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Original Article

Immediate Effects of Strain Counter-Strain Versus Graston Technique on Pain and Range of Motion in Patients with Patellofemoral Pain Syndrome

Saman Bukish Cheema[1], Zermeen Zerish[2], Fahad Tanveer[3], Muhammad Bin Zia[4]

[1] Department of Rehabilitation Sciences, Green International University, Lahore, Pakistan
[2] Assistant Professor, Department of Rehabilitation Sciences, Faculty of Medicine and Allied Health Sciences, Green International University, Lahore, Pakistan
[3] Professor and Head of Rehabilitation Sciences Department, Green International University, Lahore, Pakistan
[4] Lecturer, Department of Rehabilitation Sciences, Faculty of Medicine and Allied Health Sciences, Green International University, Lahore, Pakistan

***Corresponding author: Zermeen Zerish, zerish91@gmail.com**

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ABSTRACT

Background: Patellofemoral pain syndrome is a common knee disorder characterized by anterior or peripatellar pain aggravated by activities that load the patellofemoral joint, including squatting, stair climbing, running, and prolonged sitting. Manual therapy techniques such as Strain Counterstrain and the Graston Technique are used clinically to reduce pain and improve mobility, but direct comparative evidence remains limited. **Objective:** To compare the short-term effects of Strain Counterstrain and the Graston Technique on pain intensity and knee range of motion in patients with patellofemoral pain syndrome. **Methods:** This assessor-blinded, parallel-group randomized controlled trial was conducted at the Department of Physiotherapy, Sir Ganga Ram Hospital. Ethical approval for this study was obtained from the Ethics Committee of Green International University under approval number NTC 07589933, Sixty participants with patellofemoral pain syndrome were allocated equally to Strain Counterstrain or Graston Technique groups. Both groups received 12 treatment sessions over four weeks. Pain was assessed using the Numerical Pain Rating Scale, and knee flexion and extension range of motion were assessed clinically. Data were analyzed using SPSS version 26. Because outcome variables were not normally distributed, Wilcoxon signed-rank and Mann-Whitney U tests were used. **Results:** Pain improved significantly in both groups, with large within-group effects for the Graston Technique ($r = 0.90$) and Strain Counterstrain ($r = 0.89$). Extension range of motion also improved significantly in both groups. Between-group analysis favored Strain Counterstrain for pain change ($U = 12.00$, $p < 0.001$) and extension change ($U = 24.00$, $p < 0.001$), while flexion change favored the Graston Technique ($U = 63.00$, $p < 0.001$). **Conclusion:** Both interventions produced short-term improvement in patellofemoral pain syndrome, with Strain Counterstrain showing stronger effects for pain reduction and extension recovery, and the Graston Technique showing comparative advantage for flexion change. **Keywords:** Patellofemoral pain syndrome, Strain Counterstrain, Graston Technique, manual therapy, knee pain, range of motion, rehabilitation.

INTRODUCTION

Patellofemoral pain syndrome is one of the most common knee-related musculoskeletal disorders encountered in young and physically active individuals, typically presenting as anterior or retropatellar knee pain aggravated by activities that increase patellofemoral joint loading, including running, stair climbing, squatting, jumping, and prolonged sitting. The condition is clinically important because it

affects mobility, physical performance, participation in routine and occupational activities, and long-term knee-related quality of life when symptoms persist or recur. Although the diagnosis is primarily clinical, accurate assessment requires careful consideration of pain location, aggravating activities, functional limitations, lower-limb mechanics, and differential diagnoses that may mimic anterior knee pain (1). Contemporary clinical literature describes patellofemoral pain as a multifactorial disorder rather than a single structural lesion, with contributing factors that may include altered patellar tracking, soft-tissue tightness, quadriceps and hip muscle imbalance, abnormal lower-limb alignment, overuse, and impaired neuromuscular control (2).

The burden of patellofemoral pain is supported by epidemiological data showing that the condition is frequent in both males and females, although several studies report higher prevalence among females and physically active populations. Reported risk factors include genu valgum, genu recurvatum, external tibial torsion, femoral anteversion, soft-tissue restriction, muscular weakness, and imbalance between local knee stabilizers and proximal hip musculature (3). Additional work has highlighted intrinsic biomechanical contributors and training-related factors that may predispose individuals to the development or persistence of patellofemoral symptoms (4). Population-based data further indicate that patellofemoral pain is not limited to athletes and may also affect adults in community settings, with prevalence estimates varying across regions, populations, diagnostic definitions, and activity levels (5). This variability reinforces the need for treatment strategies that are clinically practical, symptom-specific, and adaptable to different patient presentations.

The pathophysiology of patellofemoral pain is closely related to the interaction between patellofemoral joint mechanics, periarticular soft tissues, neuromuscular control, and pain modulation. The patella functions as a biomechanical lever within the extensor mechanism, and its alignment and contact forces are influenced by quadriceps function, hip control, femoral rotation, tibial mechanics, and soft-tissue extensibility (6). When these factors are altered, repetitive loading may increase patellofemoral stress and contribute to pain, movement avoidance, reduced range of motion, and impaired functional performance. Clinical evaluation therefore often focuses not only on pain intensity but also on knee range of motion, functional capacity, muscle performance, and movement-related symptom provocation (7).

Conservative rehabilitation remains the preferred first-line approach for most patients with patellofemoral pain syndrome. Exercise therapy, activity modification, patient education, and progressive strengthening of the knee and hip musculature are widely used to reduce pain and improve function (8). Recent evidence also suggests that multimodal rehabilitation may be beneficial when manual therapy is integrated with exercise-based care, although the magnitude of added benefit varies across studies and depends on the selected technique, outcome measure, treatment dose, and follow-up duration (9). Manual therapy is commonly used to address soft-tissue restrictions, pain sensitivity, muscle guarding, and joint mobility limitations; however, the comparative effectiveness of specific manual techniques remains incompletely established.

Instrument-assisted soft-tissue mobilization, including the Graston Technique, is intended to improve soft-tissue mobility through controlled mechanical stimulation using specialized instruments. The proposed therapeutic effects include reduction of soft-tissue restriction, improvement in fascial glide, modulation of pain, and enhancement of joint mobility, particularly where movement limitation is associated with local tissue tightness or adhesions (10). The Graston Technique has been described as a structured form of instrument-assisted soft-tissue therapy used for musculoskeletal pain and mobility restrictions (11). Related studies on instrument-assisted mobilization have reported improvements in pain, flexibility, lower-limb function, and biomechanical outcomes in musculoskeletal populations, although protocols and clinical contexts differ substantially across trials (12,13).

Strain Counterstrain is a positional release technique that aims to reduce musculoskeletal pain by placing the involved tissues in a position of comfort, thereby decreasing nociceptive input, muscle

guarding, and abnormal neuromuscular tone. This technique is typically applied to tender points and shortened tissues, with the therapeutic goal of promoting relaxation and restoring more comfortable movement (14). Evidence from manual therapy literature suggests that positional release approaches may provide short-term pain relief in selected musculoskeletal conditions, although high-quality comparative evidence remains limited and condition-specific conclusions should be made cautiously (15).

Recent trials have examined soft-tissue mobilization and related manual therapy approaches in patellofemoral pain and comparable musculoskeletal conditions. Instrument-assisted soft-tissue mobilization has been associated with short-term improvements in pain and function among female runners with patellofemoral pain, although differences between treatment application sites were not consistently significant (16). In myofascial pain populations, Graston-based treatment has shown additional benefits for disability, depression, and quality-of-life domains when combined with exercise, while its isolated superiority over sham or exercise-only approaches has been less consistent for pain-related outcomes (17). In patients with patellofemoral pain syndrome, combined approaches such as dry needling plus instrument-assisted soft-tissue mobilization have produced greater improvements than single-modality interventions, supporting the clinical relevance of multimodal care while also suggesting that the independent contribution of each technique requires clearer evaluation (18). Comparative work has also reported that instrument-assisted soft-tissue mobilization may improve pain, function, and mobility more than massage-based approaches in some patients with patellofemoral joint pain (19). Exercise-focused trials further demonstrate that functional strengthening, hip-focused strengthening, and flexibility interventions can improve pain and function, emphasizing that patellofemoral rehabilitation is influenced by both local and proximal biomechanical factors (20–22). Evidence comparing local exercise therapy with spinal manual therapy also suggests that manual approaches may affect pain and function, although the optimal manual technique and patient subgroup remain uncertain (23).

Despite the growing body of literature on exercise therapy, instrument-assisted soft-tissue mobilization, and manual therapy for patellofemoral pain, direct comparative evidence between Strain Counterstrain and the Graston Technique remains limited. These two interventions differ mechanistically: Strain Counterstrain primarily targets neuromuscular relaxation and pain modulation through passive positioning, whereas the Graston Technique primarily targets soft-tissue mobility through instrument-assisted mechanical stimulation. This distinction is clinically relevant because patients with patellofemoral pain may present with different dominant problems, such as pain sensitivity, restricted extension, limited flexion, or soft-tissue tightness. A direct comparison of these approaches may therefore help clinicians select treatment according to the desired therapeutic target rather than applying manual therapy as a single undifferentiated category.

The present study was designed to compare the short-term effects of Strain Counterstrain and the Graston Technique on pain intensity and knee range of motion in patients with patellofemoral pain syndrome over a four-week treatment period. The research question was whether Strain Counterstrain and the Graston Technique differ in their effects on pain reduction, knee flexion range of motion, and knee extension range of motion among patients with clinically diagnosed patellofemoral pain syndrome. It was hypothesized that both interventions would improve pain and range of motion, but that the magnitude of improvement would differ between techniques according to the outcome assessed.

MATERIALS AND METHODS

This study was conducted as a parallel-group, assessor-blinded randomized controlled trial comparing Strain Counterstrain with the Graston Technique in patients with patellofemoral pain syndrome. The trial design was selected because the study objective required direct comparison of two active manual therapy interventions while minimizing selection bias through random allocation and reducing

measurement bias through blinded outcome assessment. The study was carried out in the Department of Physiotherapy, Sir Ganga Ram Hospital, over a total duration of nine months following approval of the research synopsis.

Participants were recruited through non-probability purposive sampling from patients presenting with clinical features consistent with patellofemoral pain syndrome. Eligible participants were adults aged 18 to 45 years with anterior or peripatellar knee pain reproduced by at least two patellofemoral loading activities, such as squatting, stair climbing, running, or prolonged sitting. Participants were required to have baseline pain intensity of at least 3 on the Numerical Pain Rating Scale and a symptom duration of at least two months. Participants were excluded if they had undergone lower-limb surgery during the preceding 12 months, had clinical evidence of another knee pathology such as meniscal locking, tibiofemoral osteoarthritis, inflammatory arthritis, open wound or skin infection at the treatment site, bleeding disorder, anticoagulant use, corticosteroid injection within the preceding three months, or manual therapy involving Strain Counterstrain, instrument-assisted soft-tissue mobilization, or the Graston Technique to the affected knee during the preceding four weeks.

After screening for eligibility, participants received a clear explanation of the study purpose, procedures, potential discomforts, expected benefits, voluntary participation, and right to withdraw without effect on their routine care. Written informed consent was obtained before enrollment. Participants were then randomly allocated into two equal groups using computer-generated block randomization with allocation concealment. Group A received Strain Counterstrain, and Group B received the Graston Technique. Outcome assessment was performed by an assessor who was blinded to group allocation. The treating therapist was not blinded because of the nature of the manual interventions, but participants were instructed not to disclose their allocated intervention to the assessor during follow-up assessment.

The a priori sample size was calculated using G*Power 3.1 for a two-tailed independent-samples comparison with statistical power of 80%, alpha of 0.05, and an estimated effect size of 0.74, indicating that 60 participants were required, with 30 participants in each group. To account for an anticipated dropout rate of 20%, the recruitment target was increased to 72 participants. The final analysis included 60 participants with complete baseline and post-intervention outcome data, distributed equally between the two intervention groups.

Both groups received 12 treatment sessions over four weeks, with three sessions delivered per week. Participants in the Strain Counterstrain group were treated using positional release directed at painful or tender periarticular soft-tissue regions related to patellofemoral symptoms. The involved tissue was positioned passively into a position of maximal comfort and reduced tenderness, maintained for a therapeutic hold period, and then returned slowly to the neutral position to minimize reflex guarding. The technique was applied in a controlled manner according to participant tolerance, with attention to pain reduction, relaxation of shortened tissues, and restoration of comfortable knee movement. Participants in the Graston Technique group received instrument-assisted soft-tissue mobilization using a stainless-steel Graston instrument applied to relevant soft-tissue structures around the knee, including the quadriceps and peri-patellar soft tissues, according to clinical presentation and tolerance. Treatment was applied with controlled strokes and pressure sufficient to mobilize superficial and deep soft tissues without causing excessive pain or skin injury. All treatment sessions were delivered by trained physiotherapy personnel, and any discomfort, excessive tenderness, bruising, or adverse response during treatment was monitored during each session.

The primary clinical outcome was pain intensity measured using the Numerical Pain Rating Scale, scored from 0 to 10, where higher scores indicated greater pain. Secondary outcomes were knee flexion and knee extension range of motion, measured using standard clinical range-of-motion assessment procedures, and knee-related functional status assessed using the Kujala Anterior Knee Pain Scale. Baseline demographic and clinical variables included age, gender, affected knee, and symptom duration. Pain and range-of-motion outcomes were recorded at baseline and after completion of the four-week

treatment period, with interim assessment conducted at two weeks as part of the study follow-up procedure. For participants with bilateral symptoms, the more symptomatic knee was used for primary outcome assessment to maintain consistency of analysis.

Pain intensity was operationally defined as the participant's self-reported knee pain severity on the Numerical Pain Rating Scale during activities associated with patellofemoral loading. Knee flexion range of motion was defined as the measured degree of knee bending available during clinical assessment, while knee extension range of motion was defined as the measured ability to return the knee toward full extension. Treatment response was defined as the change in outcome score from baseline to post-treatment assessment. Group allocation was treated as the independent variable, while pain change, flexion change, and extension change were treated as dependent outcome variables. Age, gender, affected side, and symptom duration were considered baseline clinical variables with potential relevance to outcome interpretation.

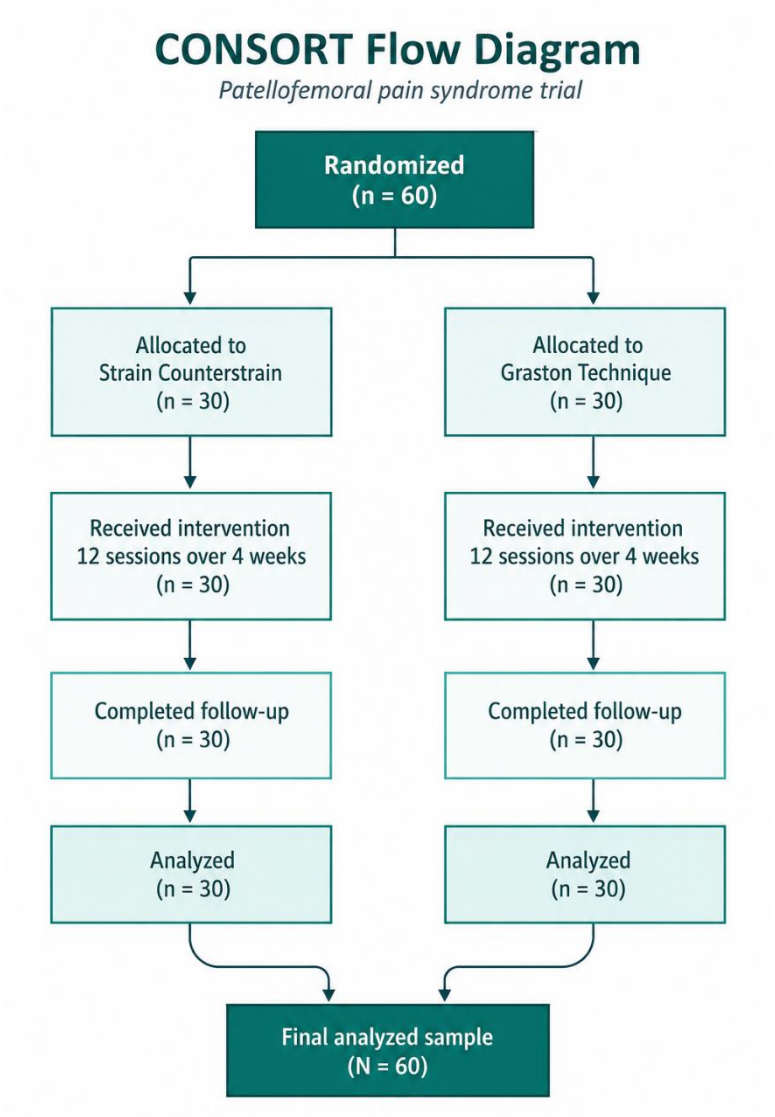

Figure 1 CONSORT Flowchart

Several procedures were used to reduce bias and improve internal validity. Random allocation was used after eligibility confirmation, and outcome assessment was performed by a blinded assessor. The same outcome measures were used across both groups at the same assessment time points. Eligibility criteria were applied before allocation to reduce selection-related imbalance, and treatment frequency and duration were kept equivalent across groups. Data were coded to preserve confidentiality, and outcome data were checked for completeness and consistency before statistical analysis. Participants with

complete baseline and post-treatment data were included in the final comparative analysis, and missing values were not imputed.

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics were calculated for demographic and clinical characteristics. Continuous variables were summarized using mean and standard deviation where appropriate, and categorical variables were summarized using frequency and percentage. Normality of outcome variables was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Because the outcome distributions were not consistently normal, non-parametric tests were used for inferential analysis. Within-group pre-post changes were assessed using the Wilcoxon signed-rank test. Between-group differences in change scores were assessed using the Mann-Whitney U test. Statistical significance was set at $p < 0.05$. For publication reporting, treatment effects should be presented with the relevant test statistic, p-value, and an appropriate non-parametric effect-size estimate, with confidence intervals where available.

Ethical approval was obtained from the Ethical Review Committee of Green International University before commencement of the study. Participant confidentiality was maintained through coded data collection forms and restricted access to study records. Participation was voluntary, and participants were allowed to withdraw at any stage without penalty or compromise of their standard care. The interventions were delivered by trained physiotherapy personnel using clinically accepted manual therapy procedures, and participant safety was monitored throughout treatment. Scientific integrity was maintained through prospective eligibility criteria, random allocation, blinded outcome assessment, standardized data collection, and truthful reporting of analyzed outcomes.

RESULTS

A total of 60 participants with patellofemoral pain syndrome completed the study and were included in the final analysis, with 30 participants allocated to the Strain Counterstrain group and 30 participants allocated to the Graston Technique group. The overall sample had a mean age of 32.57 ± 6.01 years, with ages ranging from 20 to 45 years. The mean symptom duration was 2.00 ± 0.82 months, with reported values ranging from 1 to 3 months. Among valid cases, 31 participants were male and 29 were female, representing 51.7% and 48.3% of the analyzed sample, respectively. Left knee involvement was reported in 25 participants, right knee involvement in 23 participants, and bilateral symptoms in 12 participants, corresponding to 41.7%, 38.3%, and 20.0% of valid cases, respectively. Baseline Kujala Anterior Knee Pain Scale scores ranged from 19 to 87, indicating variability in baseline knee-related functional status across the sample.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Participants

Variable	Valid N	Minimum	Maximum	Mean ± SD or n (%)
Age, years	60	20	45	32.57 ± 6.01
Symptom duration, months	60	1	3	2.00 ± 0.82
Male sex	60	—	—	31 (51.7%)
Female sex	60	—	—	29 (48.3%)
Left knee affected	60	—	—	25 (41.7%)
Right knee affected	60	—	—	23 (38.3%)
Bilateral knee involvement	60	—	—	12 (20.0%)
Baseline Kujala score	60	19	87	

The distribution of baseline characteristics showed that the sample was nearly balanced by sex, with males representing 51.7% and females representing 48.3% of valid participants. Unilateral symptoms were more common than bilateral involvement, as 48 of 60 participants had either left- or right-sided symptoms, while 12 participants had bilateral knee involvement. The age range of 20–45 years indicates that the study primarily represented young to middle-aged adults with patellofemoral pain syndrome. The baseline Kujala score distribution ranged widely from 19 to 87, suggesting that participants entered the trial with heterogeneous levels of knee-related functional limitation.

Normality testing was performed before inferential analysis. The Shapiro-Wilk and Kolmogorov-Smirnov tests showed that several primary outcome variables deviated from normality across the treatment groups. Pain before treatment was non-normally distributed in the Strain Counterstrain group using both Kolmogorov-Smirnov and Shapiro-Wilk tests, and pain after treatment also showed non-normal distribution in the Strain Counterstrain group. Range-of-motion variables, particularly flexion and extension measures, also demonstrated non-normal distribution in several comparisons. Therefore, non-parametric tests were used for within-group and between-group analyses.

Table 2. Normality Testing of Pain, Range of Motion, and Kujala Score by Treatment Group

Outcome Variable	Treatment Group	Kolmogorov-Smirnov p-value	Shapiro-Wilk p-value
Pain before treatment	Strain Counterstrain	0.028	0.017
	Graston Technique	0.121	0.041
Pain after treatment	Strain Counterstrain	0.006	0.019
	Graston Technique	0.013	0.092
ROM flexion before treatment	Strain Counterstrain	<0.001	0.003
	Graston Technique	0.002	0.063
ROM flexion after treatment	Strain Counterstrain	0.015	0.025
	Graston Technique	<0.001	0.025
ROM extension before treatment	Strain Counterstrain	<0.001	<0.001
	Graston Technique	<0.001	<0.001
ROM extension after treatment	Strain Counterstrain	0.085	0.029
	Graston Technique	<0.001	<0.001
Total Kujala score	Strain Counterstrain	0.008	0.007
	Graston Technique	<0.001	<0.001

Within-group analysis using the Wilcoxon signed-rank test showed statistically significant reductions in pain in both treatment groups. The Graston Technique group demonstrated a significant pre-post reduction in pain score, with $Z = -4.904$ and $p < 0.001$, corresponding to a large effect size of $r = 0.90$. The Strain Counterstrain group also showed a significant reduction in pain, with $Z = -4.893$ and $p < 0.001$, corresponding to a similarly large effect size of $r = 0.89$. For knee flexion range of motion, the Strain Counterstrain group showed a statistically significant within-group improvement, with $Z = -4.836$ and $p < 0.001$, while the Graston Technique group did not reach statistical significance for within-group flexion change, with $Z = -1.644$ and $p = 0.100$. For knee extension range of motion, both interventions produced statistically significant improvements, with $Z = -4.875$ and $p < 0.001$ in the Graston Technique group and $Z = -4.811$ and $p < 0.001$ in the Strain Counterstrain group. The effect sizes for extension improvement were large in both groups, with $r = 0.89$ for the Graston Technique and $r = 0.88$ for Strain Counterstrain.

Table 3. Within-Group Pre-Post Comparison of Pain and Range of Motion

Outcome	Treatment Group	N	Z-value	p-value	Effect Size r
Pain score	Graston Technique	30	-4.904	<0.001	0.90
Pain score	Strain Counterstrain	30	-4.893	<0.001	0.89
Flexion ROM	Graston Technique	30	-1.644	0.100	0.30
Flexion ROM	Strain Counterstrain	30	-4.836	<0.001	0.88
Extension ROM	Graston Technique	30	-4.875	<0.001	0.89
Extension ROM	Strain Counterstrain	30	-4.811	<0.001	0.88

Effect size r was calculated as $|Z|/\sqrt{N}$ for within-group comparisons, where $N = 30$ per group.

Table 4. Between-Group Comparison of Change Scores for Pain and Range of Motion

Outcome Change Variable	Strain Counterstrain Mean Rank	Graston Technique Mean Rank	Mann-Whitney U	Z-value	p-value	Rank-Biserial Effect Size
Pain change	45.10	15.90	12.00	-6.658	<0.001	0.97
Flexion ROM change	17.60	43.40	63.00	-5.864	<0.001	0.86
Extension ROM change	44.70	16.30	24.00	-6.402	<0.001	0.95

Rank-biserial effect size was calculated from the reported Mann-Whitney U statistic using $n_1 = 30$ and $n_2 = 30$. Values closer to 1.00 indicate stronger separation between groups.

Between-group analysis using the Mann-Whitney U test showed statistically significant differences between the Strain Counterstrain and Graston Technique groups for all change outcomes. Pain

reduction differed significantly between groups, with U = 12.00, Z = -6.658, and p < 0.001. The Strain Counterstrain group had a substantially higher mean rank for pain change than the Graston Technique group, with mean ranks of 45.10 and 15.90, respectively. This pattern indicates that pain reduction was greater in the Strain Counterstrain group, with a very large rank-biserial effect size of 0.97. Flexion range-of-motion change also differed significantly between groups, with U = 63.00, Z = -5.864, and p < 0.001. In contrast to the pain outcome, the Graston Technique group had the higher mean rank for flexion change, with a mean rank of 43.40 compared with 17.60 in the Strain Counterstrain group, indicating greater improvement in knee flexion in the Graston Technique group. The rank-biserial effect size for this between-group difference was 0.86, indicating a large effect. Extension range-of-motion change also favored Strain Counterstrain, with U = 24.00, Z = -6.402, and p < 0.001. The mean rank for extension change was 44.70 in the Strain Counterstrain group and 16.30 in the Graston Technique group, corresponding to a very large rank-biserial effect size of 0.95.

The between-group findings indicate outcome-specific superiority rather than uniform superiority of one intervention across all clinical domains. Strain Counterstrain produced greater improvement in pain and knee extension range of motion, while the Graston Technique produced greater improvement in knee flexion range of motion. The largest between-group effect was observed for pain change, where the rank-biserial effect size was 0.97 in favor of Strain Counterstrain. Extension improvement also strongly favored Strain Counterstrain, with a rank-biserial effect size of 0.95. Flexion improvement favored the Graston Technique, with a rank-biserial effect size of 0.86. Although the within-group analysis showed that flexion improvement in the Graston Technique group did not reach statistical significance, the between-group change-score analysis favored the Graston Technique for flexion. This finding should be interpreted cautiously and verified against the raw change-score distributions, because between-group rank differences can occur even when one group does not show a statistically significant within-group pre-post change.

Overall, both manual therapy approaches were associated with significant clinical improvement in key outcomes over the four-week intervention period. Pain intensity improved significantly in both groups, and knee extension range of motion improved significantly in both groups. Strain Counterstrain showed stronger comparative effects for pain reduction and extension range of motion, whereas the Graston Technique showed stronger comparative performance for flexion range-of-motion change. These results suggest that the two interventions may have different outcome-specific therapeutic profiles in patients with patellofemoral pain syndrome.

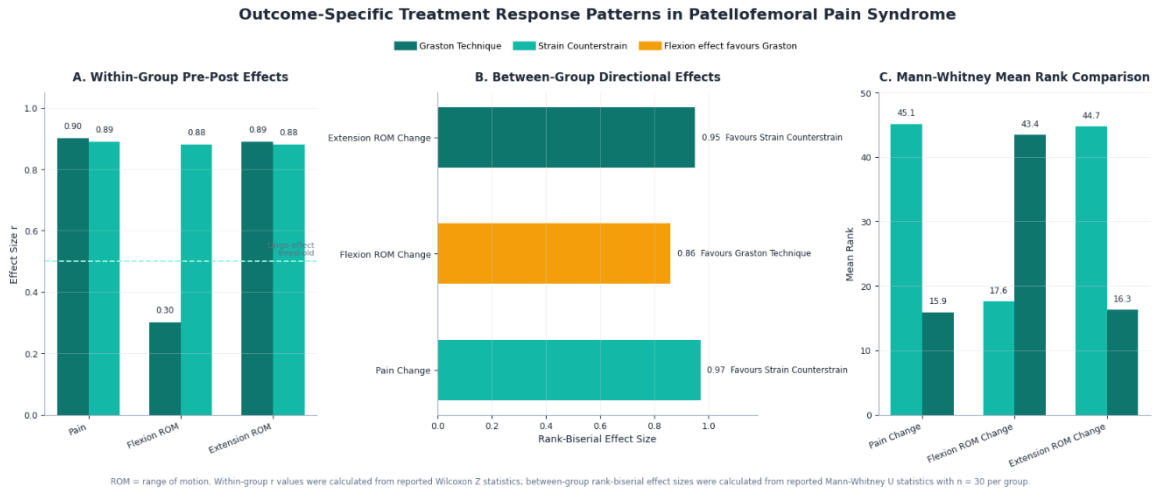

Figure 1. Outcome-Specific Treatment Response Patterns in Patellofemoral Pain Syndrome

The panelled figure demonstrates distinct outcome-specific response patterns between Strain Counterstrain and the Graston Technique. Within-group effects were large for pain reduction in both groups, with effect sizes of r = 0.90 for the Graston Technique and r = 0.89 for Strain Counterstrain, and

similarly large for extension ROM improvement, with r = 0.89 and r = 0.88, respectively. Flexion ROM showed a divergent pattern, with a smaller within-group effect in the Graston Technique group (r = 0.30) and a large effect in the Strain Counterstrain group (r = 0.88), although between-group rank analysis favored the Graston Technique for flexion change. Between-group effects were strongest for pain change, favoring Strain Counterstrain with a rank-biserial effect size of 0.97, followed by extension ROM change favoring Strain Counterstrain with an effect size of 0.95, while flexion ROM change favored the Graston Technique with an effect size of 0.86. Mean-rank gradients further support this outcome-specific pattern, with Strain Counterstrain showing higher ranks for pain change (45.10 vs. 15.90) and extension change (44.70 vs. 16.30), whereas the Graston Technique showed higher ranks for flexion change (43.40 vs. 17.60). These findings suggest that Strain Counterstrain may be more strongly associated with pain reduction and extension recovery, while the Graston Technique may have a comparative advantage for flexion-related mobility change.

DISCUSSION

The present randomized controlled trial compared the short-term effects of Strain Counterstrain and the Graston Technique on pain intensity and knee range of motion in patients with patellofemoral pain syndrome. The findings indicate that both interventions produced statistically significant improvements in pain and knee extension range of motion after the four-week intervention period, while the comparative response pattern differed across outcomes. Strain Counterstrain showed stronger between-group effects for pain reduction and extension range-of-motion improvement, whereas the Graston Technique showed a stronger between-group effect for flexion range-of-motion change. This outcome-specific pattern suggests that the two manual therapy approaches may not be interchangeable in clinical practice and that intervention selection may need to be guided by the patient's dominant impairment, such as pain sensitivity, restricted extension, or flexion-related soft-tissue limitation.

Pain intensity improved significantly in both groups, with large within-group effects observed for the Graston Technique and Strain Counterstrain. However, the between-group analysis favored Strain Counterstrain, with a substantially higher mean rank for pain change and a very large rank-biserial effect. This finding is clinically plausible because Strain Counterstrain is designed to reduce tenderness and muscle guarding through passive positioning of the symptomatic tissues into a position of comfort. By reducing nociceptive input and promoting neuromuscular relaxation, Strain Counterstrain may produce a stronger short-term analgesic response in patients whose patellofemoral symptoms are influenced by protective muscle tension or soft-tissue irritability. This mechanism is consistent with the broader manual therapy literature describing positional release techniques as approaches aimed at reducing pain sensitivity and improving comfort during movement (14,15).

The pain-related findings are also consistent with previous evidence showing that manual therapy and soft-tissue interventions can reduce symptoms in patellofemoral pain syndrome, although the magnitude and superiority of individual techniques vary across studies. Cho and Kim reported improvements in pain and function after instrument-assisted soft-tissue mobilization in female runners with patellofemoral pain, but between-group differences related to treatment application site were not consistently significant (16). Liu and Wang also reported that instrument-assisted soft-tissue mobilization improved pain, function, and lower-limb mobility in patients with patellofemoral joint pain, supporting the clinical value of soft-tissue mobilization approaches in this population (10). In contrast, the present trial found that Strain Counterstrain produced greater comparative pain reduction than the Graston Technique, suggesting that neuromuscular pain modulation may be particularly relevant for short-term analgesia in this sample.

Knee extension range of motion improved significantly in both treatment groups, but between-group analysis favored Strain Counterstrain. This may reflect the effect of positional release on muscle guarding and periarticular tone, which can restrict terminal knee extension in symptomatic individuals.

In patellofemoral pain syndrome, pain-related inhibition, altered quadriceps control, and protective movement patterns may limit comfortable extension during activity and assessment. By reducing discomfort and allowing the involved tissues to relax, Strain Counterstrain may facilitate improved extension range without requiring direct mechanical loading of the soft tissues. This interpretation should be made cautiously because the present manuscript does not provide raw pre-treatment and post-treatment extension values; nevertheless, the reported Wilcoxon and Mann-Whitney statistics consistently indicate a strong extension response favoring Strain Counterstrain.

Flexion range of motion demonstrated a more complex pattern. Within-group analysis showed a statistically significant flexion improvement in the Strain Counterstrain group, whereas the Graston Technique group did not reach statistical significance for within-group flexion change. However, the between-group Mann-Whitney analysis of flexion change favored the Graston Technique, with a higher mean rank and a large rank-biserial effect. This apparent discrepancy may occur when the distribution of change scores differs between groups even though one group does not show a statistically significant within-group pre-post change. It may also reflect skewed data, baseline variability, or coding direction in the change-score variable. Therefore, the finding that the Graston Technique favored flexion change should be interpreted as a between-group rank-based result rather than as definitive evidence of uniform within-group improvement. The authors should verify the raw flexion change scores and report median change with interquartile range to strengthen interpretability.

The comparative flexion finding is nevertheless biologically plausible if the Graston Technique improved soft-tissue extensibility, fascial mobility, and tolerance to flexion-related tissue deformation. Instrument-assisted soft-tissue mobilization is commonly used to address soft-tissue restriction, adhesions, and impaired fascial glide, which may contribute to movement limitation around the knee (11,12). Prior studies have reported improvements in range of motion and functional performance after instrument-assisted mobilization in musculoskeletal populations, including patellofemoral pain and related lower-limb conditions (16,19). However, because the present study did not report tissue-specific assessment, flexibility measures, or raw ROM change values, the proposed mechanism remains explanatory rather than directly proven.

The findings should be interpreted in relation to the wider evidence base for patellofemoral pain rehabilitation. Exercise therapy, especially programs targeting hip and knee strength, remains a central component of conservative management and has been associated with improvements in pain, function, and lower-extremity biomechanics (8,20). Systematic review evidence also supports strengthening of hip abductors and lateral rotators for improving pain and function in adults with patellofemoral pain (19). Manual therapy may provide additional short-term symptom modulation, but it should not be viewed as a substitute for progressive exercise-based rehabilitation. Abdo and colleagues reported that adding manual therapy to hip and knee exercises did not produce clearly superior between-group effects across all outcomes, although clinical improvement was observed (9). This supports a balanced interpretation of the present results: Strain Counterstrain and the Graston Technique may be useful short-term adjuncts, but their role should be integrated within a broader rehabilitation plan addressing strength, movement control, activity modification, and functional progression.

The present study has several strengths. It used a randomized comparative design, equal group allocation, assessor blinding, and clinically relevant outcomes including pain intensity and knee range of motion. The use of non-parametric tests was appropriate because several outcome variables showed non-normal distribution. The study also directly compared two manual therapy techniques that are commonly used in clinical practice but not frequently compared head-to-head in patellofemoral pain syndrome. This gives the findings practical value for clinicians deciding between pain-modulating and soft-tissue mobilization approaches.

Several limitations must be acknowledged. First, the study was short-term and assessed outcomes over four weeks, so the findings should not be interpreted as evidence of long-term effectiveness, recurrence

prevention, or sustained functional recovery. Second, the use of non-probability purposive sampling may limit generalizability beyond the study setting. Third, the manuscript does not provide complete baseline and post-treatment medians or interquartile ranges for pain, flexion, and extension outcomes, limiting clinical interpretation of the magnitude of change. Fourth, although the Kujala Anterior Knee Pain Scale was listed as an outcome, the available results present only its distribution and do not provide pre-post or between-group treatment effects. Fifth, the intervention protocols require more detail regarding exact treatment sites, duration of application, therapist training, pressure/intensity, co-interventions, adherence, and adverse events. Sixth, the sample-size reporting requires clarification because the methods describe a planned increase to 72 participants for anticipated dropout, while the final analysis includes 60 participants. Finally, no adjustment for multiple comparisons, confidence intervals, intention-to-treat analysis, or trial registration details were reported, which should be addressed in a revised manuscript.

Overall, the results suggest that both Strain Counterstrain and the Graston Technique can produce short-term clinical improvement in patients with patellofemoral pain syndrome, but their strongest effects appear to differ by outcome. Strain Counterstrain may be more suitable when the immediate clinical priority is pain reduction or restoration of knee extension, while the Graston Technique may be considered when flexion-related mobility limitation is the dominant impairment. Future trials should include larger samples, complete CONSORT reporting, standardized intervention protocols, raw pre-post outcome values, confidence intervals, adverse-event monitoring, longer follow-up, and combined intervention arms to determine whether integrating both techniques with exercise therapy produces superior and sustained outcomes.

CONCLUSION

Both Strain Counterstrain and the Graston Technique were associated with short-term improvement in patients with patellofemoral pain syndrome after a four-week intervention period. Pain intensity and knee extension range of motion improved significantly in both groups, with between-group findings favoring Strain Counterstrain for pain reduction and extension recovery. Flexion range-of-motion change favored the Graston Technique in the between-group rank analysis, although this finding should be interpreted cautiously because the within-group flexion change in the Graston Technique group was not statistically significant. These results indicate that manual therapy selection may be guided by the patient's primary clinical limitation, with Strain Counterstrain appearing more relevant for pain and extension-related impairment and the Graston Technique potentially more relevant for flexion-related mobility restriction. Further well-reported randomized trials with complete outcome values, longer follow-up, and standardized multimodal rehabilitation protocols are required to confirm these findings.

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