Patellofemoral Knee Pain Treatment Using Neuromuscular Retraining of the Hip Musculature in an Adolescent Female: A Case Report

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Abstract
Frounfelter, GG and Stutzriem, DE. Patellofemoral knee pain treatment using neuromuscular retraining of the hip musculature in an adolescent female: A case report. J Strength Cond Res 25(10): 2828–2834, 2011—The purpose of this case study is to demonstrate the treatment of patella–femoral knee pain in an adolescent female athlete with emphasis on neuromuscular training of the knee and hip in synergy movement strategies. A 1.67-m, 61.5-kg, 15-year-old woman athlete reported to rehabilitation with the complaint of a 1-year history of bilateral knee pain. The patient noted that the symptoms were exacerbated with any sports-specific training. The patient played softball as an infielder. The athlete was referred by her family practice physician. After the patient was assessed, a clinical hypothesis was generated. It was thought that neuromuscular dysfunction of the hips and knees was causing faulty knee mechanics. These abnormal mechanics were presenting as patella–femoral knee pain. Initially, the athlete was assigned a home exercise program of side-lying hip abduction and lateral step-downs. At her first follow-up appointment, she noted increased symptoms that were aggravated with her home program. Upon inspecting her exercise technique, faulty step-down mechanics were contributing to her symptoms. Step-downs were discontinued, and the patient was instructed in and performed a chair squating exercise, which was added to her home program. At her next follow-up, the patient noted being asymptomatic for 2 days. Her exercises were increased in intensity to include a Stairmaster and hip abduction and adduction on a 4-way hip machine. Eventually, over her treatment course, perturbation and proprioceptive training were initiated. By the sixth visit, the patient reported no symptoms and felt comfortable with self-management. A phone interview 3 months later indicated that the patient had no recurrent symptoms and was participating in sports without difficulty. This case demonstrates effectiveness of using hip and knee joint synergy to treat patella–femoral pain (PFP). The use of this synergy promotes proper patella–femoral alignment and improved knee mechanics. This case also is unique in the lack of physical agents and taping used to improve the patient’s condition. It reinforces how exercise technique can carry over to functional athletic activities. This study provides a case for the use of hip and knee mechanical retraining in the treatment of PFP in adolescent female athletes who do not exhibit abnormal foot mechanics in weight bearing. It is important that sports medicine professionals be aware of these treatment options and are able to use them to correct these deficits in order to facilitate return to training and competition as quickly and safely as possible.

Key Words: anterior knee pain, knee and hip joint synergy, knee mechanics

Introduction
The knee is perhaps one of the most widely studied joints in female athletics. Injuries or dysfunctions of the knee seen by sports medicine professionals in female athletes can range from ligamentous instability to mechanical dysfunction such as patella–femoral syndrome (PFS). The PFS or anterior knee pain is one of the most common knee issues experienced by female adolescent athletes (10). Causes of PFS knee dysfunction are multifactorial (1,2,3,8). Several authors believe that the risk for certain injuries can be avoided by training neuromuscular mechanisms that allow muscles surrounding and crossing the knee to bear applied loads for stabilization with dynamic activity (5,8,9,15). It was once speculated that PFS or anterior knee pain was a direct cause from muscle imbalances between the vastus medialis and lateralis of the quadriceps...
muscle group (8). The PFS was thought to also be com-
pounded by excessive pronation of the foot in weight bearing
(4,16). This situation would result in increased valgus loading
at the knee and cause subsequent maltracking of the patella in
the femoral groove. More recently, current trends indicate
that the proper sequencing of muscular contraction between
the pelvic girdle and knees may be as important or possibly
more important for knee joint alignment and optimal joint
function (2,10,12,14,18). If these factors are not addressed
by training or natural selection, it could be argued that an
athlete’s knee that does not use these neuromuscular
schemes in activity could be predisposed to injury. The
purpose of this case study is to illustrate the importance
of hip strengthening and knee alignment to treat PFS in a
high school–aged female athlete.

**METHODS**

**Experimental Approach to the Problem**

There is much research regarding exact mechanical loading
patterns that can lead to knee injury. Taking into account
the various mechanical issues that can contribute to PFS,
it is easily determined that there are many different ways to
correct their effects. This study is a case study design that
emphasizes the retraining neuromuscular coordination and
control in the treatment of PFS.

**Subjects**

A 1.67-m, 61.5-kg, 15-year-old woman had a 1-year history
of bilateral anterior knee pain. Her symptoms increased
with squatting, going downstairs, and with softball activities
such as hitting. She also noted pain at night with sleeping.
She would awaken with pain in both knees that would
improve after being up for 2 hours. The symptoms would
vary throughout the day but increased with weight-bearing
activity. At this time, the patient and her parents were
concerned this would limit the patient’s ability to play third
base in softball as it had the previous season. The patient
could not remember a specific mechanism of injury but
rather an insidious onset. She noted that her symptoms
were intermittent and currently 4/10 on a 0–10 pain scale,
where 0 represents no pain, and 10 represents the worst pain
the patient could imagine. Medical history was non-
contributory. Initial evaluation findings are outlined in
Table 1. Because of the retrospective and noninvasive
nature of this case, our healthcare system’s risk manage-
ment department (Acting as our Institutional Review
Board) approved this case study. Permission to use this
patient’s medical history to complete this study was
obtained by both the patient and her mother.

After assessment on the initial visit, it was theorized that in
the absence of abnormal foot mechanics during gait and
unremarkable knee musculature findings, pelvic muscle
imbalances could disrupt the ability of the body to maintain
proper knee alignment during activity. The treatment plan
reflected this approach by focusing on motor retraining of the
kinetic chain between the knee and hip.

As a result of this clinical rationale, the patient was
instructed a clam-shell exercise to strengthen hip abduction
and external rotation (Figures 1 and 2). See Table 2 for
exercise description and technical performance points.
Closed kinetic chain motor learning was used by assigning

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**Table 1. Initial assessment findings.**

<table>
<thead>
<tr>
<th>Test performed</th>
<th>Findings and indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic assessment of gait-looking specifically at knee and feet mechanics</td>
<td>Bilaterally increased genu varum with significantly inferiorly placed patellas and medial thigh rotation</td>
</tr>
<tr>
<td>Palpable tenderness and edema</td>
<td>Feet appeared within normal limits without increased pronation or supination.</td>
</tr>
<tr>
<td>Patellar mobility</td>
<td>None</td>
</tr>
<tr>
<td>Patellar compression</td>
<td>Normal</td>
</tr>
<tr>
<td>Ligament testing (15)</td>
<td>Positive-elicited patient’s symptoms</td>
</tr>
<tr>
<td>Anterior cruciate</td>
<td>Negative</td>
</tr>
<tr>
<td>Medial collateral</td>
<td>Negative</td>
</tr>
<tr>
<td>Lateral collateral</td>
<td>Negative</td>
</tr>
<tr>
<td>Meniscus testing (15)</td>
<td>Quadriceps bilaterally 5/5</td>
</tr>
<tr>
<td>Manual muscle testing (12)</td>
<td>Nonspecific hamstring 4-/5 with anterior knee pain</td>
</tr>
<tr>
<td>Functional muscle testing (13)</td>
<td>Positive right Trendelenburg’s sign</td>
</tr>
<tr>
<td></td>
<td>Indicating same-sided hip abductor weakness</td>
</tr>
<tr>
<td></td>
<td>Evident by not being able to keep pelvis level in frontal plane in a single leg stance</td>
</tr>
</tbody>
</table>
**Table 2. Corrective exercise and technical coaching points.**

<table>
<thead>
<tr>
<th>Corrective exercise</th>
<th>Technical points</th>
</tr>
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<tbody>
<tr>
<td><strong>Clam-shell exercise</strong></td>
<td>Lying on side with knees flexed 90° and hips flexed 45°</td>
</tr>
<tr>
<td></td>
<td>Sequentially lift top knee, then foot</td>
</tr>
<tr>
<td></td>
<td>Hold 10 s and slowly return to starting position in reverse sequence</td>
</tr>
<tr>
<td><strong>Lateral step-downs</strong></td>
<td>Starts at the top of a 6” step and slowly lower down slope leg to the floor</td>
</tr>
<tr>
<td></td>
<td>Return to top of step</td>
</tr>
<tr>
<td></td>
<td>Maintain proper alignment of the upslope knee in the sagittal plane</td>
</tr>
<tr>
<td><strong>Wall slide/sit</strong></td>
<td>Stand with back against a wall and heels 18–24 in. away from wall base</td>
</tr>
<tr>
<td></td>
<td>Then bend the knees until the back thighs are parallel to the floor</td>
</tr>
<tr>
<td><strong>Chair squat</strong></td>
<td>Stand in front of a chair</td>
</tr>
<tr>
<td></td>
<td>Descend to a sitting position on the chair</td>
</tr>
<tr>
<td></td>
<td>Descend onto the back half of the chair</td>
</tr>
<tr>
<td></td>
<td>Knees spread wide on the descent to emphasize proper alignment</td>
</tr>
<tr>
<td></td>
<td>Return to the starting position using only the leg muscles</td>
</tr>
<tr>
<td></td>
<td>Maintain neutral spine position by holding chest and head up</td>
</tr>
<tr>
<td></td>
<td>After the basic technique is demonstrated, do not rest chair-start ascent</td>
</tr>
<tr>
<td><strong>Dynamic hip adduction</strong></td>
<td>Lever arm is set so hip is in abducted position with the hip externally</td>
</tr>
<tr>
<td>on 4-way hip machine</td>
<td>rotated with toes pointing up to the ceiling</td>
</tr>
<tr>
<td></td>
<td>Adduct hip and internally rotate as far as possible</td>
</tr>
<tr>
<td></td>
<td>Toes continue to point at ceiling in finished position</td>
</tr>
<tr>
<td></td>
<td>Do not let the weight-bearing foot pivot and keep the pelvis level in frontal plane</td>
</tr>
<tr>
<td><strong>Dynamic hip abduction</strong></td>
<td>Thigh on the lever pad so that the hip is internally rotated and maximally added</td>
</tr>
<tr>
<td>on 4-way hip machine</td>
<td>The same motion is performed but end position is maximal</td>
</tr>
<tr>
<td></td>
<td>abduction and external rotation</td>
</tr>
<tr>
<td><strong>Stability ball glute–hamstring</strong></td>
<td>Lay supine with feet resting on 55-cm stability ball</td>
</tr>
<tr>
<td>bridging</td>
<td>Curl knees toward chest until they are at 100–120° of flexion-feet stay on ball</td>
</tr>
<tr>
<td></td>
<td>Lift butt off ground</td>
</tr>
<tr>
<td></td>
<td>Hold 10 s and slowly return to starting position</td>
</tr>
</tbody>
</table>

Figure 1. Clam-shell exercise starting position.

Figure 2. Clam-shell exercise ending position.
the patient lateral step-downs as part of her home program (Table 2). The patient was able to demonstrate proper technique during her initial visit.

The patient’s next follow-up visit was 1 week later. At that time, she noted her pain was on average a 6/10 and aggravated by performing lateral step-downs. Overall, the patient noted very little improvement in her condition. Treatment began with a warm-up on a stationary bicycle for 5 minutes followed by lateral step-downs. It was found that she was performing them with a greater than normal valgus load with femoral medial rotation. This motor pattern is often seen in female adolescent athletes (10,17,18) (Figure 3). It was decided to discontinue this exercise at home because of the increase in the athlete’s symptoms and improper mechanical execution.

A new treatment plan was developed to incorporate double leg exercises into her home exercise program. The patient was instructed and able to perform wall slides with a sit and chair squats (double and single legged) without increased symptoms and with proper mechanical alignment (7) (Table 2). These exercises were selected and added to her home program because they could be used to emphasize knee placement in both sagittal and frontal planes.

Two days later, the patient returned for her third rehabilitation visit. She reported no symptoms since her last visit, and she was consistent with her home program 3 times per day. She biked as part of a warm-up and then performed double- and single-leg press to reinforce knee and hip mechanics. Dynamic stabilization of the hip was then performed by doing abduction and adduction on a 4-way hip machine (Table 2). By performing these exercises in this fashion, you can allow for maximal functional training of the pelvic stabilizers of the weight-bearing lower extremity while exercising the contralateral musculature in open kinetic chain (6). The patient also performed stability ball bridging to activate glute and hamstring muscle contraction (Table 2; Figures 4 and 5).
The patient refused cryotherapy after treatment because of being asymptomatic. She demonstrated better mechanical alignment of the knee during this treatment. She was able to maintain proper sagittal alignment by keeping her knee over her second toe. This allowed her to avoid putting her knee in excessive valgus with eccentric loading during step-downs. This was a marked deviation from how her technique looked previously, and it also shows that she was starting to understand mechanical alignment issues and how it pertained to her symptoms. The next treatment goal was to integrate this awareness into functional and athletic activity.

During her fourth visit, the patient had no symptoms and was doing her home program regularly. She was able to tolerate 5 minutes on a Stairmaster using the “quick start” program at level 5. The purpose of using a Stairmaster instead of a bike was to provide a more fatiguing environment while forcing the maintenance of proper lower extremity alignment. Her knees were kept in proper alignment during this activity. She then performed single-leg press and stability ball hamstring bridging. Treatment progressed to functional positioning by having her assume a single-leg stance while performing medicine ball chest passes with a 1.8- to 2.3-kg ball. Knee alignment was maintained, and the patient once again refused any icing because of no pain. At that time, we decided to continue 1–2 more visits and then progress to self-management via home program.

On her fifth visit, the patient noted that earlier that day, she felt her knee pop during physical education class but did not have any current symptoms. She performed biking, single-leg press, and single-leg bridging on a stabilization ball. She also performed heel raises on a step and performed quadriceps and calf stretching.

On her sixth and last visit, the patient had no symptoms for 2 weeks, and she was participating in sporting activities without any symptoms or complaints. Overall, she felt her knees were fine. Treatment on her last visit consisted of doing a Stairmaster workout, slide board activities, lateral walking with tubing wrapped around her ankles (Figure 6), and a review of proper squatting technique. There were no complaints after the treatment, and it was agreed to discontinue the treatment. The patient and her mother were assured that they could contact our rehabilitation department if there were any concerns.

**RESULTS**

The patient was contacted 3 months after the treatment was discontinued. The patient reported that she was still actively participating in sports, and she continued to not have any knee symptoms. She was not performing her home program at that time.

**DISCUSSION**

This female athlete came to rehabilitation with a history of anterior knee pain and no apparent mechanism or mechanical cause of injury. After a thorough evaluation, several hypotheses were generated. First, the patient was experiencing noninflammatory pain because of its intermittent nature. Pain caused by chemical mediators during acute inflammation is constant. It does not simply turn on and off as this patient’s symptoms presented. It was particularly interesting that through her rather active lifestyle, she did not cause enough local irritation at the patella to start an inflammatory response. This might be explained by the patient self-limiting her activity level, based on her symptoms as noted in her initial interview. Conversely, she noted on days when she felt very little knee pain, she would often increase her activity level to the point where her symptoms returned.

Second, the patient’s symptoms appeared mechanically related based on movement patterns. Historically, patellofemoral pain (PFP) has been thought to be caused by inactivity of the vastus medialis oblique (VMO) compared to the rest of the quadriceps muscle group. This theoretically would cause the patella to track abnormally in the trochlear groove of the femur and become the cause of patellar pain. In this particular case, the patient demonstrated good quadriceps tone with no apparent VMO inhibition or atrophy.

Another proposed cause of PFP is the relationship of the foot to the knee. Increased pronation of the foot could lead to increased knee valgus load with femoral rotation causing increased medial patellar loading on the femoral groove with subsequent symptoms. Once again, this did not fit into this case’s clinical presentation. There was no indication of increased pronation during the initial evaluation.

The patient did present with abnormal hip muscle strength imbalances. At her initial evaluation, she demonstrated decreased functional hip abduction strength by having a positive Trendelenburg sign. During this test, the subject stands in single-leg stance. Hip abductor weakness will be noted with the subject adducting the closed-chain hip. This allows the subject to balance the center of gravity of the body over the hip and correct for a rotational moment around that hip. Weakness may also be present, as was this patient’s case, if the subject adducts the closed-chain hip. Normal hip abduction strength should allow the hips to maintain a level position (13).

It has been shown that decreased functional strength in the hip abductors could lead to increased compensation strategies at the knee such as increased valgus loading and external rotation of the femur. This has been postulated to be a possible neuromuscular control issue that could predispose athletes to anterior cruciate ligament injury. This lack of control is thought to be prevalent in female athletes and should be addressed by strength and conditioning professionals during in-season and off-season strength training programs.

Such neuromuscular control issues could likewise lead to abnormal patellar tracking and subsequent PFS. This was the mechanism for this patient’s symptoms and demonstrated that they were caused by a mechanical origin vs. chemically mediated pain reaction at the time she sought treatment. Neural motor changes are often thought to be the cause of initial improvement in strength and performance.
whenever a new skill is learned. This often is thought why strength gains and performance improvement can be expected along a learning curve even before neuromuscular changes such as increased protein deposition takes place. This patient’s quick response to treatment and rapid improvement with extremely limited use of modalities and emphasis on closed kinetic chain exercise with proper alignment could be considered further proof that this patient’s symptoms were related to abnormal knee positioning during activity.

This athlete used very little to no weight training in preparing for her sport, which is a fairly common finding regarding high school–aged female athletes. Not only can weight training increase strength and muscle mass but it can also be used to reinforce proper knee mechanics during activities such as squatting and lunging. Rehabilitation allowed the concept of proper knee mechanics to be introduced to this athlete. Education by coaches and strength and conditioning staff is also crucial with the prevention of PFS and to reduce the risk of possible lost training and competitive playing time for their athletes. After working with this patient, she will be able to take these principles and apply them in a weight room setting. It is especially important for this athlete because she is relatively young and will most likely be introduced to and encouraged to perform weight-training activities as she progresses through her high school athletic career. This was the reason that many of her home exercises resembled many common weight room exercises.

The PFS and anterior knee pain are common ailments for adolescent female athletes. Sports medicine healthcare providers need to take into account the cause of these symptoms to adequately address the patient’s complaints and prevent recurrence. This case study demonstrates that strengthening programs designed to treat PFS need to address the possibility of hip and pelvic strength and coordination and its impact on the patellar tracking of the knee. This should be considered when other more traditional views such as overpronation of the foot and decreased VMO tone appear to be within normal limits and not significant factors. A well-designed strengthening program that corrects imbalances and promotes coordination in a functional way could make the difference between successful recovery and a chronic condition. This case demonstrates how the use of such techniques can have a positive impact on such a patient’s functional performance and how these mechanical corrections can be applied by strength and conditioning professionals.

Perhaps the most critical point of such a treatment approach is patient education and his or her participation in the plan of care. Without the patient knowing the concepts of this treatment approach, he or she could very easily perform these exercises in such a way that would increase or propagate symptoms. Once this patient was aware of the proper technique needed for the therapist’s plan of care, she was able to use the mechanical principles and control her symptoms. Being able to identify faulty muscular coactivation patterns and designing programs that can address individual deficits may greatly aid this athletic population in training and obtaining their individual goals related to his or her chosen endeavors.

**Practical Applications**

Adolescent female athletes can present with decreased strength, flexibility, and faulty motor coordination that can predispose them to anterior knee pain. The symptoms of such pain can range from a mild inconvenience to disabling. Sports medicine and strength and conditioning professionals can use the ideas presented in this case to create exercise programs that can address common mechanical faults seen in such a population. Special attention needs to be paid to how the hip and knee interact and how foot position can alter knee mechanics. Such programs could be used as an integrated part of a comprehensive conditioning program, or, as in this case, as a separate intervention strategy to retrain neuromuscular coordination for advanced athletic participation.

**References**


