Efficacy of Feedback on Running Gait Retraining in Patients With Patellofemoral Pain: A Critically Appraised Topic

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Clinical Question: Is it beneficial to utilize feedback motion retraining in improving gait biomechanics, pain, and self-reported function on patients with patellofemoral pain (PFP)? **Clinical Bottom Line:** There is sufficient evidence to support the use of feedback motion retraining to improve gait, pain, and function in PFP rehabilitation.

Keywords: motion retraining, kinematics, patient-reported function

Introduction/Clinical Scenario

Healthcare providers frequently encounter patients with patellofemoral pain (PFP), a nontraumatic and nonabnormal structural pathology which is localized in the retropatellar region.⁵ PFP accounts for up to 17% of visits to general practice physicians for knee pain.⁶ In recreational athletes, the prevalence may be closer to 25%, with individuals participating in running- and jumping-related activities most commonly affected.^{5,7} Patients with PFP often experience limitations of daily and physical activities.⁸ Athletes with prolonged symptoms

of PFP may experience decreased performance and early cessation of their athletic careers.⁸ Recent evidence suggests that PFP in young adults is a precursor to subsequent patellofemoral osteoarthritis.⁹

A systematic review established numerous risk factors of PFP, including dysfunction of knee extensor and/or hip abductor musculature, increased Q-angle, abnormal vastii reflex timing, patellar compression or tilting, and increased ground reaction forces during landing.¹⁰ In combination with these risk factors, dynamic

knee valgus during various movements may increase patellofemoral pressure and result in development of PFP.^{5,11,12} To correct dynamic valgus, researchers incorporated hip abductor musculature strengthening exercises, such as side lying hip abduction, clamshell, and resistive band exercises, into treatments.¹² Most of these investigations resulted in pain alleviation and improved self-reported function, but biomechanics were not improved.¹³

Due to the ineffectiveness of the hip strengthening exercise in altering biomechanics, researchers and clinicians have begun incorporating feedback of biomechanical movement patterns into PFP rehabilitation.¹⁴ This feedback is often either verbal or visual. Notably, a single, verbal feedback session has demonstrated immediate reductions in vertical ground reaction force during landing.¹⁵ Visual feedback is often provided via mirrors or videotape and has demonstrated improvements in dynamic valgus.¹⁶ Collectively, these studies suggest that using feedback during motion retraining is a beneficial addition to PFP rehabilitation treatment. This Critically Appraised Topic (CAT) serves to review the current evidence regarding the effectiveness of feedback motion retraining on pain, function, and running kinematics in patients with PFP. Running was selected because PFP is a common injury among runners.¹⁷ This will help healthcare providers to make evidence-based decisions regarding whether or not to use feedback gait retraining in treating PFP.

KEY POINTS

Three included studies¹⁻³ found significant improvements in gait, specifically observing reductions in hip adduction angle, contralateral pelvic drop, internal hip abduction moment, and vertical loading impact after intervention.

Concurrent increases in knee abduction and ankle plantar flexion angles at initial contact were also noted. Significant pain reduction¹⁻⁴ and improvement of self-reported function¹⁻³ were observed throughout the included studies.

Focused Clinical Question

Is it beneficial to utilize feedback motion retraining in improving gait biomechanics, pain, and self-reported function on patients with PFP?

Search Strategy

A database search was conducted in July of 2017. The search terms used were:

- Patient/client group: patellofemoral pain
- Intervention: Feedback motion retraining, augmented feedback
- Outcome: kinematics, function

The sources searched included:

- CINAHL
- Medline
- PubMed
- Google Scholar

Inclusion criteria were:

- Strength of Recommendation Taxonomy (SORT) Level 3 evidence or higher
- Studies that identify PFP criteria
- Studies that describe feedback motion retraining

Exclusion criteria were:

- Studies that did not perform motion analysis in lower extremities
- Studies using feedback motion retraining in combination with other treatments
- Articles published prior to 2010
- Pilot studies

Evidence Quality Assessment

Studies included were assessed with the Physiotherapy Evidence Database (PEDro) scale for randomized controlled trials (RCT) and the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement for non-RCT studies. All studies were evaluated using SORT. All assessments were performed by a single author (HJ).

Results of Search

Summary of Search, Evidence Appraised, and Key Findings

The literature search was conducted to find studies that investigated the effectiveness of feedback running gait retraining on biomechanical, pain, and self-reported function in patients with PFP. All four studies used 2-week feedback gait retraining in movement pattern modification in patients with PFP that also displayed faulty movement patterns. The initial search process resulted in 21 possible studies for inclusion and total of four relevant articles met the inclusion criteria (Figure 1, Table 1).

All four studies used 2-week feedback gait retraining in movement pattern modification in patients with PFP. One study³ used a computer-programmed visual feedback and three studies used a combination of mirror, script, and verbal feedback (Table 2).^{1,2,4} All studies¹⁻⁴ analyzed lower extremity kinematics and reported pain during running, and three studies additionally reported changes of self-reported function.¹⁻³ A 1-month follow-up was performed

in all included studies and an extra 3-month follow-up was reported in two studies.^{1,2} Hip adduction angle and contralateral pelvic drop was significantly reduced in three studies^{1,3} and knee abduction angle⁴ was improved immediately after the conclusion of the 2-week feedback training. Pain reduction retained at 1 and 3 months and kinematic improvement was also reported in three studies.^{1,3,4}

Results of Evidence Quality Assessment

Only one study⁴ utilized random allocation, using a random numbers generator which distributed participants into experimental and control groups. However, neither participants nor the investigator performing the intervention were blinded. Two studies^{1,3} were pretest/posttest studies that did not include a control group. One study² was a case report of two participants from previous research.¹ Our search process did not solely focus on RCTs since there was a lack of literature with a RCT design. For those reasons, studies received a PEDro score of 8/10; STROBE scores of 15/20, 17/20, and 10/20; and SORT ranging from 1 to 3 (Table 1).

Clinical Bottom Line

There is sufficient evidence to support the use of feedback motion retraining to improve gait, pain, and function in PFP rehabilitation. Three included studies¹⁻³ found a significant reduction in hip adduction angle ($p < .05$),^{1,3} contralateral pelvic drop ($p = .001$),^{1,2} internal hip abduction moment ($p = .008$),¹ and vertical loading impact ($p < .05$)³ after intervention. Additionally, knee abduction angle and ankle plantar flexion improved after the gait retraining.^{1,4} Lastly, significant pain reduction¹⁻⁴ and improvement of self-reported function¹⁻³ was observed throughout the included studies, with Willy et al. observing very large effect sizes (pain: $d = 7.61$, $p < .05$; function: $d = 3.81$, $p < .05$).¹

SORT appraisal for the included articles resulted in scores ranging from level 1 to 3 (Table 1). The level 1 evidence⁴ to support the use of feedback motion retraining was chosen because of its consistency and good quality patient-oriented evidence. The level 2 evidence was selected because one of the studies¹ used an identical feedback method to the level 3 study and the other study used a unique mode of visual feedback.³ The level 3 evidence² was included since it featured expanded outcome measures that were not included in the identical level 2 study.¹ A single RCT⁴ was included and scored 8/10 on the PEDro scale with the only points lost being due to lack of blinding. According to the STROBE assessment, two articles^{1,3} were rated as high quality ($\geq 14/20$) and one² was rated as having a high risk of bias ($\leq 13/20$). Collectively, the included evidence received a grade of B since the findings were consistent among included studies despite utilization of weak research designs. These studies suggest that providing feedback of movement patterns during gait retraining to patients with PFP is necessary to improve gait kinematics, pain, and self-reported function.

Implications for Practice, Education, and Future Research

PFP is a chronic condition resulting in retropatellar knee pain often exacerbated by faulty biomechanics, including increased hip adduction.¹⁸ The included studies identified consistent improvements in these aberrant gait kinematics after eight sessions (15–30 min each) of feedback gait retraining. Providing programmed

Figure 1 — Flow diagram to illustrate the search results.

visual³ and combination of mirror, script, and supplemental verbal feedback^{1,2,4} during motion retraining not only improved biomechanics but also improved pain and self-reported function in all included studies. Therefore, incorporation of the aforementioned modes of feedback to decrease hip adduction, internal rotation, knee valgus, and contralateral pelvic drop and increase ankle plantar flexion and range of motion appears beneficial to patients with PFP, especially those who displayed faulty movement patterns.

The feedback protocols examined were similar among included studies (Table 2). Specifically, all included research used eight training sessions during a 2-week period and reduced the amount of feedback during the last four sessions. Also, all included studies targeted PFP patients who displayed faulty movement patterns. Noehren et al.³ utilized real-time visual feedback of participants' hip adduction angles during stance phase as a graph generated from 3D motion capture software. Participants observed their hip adduction angles during running and were instructed to keep the angle within one standard deviation of mean hip adduction

angles obtained from healthy individuals. Participants were also instructed to contract their gluteal muscles and run with their knees pointing straight ahead; however, no additional verbal cues were provided when participants demonstrated any biomechanical errors during running.³ Willy et al.¹ combined visual and verbal feedback during gait retraining. Participants were first shown video of their baseline movement so they could see their aberrant biomechanics. For the feedback portion, participants ran with a mirror in front of them so they could see their biomechanics in real time. They were provided the same instructions as in the Noehren et al.³ study prior to the start of each feedback session, which was to keep their knees apart and patella facing forward. Additional verbal feedback was provided once the faulty biomechanics were noticed. Roper et al.⁴ used the same mirror feedback as Willy et al.,¹ but provided different verbal instructions to encourage participants to run with a forefoot striking pattern since the purpose of the study was to alter the rearfoot strike pattern. Similar to Willy et al.,¹ verbal feedback was given if movement error was detected. Feedback methods of included studies altered faulty kinematics which were risk factors

Table 1 Characteristics of Included Studies

	Noehren et al. ³	Willy et al. ¹	Willy et al. ²	Roper et al. ⁴
Study title	The Effect of Real-Time Gait Retraining on Hip Kinematics, Pain and Function in Subjects with Patellofemoral Pain Syndrome	Mirror Gait Retraining for the Treatment of Patellofemoral Pain in Female Runners	Varied Response to Mirror Gait Retraining of Gluteus Medius Control, Hip Kinematics, Pain, and Function in 2 Female Runners with Patellofemoral Pain	The Effects of Gait Retraining in Runners with Patellofemoral Pain: A Randomized Trial
Study participants	10 female subjects with patellofemoral pain Average age: 23.3 years Duration of pain: 75.7 months	10 female runners with patellofemoral pain Average age: 22.4 years Duration of pain: 4.3 years	2 female runners with patellofemoral pain Age: 20, 23 Duration of pain: 12, 30 months	16 subjects (11 females, 5 males) were randomly placed in the control (n = 8) or experimental group (n = 8) Average ages: control 21.5 years; experimental: 24.6 years
Inclusion/exclusion criteria	Inclusion criteria: patellofemoral pain; recreational runners (3 times/week, total 6 miles/week or greater); between ages of 18 and 45; symptoms longer than 2 months; excessive hip adduction, pelvic drop during treadmill running Exclusion criteria: cardiovascular condition, injury which can influence gait	Inclusion criteria: patellofemoral pain; run at least 10 km/week; comfortable with treadmill running at 3.35 m/s; free of any cardiac risk factors; retropatellar or peripatellar pain; visual analog scale ≥ 3 during running Exclusion criteria: patellar instability or other knee diagnoses; history of any lower extremity surgery; unhealthy	Inclusion criteria: patellofemoral pain; run at least 10 km/week; comfortable with treadmill running at 3.35 m/s; free of any cardiac risk factors; retropatellar or peripatellar pain; visual analog scale ≥ 3 during running; excessive hip adduction during running Exclusion criteria: patellar instability or other knee diagnoses; history of any lower extremity surgery; unhealthy	Inclusion criteria: patellofemoral pain during/after running, squatting, kneeling, stair ascent/descent, and prolonged sitting; visual analog scale between 3 and 7; self-reported rearfoot strike runner Exclusion criteria: pregnancy; history of knee surgery on the affected knee; traumatic patellar dislocation; any neurological impediments that would influence gait
Outcome measures	Data points: Pre-post treatment Follow-up: 1 month Hip adduction angle, hip internal rotation angle, contralateral pelvic drop angle, visual analog scale, lower extremity function index, vertical impact load	Data points: Pre-post treatment Follow-up: 1, 3 month Hip adduction angle, contralateral pelvic drop angle, hip internal rotation, internal hip abduction moment, thigh adduction, lower extremity function scale, visual analog scale During: running, squatting, stepping	Data points: Pre-post treatment Follow-up: 1, 3 month Contralateral pelvic drop; hip adduction angle; hip internal rotation angle; gluteus medius electromyographic activity; during running, step ascending; pain (visual analog scale); self-reported function (lower extremity functional scale)	Data points: Pre-post treatment Follow-up: 1 month Knee pain during and after running, knee abduction at initial contact, knee flexion at initial contact, range of motion in the sagittal plane through the loading response, ankle plantar/dorsiflexion at initial contact, peak patellofemoral stress, Achilles tendon force, patellofemoral contact force

(continued)

Table 1 (continued)

	Noehren et al. ³	Willy et al. ¹	Willy et al. ²	Roper et al. ⁴
Results	Hip adduction significantly decreased (pre = 22.0° ± 1.5, post = 16.5° ± 2.2, mean diff = 5.1, $p < .01$). Pelvic drop decreased (pre = -9.4° ± 2.5, post = -7.1° ± 1.6, mean diff = -2.3, $p < .05$) during running. Pain (pre = 5.0 ± 2.0, post = 0.5 ± 1.3) decreased by 86% at the end of gait retraining. Lower extremity function index improved by 11 points. (pre = 64.0 ± 11, post = 75.0 ± 3.5) Impact loading variables reduced with moderate to large effect sizes (0.45–1.10). Improvements in running mechanics, pain, and function retained at 1-month follow-up.	Running: significant ($p < .05$) visible reduction in peak hip adduction ($d = 2.91$), contralateral pelvic drop ($d = 0.82$), thigh adduction angle ($d = 1.32$), internal hip abduction ($d = 0.69$) moment, hip internal rotation ($d = 0.21$). Squat: hip adduction angle ($d = 1.35$), thigh adduction angle ($d = 0.68$), internal hip abduction moment ($d = 0.91$) were reduced ($p < .05$). Stepping: hip adduction angle was reduced ($d = 0.69$, $p < .05$). Pain and lower extremity function scale improved with large effect sizes ($d = 7.61$, $d = 3.81$). Retention was observed in hip adduction angle and internal hip abduction moment improvement for 3 months during running.	During running, peak contralateral pelvic drop (runner 1: 2.6°, runner 2: 1.7°) and peak hip adduction (runner 1: 5.2°, runner 2: 6.3°) were reduced after intervention. Earlier activation of the gluteus medius relative to foot strike (runner 1: 12.6 ms, runner 2: 37.3 ms) and longer duration of gluteus medius activity (runner 1: 55.8 ms, runner 2: 44.4 ms) after intervention. Early onset of gluteus medius activity during step ascent (runner 1: 48.0 ms, runner 2: 28.3 ms). Improvements in pain and function maintained for 3 months.	Significant knee abduction angle improvement immediately postretraining ($\eta^2 = 0.29$, $p < .05$) and at 1-month follow-up ($p < .05$). Increased ankle plantar flexion ($\eta^2 = 0.55$) and ankle range of motion ($\eta^2 = 0.43$) immediately postretraining ($p < .05$) and at 1-month follow-up ($p < .05$). Significant reduction in knee pain immediately postretraining ($\eta^2 = 0.29$, $p < .05$) and at 1-month follow-up ($p < .05$).
SORT	2	2	3	1
Quality assessment	STROBE 15/20	STROBE 17/20	STROBE 10/20	PEDro 8/10
Support for the answer	Yes	Yes	Yes	Yes

Abbreviations: SORT = Strength of Recommendation Taxonomy; STROBE = Strengthening the Reporting of OBservational studies in Epidemiology.

for PFP and could have potentially contributed to the reduction of pain and improvement of function.¹⁹

Feedback of proper movement patterns is not unique to the PFP population. Biomechanical feedback to correct faulty movements is widely used to reduce the risk of sustaining other knee injuries, including anterior cruciate ligament (ACL) injuries. In fact, based on the success of feedback at improving jump-landing biomechanics,^{20–23} the use of feedback on proper movement technique is a key recommendation on the prevention of ACL injury.²⁴ Further, feedback has been deemed beneficial in patients after ACL reconstruction to improve biomechanics.²⁵ Collectively, these studies suggest the benefit of feedback to improve biomechanics across lower extremity injuries.

Both the immediate benefits and retention (1 and 3 months postretraining) of the treatment were studied.^{1–4} Noehren et al.³ reported reduced pain (mean difference [MD] = 4.3, $p = .001$) and improved self-reported function (MD = 11.4, $p = .008$) immediately after the interventions. Immediate improvements in running mechanics were also observed across studies. Specifically, Willy et al.¹ reported hip adduction angle improvement ($p < .001$, $d = 2.91$) during running immediately after the intervention. One month after termination of the feedback interventions, patients continued to experience improvements. Hip adduction angle during running increased by 1.1° at the 1-month follow-up; however, this change was associated with a small effect size ($d = 0.37$) since the magnitude of change was minimal compared to the initial improvement between baseline and immediate postretraining.¹ Both Noehren et al.³ and Roper et al.⁴ reported that patients continued to experience

reduced knee pain, knee abduction, and vertical loading with concurrent increased ankle range of motion at 1-month follow-up, with Roper et al. reporting a large effect size ($\eta^2 = 0.43$). Finally, reductions in pain ($d = 7.61$) and improvements in lower extremity function ($d = 3.81$) were also reported 3-months postretraining.¹ Examining other interventions for patients with PFP suggests similar retention of improvements. Specifically, hip and knee strengthening exercises are widely adopted in the treatment of PFP and are effective in improving patient-reported outcomes through 1-year follow-up.²⁶

Participants who underwent mirror gait retraining showed the greatest improvements with large effect sizes (pain: $d = 7.61$, function: $d = 3.81$) and residual effect for 3 months.¹ Importantly, all participants included in these feedback studies presented with faulty movement patterns prior to gait retraining. Targeting individuals who present with faulty biomechanics appears critical to intervention success as these individuals have more room to improve their biomechanics than persons not presenting with excessive hip adduction.²⁷

Future research should investigate the optimal treatment duration, dosage of feedback, and instructions provided. Instructions provided are important to consider given that the most recent and best quality evidence included presently demonstrated that instructing patients to modify their foot strike pattern improved both hip and knee biomechanics, which is of great importance to patients with PFP.⁴ Additionally, future studies should determine if including lower extremity strengthening exercises, which are popular during traditional rehabilitation, into these feedback interventions

Table 2 Feedback Interventions

Study	Type	Duration	Sessions	Volume	Aid	Feedback cues	Removal	Follow-up
Noehren et al. ³	Gait retraining	2 weeks	8	15–30 min of treadmill running	Visual	Real-time system, valgus angle	Last 4 sessions	1 month
Willy et al. ¹	Gait retraining	2 weeks	8	15–30 min of treadmill running with gradual increment	Mirror, script, *verbal	Script: Run with your knees apart with your kneecaps pointing straight ahead; squeeze your buttocks	Last 4 sessions	1 month, 3 month
Willy et al. ²	Gait retraining	2 weeks	8	15–24 min of treadmill running with gradual increment	Mirror, script, *verbal	Script: Run with your knees apart with your kneecaps pointing straight ahead; squeeze your buttocks	Last 4 sessions	1 month, 3 month
Roper et al. ⁴	Gait retraining	2 weeks	8	15–30 min of treadmill running with gradual increment	Mirror, script, verbal	Script: Run on your toes; run on the balls of your feet	Last 4 sessions	1 month

*Verbal: Additional verbal feedback was provided if faulty biomechanics were observed.

will yield a greater magnitude of training effect and longer residual benefits. Finally, research should include control groups to ensure the treatment effect is not simply due to time or random chance.

CAT Kill Date: January 2021

CATs have limited life and should be revisited approximately 2 years after publication (see <https://doi.org/10.1123/ijatt.2018-0093>).

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