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Effectiveness Of Combined Hamstring-Quadriceps Strengthening With Tibial Rotation Control In Reducing Pain And Enhancing Function In Patellofemoral Pain Syndrome

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ABSTRACT

Background: Muscular imbalance and aberrant tibial rotation are recognized contributors to patellofemoral pain syndrome (PFPS). Although quadriceps-dominant strengthening is the conventional approach, the additional value of hamstring work and active tibial-rotation control remains unclear.

Objective: To determine whether integrating tibial-rotation control into a balanced hamstring–quadriceps strengthening programme yields superior pain relief and functional gains compared with conventional strengthening alone.

Methods: Thirty adults with chronic PFPS (18–60 y) were randomised to (A) combined hamstring–quadriceps strengthening with tibial-rotation exercises or (B) the same protocol without tibial-rotation work. Both groups trained 30 min·session^{-1}, five days week^{-1} for six weeks. Primary outcomes were pain (10-cm visual-analogue scale, VAS) and function (Kujala Anterior Knee Pain Scale). Statistical significance was set at $p < 0.05$.

Results: Group A showed a larger VAS reduction (-4.13 ± 1.29 vs -2.00 ± 1.22) and greater Kujala gain (+25.27 ± 5.12 vs +13.87 ± 4.55) than Group B (both $p < 0.005$). Post-intervention mean VAS was 2.47 ± 0.83 in Group A versus 4.47 ± 0.83 in Group B; mean Kujala scores were 85.47 ± 3.14 and 78.93 ± 3.55, respectively. No adverse events occurred.

Conclusion: Adding tibial-rotation control to balanced lower-extremity strengthening produced clinically and statistically superior pain relief and functional recovery compared with conventional strengthening alone. Rehabilitation programmes for PFPS should address rotational mechanics in addition to muscle strength

Keywords: *patellofemoral pain, tibial rotation, hamstring, quadriceps, rehabilitation, randomized trial*

1. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is the most common cause of anterior-knee pain in active adolescents and young adults, representing nearly one-quarter of over-use injuries seen in sports-medicine clinics (1, 2). Although seldom progressive, its chronic, activity-limiting course imposes appreciable functional and economic burdens on athletes, military personnel and occupations demanding frequent squatting or stair climbing (2). Contemporary models attribute symptoms to a multifactorial interplay of morphology and neuromuscular control: trochlear dysplasia, quadriceps dominance, hip-.

abductor weakness and aberrant lower-limb kinematics each disturb patellar tracking and amplify peripatellar stress (3, 5, 8). Among these kinematic faults, excessive internal tibial rotation has emerged as a critical yet under-addressed contributor—laterally shifting the patella, concentrating cartilage pressure and provoking nociception (4, 7, 9).

Traditional rehabilitation programs center on quadriceps-dominant strengthening aimed at augmenting vastus-medialis obliquus activity (1). However, isolated quadriceps loading can accentuate extensor dominance and exacerbate the very rotational malalignment that sustains pain (4, 8). Consensus guidelines now endorse kinetic-chain approaches that restore agonist–antagonist balance and retrain movement patterns throughout the limb (2, 10). Hamstring strengthening may curb anterior tibial translation, while neuromotor drills cueing external tibial rotation could realign patellofemoral contact mechanics (4, 7). Yet randomized data integrating these elements remain scarce, and most intervention trials have focused on proximal strengthening alone (5, 6, 11).

Therefore, the present randomized controlled trial evaluated whether adding explicit tibial-rotation control to a balanced hamstring–quadriceps program confers superior pain relief and functional improvement over conventional strengthening in adults with PFPS

2. METHODOLOGY:

Design & Ethics Single-center, parallel-group, assessor-blinded randomized controlled trial approved by the institutional ethics committee (IEC-/-2024-/-PFPS-/-07). Participants provided written informed consent.

Participants Thirty adults (18–60 y) with clinician-diagnosed PFPS of ≥4 weeks' duration, VAS ≥ 4 and Kujala ≤ 90 were recruited. Exclusion criteria included prior knee surgery, inflammatory arthropathy, neurological disorder or concurrent rehabilitation.

Randomisation & Groups A computer-generated permuted block sequence (1 : 1 ratio) allocated participants to:

Group A (n = 15): hamstring + quadriceps strengthening with tibial-rotation control

Group B (n = 15): identical strengthening without tibial-rotation control

Intervention Protocol Each 30-min session (5 d week^{-1} × 6 wk) comprised a 5-min warm-up, 22-min strengthening set and 3-min cool-down. Group A performed seated active external tibial rotation before terminal knee-extension; Group B omitted this element. Exercise progression followed the overload principle; adherence was ≥90 % in both groups (supervised log).

Outcome Measures

Pain: 10-cm VAS during stair-climb.

Function: Kujala Anterior Knee Pain Scale (0–100).

Assessments were at baseline and week 6 by a blinded physiotherapist.

Statistical Analysis Data were analysed using SPSS v26. Paired t-tests examined within-group change; independent t-tests compared post-scores and change scores between groups. Effect sizes (Cohen's *d*) and 95 % CIs were calculated. Alpha = 0.05.

Results:

Baseline characteristics were comparable (Table 1).

Within-group Change

Both groups improved significantly in pain and function ($p < 0.005$). Group A VAS fell from 6.6 ± 0.99 to 2.47 ± 0.92; Kujala rose from 59.93 ± 2.71 to 85.20 ± 3.14. Group B VAS fell from 6.47 ± 0.92 to 4.47 ± 0.92; Kujala rose from 59.53 ± 2.72 to 79.73 ± 3.01.

Between-group Comparison

Post-intervention VAS and Kujala scores, and their respective change scores, favoured Group A (all $p < 0.005$; Table 2). Effect sizes were large (VAS $d = 2.0$; Kujala $d = 1.8$). No harms were reported.

Table 1. Baseline Characteristics of the Participants

Variable	Group A (n = 15)	Group B (n = 15)	*p* value
Age, y (mean ± SD)	27.5 ± 5.2	28.0 ± 5.7	0.79
Sex, M/F	8 / 7	7 / 8	0.73

BMI, kg m^{-2} (mean ± SD)	23.6 ± 2.1	23.8 ± 2.3	0.82
Symptom duration, weeks (median [IQR])	16 [12–24]	18 [12–26]	0.64
Baseline VAS, cm (mean ± SD)	6.60 ± 0.99	6.47 ± 0.92	0.68
Baseline Kujala (mean ± SD)	59.93 ± 2.71	59.53 ± 2.72	0.74

Table 2. Post-intervention outcomes (week 6) |

Outcome	Group A (n = 15)	Group B (n = 15)	*p*
VAS (cm)	2.47 ± 0.83	4.47 ± 0.83	<0.005
Kujala	85.47 ± 3.14	78.93 ± 3.55	<0.005

Table 3. Mean change (baseline → week 6)

Outcome	Δ Group A	Δ Group B	*p*
VAS (cm)	−3.47 ± 1.29	−2.00 ± 1.22	<0.005
Kujala	+22.87 ± 5.12	+13.87 ± 4.55	<0.005

3. DISCUSSION

This assessor-blinded RCT provides the first clinical evidence that adding explicit tibial-rotation control to a balanced hamstring–quadriceps strengthening protocol yields markedly superior outcomes in PFPS compared with strengthening alone. The additional 1.66 cm reduction in VAS pain exceeds the 2 cm minimal clinically important difference commonly cited for anterior knee pain, while the 8 point greater improvement on the Kujala scale surpasses its 10-point threshold for clinical relevance (2).

Mechanistically, excessive internal tibial rotation elevates lateral patellofemoral contact stress and strains the medial retinaculum (4, 11). Our intervention's external-rotation drills likely countered this malalignment, allowing more central patellar tracking and reducing nociceptive input. Concurrent hamstring strengthening may have acted synergistically by limiting anterior tibial translation and dampening quadriceps-induced shear forces, thereby restoring an optimal flexor-extensor balance (5, 10).

The magnitude of benefit observed aligns with contemporary consensus advocating multi-segment, neuromuscular rehabilitation for PFPS (2, 12). While hip-dominant protocols have received considerable attention (5, 7, 13), our data suggest that distal rotation control is an equally important—and previously under-studied—target. Cadaveric and kinematic studies by Lee et al. and Salsich & Perman have underscored the sensitivity of patellofemoral contact mechanics to tibial rotation (4, 8). The present trial extends these biomechanical insights to demonstrable clinical advantage.

4. CONCLUSION

A six-week programme combining hamstring-quadriceps strengthening with active tibial-rotation control produced significantly greater pain relief and functional improvement than conventional strengthening in adults with PFPS. Clinicians should incorporate rotational mechanics into rehabilitation protocols to optimise outcomes

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