Functional Movement Pattern Training Improves Mechanics in a Female Runner With External Snapping Hip Syndrome

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Running-related musculoskeletal injuries occur with an overall yearly incidence rate between 19.4% and 79.3%. Most of these injuries are to the lower extremity, with 50% to 75% of all running injuries classified as overuse and occurring more often in females than males. Faulty running biomechanics have been linked to overuse injury in runners, specifically in runners with iliotibial band syndrome (ITBS), patellofemoral pain, Achilles tendon pathology, and tibial stress fractures. Evidence suggests that altered neuromuscular control of the hip abductors and external rotators contributes considerably to the development of ITBS. Runners with ITBS display frontal and transverse plane deviations including increased hip adduction, internal rotation, and contralateral pelvis drop (CPD) at initial contact. Patients with symptomatic external coxa saltans, or external snapping hip syndrome (ESHS), display reduced eccentric hip abductor strength. The incidence of ESHS in runners is not known, and running gait pathomechanics have not been published. In a case report, Spina described a patient with increased hip adduction and knee valgus on the affected limb and a positive CPD during walking. Researchers and practitioners have advocated therapy interventions such as hip strengthening and mirrored gait retraining with inconsistent results. Snyder et al. significantly increased strength of hip abductor and external rotator muscles and decreased stance phase rearfoot eversion in a group of healthy runners using a six-week hip strengthening program, but failed to significantly alter hip adduction or internal rotation motion. Sato and Mokha improved 5 km run times in a group of 10 healthy runners with six weeks of Swiss ball core training, but did not significantly change impact, breaking, or propulsive forces. Runners with patellofemoral pain who underwent a three-week hip strengthening program demonstrated increased strength, less pain, and reduced stride-to-stride knee joint variability, but saw no change in peak genu valgum angle. No significant changes were produced in hip or knee running biomechanics in a group of female runners.
who completed a six-week hip strengthening and movement education program consisting of mirror and verbal feedback on proper mechanics.24

Mirror feedback,25 the conscious changing of the running pattern through step rate manipulation and real-time kinematic feedback26 has shown promise. Noehren, Schultz, and Davis27 and Willy, Scholz, and Davis25 used gait retraining, where participants were cued to contract their gluteal musculature to produce reductions in excessive hip adduction and CPD during treadmill running. Subjects in both studies exhibited reduced peak hip adduction and CPD, and significant decreases in pain.

Exercise interventions attending to multiple segments of movement designed to influence proprioceptive response and motor planning have been shown to have efficacy in the rehabilitation of neurologically-impaired individuals.26,28 Pain and injury affect central processing of motor control and can result in movement pattern alterations.29-31 Functional movement patterns are considered foundational movements, such as stepping and squatting, that elicit simultaneous demands of strength, reflex stabilization, mobility, and motor control.32 They are considered the basis for more complex activity-specific movement patterns such as running and throwing. Improving functional movement patterns may change aberrant biomechanics commonly seen in runners with injury history. Therefore, the purpose of this report is to describe the changes in lower extremity mechanics as a result of a four-week corrective exercise program aimed at improving functional movement patterns in a female collegiate runner with ESHS history.

**Case Description**

A 19-year-old female collegiate runner (height: 174.4 cm; mass: 54.9 kg; right leg dominant) in her sophomore year with a history of right hip ESHS was referred to the primary investigator via her team’s certified athletic trainer, who was requesting consultation regarding abnormal running mechanics he and her coach had observed. She then became part of a larger study investigating the role of functional movement pattern training on faulty running mechanics, and volunteered for this more in-depth investigation. This study was approved by the university’s institutional review board (protocol No. 10011302Exp.), and this participant provided written informed consent for participation.

**Differential Diagnoses**

A diagnosis of ESHS was made by both a certified athletic trainer and board certified orthopedic physical therapist. ESHS was defined as the reproduction of an audible or palpable “snap” concurrent with pain experienced at the lateral hip as the iliotibial band and anterior border of the gluteus maximus slide abruptly over the greater trochanter during hip rotation or flexion.33 ESHS occurs in 5% to 10% of the general population, while its incidence in runners is not known.34 Differential diagnoses for coxa saltans include greater trochanteric bursitis, iliopsoas tendonitis, and intra-articular lesions.20

**Medical History and Physical Examination**

The runner in this case reported a three-year history of ESHS symptoms that she denied ever kept her from training or competing, but did worsen significantly over the past year as training volume increased. Her average mileage during the study was 60 miles per week. On a visual analog scale, she rated her pain during runs as 4/10. No other self-reported pain or function scales were used. She denied any other lower extremity pain or any previous surgeries.

During the physical examination, she presented with a palpable snapping sensation at the lateral hip during hip flexion and external rotation, and was tender to palpation over the right greater trochanter. She was not tender along the distal iliotibial band (ITB). All right side active and passive hip motions were full and pain-free except for pain during passive hip external rotation, consistent with the pain experienced during running. Manual muscle testing for the hip showed 3/5 with side lying abduction, 3+/5 prone external rotation, 4/5 prone internal rotation, 3/5 prone extension, 4/5 side lying adduction, and 5/5 supine flexion. All left side hip range of motion and strength measures were within normal limits. Ober’s and FABER tests were negative.

**Movement Screen Findings**

The runner’s functional movement patterns were assessed using the Functional Movement Screen™ (FMS) according to protocol32 as part of her team’s standard preparticipation examination in mid-August 2013. Pre- and posttraining FMS scores are shown in Table 1. The FMS assesses seven functional movement patterns for pain, asymmetries, and dysfunction.
Scores of 0 indicate painful movement patterns. This subject had no scores of 0. Asymmetries are assessed left to right; this subject had asymmetries in the rotary stability (left: 2/right: 3) and inline lunge (left: 3/right: 2) tests. Incomplete patterns are identified as those with scores of 1. This subject had an incomplete trunk stability push-up pattern. Scores of 2 are defined as movement patterns that are completed, but with compensation, faculty form, or loss of alignment. The Selective Functional Movement Assessment (SFMA) was also conducted according to protocol, but not until mid-September 2013, when she was referred for biomechanical analysis. The SFMA is an extension of the FMS and is used in the presence of pain. The SFMA allows the athletic trainer to determine if pain is complicated by movement dysfunction. The SFMA consists of seven top-tier basic movement patterns (cervical movement, upper extremity movement, multisegmental flexion, multisegmental extension, multisegmental rotation, unilateral standing balance, overhead squatting) that are screened for pain and dysfunction. Each pattern is scored as functional nonpainful (FN), dysfunctional nonpainful (DN), functional painful (FP), or dysfunctional painful (FP). The movement patterns that demonstrated dysfunction in this runner were the multisegmental flexion, multisegmental extension, and multisegmental rotation patterns. Pre- and posttraining SFMA findings are shown in Table 2. A more detailed description of the specific criteria and findings for these three patterns is found in Table 3.

Running Mechanics

Running mechanics were captured using a 10-infrared camera (120 Hz) Vicon motion analysis system (Vicon Peak, Lake Forest, CA) with Vicon Nexus software (version 1.7.1), and a synchronized Bertec force plate (Bertec, Columbus, OH) sampling at 1000 Hz. Anthropometric measures were collected and retroreflective markers were placed bilaterally on the subject according the specifications of Vicon’s Plug-in Gait model. The runner began both testing sessions with a warm-up consisting of general stretching and a 5-min run on a treadmill at 6.0 mph (9.66 kph). She then ran the length of the laboratory’s runway (15 m) at a speed of 3.83 m/s. This running speed was recorded and presented using Polygon version 4.0 and was consistent to that of the posttraining trial (3.90 m/s). While a pain scale measure was not assessed, she was asked if any of the activities during the sessions caused an increase in pain. She denied any increase in pain. Right (affected) foot contact was made on the force plate located in the middle of the runway. Data were captured so that two steps for the right leg and two steps for the left leg were viewed. Data were averaged across two usable trials for analysis. Specific variables of interest were peak right and left hip adduction and internal rotation.

### Table 2. Pre- and Posttraining SFMA Results

<table>
<thead>
<tr>
<th>SFMA Movement</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical mobility</td>
<td>FN</td>
<td>FN</td>
</tr>
<tr>
<td>Upper extremity mobility</td>
<td>FN</td>
<td>FN</td>
</tr>
<tr>
<td>Multisegmental flexion</td>
<td>DN</td>
<td>FN</td>
</tr>
<tr>
<td>Multisegmental extension</td>
<td>DN</td>
<td>FN</td>
</tr>
<tr>
<td>Multisegmental rotation</td>
<td>DN</td>
<td>FN</td>
</tr>
<tr>
<td>Unilateral standing</td>
<td>FN</td>
<td>FN</td>
</tr>
<tr>
<td>Overhead squat</td>
<td>FN</td>
<td>FN</td>
</tr>
</tbody>
</table>

Note: SFMA = Selective Functional Movement Assessment; FN = functional nonpainful; DN = dysfunctional nonpainful.

### Table 1. Pre- and Posttraining FMS Scores

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre</th>
<th></th>
<th>Total</th>
<th>Post</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td></td>
<td>Left</td>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Deep squat</td>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hurdle step</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Inline lunge</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Shoulder mobility</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Active straight leg raise</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Trunk stability push-up</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rotary stability</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total FMS</td>
<td>15</td>
<td></td>
<td></td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of Findings

Significant findings of the history, physical examination, and functional assessment included chronic right hip pain; weak right hip abduction, external rotation, and extension; asymmetries in the FMS inline lunge and rotary stability tests; incomplete patterns in the FMS trunk stability push-up; and DN patterns of multisegmental flexion, extension and rotation from the SFMA (Figures 1–3). The running mechanics analysis yielded large values of hip adduction and internal rotation, CPD, and rearfoot eversion. Based on these findings, the goals of the intervention were to decrease pain and improve the faulty running biomechanics. Given the inconsistent outcomes of using isolated strength training and gait retraining, we decided to focus on correcting the functional movement patterns identified with the SFMA, with the hypothesis that improving the underlying movement patterns would carry over into improving the more sport-specific activity of running.

Corrective Exercise Program

The runner attended a total of 12 corrective exercise sessions over four weeks with the athletic trainer or physical therapist, lasting approximately 30 min each. The focus of all sessions was correcting functional movement pattern impairments as identified using the SFMA. No corrective exercises directly targeted running technique, meaning the patient was not instructed to change any aspect of her running technique. We hypothesized that by improving basic, foundational movement patterns that underlie sport-specific movements, she would experience positive changes in her faulty running mechanics, as well as decreased pain. The program is found in Table 4.

Outcomes

The runner reported feeling that she was running more naturally, “without kicking out so much” on her right side during training and competitions. Pain decreased from 4/10 at baseline to 0/10 at posttraining. She displayed a 76.5 N (15% BW) decrease in vertical
ground reaction forces at impact at similar pre- and posttraining running speeds.

Reductions were experienced in hip adduction and rearfoot eversion on the right (affected) side. No clinically meaningful changes were found in right hip internal rotation or CPD (see Table 5). Figure 4 depicts the runner at right midstance during her treadmill runs at the pre- and posttraining sessions. Left side reductions were seen in hip internal rotation. Hip adduction increased. No clinically meaningful changes were found in left rearfoot eversion and CPD (Table 5). Midstance mechanics for the left side can be observed for pre- and posttraining sessions in Figure 5. The runner’s SFMA findings initially exposed three DN movement

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**Table 4. Corrective Exercise Program for Each Area of SFMA Dysfunction**

<table>
<thead>
<tr>
<th>Multisegmental Extension Interventions</th>
<th>Multisegmental Flexion Interventions</th>
<th>Multisegmental Rotation Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine upper and lower torso lift with shoulders in full flexion</td>
<td>Hook-lying alternating hip flexion with emphasis on pelvic stability</td>
<td>Rolling supine → prone leading with upper body</td>
</tr>
<tr>
<td>Unilateral bridge with legs crossed</td>
<td>Progression to straight leg lowering from full hip flexion with knee extension position, emphasis on stability of contralateral/nonmoving leg</td>
<td>Rolling prone → supine leading with lower body</td>
</tr>
<tr>
<td>Prone upper and lower torso extension with shoulders flexed</td>
<td>Segmental flexion supine → long sitting</td>
<td>Quadruped contralateral UE/LE raise balancing ball on spine Hook-lying on foam roller alternating hip flexion without UE support Half-kneeling tandem balance</td>
</tr>
</tbody>
</table>

*Note: SFMA = Selective Functional Movement Assessment; UE = upper extremity; LE = lower extremity.*
At the completion of the program, all progressed to FN. Her total FMS score increased two points, from 15/21 to 17/21. Specifically, she improved her left inline lunge pattern from a 2 to a 3, and her active straight leg raise on both sides from a 2 to a 3. The trunk stability push-up and the rotary stability patterns remained unaffected.

**Discussion**

We have described a case where correcting dysfunctional movement patterns, as identified using the SFMA and FMS, has modified running biomechanics and improved pain in a runner with ESHS. This approach was unique in that the focus was on improving foundational, basic movement patterns rather than targeting the running technique itself or strengthening specific muscles (e.g., hip abductors). After four weeks of intervention, the participant experienced reductions in known faulty running mechanics, such as impact ground reaction force, hip adduction (right side) and internal rotation (left side), and rearfoot eversion (right side).

### Impact Ground Reaction Force

Peak impact ground reaction force occurs within the first 10% of stance (< 30 ms), and runners with relatively low levels of impact forces are at reduced risk of incurring an overuse injury. The intervention of functional movement pattern correction resulted in a reduction in peak impact ground reaction force. The pre- and posttest impacts of 1,215.6 N (2.26 BW) and 1,139.1 N (2.11 BW) are in agreement with previously reported impacts during running, and the 76.5 N (15% of BW) decrease is noteworthy and may be considered protective for this athlete regarding reinjury.

### Hip and Pelvis Kinematics

Symptomatic ESHS can be a chronic condition affecting physical function in younger people 15 to 40 years. Gluteal weakness has been suggested to be associated with ESHS. At baseline, the participant exhibited weak hip abduction and external rotation and extension, consistent with this claim. Since the gluteus maximus, a powerful extensor, inserts into the tensor fascia latae, it follows that the actions of these muscles would be compromised in someone

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**Table 5. Peak Kinematic Values for Right and Left Sides During Running Pre-and Posttraining**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip adduction</td>
<td>19.3 ± 1.13</td>
<td>17.4 ± 0.21</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>23.0 ± 0.49</td>
<td>23.2 ± 0.35</td>
</tr>
<tr>
<td>Contralateral pelvis drop</td>
<td>-11.1 ± 0.14</td>
<td>-10.8 ± 1.70</td>
</tr>
<tr>
<td>Rearfoot eversion</td>
<td>7.2 ± 0.00</td>
<td>3.7 ± 0.00</td>
</tr>
</tbody>
</table>

**Left**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip adduction</td>
<td>16.3 ± 2.33</td>
<td>19.4 ± 1.13</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>34.0 ± 1.48</td>
<td>29.2 ± 3.39</td>
</tr>
<tr>
<td>Contralateral pelvis drop</td>
<td>-1.8 ± 0.21</td>
<td>-1.7 ± 0.85</td>
</tr>
<tr>
<td>Rearfoot eversion</td>
<td>6.5 ± 0.99</td>
<td>6.9 ± 1.99</td>
</tr>
</tbody>
</table>

*Values are degrees. Values are means and standard deviations over two trials.*

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**Figure 4** Right leg stance: (A) runner at baseline and (B) posttraining.

**Figure 5** Left leg stance: (A) runner at baseline and (B) posttraining.
with ESHS. Spina20 described a patient with ESHS who exhibited increased hip adduction and knee valgus on the affected limb and a positive CPD during walking. Our runner displayed excessive hip adduction and CPD relative to the affected limb. Changes in CPD can affect hip segment position. CPD moves the thigh and pelvis closer medially, accounting for the increased hip adduction at baseline. In our subject, hip adduction was reduced after intervention, while CPD remained fairly unchanged. Interestingly, hip adduction increased by 3.1° on the left (unaffected) hip and CPD did not change. This seems counter-protective in terms of injury risk. Foch and Milner18 found decreased hip adduction in runners with a history of ITB pathology. They postulated that this may have been a compensatory strategy adopted to limit strain on the ITB that persisted even when the injury was healed. It is possible that our runner became less constrained on the left side due to her functional movement pattern corrections. Thus, this increased hip adduction may be a positive attribute of the training. However, larger scale studies need to be conducted to determine the meaning of this adaptation.

Using mirror gait retraining, Willy and Davis36 were able to reduce CPD and hip adduction in two runners with patellofemoral pain. Hunter, Louw, and van Niekerk37 reduced pain and improved foot-progression angle in a female recreational runner with ITB using real-time visual feedback. At this time, it is not known whether correcting underlying functional movement patterns is superior to gait retraining, but they may call upon similar demands from a motor control standpoint. Both may be methods of neuromuscular reeducation and require further investigation.

**Rearfoot Kinematics**

Rearfoot eversion has been studied in relationship to chronic injury.8,11-13,21 Excessive rearfoot motion has been implicated in runners with Achilles pathology,11-13 but there is no evidence to support the relationship between excessive rearfoot motion and ESHS. Noehren et al.8 reported 8.2 ± 2.39° in a group of female runners with patellofemoral pain versus 10.4 ± 4.2° in an uninjured control group. They hypothesized that the larger values in the control group represented a compensatory mechanism to counter the medial collapse of the lower extremity that occurs with increased hip adduction. The athlete in the current study experienced reductions in right (affected) side hip adduction and rearfoot eversion. She exhibited an increase in hip adduction on the left side with a miniscule increase in rearfoot eversion. Her changes may support the compensatory strategy suggested in the previous study.8

**Selective Functional Movement Assessment and FMS scores**

Cook describes movement pattern corrective strategy as a form of exercise that “focuses more on improving mobility, stability, basic motor control, and whole movement patterns than the parameters of physical fitness and performance” (p. 17). Pain-free and adequately performed movement patterns then create the platform for fitness and sport development. For this patient, the SFMA was used to guide intervention. It is well established that pain and injury result in altered patterns of muscle activity and can effect areas adjacent to, or remote from, the site of injury. If unaddressed, these alterations in muscle responsiveness have been shown to result in an increased risk of injury in active populations.38,39 In this case, the runner exhibited the inability to move her body fully into multisegmental flexion, extension, and rotational patterns. The loss of mobility was not attributed to joint mobility and tissue extensibility limitations, as mobility assessments showed no cause for movement restriction. Limitations in these patterns were attributed to motor control dysfunctions, which implies that there is an alteration in muscle timing and muscle force production causing this athlete to be unable to complete a movement with her body that she should be capable of completing.

Traditionally, targeting muscle groups identified as weak by muscle testing was a method of attempting to improve motor control processes. There is evidence that isolated strengthening does not result in changes to functional, multiplanar movement patterns.21,23,40-42 Farquhar et al.6 found that quadriceps weakness in patients who underwent total knee arthroscopy correlated with altered mechanics that avoided quadriceps activity during sit-to-stand transitions. Improvement in quadriceps strength did not change the movement pattern. The authors concluded that learned movement patterns may not resolve without movement pattern retraining.6 In the case of our runner with ESHS, it appears that correcting dysfunctional patterns as identified by the SFMA and FMS had a carryover effect in improving faulty running mechanics and reducing pain.
The presence of asymmetrical or dysfunctional patterns as identified in the FMS have been identified as risk factors for injury in intercollegiate athletes. Thus, the elimination of the asymmetry in the inline lunge is seen as positive for this athlete. Also of note is the improvement in the straight leg raising test of the FMS. This is a similar movement pattern to multisegmental flexion in the SFMA, which was also improved by corrective exercises addressing motor control dysfunction in this pattern. The fact that the runner could not actively raise her leg was not related to hamstring length, but the inability to stabilize about the lumbopelvic rim while performing an active straight leg raise led to a limitation in the ability to perform a straight leg raise. Alterations in motor control as a response to pain and injury have been shown to originate from central processes. The motor cortical representation of muscles is altered in response to pain, and changes in corticospinal excitability have been associated with altered biomechanics in a functional task. The runner in this study reported an absence of pain as a result of functional movement pattern correction.

Limitations
This case study is not without limitations. The lack of a follow-up observation limits our knowledge of any persistence in the biomechanical changes. However, it was known that at the time of this submission, the patient was symptom-free. Shoes used by the runner during the posttest were not the same ones used during the pretest. However, they were the same brand (Asics) and model type (stability), and we do not believe the notable changes in mechanics could be attributed to shoes alone. Finally, while changes in muscle function such as strength or contraction timing were not targets of this intervention, objective measures utilizing dynamometers and electromyography would aid in understanding gait changes.

Conclusions
Correcting faulty fundamental movement patterns had positive effects on reducing known running pathomechanics and relieving pain in this female competitive runner with ESHS. Athletic trainers and therapists may benefit by utilizing a functional movement screen to guide corrective exercise selection when running pathomechanics have been identified.
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