Use of Anterior Tibial Translation in the Management of Patellofemoral Pain Syndrome in Older Patients: A Case Series

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Abstract: The currently most plausible pathophysiologic theory for the etiology of pain in patients with patellofemoral pain syndrome involves abnormal mechanical stress to the patellofemoral joint. At this time, there is no consensus nor is there a sufficient body of research evidence to guide management of patients with patellofemoral pain syndrome. This means that clinicians have to rely to some extent on a mechanism-based approach. Decreased quadriceps flexibility and muscular endurance have been identified as possibly relevant impairments in patients with patellofemoral pain syndrome. Surgical anterior translation of the tibial tuberosity with the Maquet procedure has a proven positive effect on patellofemoral contact forces. This case series studied the effects of a physical therapy management approach that included translating the tibia anteriorly while performing open kinetic chain quadriceps training and manual muscle stretching of the rectus femoris muscle. Outcome measures used included the numeric pain rating scale and goniometric measurement of rectus femoris muscle length in a standardized test position. Anterior tibial translation reduced pain during both interventions and also produced clinically and statistically significant pre- to post-intervention improvements in pain during manual muscle testing and rectus femoris length testing in addition to statistically significant pre- to post-intervention increases in rectus femoris muscle length. The results of this quasi-experimental study indicate the need for future experimental study. Future study should include functional in addition to impairment-based outcome measures, standardization and blinding for the rectus femoris muscle length test (should future researchers chose to again use this outcome measure), a pilot study establishing reliability of outcome measures collected by the therapist, younger subjects, and the collection of longer-term outcome data.

Key Words: Patellofemoral Pain Syndrome, Anterior Tibial Translation, Rectus Femoris Stretching, Open Kinetic Chain Quadriceps Training, Anterior Knee Pain

As the average age of the United States population has increased, so has the prevalence of osteoarthritis (OA). Whereas in 2000 approximately 43 million individuals had arthritis, it was estimated that by the year 2020 some 59.4 million people in the US would be affected by OA[1]. The cost of OA to the US economy currently exceeds $60 billon per year[2]. Of the arthritic disorders affecting the lower extremity, patellofemoral pain syndrome (PFPS) is one of the most prevalent[3]. Prospective cohort studies have reported an incidence of 7% in young active adults and 1–15% in armed forces recruits; however, data on older subjects are not available. Of those visiting sports medicine practices, 2–30% are diagnosed with PFPS[4]. It is also one of the most common musculoskeletal conditions seen in orthopedic physical therapy practice[5].

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Despite its high incidence, the pathophysiology of PFPS is not readily understood. One commonly accepted theory is that abnormal patellar tracking causes increased patellofemoral joint stress and subsequent articular cartilage damage[6]. This increased mechanical stress is believed to stimulate pain receptors in the innervated subchondral bone[7]. Dye[8] proposed that the pain reported by patients with PFPS might result from a loss of tissue homeostasis in response to repetitive high-loading conditions. The problem is likely not limited to the cartilage and subchondral bone; loss of tissue homeostasis with a subsequent change in metabolic activity might also affect synovial plicae, the infrapatellar fat pad, tendons, capsule, and retinacula[9]. The pathophysiologic theory linking abnormal mechanical stresses to loss of tissue homeostasis and subsequent pain seems supported by the fact that patients with PFPS have reported functional deficits associated with prolonged sitting, squatting, stair-climbing, and running[4]. Patellofemoral symptoms are often reproduced during activities that cause high (or sustained) patellofemoral joint forces and pressures[10].

The described management approaches for patients with PFPS vary widely. Historically, researchers advocated the use of solely open kinetic chain exercises[11]. However, a recent 5–year prospective randomized study demonstrated that both open and closed kinetic chain exercise intervention led to equally good long-term outcomes in patients with PFPS[12]. A recent meta-analysis on exercise therapy for the management of PFPS found that there was limited evidence for exercise therapy as more effective than no exercise with regard to reducing pain[13]. The literature also indicates that multiple treatment modalities are being used clinically that have little or no research support with regard to their efficacy[14].

In the absence of a clear evidence base or even consensus on the management of patients with PFPS, as clinicians we have to rely to some extent on a mechanism-based approach. In that approach, the therapist assumes impairments identified on examination to be causally related to limitations in activities and restrictions in participation; these identified impairments then become the focus of intervention with the eventual goal of increasing patient function. Relevant impairments in patients with PFPS are decreased muscle length and decreased strength and endurance of the quadriceps muscles. Flexibility deficits in knee extensor soft tissues have been noted as a potential factor in the development or perpetuation of anterior knee pain[15,16]. Brody[17] associated quadriceps flexibility deficits with PFPS in figure skaters. Bohnsack[18] proposed muscle stretching and strengthening for the knee flexor and extensors as the main treatment approach for PFPS. In a cross-sectional study of 2472 men and women over the age of 60, quadriceps weakness was significantly associated with both tibiofemoral and patellofemoral OA[19]. Indicating the potentially positive effect of impairment-based intervention, Witvrouw[15] demonstrated a statistically significant decrease in anterior knee pain as a result of quadriceps training. With regard to muscle training, we have to recognize that pain-related inhibition may negatively affect intervention-related strength gains[20]. Research has also shown that OA adversely affects lower extremity muscular endurance indicating that perhaps endurance training with lower loads and likely less pain-related inhibition may be a more appropriate intervention than high-intensity strength training[21].

There are, of course, also surgical techniques developed to minimize patellofemoral pain. Of most relevance to this current study is the Maquet procedure. During this procedure, the tibial tuberosity is surgically separated from the tibia and advanced in an anterior direction by approximately 2 (cm) by packing bone material between the tibia and the detached tuberosity. The aim of this surgical technique is to reduce contact stress on the patellofemoral cartilage and thereby reduce anterior knee pain[22,23]. Research has shown that contact force on the patellofemoral cartilage decreases with anterior advancement of the patellar tendon at its modified attachment point[23]. Unfortunately, as with all surgical interventions, there is risk. Specific to this procedure is the risk of a great deal of post-surgical discomfort until bony healing is complete. Further, while short-term patient satisfaction outcomes were reported as fairly good, many patients have not been satisfied with the long-term results of this surgery[24,25].

To summarize the above information:

- Abnormal mechanical stress to the patellofemoral joint has been implicated in the etiology of pain in patients with PFPS.
- Decreased quadriceps flexibility and muscular endurance have been identified as possibly relevant impairments in patients with PFPS.
- Surgical anterior translation of the tibial tuberosity has a proven positive effect on patellofemoral contact forces.

In light of the above three points, over the past few years we have incorporated anterior tibial translation in the management of patients with PFPS who demonstrated flexibility deficits and an inability to train muscular endurance using closed kinetic chain exercises due to provocation of anterior knee pain. The purpose of this case series was to determine if the application of this anterior tibial translation during the performance of an open kinetic chain quadriceps muscle endurance exercise and manual stretching of the rectus femoris muscle was able to successfully reduce reported pain during the application of these interventions. We also wanted to determine whether there were pre- to post-intervention:

1. Reductions in anterior knee pain during muscle length testing of the rectus femoris muscle

2. Reductions in anterior knee pain during isometric manual muscle testing of open kinetic chain knee extension
3. Increases in rectus femoris muscle length

Case Series

Subjects

Subjects were a sample of convenience recruited from among patients undergoing treatment for knee pain in an outpatient orthopaedic physical therapy clinic in southeastern Michigan. Subjects were referred to physical therapy with a medical diagnosis of patellofemoral chondrosis, chondromalacia patellae, or patellar arthritis.

Inclusion criteria consisted of the following:

1. Reproduction of the subject's anterior knee pain during active open kinetic chain knee extension from 90° to 0° performed without manual resistance
2. Crepitation audible upon auscultation of the symptomatic patellofemoral joint during this same active movement
3. Reproduction of the subject's anterior knee pain during resisted isometric manual muscle testing of the knee extensor muscles when the knee was positioned at 45°
4. Goniometric evidence of a shortened rectus femoris muscle as compared to the non-symptomatic side established during the rectus muscle length testing procedure (Figure 1)

In the absence of a single gold standard physical examination test, physical therapy diagnosis of PFPS usually involves a test cluster[26]. The test cluster used in this study was chosen based on biomechanical similarities between the tests and the interventions that were evaluated[15-17,19,27]. Also relevant to the exclusion criteria below, Piva et al[28] reported high inter-rater reliability (ICC = 0.85–0.97) for lower extremity muscle-length testing and proximal hip muscle-strength testing in patients with PFPS. Testing for patellofemoral crepitus has demonstrated high reliability in patients with knee osteoarthritis (r=0.96)[29]. Patellofemoral crepitation identified during the physical exam correlates with operative findings of cartilaginous damage in patients with chondromalacia patellae, lending validity to this test[30].

Exclusion criteria included:

1. Visual evidence of excessive femoral adduction and internal rotation during the loading phase of gait on the involved lower extremity
2. Weakness (≤ 3+ on a 0–5 scale) of the hip extensor and hip abductors muscles on the involved lower extremity established with manual muscle testing

Fig. 1. Rectus Femoris muscle length examination technique (standard position).

Powers[31] discussed the role of impairments in the hip, ankle, and foot in patients with PFPS. The exclusion criteria were used to identify those patients with impairments in these joints, who were, therefore, less likely to benefit from the intervention solely aimed at the knee as implemented in this study. Bohannon[32] calculated a specificity of manual muscle testing of greater than 80% and a sensitivity to detect between-side differences or deficits relative to a grade of normal that did not exceed 75%. This indicates that we can be fairly confident that a positive finding of weakness with manual muscle testing as defined in the exclusion criteria implicates the presence of a relevant hip dysfunction. We found no data on reliability or validity of the visual assessment used here.

All subjects presented with four inclusion criteria, and no subject was positive on any exclusion criterion (Table 1). We obtained ethical approval from the Institutional Review Board of Oakland University for this case series.

Outcome Measures

The outcome measures used for this study were the 0–10 numeric pain rating scale (NPRS) and a goniometric measurement of rectus femoris muscle length. In a review of the literature addressing commonly used pain-rating scales, the NPRS was noted to be valid, reliable, responsive, and appropriate for clinical use[33]. Admittedly in a sample of patients with low back pain, Childs et al[33] calculated a 2-point change as the minimal clinically important difference for the NPRS, indicating that a clinically significant change had occurred.

Clinical use of a standard goniometer for measuring knee range of motion has been shown to be both reliable and valid[35,36]. Rectus femoris muscle length testing was performed in a patient position first described by Evjenth[37] (Figure 1). With the patient prone, the unaffected leg is positioned off the examination table by flexing the hip and placing the subject's foot on the floor, thereby stabilizing the proximal insertion of the rectus femoris on the pelvis. Passive knee flexion is then measured with a goniometer and taken as indicative of muscle length.

Interventions

The two interventions studied in this case series were manual stretching of the rectus femoris muscle and an open kinetic chain quadriceps muscle endurance exercise. The unique aspect was the application of anterior tibial translation during the performance of both interventions.

For the rectus femoris muscle stretch, the patient was positioned on the asymptomatic side drawing the lower-most leg to the chest. This movement promoted a posterior rotation of the pelvis and a flattening of the lumbar lordosis, thereby stabilizing the pelvis for the subsequent stretching maneuver. Next, the therapist flexed the subject's symptomatic leg at the hip joint and then placed a padded mobilization wedge in the popliteal region at the level of the proximal posterior tibia. The symptomatic knee was flexed, and then the hip was extended until the subject perceived a strong stretching sensation in the anterior thigh. At that point, the subject was asked to rate the anterior knee pain using a 0–10 NPRS. The therapist then translated the tibia anteriorly by pressing the padded mobilization wedge against the posterior surface of the proximal tibia (Figure 2) The amount of anterior tibial translation was increased until the subject reported a 0 on the NPRS for anterior knee pain (Table 2). Sustained stretching with anterior tibial translation was held for 2 (min).

For the open kinetic chain quadriceps muscle endurance exercise, the subject was seated next to a pulley system

TABLE 1. Subject characteristics

Participant	1	2	3	4	5	6
Age/Gender	38-year-old female	51-year-old female	54-year-old female	38-year-old female	57-year-old female	74-year-old-female
Medical Diagnosis	Patellofemoral chondrosis	Patellofemoral chondrosis	Chondromalacia patella	Anterior knee pain	Patellofemoral arthritis	Patellofemoral arthritis
Pain Distribution	Constant left anterior knee pain	Left anterior knee	Left anterior knee	Right anterior knee	Right anterior knee	Right anterior knee pain
Functional Deficits	Unable to sit for greater then 30 minutes secondary to development of left anterior knee pain	Unable to sit for greater then 30 minutes secondary to development of left anterior knee pain	Unable to ascend and descend stairs without anterior left knee pain	Unable to squat or descend without anterior right knee pain	Unable to ascend and descend stairs without anterior right knee pain	Unable to squat, kneel, ascend or descend stairs without right anterior knee pain.

Fig. 2. Rectus femoris manual muscle stretching technique with anterior tibial translation.

TABLE 2. Numeric Pain Rating Scale (NPRS) average scores (over 6 interventions) during open kinetic chain quadriceps muscle training and rectus femoris manual muscle stretching with anterior tibial translation.

	Subjects					
Measure	**1**	**2**	**3**	**4**	**5**	**6**
NPRS (average) for anterior knee pain during open kinetic chain assisted knee extension exercise with anterior tibial translation	1.6	1.3	1.3	1.3	0	0
NPRS (average) for anterior knee pain during the side-lying rectus femoris stretch with anterior tibial translation	0	0	0	0	0	0

with the symptomatic knee closest to the pulley. A Thera-Band™ was wrapped around the subject's distal lower extremity and secured to a pulley attachment such that it would assist in the active knee extension movement that was performed from approximately 75⁰ of flexion to full extension (Figure 3). During the first few assisted knee extension motions, the therapist assessed the subject for crepitation and anterior knee pain brought on by this movement. In all subjects, both anterior knee pain and crepitation were still present. At this point, the therapist wrapped a leather strap around the subject's proximal tibia and attached the strap to the cable of the pulley system. Each subject continued to perform assisted open kinetic chain knee extension as weight was added in 5- (lbs) increments with the intent of translating the proximal tibia in an anterior direction. Weight was added while anterior knee pain and crepitation were monitored until all symptoms were alleviated (NPRS = 0; no crepitation), the assumption being that some of the compressive load was taken off the patellofemoral joint because crepitation was not appreciated and anterior knee pain was alleviated. Each subject performed this exercise at a comfortable self-selected rate comparable to their own walking pace for 20 minutes, taking three 30 (s) rest breaks at 5, 10, and 15 (min) as needed. The maximum weight used to translate the tibia in an anterior direction was 20 (lbs). During the course of this exercise intervention, the PF joint was auscultated

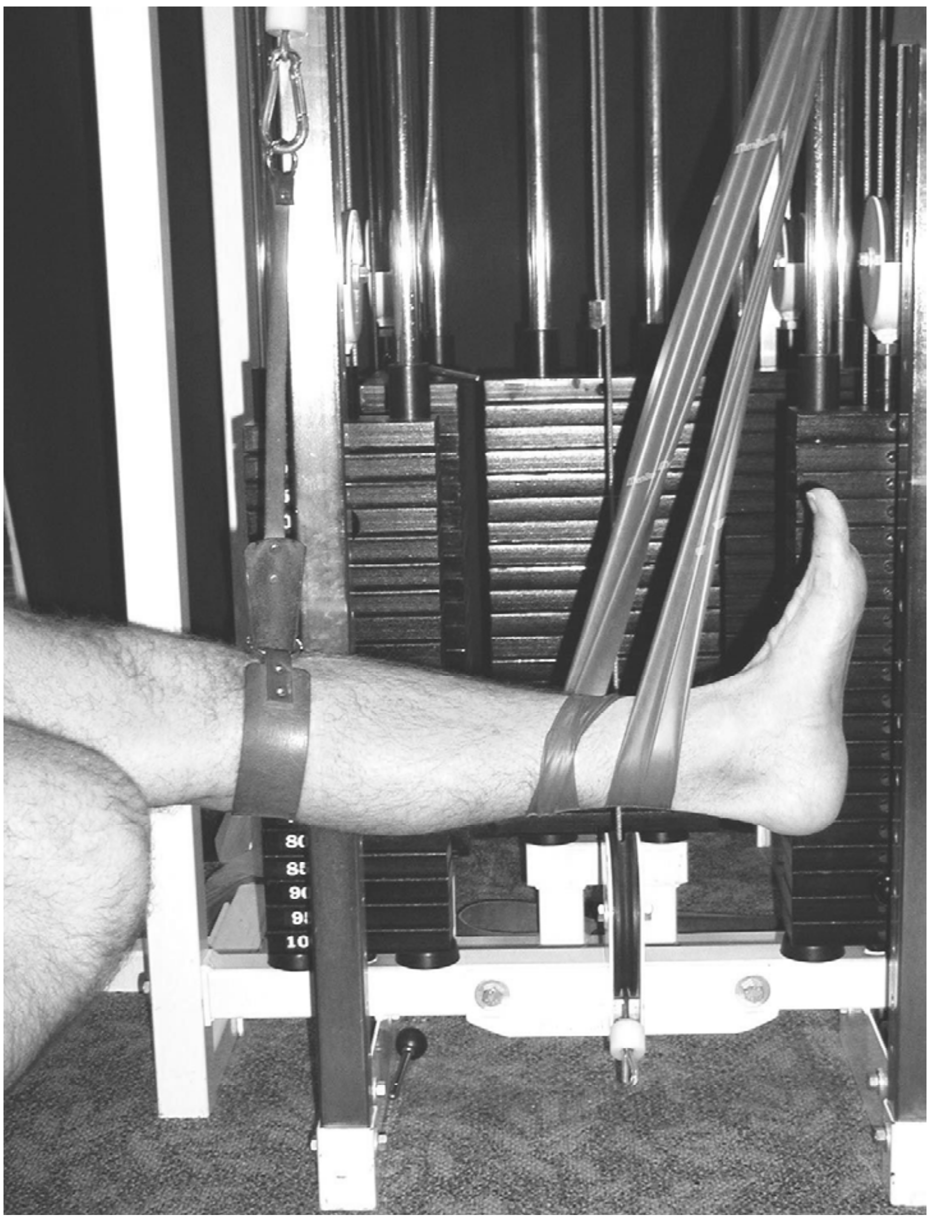

Fig. 3. Open kinetic chain assisted quadriceps training exercise with anterior tibial translation.

and palpated to ensure absence of crepitation; NPRS data were collected one minute prior to the end of this intervention (Table 2).

Statistical Analysis

Making the assumption that NPRS data can be treated as metric scale data as is commonly done in research, we calculated the mean of the NPRS data during the two interventions to determine if the application of anterior tibial translation during the performance of an open kinetic chain quadriceps muscle endurance exercise and manual stretching of the rectus femoris muscle was able to successfully reduce reported pain during the interventions.

We used the Wilcoxon Signed Ranks Test for comparing pre- to post-intervention NPRS data during manual muscle testing and rectus femoris length testing. A paired *t*-test was used to compare pre- to post-intervention rectus femoris muscle length findings.

Results

Adding anterior tibial translation during the performance of an open kinetic chain quadriceps muscle endurance exercise and during manual stretching of the rectus femoris muscle was able to successfully reduce reported pain. During the open kinetic chain quadriceps muscle endurance exercise, adding anterior tibial translation resulted in an average NPRS of 0.92 (range 0–1.6). Adding anterior tibial translation to manual stretching of the rectus femoris muscle resulted in an average NPRS of 0.0 (Table 2).

Comparing anterior knee pain as measured with the NPRS prior to the start of intervention and after 6 treatment sessions showed a significant pre- to post-intervention decrease in pain with manual muscle testing (P = 0.016) and during knee extension open kinetic chain manual muscle testing (P = 0.016). In addition to these clinically significant changes, the subjects also demonstrated clinically significant pre-to post-intervention changes for pain during both tests with all subjects reporting a decrease in excess of 2 points on the NPRS. Muscle length of the rectus femoris was also increased to a statistically significant level (P = 0.000) from pre- to post-intervention (Table 3).

Discussion

Applying biomechanical principles derived from research in the area of surgical intervention for PFPS[26–29,38], we developed two conservative physical therapy interventions aimed at affecting impairments commonly associated with PFPS. The interventions are unique in that they have not been described previously in the literature. This study showed that

TABLE 3. Impairment-based outcome findings

	Subjects					
Outcome Measures	**1**	**2**	**3**	**4**	**5**	**6**
NPRS for anterior knee pain standard rectus femoris stretching position—initial	8	6	4	7	8	4
NPRS for anterior knee pain standard rectus femoris stretching position at discharge	0	3	1	1	0	0
NPRS for anterior knee pain during isometric muscle testing of knee extension at 45° at initial	9	6	4	7	9	3
NPRS for anterior knee pain during isometric muscle testing of knee extension at 45° at discharge	3	3	1	1	0	0
Goniometric values for rectus femoris muscle length at initial	87°	94°	87°	92°	88°	118°
Goniometric values for rectus femoris muscle length at discharge	132°	131°	122°	125°	118°	138°

adding anterior tibial translation to an open kinetic chain quadriceps muscle endurance exercise and during manual stretching of the rectus femoris muscle was able to successfully reduce reported pain. This study also showed that in 6 treatment sessions the participating subjects achieved clinically and statistically significant pre- to post-intervention improvements in pain during manual muscle testing and rectus femoris length testing in addition to statistically significant pre- to post-intervention increases in rectus femoris muscle length. The findings in this quasi-experimental study would seem to warrant further study of these techniques in isolation or combined with other research-based interventions for patients with PFPS.

We recognize that this case series has several limitations. First, its quasi-experimental design results in a low level of internal validity; we can, therefore, not state with sufficient certainty that the pre- to post-intervention changes observed were indeed the result of the intervention provided. A possible future true experimental design could address this limitation. Second, the three outcome measures that were evaluated were impairment-based rather than at the more important level of limitations in activities or even restrictions in participation. Future study of these interventions should include outcome measures at the latter two levels. Third, without controlling for the force applied during the manual muscle-length test and without blinding the therapist to the measures taken in this test, we cannot exclude the effect of either increased force used during the length test or rater bias as being responsible for the reported increases in muscle length. Future studies should standardize the force used during this test by way of a handheld dynamometer and blind the therapist to the goniometric readings. Fourth, we did not establish intrarater reliability for the muscle length measurement. This would have allowed us to calculate the minimal detectable change, which would in turn have allowed us to report whether the increase in muscle length was due to measurement error or true change. Fifth, we realize that the subjects in this study had an average age of 52. As the pathophysiology of PFPS may differ between age groups resulting in age-specific effects of the interventions researched in this study, future studies should also include younger subjects and analyze the effect of age on outcome. Finally, as we collected only short-term outcome data, this study does not allow us to make any inferences about potential positive long-term outcome. Future study should attempt to collect longer-term outcome data.

Conclusion

Two unique physical therapy interventions derived from research in the area of orthopaedic surgery were performed with reduced pain during the interventions in patients with PFPS. They also resulted in clinically and statistically significant pre- to post-intervention improvements in pain during manual muscle testing and rectus femoris length testing in addition to statistically significant pre- to post-intervention increases in rectus femoris muscle length. The results of this quasi-experimental study indicate the need for future experimental study. Future study should include functional in addition to impairment-based outcome measures, standardization and blinding for the rectus femoris muscle length test (should future researchers chose to again use this outcome measure), a pilot study establishing reliability of outcome measures collected by the therapist, younger subjects, and the collection of longer-term outcome data. ■

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