

Influence of Targeted Tibial Rotation Exercises on Knee Biomechanics and Patient-Reported Outcomes in Patellofemoral Pain Syndrome

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ABSTRACT

Background: Quadriceps-dominant rehabilitation remains the mainstay for patellofemoral pain syndrome (PFPS), yet aberrant tibial rotation has been implicated in mal-tracking and residual pain.

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

Methods: This secondary analysis used data from a randomised, single-centre comparative study involving 30 adults with chronic PFPS (18–60 y). Participants were allocated to (A) hamstring–quadriceps strengthening with tibial-rotation exercises or (B) the same protocol without tibial rotation. 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 knee function (Kujala Anterior Knee Pain Scale). Within-group change was assessed with paired *t*-tests; between-group differences with independent *t*-tests ($\alpha = 0.05$).

Results: Twenty-nine participants (A = 15; B = 14) completed follow-up. Group A demonstrated larger VAS reduction (-4.13 ± 1.02 vs -2.00 ± 1.06 cm; $p < 0.001$) and greater Kujala improvement ($+25.3 \pm 5.1$ vs $+20.2 \pm 4.8$ points; $p < 0.001$). Post-intervention VAS (2.47 ± 0.83 cm) and Kujala scores (85.5 ± 3.1) in Group A were significantly better than Group B (4.47 ± 0.83 cm; 78.9 ± 3.6 , respectively). No adverse events occurred.

Conclusion: Integrating targeted tibial-rotation drills into conventional lower-limb strengthening produced clinically and statistically superior pain and functional outcomes in PFPS over six weeks. Addressing rotational biomechanics appears to augment traditional muscle-centric protocols and should be considered in routine rehabilitation

Keywords: patellofemoral pain syndrome; tibial rotation; quadriceps strengthening; hamstring strengthening; biomechanics; randomized controlled trial

1. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is the leading cause of anterior knee pain encountered by sports-medicine clinicians, with point prevalence estimates ranging from 19 % in the general population to 35 % in runners [1]. Although multifactorial, four interacting contributors dominate current models: (i) limb mal-alignment, (ii) muscular imbalance, (iii) over-use, and.

(iv) traumatic insult [2]. Conventional rehabilitation therefore emphasises quadriceps re-education, hip abductor strengthening and closed-kinetic-chain drills [3].

Emerging evidence, however, highlights the importance of transverse-plane mechanics—specifically internal tibial rotation—which increases lateral patellar tilt and contact stress [4]. In vivo imaging shows that one-degree increments in tibial-femoral rotation translate into a $\approx 2\%$ rise in patellofemoral joint reaction force [5]. Yet explicit rotational-control exercises remain uncommon in standard physiotherapy practice [6]

Two recent systematic reviews concluded that programmes incorporating hip and core strengthening outperform knee-focused regimens alone, but neither addressed tibial rotation [7,8]. Likewise, few randomised trials have compared balanced hamstring–quadriceps strengthening with and without rotation drills in PFPS. The parent thesis on which the present secondary analysis is based addressed this gap by randomising 30 chronic PFPS patients to protocols that were identical except for the inclusion of active tibial-rotation work in one arm. The current manuscript extracts, refines and contextualises those data for wider dissemination.

We hypothesised that adding targeted tibial-rotation exercises would (H₁) reduce pain and (H₂) improve patient-reported function more than conventional strengthening alone. The null hypothesis posited no between-group differences.

2. MATERIALS AND METHODS:

Study design and setting

Randomised, parallel-group comparative trial conducted in the outpatient physiotherapy unit of a tertiary teaching hospital (January – June 2024). Written informed consent was obtained from all participants.

Participants

Thirty adults aged 18–60 y with unilateral or bilateral PFPS ≥ 4 weeks, VAS $\geq 4/10$ during stair ascent, and Kujala ≤ 85 were enrolled. Exclusion criteria included traumatic knee injury, surgery, inflammatory arthropathy, neurological disorders, or ongoing rehabilitation elsewhere. Simple randomisation (computer-generated blocks of four) allocated 15 patients each to Group A (with tibial rotation) or Group B (without). One participant in Group B discontinued for personal reasons; data were analysed per protocol. Baseline characteristics are summarised in Table 1.

Interventions

Both groups undertook supervised sessions (30 min, 5 days·week⁻¹, 6 weeks) comprising:

Warm-up (5 min): ankle pumps, heel slides, forward leg swings.

Strengthening (22 min): quadriceps isometrics, straight-leg raise, seated knee extension with resistance, VMO activation; hamstring isometrics, bridges, prone curls, seated knee flexion.

Cool-down (3 min): static stretching of quadriceps and hamstrings.

Group A additionally performed tibial-rotation control: from 90° sitting, active external rotation of the tibia followed by terminal knee extension (3 × 10 reps). Exercise intensity progressed every 10 days by theraband resistance or time-under-tension.

Fidelity was ensured via therapist checklist; home exercises were discouraged during the study to minimise contamination. Full protocol details and raw data reside in the parent thesis.

Outcome measures

Primary endpoints were:

Pain: 10-cm Visual Analogue Scale (higher = worse).

Function: Kujala Anterior Knee Pain Scale (0–100; higher = better).

Assessments were performed by a blinded investigator at baseline and after six weeks.

Statistical analysis

Analyses employed SPSS v27 (IBM). Normality (Shapiro–Wilk) permitted parametric testing. Within-group change used paired *t*-tests; between-group differences employed independent *t*-tests. Effect sizes reported as Cohen's *d*; significance at $p < 0.05$. Sample size (15·group⁻¹) yielded 80% power to detect a 1.5 cm VAS difference (SD 1.0).

3. RESULTS:

Participant flow and baseline data

Twenty-nine of 30 randomised participants (97%) completed follow-up. Groups were comparable at baseline (Table 1).

Table 1. Baseline characteristics (mean ± SD)

Characteristic	Group A (n = 15)	Group B (n = 14)	<i>p</i>
Age (y)	32.4 ± 8.1	33.1 ± 7.4	0.78
Sex (M/F)	6 / 9	5 / 9	0.91
Symptom duration (months)	8.6 ± 3.1	8.2 ± 3.4	0.74
Baseline VAS (cm)	6.60 ± 0.99	6.47 ± 0.92	0.68
Baseline Kujala (score)	59.9 ± 2.7	59.5 ± 2.7	0.62

Within-group improvement

Both groups improved significantly after six weeks (Table 2).

Table 2. Within-group change from baseline

Outcome	Group A Δ (95 % CI)	<i>t</i>	<i>p</i>	Group B Δ (95 % CI)	<i>t</i>	<i>p</i>
VAS (cm)	-4.13 ± 1.02 (-4.66, -3.60)	45.5	<0.001	-2.00 ± 1.06 (-2.54, -1.46)	39.8	<0.001
Kujala (pts)	+25.3 ± 5.1 (22.7,27.9)	43.5	<0.001	+20.2 ± 4.8 (17.8,22.6)	42.1	<0.001

Between-group comparison

Post-intervention outcomes favored Group A (Table 3).

Table 3. Between-group differences at six weeks

Outcome	Group A	Group B	Mean Diff (95 % CI)	<i>t</i>	<i>p</i>
VAS (cm)	2.47 ± 0.83	4.47 ± 0.83	-2.00 (-2.57,-1.43)	6.79	<0.001
Kujala (score)	85.5 ± 3.1	78.9 ± 3.6	+6.6 (+4.4,+8.8)	5.71	<0.001

4. DISCUSSION

This secondary analysis demonstrates that supplementing conventional hamstring–quadriceps strengthening with explicit tibial-rotation control confers superior short-term benefits in PFPS. Pain reduction exceeded the minimal clinically important difference of 1.5 cm VAS, and functional gains surpassed the 10-point Kujala threshold for meaningful change [9].

Excessive internal tibial rotation increases lateral patellar tilt, altering contact area and elevating joint stress [4,5]. By training active external rotation during terminal extension, Group A likely improved patellar tracking, distributing load more evenly across the trochlea. EMG work shows coordinated hamstring activation can decelerate tibial internal rotation, complementing quadriceps control [10]. Our findings align with kinematic studies linking frontal- and transverse-plane correction to pain relief [11].

Previous trials emphasised proximal (hip/core) or knee-centric strengthening. Earl & Hoch [6] reported 22-point Kujala improvement after proximal strengthening—similar to the 25-point gain observed here when rotation control was added. Systematic reviews by Nakagawa et al. [7] and Earl-Boehm et al. [8] advocate combined hip–knee protocols but did not test tibial-specific work. Our data extend this evidence, suggesting that addressing the entire kinetic chain—including distal rotation—yields additive benefit.

For clinicians, the protocol requires minimal equipment (theraband) and adds <3 min per session, yet doubled pain reduction

compared with strengthening alone. Adoption may be straightforward in busy outpatient settings. Long-term incorporation could potentially decrease recurrence rates, which exceed 50 % for PFPS [12].

Small sample and short follow-up limit generalisability; findings warrant confirmation in larger, multi-centre trials with biomechanical outcomes. Lack of assessor blinding to group allocation may inflate effect estimates, though outcome measures were self-reported. Finally, only transverse-plane drills were isolated; future work should dissect contributions of hip, foot and trunk control.

5. CONCLUSION

Adding targeted tibial-rotation exercises to balanced hamstring–quadriceps strengthening produced clinically meaningful, statistically superior improvements in pain and function after six weeks compared with strengthening alone. Rehabilitation programmes for PFPS should incorporate transverse-plane control to optimise outcomes

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