Lumbopelvic manipulation in patients with patellofemoral pain syndrome

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Objectives: A recent clinical prediction rule (CPR) identified characteristics that may predict an immediate reduction in pain following lumbopelvic manipulation in patients with patellofemoral pain syndrome. The purpose of this single-arm cohort study was to replicate the proposed CPR in a different population and investigate changes in self-reported pain, hip range of motion, strength, and function immediately following lumbopelvic manipulation.

Methods: Forty-four subjects (63.6% female; mean age 27.4 years) met inclusion criteria. Hip internal rotation range of motion, lower extremity strength using a handheld dynamometer, and single/triple hop tests were assessed prior to and immediately following a spinal manipulation. A global rating of change questionnaire was administered after testing and telephonically at 1 week. Paired *t*-tests compared pre- and post-manipulation range of motion, strength, and hop test limb symmetry indices (α=0.05).

Results: Fifty-seven percent of subjects had a successful outcome measured by the numerical pain rating scale immediately following manipulation. Twenty-five of subjects experienced a successful outcome as measured by the global rating of change questionnaire at 1 week. No single individual or combination of predictor variables predicted a positive outcome immediately following the lumbopelvic manipulation (+likelihood ratio 0.7 with three of five predictor variables present). Statistically significant differences ($P<0.05$) were found in hip extension and abduction strength and hip internal rotation symmetry post-manipulation, but do not appear to be clinically meaningful.

Discussion: The previously identified CPR was not able to be replicated and no clinically meaningful changes in range of motion, strength, or function were apparent. Future research should focus on a comprehensive impairment-based treatment approach in patients with patellofemoral pain syndrome.

Keywords: Patellofemoral pain syndrome, Anterior knee pain, Rehabilitation, Manipulation

Introduction

Patellofemoral pain syndrome (PFPS) is a common source of knee pain, particularly in young, active individuals,[1–6] and may account for 25–40% of all knee problems seen in sports medicine centers.[7] Despite its prevalence, the etiology of PFPS is currently not well understood.[5,8,9] Some researchers have proposed that abnormal neuromuscular[10–13] and biomechanical[14–16] factors alter patellar tracking and contribute to increased patellofemoral joint contact pressures that ultimately lead to pain and dysfunction.[5,9,17,18] Research conducted over the past decade suggested that PFPS may also have a proximal origin. Patients with PFPS, especially females, demonstrated decreased hip strength[19–23] and impaired control of femoral rotation[19,20] when compared to healthy controls.

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Because of its unclear etiology and wide variation in presentation, numerous treatment options have been proposed for PFPS, including attempts at classifying patients based upon common historical items and physical examination findings.[21–24] Various exercise programs, taping, bracing, foot orthoses, acupuncture, modalities, and medications are all conservative treatment options that have shown some benefit for this condition.[5,7–9,25] Restoration of quadriceps strength and function is the goal of many treatment programs[5,8,9,12] and increasing hip strength and stability has been shown to be beneficial in some non-randomized studies[26–28] and in a recently published randomized clinical trial.[29]

A clinical prediction rule (CPR) was developed to identify patients with PFPS who may respond favorably immediately following lumbopelvic manipulation (Table 1).[21] Although the mechanism that accounts for symptom relief is not known, the authors theorized that neurophysiologic changes or

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regional interdependence may have been responsible for the observed changes.[21] Previously, Suter and colleagues[30,31] demonstrated that a lumbopelvic manipulation led to a significant decrease in quadriceps inhibition, and Hillermann *et al.* reported that quadriceps muscle strength increased significantly following sacroiliac joint manipulation in patients with PFPS.[32] However, none of these studies was able to show any benefit beyond the immediate effects of the treatment. A case report of a patient with medial knee pain who returned to marathon running following sacroiliac joint and lumbopelvic manipulation is currently the only published evidence showing any long-term benefit following this particular intervention.[9]

Although the CPR was a reasonable initial investigation to identify patients with PFPS who may benefit from lumbopelvic manipulation, the authors acknowledged that the short follow-up period, limited sample size, and marginable reliability of some of the predictors were all limitations of the study.[21] The authors also recommended that future replication or validation studies should determine if any changes in hip internal rotation or muscle activation occur following lumbopelvic manipulation or if those objective changes are related to the subjects' response to treatment.[21]

Therefore, the purposes of this study were: (1) to attempt to both replicate the previously identified CPR in a different sample and assess the validity of its individual components; (2) to investigate changes in self-reported pain, hip internal rotation range of motion, hip and quadriceps muscle strength, and performance on functional hop testing in patients with PFPS following a lumbopelvic manipulation; and (3) to determine if any subjective improvement would be maintained over a 1-week follow-up period. We hypothesized that the previously identified CPR would predict a positive outcome in our patient population and patients who were successful with the manipulation would demonstrate significant post-test changes in range of motion, strength, and functional testing.

Methods

Study design

This was a single-arm prospective cohort design. Pain with three basic functional tasks (squat, step-up, and step-down), hip internal rotation range of motion, hip and quadriceps strength, and functional hop tests were measured at baseline and immediately following a lumbopelvic manipulation. A global rating of change (GRC) questionnaire was administered immediately following the manipulation and at 1 week.

Table 1 Clinical prediction rule for determining success with a lumbar manipulation for patients with PFPS[22]

1. Side-to-side difference in hip internal rotation greater than 14 degrees*
2. Ankle dorsiflexion with the knee flexed greater than 16 degrees
3. Navicular drop greater than 3 mm
4. No stiffness with sitting greater than 20 minutes
5. Squatting is the most painful activity

Note: *Most powerful individual predictor of treatment success.

Participants

A convenience sample of 44 subjects was recruited via e-mail and posted flyers in the Savannah area for participation in the study. Subjects were included if they were between 18 and 50 years of age with signs and symptoms consistent with a clinical diagnosis of PFPS. The clinical diagnosis of PFPS was formed if the subject had a complaint of atraumatic anterior knee pain that was aggravated with at least two of the following activities: stair ascent, stair descent, squatting, prolonged sitting, kneeling, or isometric quadriceps contraction.[12,33–35] Exclusion criteria included prior knee or spine surgery, severe lumbosacral nerve root compression signs, or tenderness to palpation at the tibiofemoral joint lines or patellar tendon.[21] Other exclusion criteria included clinical signs of ligamentous instability or suspected meniscal injury, systemic disease or connective tissue disorders, pregnancy, osteoporosis with documented compression fracture, or individuals who were currently undergoing treatment for knee pain.[21] All subjects provided informed consent to participate and the study was approved by the Institutional Review Board of Armstrong Atlantic State University, Savannah, Georgia.

Procedure

A medical history questionnaire was administered to each subject. The first examiner performed a standard screening examination to rule out ligamentous instability, potential meniscal or patellar tendon pathology, or any potential neurological conditions. The second examiner then measured hip internal rotation active range of motion, dorsiflexion with knee flexed to 90°, and navicular drop. All angular measures were assessed using a 17.8 cm plastic goniometer and were performed in prone. The second examiner also measured lower extremity strength using a handheld dynamometer (HHD) with the first examiner reading and recording the measurements and then instructed each subject on performance of the single and triple hop tests. The subject rated his or her pain on the numerical pain rating scale (NPRS) during three basic functional tasks (step-up, step-down, and squat).

After completion of the three functional tasks, the subject returned to the plinth and was instructed to lie supine. The first examiner performed a lumbopelvic manipulation to the symptomatic side, as previously described by Flynn *et al.*[21,36] If a cavitation was

experienced by either the subject or examiner during the thrust portion of the manipulation, it was deemed to be complete. If no cavitation was experienced, the examiner would reposition the subject and perform the manipulation again. Each subject received a maximum of two manipulations on the symptomatic side. If both knees were symptomatic, the patient was asked to choose the most symptomatic side to be treated. The three functional tasks were repeated, with the subject instructed to squat to the same angular measurement measured initially, and a pain-rating was recorded.

The second examiner reassessed hip internal rotation active range of motion as well as all strength and functional hop tests in the order previously described. The order of testing remained unchanged throughout the duration of the study. Once all post-intervention tests and measures were completed, the subject was asked to assess the overall change in his or her condition using the GRC questionnaire. One week following the initial visit, the first examiner followed up with each subject via telephone and completed a second GRC questionnaire.

Outcome measures

The NPRS is an 11 point scale which measures a subject's subjective report of pain. The scale has criteria that range from 0 (no pain) to 10 (worst possible pain). This scale has been shown to be a valid and reliable measure of pain.[37,38] A 30% change on the NPRS has been proposed as a clinically meaningful reduction in pain in subjects with a variety of disorders.[39] The NPRS was used to verbally assess the subject's pain level during the three functional tasks (stepping up onto an 8-inch step, stepping down from an 8-inch step, and squatting). After completing each task, the first examiner asked the subject to verbally rate his or her pain experienced during that task according to the NPRS and the value was recorded. During the squat test, each subject was instructed to squat as far as possible and a measurement of knee flexion using a goniometer was taken at the maximal squatting position. The sum of each of the scores formed the composite NPRS used during data analysis.

The GRC questionnaire is a 15 point self-report scale with criteria ranging from a 'very great deal worse' to a 'very great deal better.' The GRC is a valid and useful method for assessing the overall change in the quality of life of a person.[40] The GRC was assessed immediately following testing during the initial treatment session, as well as at a 1-week follow-up via telephone by one of the examiners.

Isometric muscle strength testing was performed for the hip abductors, hip external rotators, hip extensors, and knee extensors. Strength was objectively measured with an HHD (Lafayette Instrument Co., Lafayette, IN, USA). HHD has been shown to be a valid and reliable measure of strength,[41–43] with test-retest correlation coefficients of 0.84–0.99 for hip strength measurements, indicating good to high reproducibility. Each strength test was performed twice with the joint at the midpoint of the available range of motion, and no verbal encouragement was provided. Strength testing was performed using the 'break' method, in which a force was manually applied with the HHD to break the muscle contraction.[26,44] Manual resistance was applied for 4 seconds as this amount of time has been shown to be adequate for inducing a maximal force.[42] The order of testing was hip external rotation, knee extension, hip abduction, and hip extension. For hip external rotation, the subject was seated on the edge of the plinth with hips and knees in $\sim 90^{\circ}$ of flexion while a force was manually applied just proximal to the medial malleolus with the HHD.[44] Knee extension strength was also measured with the subject in the seated position while a force was manually applied over the distal anterior tibia. Hip abduction was measured in sidelying with the hip in neutral position and the knee extended. Resistance was applied ~ 1 inch proximal to the lateral femoral condyle. The tester's free hand was used to stabilize the pelvis and the examiner visually monitored for any substitution (i.e. hip flexion). Hip extension was measured in prone with the knee extended and resistance was applied ~ 1 inch proximal to the popliteal fossa. The examiner again visually monitored for any substitution patterns, such as lumbar extension.

Two functional hop tests were administered: the single hop for distance and triple hop for distance. Hop tests have been shown to be a valid and reliable measure of knee function following anterior cruciate ligament reconstruction.[45] For each hop test, the subject performed one practice trial on the uninvolved limb, followed by one measured and recorded trial. The subject then performed the same test on the involved limb. No additional warm-up activity was performed. No restrictions were given on upper extremity movement during the test. The subject stood on the test leg, hopped, and landed on the same limb. The distance hopped was measured and recorded to the nearest centimeter. The triple hop test was performed in a similar fashion to the single hop test. Subjects were instructed to stand on the test limb and perform three consecutive hops as far as possible, landing on the same foot. Again, the total distance was measured and recorded to the nearest centimeter.

Data analysis

In the predictive validity portion of the study, each subject was classified as either a treatment success or

Table 2 Subject characteristics

Age (years)	27.4±8.8 (18–50)
Duration of symptoms (weeks)	218.2±224 (2–939)
Body weight (kg)	77.7±17.96 (47.6–113.4)
Gender (% male)	36.4
Bilateral pain (%)	40.9
Worst side (% right)	52.3
Stiffness when sitting >20 minutes (%)	56.8
Squatting most painful activity (%)	61.4

non-success with the same cut-off as in the Iverson *et al.*'s study. Treatment success was defined as either a 50% or greater improvement on the composite NPRS or a score of +4 (moderately better) on the GRC questionnaire.[21] Previously, it has been proposed that a 30% change on an NPRS represents a clinically meaningful reduction in pain[39,46] and that changes of at least 4 on the GRC indicate a moderate change in a patient's condition.[40]

Sensitivity (Sn), specificity (Sp), and likelihood ratio (LR) with associated 95% confidence intervals were calculated for each individual predictor variable and each combination of predictor variables. Sn of a test reflects the true positive rate, and Sp of the test is the true negative rate.[47] To calculate Sn and Sp, 2-by-2 tables were used. Positive LRs (+LR) and negative LRs (−LR) were calculated as follows: +LR=Sn/(1−Sp) and −LR=(1−Sn)/Sp.

To test the effect of spinal manipulation on range of motion, strength, and hop tests, paired *t*-tests were used to compare measurements prior to and immediately following the intervention for all subjects enrolled in the study. Prior to data analysis, strength measurements, recorded in kg, were normalized to body weight for each subject and hop test data were converted to a limb symmetry index, expressed as a percentage of the score of the non-involved limb. Paired *t*-tests were also used to compare pre- and post-manipulation measurements for only those subjects who had a successful response to treatment. Missing 1-week GRC data were addressed with the last data point carried forward.

All statistical analyses were performed using Microsoft Excel 2007 (Microsoft Corp., Redmond, WA, USA) and PSPP for Windows, Version 3 (GNU Project; Free Software Foundation, Boston, MA, USA).

Results

Forty-four subjects (16 male and 28 female) were enrolled in the study and 41 subjects completed the 1-week follow-up. Baseline characteristics for all 44 subjects are shown in Table 2. Twenty-five (57%) of 44 subjects had a positive outcome immediately following lumbopelvic manipulation, based on a 50% or greater improvement on the final composite NPRS or a score of at least +4 on the GRC. At 1 week following treatment, 11 (25%) of 44 subjects reported a score of at least +4 on the GRC. The average percentage improvement in composite NPRS for the three functional tasks immediately following the manipulation was 35% (reduced to an average of 3.4±3.6 from 5.2±3.8).

No single predictor variable or combination of predictor variables from the original CPR[21] was predictive of a successful outcome immediately following the lumbopelvic manipulation. Accuracy statistics for each individual predictor variable are shown in Table 3. Accuracy statistics for each combination of predictor variables are shown in Table 4.

Statistically significant differences between pre- and post-manipulation were found in hip internal rotation range of motion, hip extension strength, and hip abduction strength (Table 5). No significant differences were found in hip external rotation strength, knee extension strength, single hop limb symmetry index, and triple hop limb symmetry index. We also

Table 3 Accuracy statistics for each item of the clinical prediction rule

	Sn	Sp	+LR	−LR
Side-to-side difference in hip internal rotation >14°	0.04 (0.01, 0.20)	0.95 (0.75, 0.99)	0.76 (0.05, 11.39)	1.01 (0.89, 1.16)
Ankle dorsiflexion with the knee flexed >16°	0.88 (0.70, 0.96)	0.05 (0.01, 0.25)	0.93 (0.78, 1.11)	2.28 (0.26, 20.23)
Navicular drop >3 mm	0.32 (0.17, 0.52)	0.79 (0.57, 0.91)	1.52 (0.54, 4.31)	0.86 (0.60, 1.23)
No stiffness with sitting >20 minutes	0.52 (0.34, 0.70)	0.30 (0.15, 0.52)	0.74 (0.46, 1.19)	1.60 (0.73, 3.50)
Squatting is the most painful activity	0.52 (0.34, 0.70)	0.37 (0.19, 0.59)	0.82 (0.49, 1.37)	1.30 (0.64, 2.67)

Note: Sn=sensitivity; Sp=specificity; LR=likelihood ratio.

Table 4 Accuracy statistics and likelihood of success for combinations of predictor variables

No. of predictor variables present	Sn	Sp	+LR	−LR
5	0.02 (0–0.07)	0.95 (0.85–1.0)	0.4 (0–10.5)	1.0 (0.9–1.2)
4	0.16 (0.02–0.30)	0.84 (0.68–1.01)	1.0 (0.3–4.0)	1.0 (0.8–1.3)
3	0.45 (0.23–0.67)	0.33 (0.14–0.52)	0.7 (0.4–1.2)	1.7 (0.8–3.3)
2	0.72 (0.54–0.90)	0.11 (0–0.24)	0.8 (0.6–1.1)	2.7 (0.6–11.4)

Note: Sn=sensitivity; Sp=specificity; LR=likelihood ratio.

analyzed the effect of the manipulation on only those subjects who had a successful response to the manipulation. When subjects who did not have a successful response to treatment were excluded from the analysis, the results of the paired *t*-tests were unchanged.

Discussion

We were unable to replicate the predictive ability of the cluster of variables reported by Iverson and colleagues in their preliminary CPR derivation study. Based on the confidence intervals published in both this study and the study by Iverson *et al.*, no definitive conclusions can be made concerning the ability of the CPR to identify patients who may respond best to a lumbopelvic manipulation. The confidence intervals are wide and include LRs that may generate either no change or large shifts in the post-test probability of a favorable response.

The differences in results between this study and the CPR may be explained in small part by differences in baseline characteristics of the study samples. Compared to the previously published CPR, our sample contained a higher proportion of female subjects (63.6% versus 46.9%), which is more representative of the prevalence of this disorder. At baseline, the composite pain level reported during the performance of the three functional tasks of our subjects was lower in both the successful and non-successful groups, which may indicate that our sample was less symptomatic than the sample studied by Iverson *et al.* This hypothesis is supported by the baseline functional hop test limb symmetry index scores of 95 and 98%, which indicate relatively little functional disability. The lower severity of PFPS in this sample may be significant due to the possible presence of a floor-effect when measuring change associated with treatment.

A secondary purpose of this study was to determine if there were any changes in objective measurements immediately following the lumbopelvic manipulation. Although we found statistically significant differences in side-to-side hip internal rotation range of motion, hip extension strength, and hip abduction strength, these differences did not appear to be clinically meaningful. The side-to-side difference in hip internal rotation range of motion was reduced by 1.8°, while the standard error of measurement associated with goniometry at the hip has been calculated to be 2.42° in subjects with femoroacetabular impingement.[51]

Although there was a statistically significant change with two of the hip strength tests, it was a negative relationship. Hip extension and abduction strength were both reduced following manipulation by 0.5 and 0.6 kg, respectively. After normalizing the data to body weight, we considered a 10% change in strength to be clinically significant, which would have equaled 1.6 kg for both hip extension and abduction. The fact that the measurements of strength actually decreased is both of concern and interest. A possible explanation for the observed decrease in strength was a poor level of overall fitness contributing to fatigue during the course of our testing protocol. When comparing baseline measurements of strength normalized to body weight to previously reported values, our subjects displayed much less strength, on the order of a 50% decrease for knee extension, hip extension, and hip abduction.[20,23,39] Regardless of whether strength increased or decreased following the manipulation, our results do not suggest that a possible mechanism for improvement is an increase in hip stabilizer or quadriceps strength.

Iverson *et al.* proposed numerous mechanisms for a successful response to manipulation, specifically reduction in quadriceps inhibition and regional interdependence. Reduction in distal muscle inhibition following spinal manipulation has been previously reported.[31,32,52,53] Although our results do not suggest that changes in lower extremity strength are responsible for the observed response to treatment, studies of lumbar stabilization training have shown that motor control and timing of muscle contraction may be more important than strength.[54,55] Improved activation of the core musculature may also be a potential mechanism for improvement through improved lower extremity biomechanics and stability,[20] as recent studies have shown improvement in activation of the

Table 5 Range of motion, strength, and functional test results

	Pre-test*	Post-test*	Difference†	*P* value
Side-to-side difference in hip internal rotation range of motion (°)	5.5 (4.8)	4.7 (5.0)	1.8 (0.4, 3.3)	0.01
Hip ext strength (kg)	16.9 (4.7)	16.4 (4.6)	0.5 (0.1, 0.9)	0.02
Hip abd strength (kg)	16.3 (4.7)	15.7 (4.7)	0.6 (0.1, 1.0)	0.03
Hip ER strength (kg)	13.0 (3.2)	12.7 (3.2)	0.3 (–0.2, 0.8)	0.27
Knee ext strength (kg)	18.1 (5.8)	17.7 (5.0)	0.4 (–0.4, 1.2)	0.35
Single hop limb symmetry index (%)	94.9 (12.0)	96.5 (12.2)	1.6 (–5.5, 2.2)	0.39
Triple hop limb symmetry index (%)	98.4 (14.6)	96.3 (9.3)	−2.1 (–5.9, 1.7)	0.27

Notes: *Data are mean (SD).
†Data are mean (95% confidence interval).

transversus abdominis and lumbar multifidus immediately following manipulation of the lumbar spine.[56–59]

Both peripheral and/or central neurological mechanisms may influence the patient's pain as both have been associated with manual therapy interventions.[60–62] Non-specific influences, such as patient expectations and placebo effect, also cannot be ignored as potential sources of the observed subject response. Patient expectations of a successful outcome with any intervention have the potential to influence self-reported outcomes.[63] The placebo effect must also be considered as a source of the observed improvement in pain rating as placebo effects have been well documented in studies of various interventions for PFPS.[21]

Continued research with a purpose of identifying a subgroup of PFPS patients who would respond best to a lumbopelvic manipulation technique does not appear to be promising. Future research involving orthopedic manual physical therapy approaches to PFPS may consider including this technique into a comprehensive impairment-based and/or multi-modal treatment approach. In a case series of patients with PFPS involving a multi-modal treatment approach that included the technique studied here, three of five patients experienced clinically meaningful changes in function, as measured by lower extremity functional scale and anterior knee pain scale, at discharge from treatment with improvements maintained at a 6-month follow-up.[27] Clinicians should continue to consider impairments of the lumbopelvic-hip complex in their examination of patients with PFPS.[14,15,20,21,26,27,48]

The major limitation of this study is the single-arm design without a control or placebo group. We cannot infer any cause and effect relationship between the intervention that we provided and the observed changes in our sample. All outcome measures, including the 1-week phone follow-up, were collected by the same individual who provided the intervention which creates a source of bias. To truly examine the validity of any CPR, a large randomized clinical trial is necessary.

Another limitation of this study is that it primarily investigated the immediate effects of the manipulation technique. Clinically meaningless immediate effects have been associated with numerous physical therapy treatment techniques and modalities.[64] Although the use of a GRCS at 1 week provides some insight into the effect of this technique over time, any observed changes cannot be attributed to the manipulation with confidence.

Conclusion

We were unable to replicate the CPR developed by Iverson and colleagues in a separate study sample. There does not appear to be any clinically meaningful changes in hip range of motion, hip strength, quadriceps strength, or functional ability immediately following a lumbopelvic manipulation in patients with PFPS. Future research involving orthopedic manual physical therapy for PFPS should focus on an impairment-based multi-modal treatment approach in a randomized clinical trial with a placebo or control group.

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