The effect of patellar taping combined with isometric strength training on pain, muscle strength, and functional performance in patients with patellofemoral pain syndrome: a randomized comparative study (#106600)

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The effect of patellar taping combined with isometric strength training on pain, muscle strength, and functional performance in patients with patellofemoral pain syndrome: a randomized comparative study

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Background: Patellar taping and quadriceps strengthening exercises are commonly used in physiotherapy to manage patellofemoral pain syndrome (PFPS). However, previous research has reported inconsistent findings regarding quadriceps strength gains at specific knee angles during strength training in individuals with PFPS. **Objective.** This study investigated the combined effects of patellar taping and isometric quadriceps strength training at 60° of knee flexion on quadriceps strength, pain, and functional performance in female patients with PFPS. **Methods.** A two-arm, parallel-group, randomized comparative design was employed. Sixty adult females with PFPS were randomly assigned to either the experimental group (n = 30), which received patellar taping combined with quadriceps strength training at 60°, or the control group (n = 30), which received placebo taping with the same training. Both interventions lasted six weeks. Pain intensity, quadriceps muscle strength, and functional performance were assessed using the numeric pain rating scale (NPRS), maximum voluntary isometric contraction (MVIC) at 60^0 knee flexion, single leg triple hop (SLTH) test, and anterior knee pain scale (AKPS). Statistical analysis was performed using Wilcoxon signed-rank and Mann-Whitney U tests, with significance set at 95%. **Results:** Within-group analysis showed significant improvements in NPRS and MVIC at 60° knee flexion, SLTH, and AKPS scores post-intervention ($p<0.05$). Between-group comparisons revealed the experimental group had significantly greater improvements in all outcomes at six weeks post-intervention. Cohen’s d test confirmed the superiority of the experimental group in reducing pain and enhancing muscle strength and functional performance. **Conclusion:** The study demonstrates that patellar taping combined with isometric quadriceps strength training at a 60° knee flexion improves pain, muscle strength, and functional performance compared to placebo taping. These findings suggest that incorporating this combined approach may enhance rehabilitation outcomes for patients with PFPS, providing a valuable addition to clinical practice. **Trial registration:** The study protocol was prospectively registered in the “ClinicalTrials.gov PRS” under a trial identifier NCT05168332 and last updated date 15/03/2024.

Original research

Title

The effect of patellar taping combined with isometric strength training on pain, muscle strength, and functional performance in patients with patellofemoral pain syndrome: a randomized comparative study

Short title

Patellar taping in patellofemoral pain

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Abstract

Background: Patellar taping and quadriceps strengthening exercises are commonly used in physiotherapy to manage patellofemoral pain syndrome (PFPS). However, previous research has reported inconsistent findings regarding quadriceps strength gains at specific knee angles during strength training in individuals with PFPS. **Objective.** This study investigated the combined effects of patellar taping and isometric quadriceps strength training at 60° of knee flexion on quadriceps strength, pain, and functional performance in female patients with PFPS. **Methods.** A two-arm, parallel-group, randomized comparative design was employed. Sixty adult females with PFPS were randomly assigned to either the experimental group (n = 30), which received patellar taping combined with quadriceps strength training at 60°, or the control group (n = 30), which received placebo taping with the same training. Both interventions lasted six weeks. Pain intensity, quadriceps muscle strength, and functional performance were assessed using the numeric pain rating scale (NPRS), maximum voluntary isometric contraction (MVIC) at 60^0 knee flexion, single leg triple hop (SLTH) test, and anterior knee pain scale (AKPS). Statistical analysis was performed using Wilcoxon signed-rank and Mann-Whitney U tests, with significance set at 95%. **Results:** Within-group analysis showed significant improvements in NPRS and MVIC at 60° knee flexion, SLTH, and AKPS scores post-intervention ($p<0.05$).

Between-group comparisons revealed the experimental group had significantly greater improvements in all outcomes at six weeks post-intervention. Cohen's d test confirmed the superiority of the experimental group in reducing pain and enhancing muscle strength and functional performance. **Conclusion:** The study demonstrates that patellar taping combined with isometric quadriceps strength training at a 60° knee flexion improves pain, muscle strength, and functional performance compared to placebo taping. These findings suggest that incorporating this combined approach may enhance rehabilitation outcomes for patients with PFPS, providing a valuable addition to clinical practice.

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Keywords: Patellofemoral Pain Syndrome; Knee pain; Strength; Maximum Voluntary Isometric Contraction (MVIC)

Introduction:

Patellofemoral pain syndrome (PFPS) is the leading cause of knee discomfort in young adults and affects generally active individuals and athletes (McConnell, 1992). Globally, the prevalence of PFPS is 22.7% in the general population, and this may potentially rise during adolescence, affecting 20–30% of individuals (Borschneck G. 2021; Smith, B.E.;

Selfe, J. 2018). In Saudi Arabia, the incidence rate of PFPS is approximately 30.3% (Aldharman; S.S.; Almuhammadi 2022).

Patellofemoral pain syndrome (PFPS) is a broad term that covers various conditions affecting the patellofemoral joint (PFJ), including chondromalacia patellae, extensor mechanism dysfunction, patellar subluxation, and runner's knee (L. Herrington et al., 2004). PFPS is usually characterized by physical and biomechanical changes within the joint, resulting in anterior knee pain during activities like running, squatting, or climbing stairs (Hasan S.et al., 2022). These changes may involve altered patellar tracking, muscle imbalances, and soft tissue restrictions, such as weakness in the quadriceps or tightness in the hamstring muscles, all contributing to joint dysfunction and pain (Alonazi A; Hasan S et al.; & Kang; K. B.; hee Lee; J.; & Yoon J. R. 2023).

Recent medical research indicates that the condition is more severe, long-lasting, and associated with early degenerative changes in young individuals experiencing anterior knee pain (K. M. Crossley 2014; H. Conchie 2016).

In such cases, some young patients diagnosed with Patellofemoral Pain Syndrome (PFPS) may face a higher risk of anterior cruciate ligament (ACL) injury. (G. D. Myer 2015).

Despite the prevalence of PFPS, there is no consensus on its causes, diagnostic criteria, or treatment approaches. (B. Choi, 2015). Patellofemoral pain has been linked to various factors, including modifiable risk elements such as weakness in the vastus medialis obliquus (VMO), patellar misalignment and hypermobility (G. S. Nunes 2013). It has been proposed that these factors contribute to the development and recurrence of PFPS (S. H. Kunene 2018; R. A. Dutton 2016). Among these, quadriceps muscle strength is a critical factor, strongly correlating with the condition (J. Verschueren, 2020; F. Halabchi, 2013;J. A. Osorio, 2013). Evidence shows that individuals with PFPS tend to have weaker quadriceps muscles than healthy individuals (J. A. Osorio 2013).

Muscular imbalances within the quadriceps, particularly between the vastus medialis oblique (VMO) and vastus lateralis (VL) (Thongduang, P et al. 2022), can exacerbate patellar tilt (S. E. Lee et al. 2013). Studies highlight the importance of strong VMO muscles in maintaining patellar stability and preventing PFPS. Delayed or insufficient activation of the VMO leads to patellar maltracking, impairing knee joint function (N. Wyndow, 2016). The McConnell Taping technique was initially developed to correct abnormal patellar alignment by centralizing the patella and enhancing quadriceps strength, mainly targeting the activation and strengthening of the vastus medialis obliquus (VMO) (McConnell, 1996). Research has demonstrated that the correct patellar taping technique effectively reduces pain during activities that exert significant patellofemoral joint reaction forces (J. E. Earl and A. Z. Hoch 2011). Taping also provides short-term pain relief during movement (P. Shahnaz 2012; P. Alba-Martin, 2015]. Studies suggest that strengthening the quadriceps, particularly the VMO, positively influences patellofemoral joint mechanics. The VMO is the only muscle capable of achieving medial movement of the patella and remains active throughout the entire range of motion (Coqueiro, K.R 2005). In addition, past studies have suggested that incorporating regular quadriceps-strengthening exercises can further enhance this effect.

A previous study by L. A. Steinkamp et al.1993, found that closed-kinetic chain exercises performed with 0 to 40 degrees of knee flexion reduce patellofemoral joint reaction forces. This suggests that individuals with PFPS may benefit more from a closed-kinetic chain training program at this range of motion than open-kinetic chain exercises. Conversely, leg-press exercises at 60 to 90 degrees of knee flexion increase patellofemoral joint stress, which is particularly relevant for individuals with lesions distant from the patella, as greater knee flexion may help alleviate stress on the distal patella (L. A. Steinkamp et al.1993).

For instance, previous research identified that maximal quadriceps torque occurs at 60 degrees of flexion (mid-range) in male and female college students. Similarly, studies by Suter and Herzog 1997 and Chan et al 2001. found that knee extensor torque peaked when the knee was bent at a 90-degree angle in healthy individuals. Another study revealed that isometric strengthening exercises performed at 90 degrees of knee flexion improved quadriceps strength more effectively than training at 45 degrees of knee flexion (J. Paul & P. Balakrishnan, 2014). However, contrasting findings from

(Honarpishe et al., 2015) showed no significant differences in muscle strength gains of the VMO and vastus lateralis (VL) at varying knee angles in individuals with PFPS.

This research examines the impact of patella taping combined with isometric strength training (at 60-degree knee flexion) on individuals suffering from Patellofemoral Pain Syndrome. The study seeks to investigate the effect of this combined intervention on pain levels, quadriceps strength, and functional Performance (precisely hop distance). The research hypothesis posits that patella taping and Isometric Strength Training at 60-degree knee flexion would significantly improve pain, quadriceps strength, and functional Performance in individuals with Patellofemoral Pain Syndrome. These findings support that the observed enhancements in pain, quadriceps strength, and Performance in PFPS patients following the combined intervention are attributed to decreased pain inhibition and alterations in patella position. This study's findings help develop an effective method for increasing quadriceps strength as a treatment for PFPS.

2. Materials and methods

Study Design

A two arm parallel group randomized comparative study design was employed to evaluate a 6-week intervention. The participants were allocated equally (1:1) to both groups (n = 30/group).

Study settings

The participants with PFPS were first diagnosed by a consultant orthopaedic surgeon and referred for physiotherapy interventions to the orthopaedic rehabilitation lab, Majmaah University, Al Majmaah, Riyadh, Saudi Arabia. Second, a team of three skilled and experienced female physiotherapists, specializing in musculoskeletal disorders, McConnell taping techniques, and over 18 years of experience, conducted screenings of adult females with PFPS. The participants were recruited from the university's physical therapy clinic, Majmaah region hospital, social media posts, and the general public for a duration of almost nine-month, starting from December 30, 2022, to September 25, 2023.

Study procedure

The participants were screened based on the study's inclusion and exclusion criteria and recruited for this study. An online random number generator (RNG) (https://www.socscistatistics.com/utilities/random/default.aspx) was used to participants' random allocation to the groups to minimizing selection bias and balancing potential confounding variables across groups, strengthen the study's reliability and internal validity. Participants were assigned to one of the groups based on the generated random numbers (1-60). The sixty generated random numbers (such as 24,1,7,33,48,11,30,3,9,55... and so on) were grouped into four segments, each consisting of 15 random numbers. The first, second, third, and fourth segments of random numbers (1-15 & 31-45 and 16-30 & 46-60 random numbers) were alternately allocated to the participants of groups 1 and 2. The participant's study inclusion serial number was matched to the same number available in the generated random number segment that further belongs to either of the intervention groups. Two assistant physiotherapist who were kept blind to group allocation documented the study's outcome measures. Assessments were conducted before and after the intervention, and all female patients in each group completed the trial session. The experimental group (Group 1) received patellar taping combined with Isometric quadriceps exercise at 60 degrees' knee flexion; the Control group (Group 2) received Placebo patellar taping combined with Isometric quadriceps exercise at 60 degrees' knee flexion. The outcome measures for this study were the quadriceps muscle strength at angles of 60 degrees, pain intensity, and functional Performance. A CONSORT (2010) flow diagram **(**Figure 1) depicts the study procedures, including Enrollment, randomization, allocation, follow up, and analysis.

Please paste Figure 1. here

Figure 1. A Consolidated Standards of Reporting Trials (CONSORT) flow diagram shows the study procedures.

Study participants

The study evaluated 150 adult females with knee pain over the phone. The study included 60 adult active females with PFPS. Their average age, height, weight, and body mass index (BMI) of group 1 were 26.10 ± 0.99 years, 156.9 ± 1.47 cm, 67.65 ± 2.99 kg, and 27.48 ± 1.07kg/cm^2, and group 2 were 26.17± 0.87 years, 157.27 ± 1.64 cm, 67.47 ± 2.9 kg, and 27.28 ± 0.98 kg/cm^2, respectively. The inclusion criteria required the participants to have at least eight weeks of knee pain aggravated by specific activities, a positive J sign, a more symptomatic and mal-aligned knee in case of bilateral involvement, and radiographic evidence of patellar malalignment. Exclusion criteria included a history of knee fracture, patella dislocation, knee deformity, flexion contracture, ligament/meniscal injuries, NSAID or intra-articular injection, or knee osteoarthritis.

Outcomes (Dependent variables)

Quadriceps muscle strength (Primary).

The quadriceps femoris muscle strength was measured using a valid and reliable ISOMOVE dynamometer set at 60 degrees of knee flexion. The Data was collected using software version 0.0.1 of the ISOMOVE system (ISO-MANSW-IT Tecnobody). Before Testing, participants underwent a comprehensive training session to ensure they were fully equipped to use the equipment. Muscle strength measurements were taken at baseline (before treatment) and again at six week's post-treatment, providing a valid and reliable data set.

Participants were carefully secured with safety belts across the chest, thighs, and hips, and the shin pad was positioned 5.1 cm (2 inches) superior to the medial malleolus. The

Testing was performed on the more symptomatic leg at 60 degrees of knee flexion. Participants were trained to keep their arms crossed over their chests and encouraged verbally to exert maximum effort during the 5-second contractions. Three consecutive trials were conducted for each test, with a 2-minute rest interval between trials. The mean score of these trials was used for statistical analysis.

Pain intensity (Secondary).

The numeric pain rating scale (NPRS) is a reliable and valid tool for measuring pain (Hasan S, 2013 & Alghadir AH, 2018). Each participant was assessed for pain intensity on a 0 to 10 scale, where 10 indicates the highest pain level, and 0 represents no pain.

Knee function (Secondary).

Knee function was assessed using the validated Kujala Anterior Knee Pain scale (Kujala UM 1993, Hamdan M 2019). This scale consists of 13 questions designed to assess various patellofemoral pain syndrome (PFPS) issues, such as walking, squatting, stair climbing, jumping, running, limp presence, need for support, pain, and abnormal or painful knee cap movement. The scores can range from 0 to 100, where the higher score represents superior knee functional capacity. Before administration to patients with patellofemoral pain, the Kujala questionnaires were translated into Arabic and reviewed by native speakers of Arabic who had a medical background and were knowledgeable about the original document.

Single-Leg Triple Hop test (SLTH) (Secondary).

The single-leg triple hop test (SLTH) encompasses the landing and propulsion phases. It is an effective screening tool commonly used in clinical practice to recognize individuals at risk of knee injury and assess progress in patients with PFPS and ACL reconstruction (Dos Reis AC 2015). The test is also a comprehensive tool for evaluating lower extremity muscle strength. It measures physical Performance requiring significant muscular activity, making it an asset in sports medicine and physical therapy.

In this study, participants' performance was evaluated based on their results from the SLTH test. Participants began by standing on their symptomatic limb with their toes directly below the starting line and then performed three consecutive hops on the same limb. The distance covered from the starting point to where the back of their heel touched the ground was measured (Figure 2). Each participant completed three trials with a three-minute rest period between each one. The best distance achieved among the three trials was selected as the baseline measure.

Please paste Figure 2. here

Interventions

Patellar taping

The taping techniques, meticulously detailed by McConnell, were expertly used by the physiotherapist to correct specific patellar malalignments, such as lateral and anteroposterior tilt and medial patellar glide. The tape was applied below the patella to relieve pressure on the infrapatellar fat pad, as illustrated in Figure 3. Initially, hypoallergenic underwrap tape was used to prevent skin tension and irritation. It was followed by rigid McConnell tape to pull the skin and patella and maintain its position medially (McConnell 1996; Hasan S., 2022). For the placebo taping, a nonrigid hypoallergenic tape (Placebo tape) was applied with a flexed knee in a vertical direction from the centre of the patella and performed quadriceps strength training at 60 degrees of knee flexion without rigid patellar taping. The tape was removed after the quadriceps femoris strength training and outcome measurement or if the participant experienced itching, redness, or discomfort.

With patellar taping, each participant was carefully instructed to perform isometric quadriceps exercises at 60° angles and isometric hip adduction exercises to strengthen quadriceps muscles as described below.

These exercises were chosen based on their ability to recruit maximal quadriceps muscle activity. Because no single exercise resulted in maximal quadriceps muscle activation, this study chose a combination of exercises rather than a single exercise to maximize the possibility of recruiting maximal quadriceps muscle activity (Rutherford DJ, 2011).

Each participant was guided to perform three sets of exercises five days a week for six weeks. The procedure was explained to them, and they were advised to monitor their quadriceps muscle activity during the exercises, holding the contraction for 5 seconds and resting for 10 seconds.

Please paste Figure 3. here

Quadriceps strengthening exercises

Patellar Taping Combined with Maximum Voluntary Isometric Contraction Exercises at 60 Degrees of Knee Flexion Angles: Participants were instructed to sit on the ISOMOVE system (ISO-MANSW-IT Tecnobody) and perform isometric contraction of quadriceps exercises at 60 degrees of knee flexion three times weekly for six weeks. They were to complete three sets of two isometric contractions of quadriceps, each lasting 5 seconds, with a 30-second rest between sets. To ensure consistency in performing the isometric exercises at the predefined knee angles, the target knee angle was preset before each session using the ISOMOVE system.

Isometric Hip Adduction Exercise:

Participants were instructed to lie supine with a pillow between their knees and press firmly to engage the muscles via isometric hip adduction exercise. They performed three sets of 10 repetitions.

Control Group (placebo patellar taping combined with isometric quadriceps exercise at 60 degrees Knee Flexion Angles:

Participants in the control group performed the same set of exercises with Placebo patellar taping. A nonrigid hypoallergenic placebo tape was applied vertically from the center of the patella with the knee flexed. They conducted quadriceps exercises without rigid patellar taping.

Ethical considerations

The institutional review board at the College of Applied Medical Science, Majmaah University, Saudi Arabia approved the study under an ethical approval number: MUREC-Nov.20/COM-2O22/18-2 dated 20/11/2022. The study protocol was prospectively registered in “ClinicalTrials.gov PRS” under trial identifier NCT05168332. Participants were informed of research risks and benefits and provided written informed consent following the Helsinki Declaration's standards.

Sample size

The effective sample size was estimated using a computer software, G*Power version 1.3.9.4 (sample size calculator tool) based on a previous study that evaluated the quadriceps muscle strength in participants with PFPS (samples from two groups and two-time points) with a calculated effect size greater than 0.08, the confidence interval 0.05 and a statistical power 0.8, an effective sample size of twenty-four in each group was estimated (Alonazi A et al., 2021 & Hasan S et al., 2022). Assuming a 20% sample attrition, a sample of thirty participants was required to conduct this study.

Statistical analysis

Data was analysed using IBM software for social statistics SPSS v.28 (IBM SPSS v.28, Armonk. NYK, Inc. USA). A Kolmogorov-Smirnov test of normality was employed for abnormal data distribution. Non-parametric tests, including a Wilcoxon Signed Rank Test and Mann-Whitney U Test, were employed to observe the efficacies of stipulated interventions on the scores of the outcome measures within and between the groups, respectively. Moreover, Cohen's *d* test determined one group's superiority over another. A confidence interval was set at 95% for all the statistical analyses.

Results

A total of 60 female participants completed the trial. The demographic and clinical data are summarized in Table 1. The Kolmogorov-Smirnov test of normality revealed that the data for the baseline demographic characteristics and outcomes measures were non-homogeneously distributed in this study (Table 1.). Therefore, non-parametric tests, including a Wilcoxon Signed Rank Test and Mann-Whitney U Test, were employed to observe the efficacies of stipulated interventions on the scores of the outcome measures within and between the groups, respectively. The mean scores and standard deviations for the demographic characteristics and baseline scores are presented in Table 1.1

Please paste Table 1. here

Within-group comparison of outcomes scores

Wilcoxon Signed Rank Test for within-group comparison: revealed a significant improvement (p<-05) for all the outcomes scores within each group when post-intervention scores were compared with baseline scores (Table 2.).

Please paste Table 2. here

Between-group comparison of outcomes scores

The Mann-Whitney U Test for between-group comparison revealed a significant difference between the groups for all the outcomes scores compared at a six weeks' post-intervention (Table 3).

Please paste Table 4. here

In addition, Cohen's *d* test revealed the magnitude of the stipulated interventions, thus revealing a superiority of group 1 over group 2 in reducing pain intensity and improving muscle strength (STN), and functional performance (SLTH & AKPS) (Table 4).

Please paste Table 4. here

Discussion

This study evaluated the effects of patellar taping combined with isometric contraction of quadriceps strength training at a 60-degree knee flexion angle on pain intensity, quadriceps strength, and functional Performance in young adult female patients with PFPS. The results showed that patellar taping combined with isometric quadriceps training at a 60-degree knee flexion angle significantly improved pain, quadriceps strength, and function for PFPS patients over six weeks of training compared to placebo taping combined with isometric quadriceps strength training at the same angle in improving pain, quadriceps strength, and functional Performance. Both experimental groups demonstrated improved outcomes after the six-week intervention training.

However, all participants in the group that combined taping with isometric quadriceps training at a 60-degree knee flexion were eventually pain-free and fully functional. In contrast, participants in the other groups experienced residual pain and weakness in the quadriceps muscles. The results indicate that combined patella taping with isometric quadriceps training at a 60-degree knee flexion provides an effective treatment component greater than a Placebo. These findings are similar to those of other investigators using similar correcting taping techniques and exercises, providing evidence for the efficacy of such interventions. Bockrath; Kelly et al. 1993; Gilleard; Wendy, 1998).

Identifying the precisely combined taping with activation of isometric quadriceps muscle mechanisms of action is not clear, but this observation is imperative for future mechanisms-based randomized control trial studies.

Some authors have asserted that, with the patella correctly taped, there should be at least a 50% reduction in pain when performing a step test. (Gilleard; Wendy 1998; McConnell; Jenny 1986). The pain experienced on performing a step test decreased by an average of 47% with active patella taping in the present study, compared to only 10% with placebo tape. There was a 2% decrease in pain in the control group when repeating the step test without taping. This compares very favourably with the reductions in pain reported by other investigators. (Bockrath; Kelly et al. 1993; Gilleard; Wendy 1998; & Wilson T.; N. Carter 2004).

Numerous studies have looked at patellar taping and found that it may be beneficial for reducing the pain that people with PFPS experience (Petersen; Wolf et al. 2016; Barton; Christian et al. 2014 & isk, Daniel 2020). The customized McConnell taping technique is a typical way to minimize pain during a functional task, such as the step-down. This technique uses rigid tape to reduce any combination of lateral patellar glide, tilt, and rotation in the knee (Cowan; Sallie M 2002). In addition, people use untailored taping on the patellar glide and medial glide (Lack; Simon; et al.2018), designed to enhance vastus muscle activation and synergy (Lee; Chang Ryeol et al. 2012). Taping the patellar tendon across the skin has been shown in multiple studies to increase proprioception by stimulating cutaneous mechanoreceptors and, as a result, boosting afferent input to the central nervous system (Kim; Hyunhee 2012; Chang; Hsiao-Yun et al. 2010; & BAYRAKCI TUNAY 2008). The increased afferent fibre input and neural inhibition following this phenomenon are called the nociceptive effect (Willy; Richard Wet al.2019; Chang; Hsiao-Yun et al. 2010; & BAYRAKCI TUNAY 2008). The Academy of Orthopaedic Physical Therapy recently recommended formulating a clinical practice guideline for treating PFPS (Willy, Richard W. et al.2019). They advocate patellar taping as part of an exercise therapy treatment plan to provide immediate pain relief and improve short-term results (4 weeks). Taping techniques are ineffective over time or with more intensive physical therapy. Additionally, they do not advocate taping to improve muscle function.

Overall, taping helps people with PFPS in the short term, but more research is needed to determine how it affects them in the long term.

Another study discovered that individuals who trained their quadriceps at a 60-degree knee angle had significantly greater quadriceps muscle strength than those who trained at 30 or 90 degrees of knee flexion. As a result of their unique anatomical traits, the three superficial quadriceps muscle segments, including VMO, can produce varying muscle torque depending on knee angle. Moreover, this causes knee angle changes to affect muscle fibre excursion length (Pincivero; Danny M. et al. 2004). It was hypothesized that performing isometric exercises while varying the angle at which the knees were bent resulted in the best development in total strength (Lum; Danny 2019; Bogdanis 2019; Rhea, Matthew R. et al. 2016). As discovered in another study, the isometric exercise of the quadriceps in the mid-range may be effective for increasing function in people who suffer from knee problems (Mellinger 2019). Most voluntary isometric knee extensor torque attribution should be given to the mechanical force-length characteristics of skeletal muscle (Maden-Wilkinson 2020). However, evidence suggests a neural component (Suter, E.1997, Becker, Roland 2001). Because both individual muscle fibre and whole-muscle levels appear to produce their best results with a moderate force generation length, the literature supports the theory that knee extensor torque is at its greatest when seated knee movement occurs in the middle of the knee flexion (Schoenfeld; Brad et al. 2021; LaStayo; Paul et al. 2014). In another study, both men and women in college found that peak quadriceps torque happened at 60° of flexion (mid-range) (Shenoy 2011).

In contrast to these findings, in a study involving 10 and 17 healthy adults, (Suter and Herzog 1997 and Chan; Addie YF et al. 2001) found that the knee extensor torque was highest when the knee was bent at 90 degrees. Similarly, another study found that isometric strengthening exercises performed at 90 degrees of knee flexion improved quadriceps muscle strength more than 45 degrees of knee flexion training (Paul, Jibi,2014). However, participant characteristics and methodology differences make directly comparing these results impossible.

Study limitations

This study has some limitations. First, it was limited to young adult female patients only with PFPS. Therefore, the findings cannot be generalized to male patients. Second, a follow-up was needed to assess the lasting effects of the intervention on pain intensity, muscle strength changes and functional Performance. Therefore, additional research is required to explore the long-term effect of corrective taping combined with

60-degree knee flexion isometric strength training in individuals with PFPS. Third, despite their potential importance, the study did not examine the individual effects of isometric quadriceps training at 60 degrees of knee flexion and patellar taping. Therefore, people with PFPS should be studied to discover if patellar tape improves muscle recruitment patterns while exercising at 60 degrees of knee flexion angles. Lastly, the study did not assess a priori power, which may limit the validity of the findings. Further research is needed to understand the association between pain, strength, and function in PFPS patients.

Clinical Implications

The results of this investigation could have significant repercussions for clinical practice. As previously stated, quadriceps muscle strength was highest at 60^0 knee flexion. This must be considered if comparing the most significant peak torque generation achieved by different approaches. This indicates that the angle may be employed for knee strength evaluation and training in patients with PFPS if a clinician or researcher is interested in boosting the strength of the quadriceps muscle. Even if the compressive force that the patella exerts on the femoral surface may be at its peak, it is essential to keep this information in mind in clinical practice when working to strengthen the quadriceps.

In the future, we recommend that PFPS be compared between activities involving an open-kinetic chain and those involving a closed-kinetic chain. At the same time, the knee is flexed at a variety of angles. As a result, it has been suggested that, in further research, the effects of patellar taping combined with isometric strength training at 60 degrees of knee flexion for PFPS rehabilitation should be examined in greater depth, explicitly focusing on the angles of the targeted training.

Conclusions

The study demonstrated that combining patellar taping with isometric quadriceps strength training at a 60° knee angle significantly enhances pain relief, muscle strength, and functional performance compared to placebo taping. These findings highlight a promising approach for clinicians, practitioners, and physiotherapists, advocating for the integration of this technique into rehabilitation protocols to improve outcomes for patients with patellofemoral pain syndrome.

Declarations

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Ethics approval and consent to participate statements

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Chair of Majmaah University for Research Ethics Committee, Saudi

Arabia (ethical approval number: MUREC-Nov./COM-2O22/18-2; dated November 20, 2022). The study protocol was prospectively registered in "ClinicalTrials.gov PRS" under trial identifier NCT05168332. A written informed consent form was obtained from each participant before start of the study.

Consent to publish

Not applicable

Data Availability Statement

All the datasets generated that support the study's findings are available from the corresponding author upon a reasonable request.

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Conflicts of Interest

The author declares no conflict of interest, either financial or non-financial in this study.

Author contribution

The primary author contributed to study's conception, design, idea, data curation, formal analysis, the results interpretation, methodology, manuscript initial and final draft writing and critical editing for the manuscript's intellectual contents, and approved the manuscript's final version to be submitted or published; and also take the responsibility for the manuscript's intellectual contents.

Authors information (optional)

Not applicable

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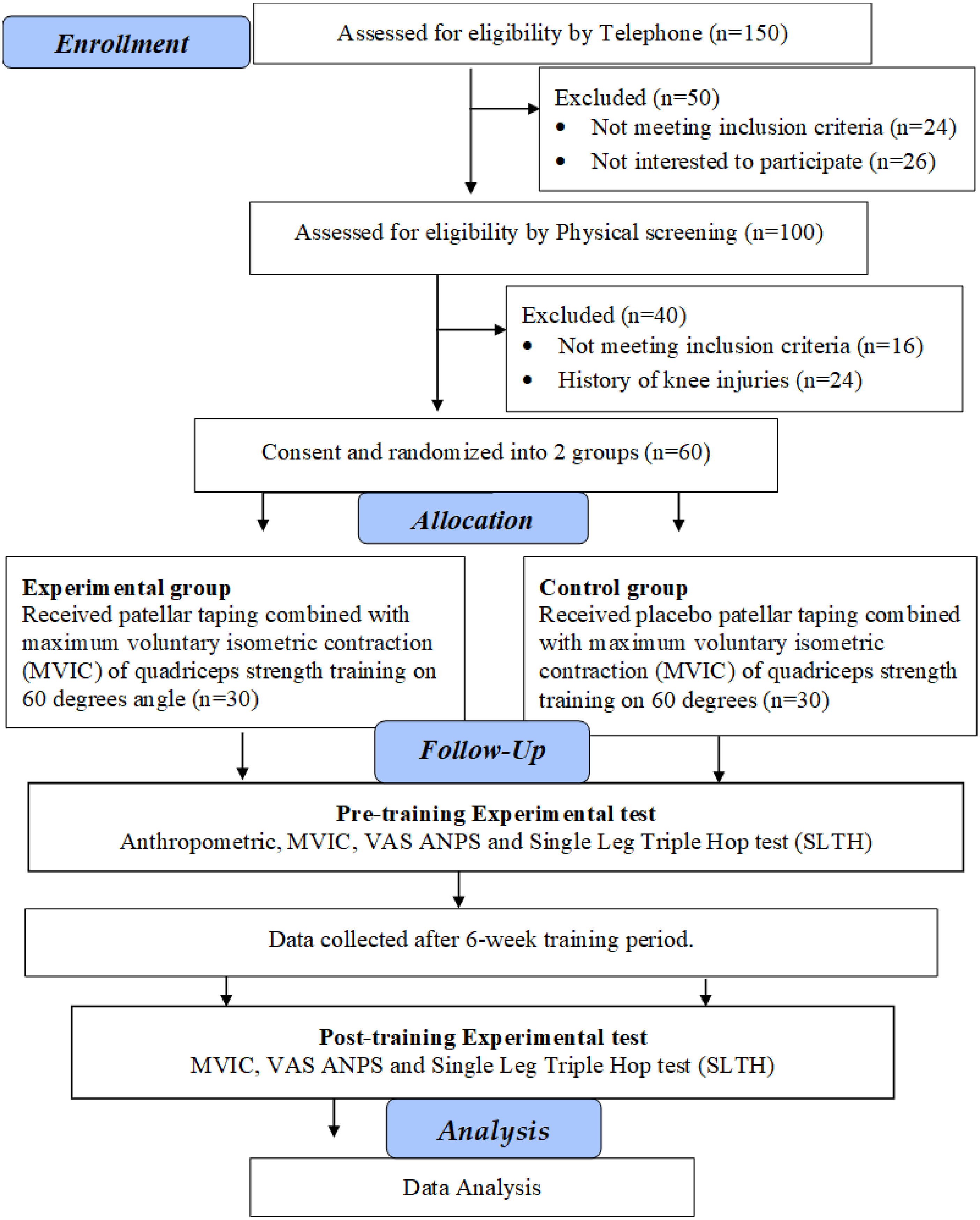
Figure 1

A CONSORT (2010) Flow Diagram



Enrollment
Assessed for eligibility by Telephone (n=150)
Excluded (n=50)
• Not meeting inclusion criteria (n=24)
• Not interested to participate (n=26)
Assessed for eligibility by Physical screening (n=100)
Excluded (n=40)
• Not meeting inclusion criteria (n=16)
• History of knee injuries (n=24)
Consent and randomized into 2 groups (n=60)
Allocation
Experimental group
Received patellar taping combined with maximum voluntary isometric contraction (MVIC) of quadriceps strength training on 60 degrees angle (n=30)
Control group
Received placebo patellar taping combined with maximum voluntary isometric contraction (MVIC) of quadriceps strength training on 60 degrees (n=30)
Follow-Up
Pre-training Experimental test
Anthropometric, MVIC, VAS ANPS and Single Leg Triple Hop test (SLTH)
Data collected after 6-week training period.
Post-training Experimental test
MVIC, VAS ANPS and Single Leg Triple Hop test (SLTH)
Analysis
Data Analysis

Table 1(on next page)

Descriptive details of the demographic characteristics and baseline outcomes scores within each group (N=30/group; 95% CI).

Table 1. Descriptive details of the demographic characteristics and baseline outcomes scores within each group (N=30/group; 95% Cl).

Variables	**Mean ± Standard deviation**		**Kolmogorov-Smirnov (95% Cl)**		
	Group 1 (n=30)	**Group 2 (n=30)**	**Statistics**	**df**	**p-value**
Age (Years)	26.10 ± 0.99	26.17 ± 0.87	0.208	60	0.001*
Height (cm)	156.90 ± 1.47	157.27 ± 1.64	0.190	60	0.001*
Weight (kg)	67.65 ± 2.99	67.47 ± 2.98	0.176	60	0.001*
BMI (kg/m^{-2})	27.48 ± 1.07	27.28 ± 0.98	0.126	60	0.019*
NRPS	7.10 ± 0.66	7.07 ± 0.70	0.189	60	0.001*
STN	109.53 ± 6.15	109.00 ± 7.17	0.126	60	0.019*
SLTH	244.97 ± 24.13	247.60 ± 18.43	0.074	60	0.200
AKPS	42.57 ± 6.76	43.70 ± 6.77	0.149	60	0.002*

*-Significance value, if p<0.05; cm: Centimetre; kg: Kilogram; NPRS: Numeric pain rating scale; STN: Strength; SLTH: Single leg triple hop; AKPS: Anterior knee pain scale

Figure 2

Single Leg Triple Hop (SLTH) test

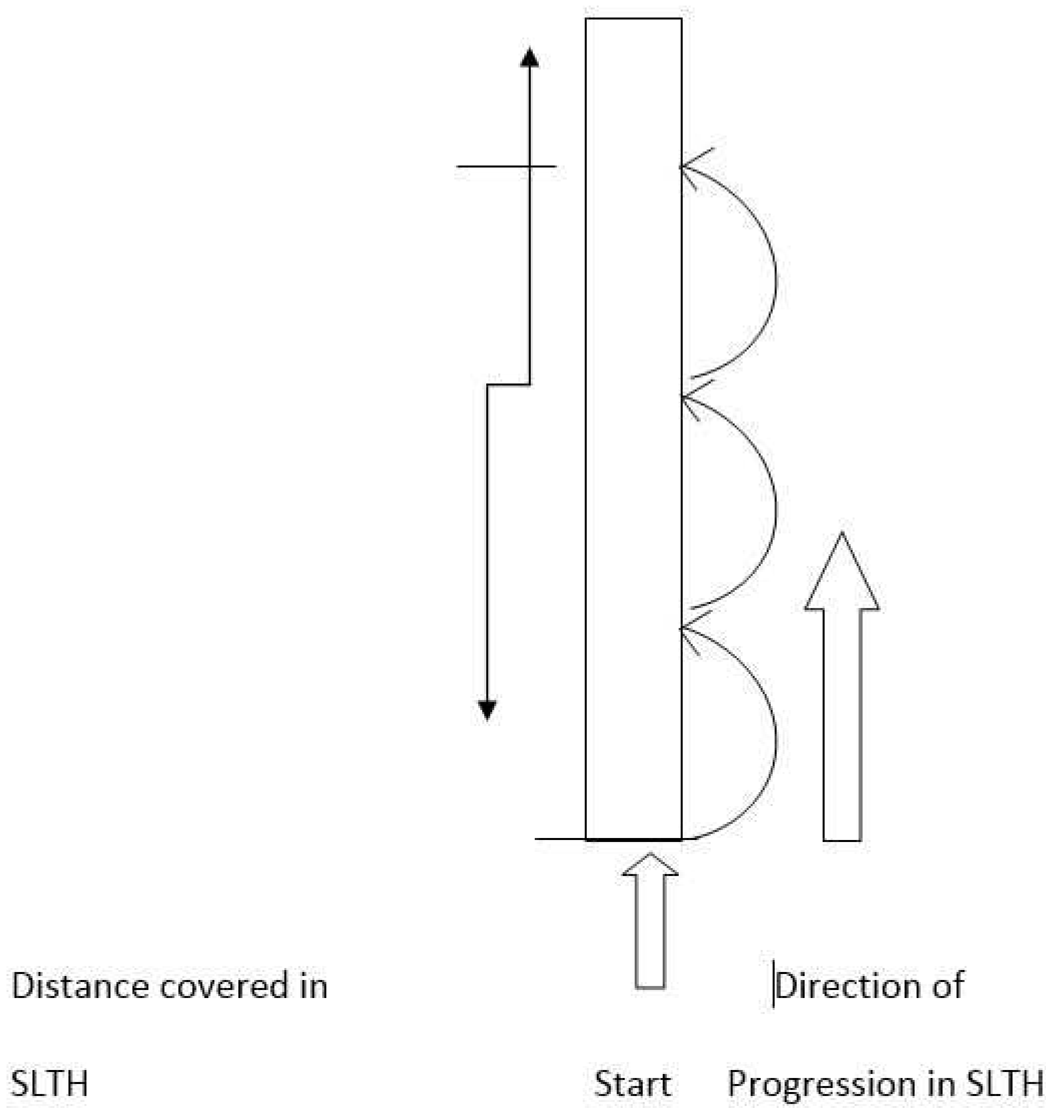


Table 2 (on next page)

Within-group comparison of the post-intervention mean scores of the outcomes with the baseline scores, using a Wilcoxon Signed Rank test (N=30/group; 95% CI).

Table 2. Within-group comparison of the post-intervention mean scores of the outcomes with the baseline scores, using a Wilcoxon Signed Rank test (N=30/group; 95% Cl).

Group 1 (n=30); Mean ± SD			**Wilcoxon Signed Ranks Test**	
Variables	**Post intervention**	**Baseline**	**Z-Statistics**	**p-value**
NPRS	1.42 ± 0.63	7.10 ± 0.66	-4.805	0.001*
STN	154.13 ± 9.29	109.53 ± 6.15	-4.810	0.001*
SLTH	354.07 ± 35.72	244.97 ± 24.13	-4.783	0.001*
AKPS	80.37 ± 5.10	42.57 ± 6.76	-4.788	0.001*
Group 2 (n=30); Mean ± SD				
NPRS	4.27 ± 0.79	7.07 ± 0.70	-4.806	0.001*
STN	122.63 ± 10.13	109.00 ± 7.17	-4.710	0.001*
SLTH	267.27 ± 14.34	247.60 ± 18.43	-4.784	0.001*
AKPS	69.53 ± 4.86	43.70 ± 6.77	-4.790	0.001*
*-Significance value, if p<0.05; NPRS: Numeric pain rating scale; STN: Strength; SLTH: Single leg triple hop; AKPS: Anterior knee pain scale				

Figure 3

Patellar taping

Table 3(on next page)

Between-group comparison of post-intervention mean outcomes scores, using a Mann-Whitney U test (N=30/group; 95% CI).

Table 3. Between-group comparison of post-intervention mean outcomes scores, using a Mann-Whitney U test (N=30/group; 95% Cl).

Variables (N=30/group)	Groups	Mean Rank	Sum of Ranks	Mann-Whitney U	Z-Statistic	Asympt. Sig. (2-tailed)
NPRS	Group 1	15.50	465.00	0.000	-6.700	0.001*
	Group 2	45.00	1365.00			
STN	Group 1	45.17	1355.00	10.00	-6.510	0.001*
	Group 2	15.83	475.00			
SLTH	Group 1	45.28	1358.50	6.50	-6.560	0.001*
	Group 2	15.72	471.50			
AKPS	Group 1	44.05	1321.50	43.50	-6.065	0.001*
	Group 2	16.95	508.50			

*-Significance value, if p<0.05; NPRS: Numeric pain rating scale; STN: Strength; SLTH: Single leg triple hop; AKPS: Anterior knee pain scale

Table 4(on next page)

A Cohen's *d* table (N = 60; 95% CI)

Table 4. A Cohen's *d* table (N=60; 95% CI)

Variables (n=30/group)	Groups (mean ± SD)			Cohen's *d* (95% Cl)
	Group 1	Group 2	Group 1 vs. 2	
NPRS	1.42 ± 0.63	4.27 ± 0.79	- 2.85 ± -0.16	3.989*
STN	154.13 ± 9.29	122.63 ± 10.13	31.50 ± -0.84	3.241*
SLTH	354.07 ± 35.72	267.27 ± 14.34	86.80 ± 21.38	3.241*
AKPS	80.37 ± 5.10	69.53 ± 4.86	10.84 ± 0.24	2.176*

*-Large effect size, if *d*>0.6; NPRS: Numeric pain rating scale; STN: Strength; SLTH: Single leg triple hop; AKPS: Anterior knee pain scale