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Impact of telehealth-based therapeutic exercise on pain, functional performance and dynamic knee valgus in young adult females with patellofemoral pain: a randomised controlled trial

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ABSTRACT

Objectives This study aimed to evaluate the effectiveness of a telehealth-based therapeutic exercise (TTE) programme with real-time video conference supervision for young adult females with patellofemoral pain (PFP).

Methods The study design was a randomised controlled trial. Forty-two participants with PFP were allocated to either the TTE group or the control (C) group. The TTE group received a 4-week telehealth-based exercise programme supervised through real-time video conferencing, while the C group followed a self-guided stretching exercise. Pain intensity was assessed using the Visual Analogue Scale, while functional performance was evaluated with hop tests and the step-down test. Dynamic knee valgus was measured by the frontal plane projection angle during a single-leg squat. In addition, the study used a specific health questionnaire which evaluated knee pain and function, including the self-administered Kujala Patellofemoral Questionnaire (KPQ). All outcomes were assessed both before and after the intervention.

Results After the 4-week interventions, the results showed a significant interaction between the group and the time of pain intensity, functional performance and dynamic knee valgus (p<0.001). The TTE group demonstrated significant pain reduction (p<0.001) and improved KPQ score (p<0.001), while the C group showed no significant changes. TTE participants also exhibited improved functional performance in the hop and step-down tests. Additionally, dynamic knee valgus was significantly decreased in the TTE group.

Conclusion The telehealth-based exercise programmes offer a convenient and effective alternative for managing PFP symptoms, providing remotely accessible and specialised care.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Patellofemoral pain (PFP) is a prevalent anterior knee condition affecting adolescents and adults engaged in physical activities and is more common in females.
- ⇒ Individuals with PFP often exhibit weaknesses in hip and knee muscles and neuromuscular deficits, contributing to excessive dynamic valgus motion.
- ⇒ Traditional in-person therapeutic exercises are recommended for managing PFP. Still, access to these programmes may be limited by transportation, time and financial constraints, prompting the exploration of telehealth as an alternative solution.

INTRODUCTION

Patellofemoral pain (PFP) is a prevalent anterior knee pain condition in adolescents and adults engaging in various physical activities, with a prevalence of 7.2%–35.7%,[1 2] more prevalent in females.[3] It is characterised by retropatellar pain exacerbated during activities such as kneeling, running, jumping, squatting, prolonged sitting and stair climbing.[4] The pain and associated symptoms often lead to limitations in sports participation.[5]

Strong evidence indicates that muscle imbalances play a key role in the pathogenesis of PFP.[6] People with PFP often exhibit notable weaknesses in the hip abductor, hip external rotator and knee extensor muscles.[7] Hip muscle weakness causes the femur's internal rotation, causing dynamic knee valgus.[8] Previous evidence reported that dynamic knee valgus malalignment is caused by internal femur and tibia rotation. The femur's internal rotation might result from weakness of the hip muscles, and foot abnormalities might cause internal rotation of the tibia.[9 10] The literature provided evidence that in a subgroup of patients with PFP, rearfoot and forefoot abnormalities contribute to the

WHAT THIS STUDY ADDS

⇒ Building on previous research in PFP, this study examined the effectiveness of telerehabilitation via video conferencing, addressing the limitations of earlier studies that relied only on phone and email communication.

⇒ This study contributed to the literature by addressing a gap in research regarding the effects of telerehabilitation, specifically through video conferencing, on the dynamic knee valgus angle in individuals with PFP.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Telehealth-based therapeutic exercise programmes provide an effective alternative to traditional in-person therapy, significantly improving access to rehabilitation services for patients who cannot attend in person. By implementing these programmes, healthcare practitioners can reach more individuals, particularly in underserved areas with limited access to specialised care. Technology enables flexible treatment plans that accommodate patients' schedules, promoting better compliance with rehabilitation guidelines. Ultimately, the practicality and effectiveness of telehealth interventions make them valuable tools for managing PFP, fostering innovative, patient-centred approaches in physical therapy that enhance the quality of life for individuals with the condition and improve overall rehabilitation outcomes.

pathogenesis of dynamic valgus.[10] Recent studies revealed that the peroneus and intrinsic foot muscles are smaller in those with PFP than in healthy controls.[11 12] Moreover, dynamic valgus malalignment influences patellar tracking because the lateralised quadriceps force vector subsequently leads to lateralisation of the patella.[13] An imbalance in the vastus medialis obliquus and vastus lateralis activation correlates with lateral patellar tracking in patients with PFP.[14] Therefore, individuals with PFP frequently exhibit abnormal control of the lower extremity and neuromuscular deficits.[15]

Exercise therapy stands as a recommended intervention for diminishing pain and improving functionality over the long term.[16] The evidence showed the efficacy of both hip and knee strengthening compared with knee strengthening alone for reducing pain and enhancing activity levels in individuals with PFP.[17] Additionally, neuromuscular training can potentially enhance pain management and physical function among patients with PFP.[18] Notably, correcting dynamic knee alignment from dynamic knee valgus during functional tasks is a key facet of the rehabilitation regimen for individuals with PFP.[19] Moreover, a previous study suggested that patient education, including patient-specific advice, information on the condition and empowering the patient to manage their expectations, was considered essential by clinicians and researchers for improving long-term outcomes. It was frequently included in PFP trials as part of a combined treatment approach or as a comparator.[20]

While traditional in-person services and therapeutic exercises are commonplace in physical therapy, many obstacles, especially transportation restrictions, can impede access to treatments.[21] Moreover, time commitments, motivation issues and financial constraints hinder in-person exercise programmes.[22] A previous study reported that individuals with PFP also had emotional problems, and increased fear was linked to high activity limitations.[23] This may further contribute to motivation issues for in-person exercise. In recent years, telehealth has emerged as a solution to these challenges, making exercise programmes more accessible, affordable and appealing for managing chronic knee pain[24] and other health conditions.[25] Therefore, telehealth, which can provide personal training, may be a choice to overcome the barriers of in-person programmes regarding time, psychological and financial issues. However, a previous study indicated that telerehabilitation employing phone and email, without incorporating videoconferencing, did not yield optimal results for individuals with PFP.[26] Moreover, while several studies have demonstrated the effectiveness of in-person exercise programmes for PFP on dynamic knee valgus,[27–29] there is a lack of research investigating the impact of telerehabilitation on the dynamic knee valgus angle.

Therefore, this study aimed to assess the effectiveness of a telehealth-based therapeutic exercise (TTE) programme using real-time video conference supervision, focusing on its impact on pain, functional performance and dynamic knee valgus in young adult females with PFP.

METHODS

Study design

This study uses a randomised controlled trial design. All assessment procedures were conducted in the laboratory of the physiotherapy department at Walailak University, Thailand, from August 2022 to February 2023. Written informed consent was obtained from all participants before the study's initiation. The study has been registered with the Thai Clinical Trials Registry (registration number: TCTR20220720005). The study reporting followed the Consolidated Standards of Reporting Trials reporting guidelines. No significant methodological changes occurred after the trial commenced. Eligibility criteria and other trial aspects remained consistent throughout the study. Figure 1 provides an overview of the study protocol.

Patient and public involvement

All participants provided written informed consent and were not involved in the study's conduct or dissemination of its outcomes. Public involvement was integrated into the development of this project from its early stages. The initial research proposal was presented to a group of public attendees, who provided valuable feedback on various aspects of the study. During this presentation, the attendees were invited to offer suggestions regarding the protocol and other elements of the project design. Based on their input, certain modifications were made

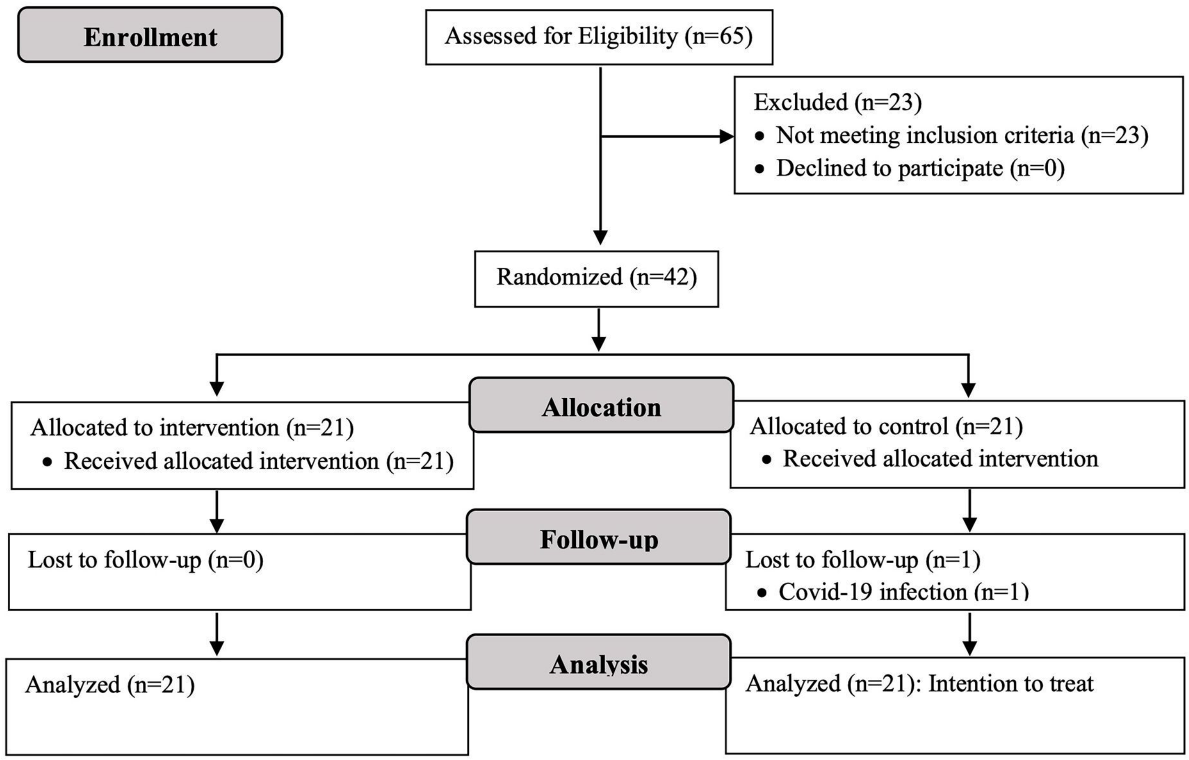

Figure 1 Consolidated Standards of Reporting Trials diagram of participant flow through the study.

to enhance the study's relevance and accessibility to the target population.

Participants

The inclusion criteria involved young adult females aged 18–40 years[18] experiencing anterior knee pain for at least 3 months.[30] Participants were diagnosed with PFP based on the criteria from a previous study, which included scoring less than 100 on the Kujala Patellofemoral Questionnaire (KPQ), experiencing retro patellar pain during at least two activities such as ascending/descending stairs, prolonged sitting with flexed knees, squatting, hopping/jogging, and kneeling, and reporting pain during patella compression and palpation of the patellar facets.[2 31] Additionally, participants had a Visual Analog Scale (VAS) score of at least 3 out of 10.[18 31] The exclusion criteria were a history of knee injury[18] or lower extremity joint replacement,[32] and systemic diseases such as diabetes or rheumatoid arthritis.[18] Athletes or people with a high level of physical activity, based on the Global Physical Activity Questionnaire, were also excluded.[2 26 33] They did not receive any physiotherapy treatment in the last 6 months and were not using pain-relieving medication during the study.[18]

Randomisation

Participants were randomised into either the TTE group or the control (C) group using a method of concealed allocation. Randomisation, conducted face-to-face and individually, occurred after eligibility was determined and the informed consent process was completed. An independent researcher, not involved in other assessments or interventions, prepared 42 small opaque papers numbered one and two. Participants then randomly selected these papers from a box, which determined their group assignment. The participants knew only that they would receive the exercise intervention; however, they were unaware of the intervention for the other group and did not know each other. Allocation concealment was maintained through sequentially numbered opaque containers, ensuring the integrity of the random allocation sequence and reducing the potential for selection bias.

Outcome measures

Pain intensity, functional performance, a specific health-related questionnaire for PFP and dynamic knee valgus were assessed before and after the 4-week interventions. The evaluation protocols were administered face to face in the laboratory of the physiotherapy department by an assessor who was not involved in the interventions for either the TTE or C groups and was blinded to group allocation. The tools and tests used for monitoring the outcomes included the VAS, the self-administered KPQ, hop tests, step-down test, and the frontal plane projection angle (FPPA) during a single-leg squat. There were no changes to trial outcomes after the trial commenced. The outcomes specified in the protocol were maintained without alteration throughout the study period.

For pain evaluation, the VAS was used. The worst intensity of anterior knee pain over the past week was measured. The VAS is one of the most reliable and validated methods for self-reporting pain intensity. It involves a 10 cm horizontal line, where 0 cm represents 'No pain', and 10 cm represents 'Worst pain'.[34]

The specific questionnaire used to evaluate knee pain and lower extremity function in individuals with anterior knee pain and PFP was the Thai version of the KPQ. This questionnaire consists of 13 questions designed to assess pain and lower extremity function. Scores range from 0 (indicating the worst possible function) to 100 (representing perfect function). The KPQ has been validated and demonstrated excellent test–retest reliability ($ICC_{2,1}$ 0.98).[35]

For functional performance assessment, hop tests and a step-down test were conducted. The hop tests included the single-leg hop test, triple hop test, cross-over hop test and single-leg 6-m timed hop test. The testing protocols were based on the previous report,[36] which demonstrated excellent reliability for these tests (0.92–0.97). Each hop test was performed for three repetitions on the affected limb, with a 2-min rest between trials. The single-leg hop, triple hop and cross-over hop tests were recorded in centimetres, while the single-leg 6-m timed hop test was reported in seconds. For the step-down test, participants stepped forward and down towards the floor using a 20-cm step. One repetition was counted when the heel of the descending limb slightly touched the floor. Weight on the heel during the step-down test was not allowed, and participants then returned to full knee extension. The number of steps performed in 30 s was recorded. This test had shown a high reliability.[37]

For the evaluation of dynamic knee valgus, the FPPA during a functional task, specifically a single-leg squat analysed in 2D, was used. This method has demonstrated reliability and criterion validity.[38] Markers were placed on key reference points: the anterior superior iliac spine (ASIS), the midpoint of femoral condyles and the midpoint of malleoli. Participants were barefoot with arms crossed over their chests. Two-dimensional data in the frontal plane were captured using a digital video recorder (PAL format, 25 frames/s, resolution 720×576 pixels, Sony HDR-PJ670, Tokyo, Japan) positioned 3 m away.[39] An assessor guided participants to achieve a 60° knee flexion depth in a practice trial. Subsequently, an adjustable tripod was placed behind each participant and set individually. Participants then performed three repetitions per leg, squatting to a 60° knee flexion depth, as indicated by their buttocks touching the tripod behind them. The descent and ascent were performed with a cadence of 2 s each, guided by metronome beats.[40] FPPA was determined at the squat's lowest point by the intersection of lines connecting ASIS to the femoral condyles midpoint and femoral condyle midpoint to the malleoli midpoint. Angle measurements were conducted using Kinovea software.[41] The average of three trials was analysed.

Figure 2 Hip and knee strengthening exercises ((A) side-lying hip abduction, (B) hip external rotation (Clamshell), (C) bridging while holding a small ball between the knees and (D) straight leg raising).

Intervention/control

All participants received individualised patient education regarding PFP pathology after the initial randomisation meeting. These activities may provoke knee pain, so traditional advice on avoiding certain activities, general care for PFP and guidance on postural correction are needed.

The TTE group received an exercise programme that included hip and knee strengthening exercises. These exercises comprised side-lying hip abduction, hip external rotation (Clamshell), bridging while holding a small ball between the knees and straight leg raising (figure 2). Additionally, neuromuscular training consisted of wall slides with a mini squat at 45° of knee flexion, forward step-up, lateral step-up and step-down (figure 3). These exercise choices were based on the positive effects demonstrated in previous studies.[18 26 32 42]

The TTE group participated in an individualised exercise programme three times a week for 4 weeks. A physical therapist supervised exercises through real-time videoconferencing (Zoom or Line VDO). Progress and symptoms were monitored via the Line official application. Participants performed exercises in a lying position on their beds. Standard steps were provided for participants to take home after the pretest session and return after completing the exercise. Before each training session, participants completed standardised stretching exercises for the quadriceps, hamstrings, iliotibial band and calf muscles. Each stretch was held for 30 s with three repetitions. Strengthening and neuromuscular exercises comprised three sets of 10 repetitions with a 2-s rest between, a 60-s rest between sets and a 3-min rest between exercises. An average exercise session lasts 60 min.

Figure 3 Neuromuscular training ((A) wall slides with a mini squat at 45° of knee flexion, (B) forward step-up, (C) lateral step-up and (D) step-down).

Depending on the exercise, progressive resistance for the strengthening exercises was achieved using weights or elastic tubing. The chosen dosage ensured that the final repetitions were challenging while allowing participants to maintain high-quality movement control throughout the programme. Participants were guided to correct and manage pelvic and knee movements using verbal and visual feedback for neuromuscular control exercises.[27] Feedback on correct body movements during exercise and motivation to reach the target were also provided. The use of cold or hot packs was allowed if needed.

The C group participated in identical stretching exercises for the quadriceps, hamstrings, iliotibial band and calf muscles, mirroring the routine of the TTE group. However, strengthening exercises and neuromuscular training were not provided for this group. These stretches were conducted thrice weekly over 4weeks, guided by instructional videos (VDO). Like the TTE group, the C group received exercise reminders through the Line official application.

Sample size calculation

The power and sample size calculations were based on the data from a previous study.[43] The formula for testing two independent means was used to calculate sample sizes.[44] The mean and SD of the anterior knee pain score of groups 1 and 2 were 85.4 (5.8) and 79.1 (7.6), respectively. Initially, a minimum of 19 participants per group was determined through the calculations. However, a 10% dropout rate was factored in. Consequently, the final sample size for this study was 21 participants per group.

No interim analyses were conducted during the trial, and stopping guidelines were not applicable. The trial proceeded according to the predetermined protocol without any deviations related to interim analyses or early stopping.

Statistical analysis

Statistical analysis was conducted using SPSS for Windows V.23 (IBM Corp.). A p value of 0.05 denoted statistical significance. The Shapiro-Wilk test confirmed data normality. Descriptive statistics were reported, including mean, SD and 95% CI. Intervention effects on outcome measures were assessed via repeated-measures analysis of variance with a 2-by-2 design (two groups and two time points). Partial eta squared (η^2) indicated effect size. Regarding significant group-by-time interactions, post-hoc tests for pairwise comparisons were employed to identify differences between and within groups. Intention-to-treat analysis was applied to account for altered results from baseline if data were lost during follow-up.

RESULTS

This study initially recruited 65 participants for screening, of which 23 were disqualified, leaving 42 participants enrolled. Twenty-one participants were randomised into the TTE group and the others into the C group. The trial concluded as planned, with 42 participants completing the study. One participant from the control group withdrew due to COVID-19, leading to a dropout. The remaining participants completed 12 sessions of exercise (three times a week for 4weeks). Some sessions may have been postponed to the next day, but they still maintained a frequency of three times per week. Due to the withdrawal, the intention-to-treat principle was used, and all 42 participants were included in the analysis (figure 1). No harm or unintended effects were observed in either group. The participants' general characteristics were not different between the two groups (table 1). Mean (SD) values of all outcome measures at baseline and postinterventions are detailed in table 2. Before interventions, no significant differences were observed between groups in any outcome measures, as indicated in table 2. No additional analyses, such as subgroup or adjusted analyses, were conducted.

Table 1 Demographic data of participants in the telehealth-based therapeutic exercise (TTE) and the control (C) groups

	TTE group (n=21)	C group (n=21)	P value
Age (years)	20.4 (1.2)	20.1 (1.1)	0.303
Weight (kg)	54.3 (6.4)	54.8 (6.6)	0.814
Height (m)	1.61 (0.53)	1.61 (0.49)	0.856
BMI (kg/m^2)	21.1 (2.7)	21.2 (2.5)	0.910
Pain duration (months)	21.5 (20.5)	19.0 (20.1)	0.695

BMI, body mass index; C, control.

Table 2 Mean (SD) scores on continuous outcome measures across time by treatment group, change within group, difference between groups and pairwise comparison within and between groups

	Baseline			Post 4 weeks			Mean change within groups			
							TTE group		C group	
	TTE group (n=21)	C group (n=21)	Mean difference (95% CI)	TTE group (n=21)	C group (n=21)	Mean difference (95% CI)	Mean change (95% CI)	P value*	Mean difference (95% CI)	P value*
VAS, cm	5.5 (0.9)	5.5 (1.1)	0.0 (−0.6 to 0.6)	1.8 (1.3)	5.4 (1.2)	−3.7 (−4.4 to −2.9)†	−3.7 (−4.2 to −3.3)	<0.001†	−0.1 (−0.8 to 0.4)	0.801
KPQ, 0–100	79.6 (5.8)	81.4 (6.0)	−1.8 (−5.8 to 2.2)	90.5 (4.4)	81.4 (7.2)	9.1 (5.4 to 12.8)†	10.9 (9.4 to 12.4)	<0.001†	0.1 (−1.5 to 1.6)	0.949
Single-leg hop, cm	82.7 (16.6)	85.9 (15.2)	−3.2 (−13.1 to 6.7)	104.0 (16.2)	86.0 (14.7)	18.0 (8.4 to 27.7)†	21.3 (17.8 to 24.8)	<0.001†	0.1 (−3.5 to 3.6)	0.970
Triple hop, cm	205.1 (39.7)	220.6 (28.7)	−15.5 (−37.1 to 6.1)	265.0 (46.1)	224.1 (30.1)	40.5 (16.6 to 65.2)†	59.9 (48.5 to 71.3)	<0.001†	3.5 (−7.9 to 14.9)	0.543
Cross-over hop, cm	177.3 (33.0)	181.1 (20.2)	−3.8 (−20.9 to 13.2)	234.9 (43.9)	181.6 (23.0)	53.3 (31.5 to 75.2)†	57.6 (47.7 to 67.5)	<0.001†	0.4 (−10.3 to 9.5)	0.933
Single-leg 6-m timed hop, s	4.82 (1.20)	4.36 (0.64)	0.46 (−0.14 to 1.06)	3.17 (0.55)	4.38 (0.78)	−1.22 (−1.64 to −0.80)†	−1.66 (−1.92 to −1.39)	<0.001†	0.02 (−0.24 to 0.28)	0.876
Step-down test, repetition	9.1 (3.5)	10.3 (2.8)	−1.1 (−3.1 to 0.8)	13.7 (2.8)	10.8 (3.2)	3.1 (1.3 to 5.0)†	4.8 (3.7 to 5.4)	<0.001†	0.3 (−0.5 to 1.2)	0.490
FPPA, degree	18.24 (7.20)	17.86 (5.34)	0.38 (−3.57 to 4.33)	6.90 (5.21)	19.00 (4.57)	−12.10 (−15.15 to −9.04)†	−11.33 (−13.40 to −9.27	<0.001†	1.14 (−0.93 to 3.21)	0.271

*Adjustment for multiple comparisons: Bonferroni.
†The mean difference is significant at the 0.05 level.
C, control; FPPA, frontal plane projection angle; KPQ, Thai version of the self-administered Kujala Patellofemoral Questionnaire; TTE, telehealth-based therapeutic exercise; VAS, Visual Analog Scale.

Pain intensity and KPQ score

Pain intensity (VAS) and KPQ score showed an interaction effect between the group and the time of measurement (VAS; p<0.001, F=159.677, η^2 = 0.800 and KPQ; p<0.001, F=105.616, η^2 = 0.725). After a 4-week intervention, the between-group comparison revealed that the TTE group significantly improved pain intensity and KPQ score (p<0.001) compared with the C group. Moreover, the within-group comparison revealed that pain intensity decreased and KPQ score increased significantly in the TTE group (VAS mean change=−3.73, p<0.001; KPQ score mean change=10.91, p<0.001). The C group had no significant improvement regarding pain and KPQ score (table 2 and figure 4).

Functional performance

All functional performance variables demonstrated an interaction effect between the group and the time of measurement (single-leg hop test; p<0.001, F=73.565, η^2 = 0.648, triple hop test; p<0.001, F=49.978, η^2 = 0.555, crossover hop test; p<0.001, F=68.567, η^2 = 0.632, single-leg 6-m timed hop; p<0.001, F=82.762, η^2 = 0.674, and step-down test; p<0.001, F=54.545, η^2 = 0.577). After 4 weeks of interventions, there was a significant improvement in all functional performance variables of the TTE group compared with the C group. Within the TTE group, there was a statistically significant increase in the distance (p<0.001) for the single-leg hop, triple-hop and crossover hop tests. The duration of the single-leg 6-m timed hop test decreased significantly. There was also a statistical improvement in the step-down test. However, no significant changes were observed in any of the performance variables within the C group (table 2 and figure 4).

Dynamic knee valgus

FPPA revealed an interaction effect between the group and the time of measurement (p<0.001, F=74.354, η^2 = 0.650). A statistically significant improvement in FPPA was found in the TTE group compared with the C group after receiving interventions (p<0.001). There was a significant improvement in FPPA within the TTE group (p<0.001), while no significant change was observed within the C group (table 2 and figure 4).

DISCUSSION

Our findings revealed that a 4-week TTE programme could relieve pain, improve functional performance and decrease the dynamic knee valgus angle. The results emphasise the viability of TTE programmes, as individuals with PFP only need to attend two assessment sessions in the physical therapy setting, thereby reducing time commitment, lowering costs and minimising work absence hours. Moreover, it circumvents transportation challenges and curtails follow-up losses. The Zoom and Line applications employed in this study were chosen for their user-friendly features, facilitating seamless video conferencing. The widespread familiarity with these applications among adolescents, young adults and

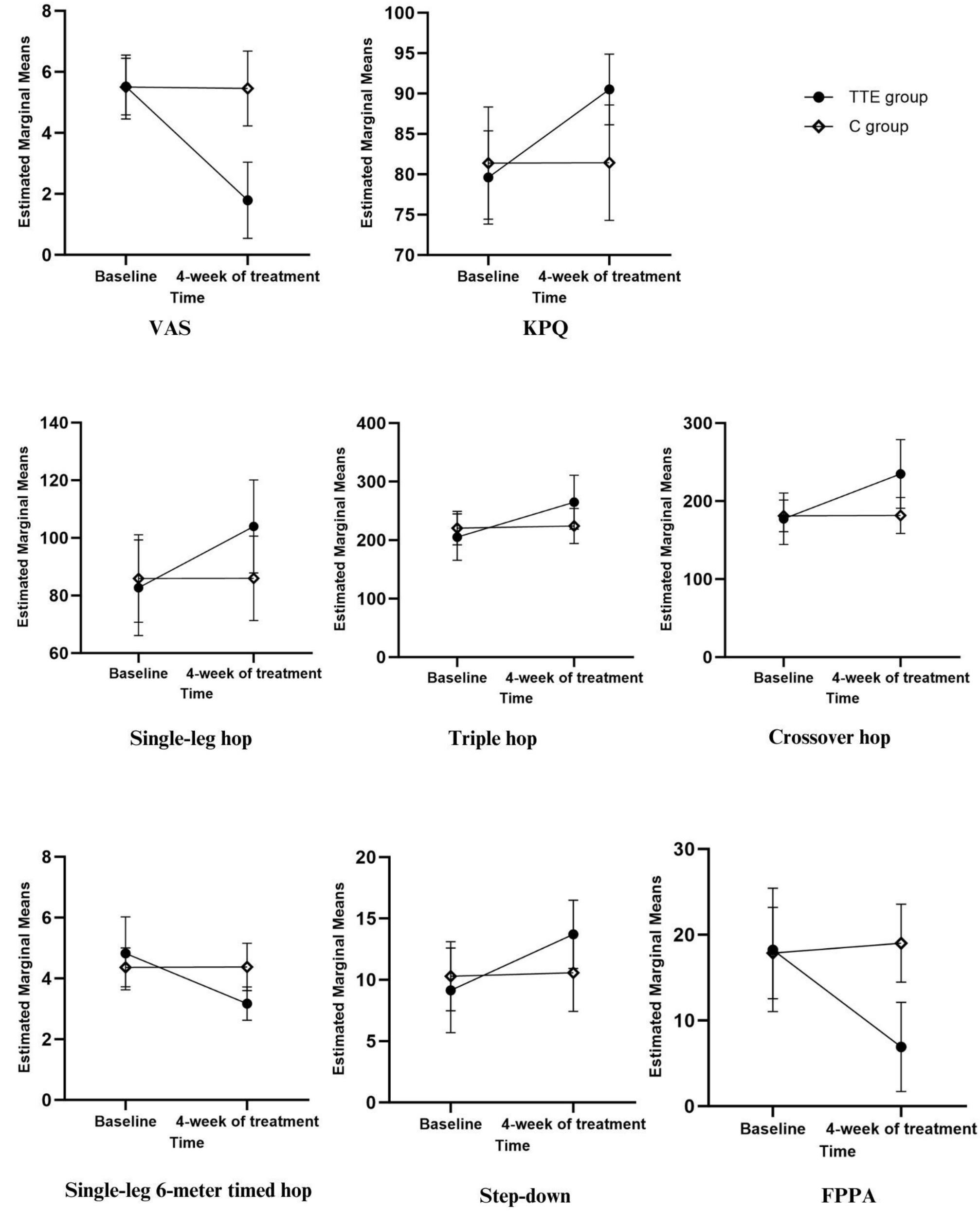

Figure 4 Estimated marginal means for all variables: Visual Analog Scale (VAS), Kujala Patellofemoral Questionnaire (KPQ), Hop tests, step-down and frontal plane projection angle (FPPA).

individuals compelled to work from home during the COVID-19 pandemic made them particularly accessible. Notably, the contemporary demographic, consisting of adolescents and young adults, is well acquainted with video conferencing applications.

This study is one of the few designed to investigate the effects of a telehealth-based exercise programme on pain, functional performance and dynamic knee valgus in individuals with PFP. Some studies provided telerehabilitation for individuals with PFP during the COVID-19 pandemic, but they were limited by the teleconference methods used[26] and by a quasi-experimental study design without randomisation.[45] Arslan *et al* did not focus on dynamic knee valgus, which is our concern,[46] while a recent study has only provided the protocol.[47] While the effectiveness of traditional, in-person exercise programmes in alleviating pain and enhancing functional performance among patients with PFP is well established, the realm of telehealth-based exercise programmes remains comparatively underexplored and less comprehended. Given this context, the outcomes of the current study hold significance in informing decision-making processes related to physiotherapy rehabilitation programmes for patients with PFP. Notably, the results indicated that a therapeutic exercise programme for individuals with PFP could be conducted via an online platform, particularly those involving neuromuscular training. These programmes, which necessitate the incorporation of verbal and visual feedback methods for exercise correction,[27] demand intense concentration, lower extremity strength and engagement of mechanoreceptors in the knee joint.[48]

Telerehabilitation has successfully addressed musculoskeletal conditions through diverse technological avenues, employing various types of technology such as mobile phones[49] and video conferencing.[50] Web-supported programmes, in which physical therapists provide advice through video conferencing, can motivate patients to engage in and manage their exercise behaviours safely, feasibly and well accepted.[51] In this study, individual exercises with real-time monitoring and encouragement to reach the goal motivated participants to continue with the programme until completing the course. Therefore, the compilation of research results on the effectiveness of telemedicine healthcare programmes may guide the application as an alternative practice and be a preparation for dealing with the epidemic situation in the future.

The exercise regimen implemented in this study was informed by the positive outcomes observed in conventional in-person exercise supervision for patients with PFP. Our results demonstrate that remote delivery of both hip and knee strengthening exercises and neuromuscular control contributed to the pain reduction in PFP. Importantly, this was achieved via videoconferencing, offering instruction, corrections and motivational support. We suggested that our exercise programme, developed based on several international studies demonstrating its effectiveness in individuals with PFP, allow people from different countries to participate via telehealth under the supervision of their physical therapists.

Quadriceps weakness, particularly in the vastus medialis oblique, has been a focus in exercises for PFP.[52] A previous study has expanded focus to include hip abductor and lateral rotator strengthening due to observed hip musculature weakness among patients with PFP.[53] Excessive hip adduction and knee abduction excursions in patients with PFP suggest a link to knee valgus orientation.[54] Combining hip and knee strengthening has shown greater effectiveness in pain reduction compared with knee strengthening alone, with significant improvements noted.[17 30 43] Furthermore, neuromuscular training in such programmes may enhance hip abductor strength and patellar alignment, reducing joint pressure and facilitating frontal plane kinematic adjustments. Previous studies also confirmed the effect of neuromuscular training on pain reduction.[27 55] This pain reduction leads to improved performance in hop and step-down tests, consistent with previous findings.[27]

Furthermore, the dynamic knee valgus angle in single leg squat task, which FPPA represents, was decreased after receiving the TTE programme. Our finding revealed that hip and knee strengthening exercises combined with neuromuscular control exercises could improve knee control during functional tasks. Previous studies have shown that valgus control instruction exercise,[27] combined hip strengthening and lower limb control exercises,[56] and hip strengthening,[29] could reduce the dynamic knee valgus.

Clinical implications

The study illuminated significant clinical implications, providing valuable insights into the efficacy of a 4-week telerehabilitation programme for individuals with PFP. The findings revealed the potential benefits of telehealth programmes in musculoskeletal rehabilitation by relieving pain, enhancing functional performance and reducing the dynamic knee valgus angle. Additionally, the accessibility and feasibility of telehealth platforms like Zoom and Line were highlighted, particularly among demographics familiar with video-conferencing applications. Telehealth-based interventions offered valuable implications for physiotherapy rehabilitation decision-making processes alongside traditional, in-person exercise programmes. Therefore, telerehabilitation emerged as a viable and effective means of delivering exercise interventions for individuals with PFP, suggesting broader applications in musculoskeletal rehabilitation.

Limitations

We did not investigate lower limb kinetic and kinematic data or proprioception, which could monitor altered movements resulting from the programme. Additionally, the strengthening exercises in this study did not include exercises for the ankle and foot muscles, which may contribute to increased dynamic knee valgus in individuals with PFP. However, neuromuscular training in this programme may help improve muscle performance in the lower extremities, including the hip, knee and ankle, as indicated by decreased FPPA after the 4-week intervention. Moreover, long-term follow-up after the intervention was not conducted. Future research should include specific exercises targeting the ankle and foot muscles and prioritise examining long-term effects to confirm the programme's effectiveness in addressing PFP-related challenges and ensuring patients' well-being.

CONCLUSION

This study demonstrates that a 4-week TTE programme for PFP, conducted via real-time videoconference, is sufficiently effective in alleviating pain, enhancing lower extremity performance, and improving knee control during functional tasks. Patients with PFP who cannot access in-person exercise programmes with a physical therapist can effectively practice the therapeutic exercises at home through the specialist-recommended videoconference sessions.

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