimize prolonged aggravating activities and reduce pain.

After six weeks, all outcome measures, including pain (VAS), functional ability (Kujala score), and dynamic balance (Y-balance test), were reassessed for both groups.

Statistical analysis

Data normality was assessed using the Shapiro–Wilk test and the independent t-test. It was used to determine the differences between the intervention and control groups. A mixed ANOVA was performed with one within-subject factor (time: pre- and post-intervention) and one between-subject factor (group: intervention versus Control). Assumptions of repeated-measures ANOVA were tested using Levene's test for homogeneity of variances and Box's M test for homogeneity of covariance matrices. Statistical significance was set at $p < 0.05$. Effect sizes were reported as partial eta squared (ηp^2), with values of 0.01, 0.06, and 0.14 representing small, moderate, and large effects, respectively.

Findings

All 28 participants completed the intervention and were included in the final analysis. The demographic characteristics of the participants are presented in Table 1, with no significant differences observed between them. Additionally, independent t-test analysis confirmed no significant differences in baseline outcome measures between the groups.

The results of the mixed ANOVA analysis are presented in Table 2. A significant main effect of time, group, and their interaction was found for pain (VAS) and functional ability (Kujala score) following the six-week exercise intervention.

Table 1) Demographic data of participants, presented as mean (SD)

Variables	Exercise group (N=14)	Control group (N=14)	p-value
Age (year)	26.21 (4.00)	25.50 (4.60)	0.550
Weight (kg)	54.44 (4.73)	55.03 (2.99)	0.319
Height (m)	1.62 (0.04)	1.63 (0.03)	0.599
BMI	20.62 (1.53)	20.63 (1.41)	0.523

BMI: Body Mass Index

Table 2) Descriptive statistics, mean (SD), and mixed ANOVA results (p-values, partial eta squared)

Variables	Before intervention Mean (SD)		After intervention Mean (SD)		Group effect	Time effect	Interaction effect
	Exercise	Control	Exercise	Control			
VAS	4.47 (0.93)	4.37 (1.01)	0.88 (0.54)	3.66 (0.97)	<0.001* (0.459)	<0.001* (0.851)	<0.001* (0.720)
Kujala Questionnaire	59.42 (4.38)	60.42 (5.35)	75.64 (3.69)	63.00 (4.86)	<0.001* (0.339)	<0.001* (0.758)	<0.001* (0.623)
Y-balance test Anterior	0.74 (0.05)	0.76 (0.06)	0.84 (0.05)	0.76 (0.07)	0.264 (0.048)	<0.001* (0.691)	<0.001* (0.645)
Y-balance test Posterio-medial	0.80 (0.08)	0.82 (0.10)	0.91 (0.07)	0.83 (0.10)	0.453 (0.022)	<0.001* (0.790)	<0.001* (0.751)
Y-balance test Posterio -lateral	0.83 (0.06)	0.86 (0.08)	0.94 (0.05)	0.86 (0.08)	0.325 (0.037)	<0.001* (0.802)	<0.001* (0.748)

VAS: Visual Analogue Scale;
*Significant difference

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As illustrated in Figure 1, the intervention group demonstrated a qualitatively greater reduction in pain and improvement in functional ability compared to the control group. Pain intensity decreased by 80.31% in the intervention group, whereas the control group exhibited only a 16.25% reduction. Similarly, functional ability, as measured by the Kujala questionnaire, improved by 27.33% in the intervention group, while the control group showed a minimal 4.27% increase.

Regarding dynamic balance, a significant time-by-group interaction was observed. As illustrated in Figure 2, the considerable interaction revealed different behaviors between the two groups, with a more pronounced improvement in all reach directions for the intervention group compared to the control group. Specifically, the anterior reach distance improved by 13.51%, while the posteromedial and posterolateral reach distances increased by 13.75% and 13.25%, respectively. In contrast, the control group exhibited negligible changes across all balance measures.

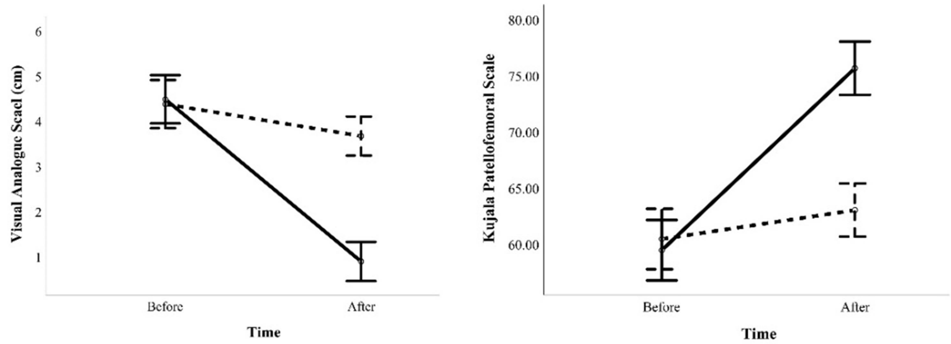

Figure 1) The results indicate a more pronounced decrease in pain and a greater improvement in Kujala scores in the intervention group (solid line) compared to the control group (dashed line).

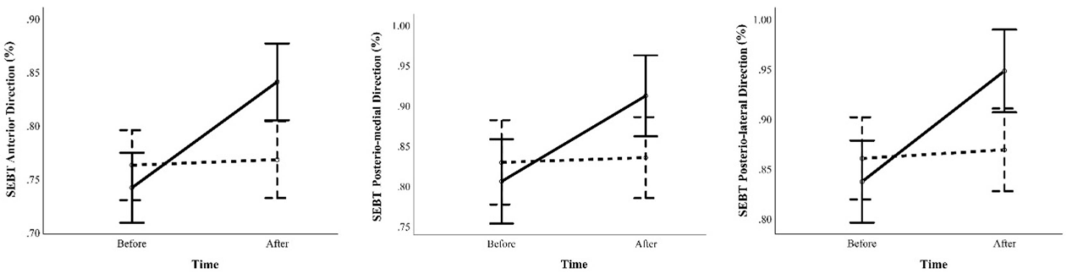

Figure 2) The results demonstrate greater improvements in anterior, posteromedial, and posterolateral reach distances in the Y-balance test for the exercise group (solid line) compared to the control group (dashed line).

Discussion

The findings of this study demonstrate that a six-week tele-rehabilitation exercise therapy program resulted in significant improvements in pain, dynamic balance, and functional ability in females with PFPS. The reduction in pain intensity observed in the intervention group aligns with previous research highlighting the benefits of targeted strengthening and stretching exercises in alleviating patellofemoral pain and enhancing function [6-12]. Quadriceps and hip muscle strengthening, key components of the intervention, likely contributed to improved patellar tracking and reduced excessive lateral patellar displacement, both of which are commonly associated with pain in patellofemoral pain syndrome (PFPS). Additionally, stretching exercises may have enhanced muscle flexibility and joint mobility, further contributing to pain relief. Additionally, stretching exercises may have improved muscle flexibility and joint mobility, further alleviating discomfort [6-12].

The improvements in dynamic balance, as evidenced by increased reach distances in the Y-balance test, suggest that the intervention positively influenced neuromuscular control and postural stability. Strengthening of the quadriceps, hip abductors, and gluteal muscles likely enhanced lower limb alignment and proprioception, critical components of balance control. These findings are consistent with previous studies emphasizing the role of exercise therapy in improving dynamic stability in individuals with PFPS [6-12, 29, 30].

Furthermore, functional ability, as assessed by the Kujala questionnaire, improved significantly following the intervention, aligning with findings from previous studies [6-12]. This improvement can be attributed to increased muscular strength, reduced pain, and enhanced neuromuscular coordination, all of which contribute to better performance in daily activities such as walking, stair climbing, and squatting. These results highlight the effectiveness of remote exercise therapy in improving functional capacity in individuals with PFPS, providing a feasible and accessible approach to rehabilitation.

A key aspect of this study is that all improvements were achieved via tele-rehabilitation, with exercises initially taught by a therapist, followed by regular phone and video call check-ins and biweekly in-person follow-ups to address any issues. Limited literature exists on hybrid tele-rehabilitation approaches, where part of the treatment is delivered remotely and part is conducted in person. Moreover, in previous studies, the delivery methods varied. One study implemented real-time video conferencing, while another relied on written instructions, supplemented with email and phone check-ins, for adherence monitoring [18, 19]. In contrast, we adopted a hybrid approach, combining initial instruction with regular phone or video check-ins to ensure proper execution and adherence. Additionally, unlike previous studies that primarily assessed pain and functional outcomes, our study also evaluated dynamic balance using the Y-balance test, offering a more comprehensive assessment of neuromuscular function. Furthermore, based on pilot findings from a preliminary group of 10 participants who reported that the exercise sessions were too lengthy, we reduced the number of prescribed exercises to enhance adherence. Despite this adjustment, meaningful improvements were still observed across all measured outcomes.

Despite its advantages, tele-rehabilitation presents challenges. While it enhances accessibility and eliminates barriers associated with in-person therapy, the limited direct interaction between therapists and patients may affect adherence and movement accuracy. Regular monitoring and progressive adjustments are essential for maintaining engagement and ensuring the correct execution of the technique. It is important to note that the participants in this study were young, physically active females with moderate activity levels, as indicated by the Tegner activity scale. Their prior familiarity with exercise and strong motivation to return to regular activity likely contributed to high adherence rates. However, implementing tele-rehabilitation for other populations, such as older adults, sedentary individuals, or those with lower intrinsic motivation, may present greater challenges. In such cases, additional strategies, such as more frequent follow-ups, interactive digital tools, or personalized motivational support, may be necessary to improve engagement and compliance. While our findings suggest that tele-rehabilitation is a viable alternative for young, active individuals, future research should explore adaptations for less active populations and investigate strategies to optimize engagement and long-term adherence.

While this study demonstrated significant benefits of tele-rehabilitation, certain limitations should be acknowledged. First, although the intervention effectively improved pain, balance, and functional ability, incorporating additional biomechanical or neuromuscular assessments could provide deeper insights into the underlying mechanisms driving these improvements. Future research should investigate kinematic and kinetic analyses to gain a deeper understanding of musculoskeletal adaptations following tele-rehabilitation. Second, although participant adherence was monitored through remote check-ins and in-person follow-ups, the level of exercise execution accuracy remains uncertain. Without continuous real-time supervision, subtle movement errors may have occurred, which could have potentially affected the outcomes. Future studies could consider incorporating wearable sensors or motion-tracking technologies to enhance remote monitoring and ensure proper exercise performance. Additionally, the duration and frequency of tele-rehabilitation sessions varied across studies, ranging from four to twelve weeks and a minimum of two sessions per week to daily sessions. While meaningful improvements were observed, these inconsistencies highlight the need for future research to determine the optimal frequency, duration, and intensity of tele-rehabilitation protocols. Establishing standardized guidelines will be essential for maximizing clinical outcomes and ensuring consistency in practice.

Conclusion

This study demonstrates that a remotely supervised exercise therapy program can effectively reduce pain, improve dynamic balance, and enhance functional ability in females with PFPS. These findings highlight the potential of tele-rehabilitation as a viable approach for managing PFPS, particularly for individuals with limited access to in-person physiotherapy services. While tele-rehabilitation presents challenges, such as reduced direct supervision, its accessibility and effectiveness make it a promising strategy for delivering exercise interventions. Future research should investigate methods to enhance adherence and tailor tele-rehabilitation programs to various populations, thereby ensuring broader applicability and long-term effectiveness.

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Authors' Contribution

FL and SB: Investigation, Methodology, and Interpretation; SB: Supervision. All authors contributed to the writing, review, and editing of the manuscript.

Conflict of Interest

The authors declare no conflicts of interest with any individuals, companies, or institutions.

Ethical Approval

The study protocol was approved by the Ethics Committee of Tarbiat Modares University code IR.MODARES.REC.1403.153 and registered with the Iranian Registry of Clinical Trials with code IRCT20201128049511N9 .

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