An impairment-based physical therapy program for runners with femoroacetabular impingement

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Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript preparation; E – Funds Collection

DOI: https://doi.org/10.34142/HSR.2023.09.02.08

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How to Cite

Abstract

Purpose. Running is a common sport and recreational activity in the United States. Due to its dysfunctional implication in runners, femoroacetabular impingement is increasingly recognized as a problematic source of anterior hip pain.

The purpose of this case series was to describe an impairment-based physical therapy intervention in non-professional runners with femoroacetabular impingement.

Materials and methods. Two males, non-professional runners with a mean age of 28.5± 2.1 years, both with a diagnosis of femoroacetabular impingement, were treated with manual therapy, dynamic neuromuscular stabilization, and functional training. At initial evaluation, subjects were examined and completed self-reported outcome measures including the visual analog scale, and the patient-specific functional scale. At discharge, they completed the same outcome measures along with the global rating of change questionnaire.

Results. Both subjects showed clinically meaningful improvement in pain and function above the minimal clinically important difference. Upon discharge, subject 1 had a 86% reduction in visual analog scale score, a 75% improvement in PSFS score, and a global rating of change score of 6; subject 2 had a 88% reduction in visual analog scale, a 64% improvement in patient-specific functional scale, and a global rating of change score of 5.

Conclusion. The overall improvement observed in this study was clinically meaningful to subjects who participated, however, because a cause and effect cannot be inferred from case series studies, follow-up randomized clinical/controlled trials are recommended to further investigate the studied intervention on runners with femoroacetabular impingement.

Keywords: dynamic neuromuscular stabilization, femoroacetabular impingement, mobilization
Мохамед Абдельмегед, Джастін Кац, Том Оддо, Санні Пандя. Програма фізичної терапії на основі порушення для бігунів із стегново-вертлужним імпінджмент синдром

Мета. Біг — поширенний вид спорту та відпочинку в Сполучених Штатах. Через його дисфункціональний вплив на бігунів, фемороацетабулярне зіткнення все частіше визнається проблематичним джерелом болю в передній частині стегна. Мета цієї серії випадків полягала в тому, щоб описати фізіотерапевтичне втручання на основі порушення у непрофесійних бігунів із ущемленням стегново-ацетабулярного відділу.

Матеріали та методи. Двое чоловіків, непрофесійних бігунів із середнім віком 28,5±2,1 року, обидва з діагнозом фемороацетабулярного удару, отримували мануальну терапію, динамічну нейром’язову стабілізацію та функціональне тренування. Під час початкової оцінки учасники були обстежені та заповнили оцінки результатів, за якими вони повідомляли себе, включаючи візуальну аналогову шкалу та функціональну шкалу для конкретного пацієнта. При виписці вони заповнили ті самі показники результатів разом із анкетою глобального рейтингу змін.

Результати. Обидва суб’єкти показали клінічно значуще покращення болю та функції вище мінімальної клінічно важливої різниці. Після виписки суб’єкт 1 мав зниження оцінки за візуальною аналоговою шкалою на 86%, покращення оцінки PSFS на 75%, а загальна оцінка змін – 6; суб’єкт 2 мав зниження на 88% у візуальної аналогій шкали, покращення на 64% у специфічній для пацієнта шкалі та загальний рейтинг зміни балів 5.

Висновок. Загальне покращення, яке спостерігалося у цьому дослідженні, було клінічно значущим для суб’єктів, які брали участь, однак, оскільки причинно-наслідкові зв’язки не можуть бути встановлені на основі досліджень серії випадків, рекомендується подальше навчання дослідників на бігунів із стегново-вертлужним імпінджментом.

Ключові слова: динамічна нервово-м’язова стабілізація, фемороацетабулярний імпінджмент, мобілізація
Introduction

Running is a popular sport/recreational activity across all ages. [1] In the United States, more than 20 million people practice running of some form. [1] The popularity of running can be attributed to its musculoskeletal, cardiovascular, psychological, and overall health benefits. Also, it is a convenient, low-cost sport that encourages social interaction. [2,3] In general, athletes presenting to physicians with limitations of activities due to groin pain account for about 5%-18%. [3,4] Runners also sustain high rates of musculoskeletal overuse injuries, which can be as high as 65% each year. Hip and pelvic injuries account for about 3.3%-11.5% of total lower limb injuries on average. [5] Femoroacetabular impingement (FAI) can result from an abnormal femoral morphology where the femoral head abnormally increases in size or diameter. This causes abnormal shear, abutment, and/or friction against the acetabulum (CAM impingement), or abnormal acetabular morphology (Pincer impingement) or can present with a mixture of both (mixed impingement). In a systematic review, the prevalence of cam and pincer types was 54.6% and 49.5% in the general population, respectively. [6] A mixed impingement has been found to be the most common. [7,8] The abutment can happen during movement between one or two abnormally-shaped articular surfaces, especially during hip flexion, adduction, and internal rotation, with resultant pain and limitation. [9,10]

FAI has been increasingly recognized as a problematic source of anterior hip pain due to its dysfunctional implications in runners. Although the exact etiology is still unknown, literature reports that it happens due to abnormal hip joint morphology, resulting in decreased joint clearance and pain. [11,12] A relatively recent systematic review found an association between FAI and hip instability due to abnormal hip joint anatomy, similar to patients with constitutionally acetabular retroversion. The patients included in their study were amateur and professional athletes and the general population. [13] Most instability signs happened during the extreme range of hip motion, especially extreme flexion, as investigated through dynamic magnetic resonance imaging (MRI) or dynamic 4D computed tomography (CT) and mainly resulted in posterior hip instability in patients with anterior FAI. It was not clear, however, if hip instability caused FAI or the other way around, but the big picture is that hips with FAI are vulnerable to instability. [14-17]

The studies documented that functional instability of the hip joint due to FAI resulted predominantly from pain inhibitory mechanism of the dynamic hip stabilizers or chronic capsular fraying or both. [18,19] Ongoing joint incongruency during physical activities as caused by FAI creates abnormal joint loading and shear stresses, which may predispose the joint to the chondral and capsular thinning and future development of hip osteoarthritis (OA). [20]

Manual therapy has been used extensively in the literature to treat different hip joint pathologies with moderate to strong evidence for its usage to improve range of motion, [21] improve joint arthrokinematics, [21] reduce pain, [22] improve motor control, [22] and activate joint mechanoreceptors. [23] On the other hand, lower extremity advanced functional training is used to improve lower extremity function by targeting strength, balance, and coordination training. [24] This will improve overall athletic functional abilities. This advanced form of rehabilitation is more complex. It incorporates sensorimotor, proprioceptive, and strength elements of different body parts to return subjects/athletes to a pre-injury level, and reduce the risk of reinjury. Because it is advanced training, it is usually performed at the end of the rehabilitation regimen since the inaccurate performance of these exercises can cause significant setbacks in the treatment plan. [25]

Dynamic Neuromuscular Stabilization (DNS) is a form of exercise therapy that is based on the principles of developmental kinesiology. DNS uses developmental kinesiology as the building block for kinetic chain activation and training to achieve or activate specific movement patterns. It is a functional approach to rehabilitation initially developed by a Czech physical therapist, Pavel Kolar. [26] DNS involves training the individual in the same positions attained during normal pediatric development while asking the individual to engage his/her core stabilizers and maintain adequate intraabdominal pressure when training for proper movement patterns. [26]

The purpose of this case series was to describe a proposed multi-modal, impairment-based physical therapy intervention consisting of hip mobility, DNS, and functional training in non-professional runners with FAI. There has been no
previous study proposing this combined intervention in such a population to the authors’ knowledge.

Materials and methods

Case descriptions and outcome measures

Two male runners aged 27 and 30 participated in this case series. They were informed that their clinical data, including pictures and videos of the assessment and treatment, will be used for educational and research purposes, and they consented to it. Subjects’ demographics and basic characteristics are shown in table 1. They were evaluated at baseline for their pain intensity using the visual analog scale (VAS), and function using the patient-specific functional scale (PSFS). The minimal clinical important difference (MCID) for the 10 cm VAS has been estimated to be 1.37. [27] The MCID for the PSFS has been estimated to be between 2 and 3 points for subjects with low back pain, cervical radiculopathy, and knee dysfunctions. [28] Same outcome measures were used after completion of therapy in addition to the global rating of change (GROC). The GROC is a single item, perception-based outcome measure that asks the subject to rate overall improvement of therapy on a scale ranging from (-7 a very great deal worse) to (0 about the same) to (+7 a very great deal better). [29] The MCID was determined to be 3 points for this scale. [29]

Table 1

Subject demographics and basic characteristics

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Duration of symptoms (wk)</th>
<th>Number of PT session received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>27</td>
<td>Male</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Subject 2</td>
<td>30</td>
<td>Male</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>

Subject 1

ED was a 27-year-old graduate student who was running 3-4 miles a week on average. He complained of insidious onset of left hip pain, which increased in intensity over two months and was aggravated by running, pivoting on the left leg, and ascending stairs. The pain was relieved by rest and pain medications. His orthopedic physician diagnosed him with a left FAI impingement (CAM type) and was referred to physical therapy. At its worst, the pain was 6-7/10 sharp, localized on the anterior left hip, preventing him from completing his running; however, the pain was rated as 2/10 on VAS at the initial evaluation.

Subject 2

SR was a 30-year-old software developer who presented with a right anterior hip pain aggravated by running and occasional clicking. He was running 5 miles a week on average. He stated that the pain appeared after like 10 minutes of starting to run if he warmed up, and after like 5 minutes if he did not warm up. Clicking, however, appears to happen after long-distance running and is a nuisance. Once he had pain, he could be able to continue for a short distance before he had to stop because of limping. He stated that he was able to continue but it was painful and caused him to limp. Radiographic examination revealed a bone spur on the right femoral head and his orthopedic physician recommended further investigation, but he was referred with a CAM femoroacetabular impingement of the right hip at the initial evaluation. Subjects’ VAS scores at baseline and discharge are shown in table 2 and PSFS’s scores in table 3.

Table 2

Baseline and discharge VAS scores

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Baseline scores*</th>
<th>Discharge scores*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Worst: 7/10</td>
<td>Worst: 2/10</td>
</tr>
<tr>
<td></td>
<td>Best: 2/10</td>
<td>Best: 0/10</td>
</tr>
<tr>
<td>Subject 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject 2</td>
<td>Worst: 6/10</td>
<td>Worst: 2/10</td>
</tr>
<tr>
<td></td>
<td>Best: 0/10</td>
<td>Best: 0/10</td>
</tr>
</tbody>
</table>

Notes: *Scores are ranged from 0= no pain to 10= maximum imaginable pain
### Table 3

Baseline and discharge PSFS scores

<table>
<thead>
<tr>
<th>Subjects</th>
<th>PSFS items</th>
<th>Baseline scores*</th>
<th>Discharge scores*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Running for more than 10 minutes Deep squat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject 1</td>
<td>Sitting on low a stool for more than 15 minutes</td>
<td>1 Total score= 2.33**</td>
<td>10 Total score= 9.33**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Subject 2</td>
<td>Long-distance running (&gt;3 miles)</td>
<td>2 Total score= 3.33**</td>
<td>9 Total score= 9.33**</td>
</tr>
<tr>
<td></td>
<td>Sitting at my desk for more than 20 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pivoting on my right leg</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

Notes: *Scores are ranged from 0= unable to perform the activity to 10= able to perform the activity at the same level as before the injury or problem

**Total score is calculated by dividing the sum of item scores by the number of the items

### Examination procedure

At the initial evaluation, subjects were asked to rate their pain intensity by placing a mark on the 10 cm VAS. They were asked to rate the pain at its worst and best. Then using the PSFS, they were asked to list at least three activities that they perceive difficult and rate the difficulty level on a scale of 10 where 0 represents an inability to perform the activity and 10 represents the ability to perform the activity at the same level as before the injury. [28] Following history taking and completing the self-reported outcome measure, the physical therapist conducted a thorough screening of the lumbar region, sacroiliac joint (SIJ), and both hips. The examination included observation, palpation, muscle testing, neurological testing, and gait assessment.

Provocation tests were conducted on the lumbar, sacroiliac, and hip regions. Lumbosacral roots involvement was ruled out using dural tension testing of straight leg raising distal imitation (SLRDI) and slump distal initiation (SDI). The active straight leg raising (ASLR) test was conducted to screen pelvic ring instability or SIJ involvement. In addition, Laslett’s cluster of tests for SIJ involvement was conducted. [30] These tests are thigh thrust, compression, distraction, sacral thrust, and Gaenslen’s tests. According to the clinical prediction rule for identifying SIJ dysfunction, the presence of 3 of 5 positive tests has a sensitivity of 0.91 and a specificity of 0.87 for ruling in an SIJ dysfunction. [30]

The hip screening included a hip range of motion (ROM), muscle testing, provocation tests, and functional movement testing to localize the source of hip pain and to confirm the diagnosis in the referral. Tests performed were hip scour, flexion, adduction, internal rotation (FADIR), flexion, abduction, external rotation (FABER) tests. Findings of the screening examination can be found in table 4.
<table>
<thead>
<tr>
<th>Indicators</th>
<th>Subject 1</th>
<th>Subject 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lumbar region and SIJ</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>Decreased lumbar lordosis</td>
<td>Decreased lumbar lordosis, the right iliac crest is higher than the left</td>
</tr>
<tr>
<td>Lumbar spine ROM*</td>
<td>WNL*</td>
<td>WNL*</td>
</tr>
<tr>
<td>Mobility assessment</td>
<td>• Slightly reactive to posterior to anterior (PA) pressure over L4-L5</td>
<td>Hypomobile (2/6) L3-L4, otherwise, not significant</td>
</tr>
<tr>
<td>Repeated movement testing</td>
<td>Repeated extension from prone and standing positions did not reproduce hip pain</td>
<td>Repeated extension from prone and standing positions did not reproduce hip pain</td>
</tr>
<tr>
<td>Neurodynamics</td>
<td>Negative SLRDI* and SDI* tests</td>
<td>Negative SLRDI* and SDI* tests</td>
</tr>
<tr>
<td>Pelvic ring instability</td>
<td>Negative ASLR* test</td>
<td>Negative ASLR* test</td>
</tr>
<tr>
<td>Laslett’s clusters SIJ* tests</td>
<td>Gaenslen’s test produced an uncomfortable feeling in the groin of the left hip. Other tests are negative</td>
<td>The sacral thrust produced slight local discomfort. Other tests are negative</td>
</tr>
<tr>
<td><strong>Hip joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip AROM*</td>
<td>Flexion: L=110, R= 120</td>
<td>Flexion: L=120, R=115</td>
</tr>
<tr>
<td></td>
<td>Extension: L=17, R=20</td>
<td>Extension: L=20, R=15</td>
</tr>
<tr>
<td></td>
<td>Abduction: L= 25, R=40</td>
<td>Abduction: L=50, R=40</td>
</tr>
<tr>
<td></td>
<td>Adduction: L= 15, R= 25</td>
<td>Adduction: L=30, R=20</td>
</tr>
<tr>
<td></td>
<td>Internal rotation: L=20, R=40</td>
<td>Internal rotation: L=40, R=25</td>
</tr>
<tr>
<td></td>
<td>External rotation: L=35, R= 55</td>
<td>External rotation: L=50, R=35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip MMT*</td>
<td>Flexors: 4+/5 left and right</td>
<td>Flexors: 5/5 left and right</td>
</tr>
<tr>
<td></td>
<td>Extensors: 4+/5 left and right</td>
<td>Extensors: 5/5 left and right</td>
</tr>
<tr>
<td></td>
<td>Abductors: L= 4-/5, R= 4+/5</td>
<td>Abductors: L= 4+/5, R= 4/5</td>
</tr>
<tr>
<td></td>
<td>Adductors: L= 4-/5, R= 4+/5</td>
<td>Adductors: L= 4+/5, R= 4+/5</td>
</tr>
<tr>
<td></td>
<td>Internal rotators: L= 3+/5, R= 4+/5</td>
<td>Internal rotators: L= 4+/5, R= 3+/5</td>
</tr>
<tr>
<td>Palpation</td>
<td>Tender to deep palpation inside the iliac fossa and over the anterior hip just distal to ASIS on the left. Pressure sensation over the right anterior hip</td>
<td>Tender to palpation over the posterior thigh over the piriformis muscle. Pressure sensation with no pain on the right anterior hip. No tenderness or pain over the left hip</td>
</tr>
<tr>
<td>Provocative testing</td>
<td>• FADIR*: L= positive and caused sharp pain. R= slightly uncomfortable</td>
<td>• FADIR*: L= negative. R= positive, produced a click with slight pain and tightness</td>
</tr>
<tr>
<td></td>
<td>• FABER*: L= negative. Overpressure caused slight pain over the back of the hip. R*= negative</td>
<td>• FABER*: L= negative with or without overpressure. R= cause stretching pain in anterior hip</td>
</tr>
<tr>
<td></td>
<td>• Scour test: L*= negative but uncomfortable. R= negative</td>
<td>• Scour test: L= negative. R= negative</td>
</tr>
</tbody>
</table>

Table 4

Summary of the screening examination and findings for the two subjects
### Functional movement testing

- Deep squat: painful on the left and caused compensatory weight shift to the right lower extremity
- Step up on a 6-inch stool: felt more unstable stepping up with the left foot and caused pelvic drop on the right with left foot stepping up
- Single leg squat: L= painful and uncomfortable. R= able to perform with no pain
- Sit to stand: 5-times sit-to-stand test was performed. The subject was able to perform with no pain

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### Gait

- Slightly limping at the initial examination with decreased stance time on the left lower extremity
- Walks with a toe-out gait, otherwise, no abnormality were observed

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**Notes:** *Abbreviations: WNL= within normal limits, PPIVM= passive physiological intervertebral movement, PAIVM= passive accessory intervertebral movement, SLRDI= straight leg raising distal initiation, SDI= slump distal imitation, ASLR= active straight leg raising, PA= postero-anterior, SIJ= sacroiliac joint, ROM= range of motion, MMT= manual muscle testing, R=right, L=left, FADIR= flexion, adduction, internal rotation, FABER= flexion, abduction, external rotation

**Intervention**

An impairment-based intervention approach was followed. Intervention consisted of hip mobility, flexibility, dynamic neuromuscular stabilization (DNS), and functional training. For hip mobility and flexibility impairment, active (by the subject) and passive (by therapist) stretching of hip muscles, mainly hip flexors, was performed to prepare the joint and the surrounding muscles, followed by passive hip mobilization in different directions. Principles of Maitland’s mobilization [31] were followed to direct treatment progression through continuous evaluation of the subject’s response to treatment immediately after imparting the mobilization force, after the therapy session, and before the start of the following session. Modification to the technique, force of mobilization, and any other relevant factors were adjusted accordingly. To address strength impairment, sensorimotor control, and to improve joint arthrokinematics and proprioceptive input, DNS and advanced functional training were performed after the stretching and mobilization techniques were concluded.

**Preparatory stretching**

To address flexibility impairment, passive stretching was performed at the beginning of every treatment session. From the same position used to test for hip flexor tightness, the therapist stood on the opposite side of the affected hip, supported the foot of the unaffected leg against the side of the therapist’s chest so that both therapist’s hands were free to stabilize and stretch the affected hip. One hand supported the ASIS of the affected side while the other hand applied pressure on the distal thigh just above the flexed knee joint as shown in figure 1-A. The pressure was applied gradually, and we made sure it is comfortable enough causing only a stretching sensation, not pain. The side of the therapist’s chest prevented undue lumbar lordosis by pushing the unaffected limb into more hip flexion. The incremental stretch force was used to gain the flexibility of the affected hip muscles. Once an end range was reached, it was maintained for 30 seconds before moving to a new range. If the affected limb moved into abduction due to tightness of the iliotibial (IT) band, the therapist used the hand that applied pressure into extension to pull the thigh into adduction while assisting the stretching force using the therapist’s leg (figure 1-B) and maintained for 30 second before moving to a new range. The stretch was performed 5 times at the start of each session.
In addition to the previous stretch, a self-stretch for hip flexors was performed from a high kneeling position where a thick rubber band was affixed to a sturdy exercise machine and around the affected thigh (figure 2). The subject was asked to lean on the front leg until the stretch is felt in the affected thigh and to hold the stretch for 30 seconds before relaxing. Stretch was repeated 5 times at the beginning of each session.

Fig. 2. Band-assisted hip flexors stretch

**Hip joint mobilization**

Hip mobilization with a mobilization belt was performed in different directions to “unlock” the affected hip. The subject was lying in a hook lying position and crossed the affected leg over the non-affected one. The affected hip was placed in flexion, abduction, external rotation (FABER) position to start with (figure 3). The mobilization belt was comfortably tightened around the subject and therapist’s proximal thighs, and counterforce was provided by the therapist’s hands around the subject’s distal thigh and knee. Mobilization was aimed to improve ROM in a single or a combined movement direction i.e., Inferior mobilization was performed to improve flexion ROM by pulling the belt away in a caudal direction using the therapist’s body (figure 3-A), and inferior, lateral glide was performed to improve flexion, abduction, external rotation combined ROM (figure 3-B).

Similarly, caudal joint mobilization was performed to improve abduction ROM from a side-lying position (figure 4). To improve extension, we used prone FABER or figure of 4 position and applied anteriorly directed force on the posterior aspect of the joint while the subject’s knee was rested on a square rubber block (figure 5). The hip was brought to further FABER positions to progress mobilization to new gained ranges.

Patients with FAI usually have pain with flexion, adduction, and internal rotation ROM of the hip. [9,10] We used mobilization with movement to improve internal rotation ROM by performing a lateral glide from an internally rotated position (figure 6) while monitoring the subject’s symptoms. As stated before, we followed the clinical guidelines proposed by Maitland [31] for assessing subjects’ symptoms during and after mobilization techniques. For example, while imparting a lateral glide, the therapist moves the limb from flexion, adduction internal rotation position toward extension, abduction, and internal rotation while asking the subject to report any pain or discomfort. If any discomfort was reported, the therapist reduced either the ROM to a more comfortable range or changed the force of the lateral glide and reassessed. The limb was continuously assessed to avoid causing pain and any provocation of any impingement signs or symptoms.
Fig. 3. A: Inferior glide and B: Inferior lateral glide from FABER position

Fig. 4. Inferior glide from side-lying hip abduction position

Fig. 5. Prone anterior glide in FABER or figure of 4 position

Fig. 6. Lateral glide with internal rotation
Dynamic neuromuscular stabilization (DNS) exercises

In this case series, we used two developmental positions and made them more challenging to subjects using some modification. The first position we used is called the “7-month oblique sitting” position. This technique uses an oblique sitting position corresponding to a pediatric developmental age of 7 to 7 and half months. There are two variations of this position called high and low oblique sitting. High oblique sitting involves a higher level of function and is more challenging, requiring multi-joint stability to fight gravity. Low oblique sitting is less strenuous, requiring fewer forces against gravity, with the subject positioned with more horizontal, single joint support. [26] In this case series, we used the low oblique sitting position where the subject supports his upper body weight on the forearm. We modified the position by adding manual or band resistance or using an unstable surface to challenge the performance.

For the first technique (figure 7), the subject assumed side-lying on the forearm on a foam roller, and the left lower extremity was crossed in front of the right one which was used to support the lower body weight. A loop resistance was added around the left knee, and while the subject lifted his pelvic off the floor, he pulled the loop resistance forward. This functional stabilization position stabilizes and strengthens the muscles around the affected hip and engages the core muscles as a stabilizing force and activates the lower and upper kinetic chain. Lifting the pelvic from the side-lying position was maintained for 60 seconds and the movement against the loop resistance was performed for 3 sets of 10 repetitions and the subject was asked to hold the end position of each movement for 6 seconds. The original description of the 7-month oblique sit exercise does not involve moving the leg against resistance or using an unstable surface. [26]

For the second technique (figure 8), the subject assumed the same oblique sitting position with support on the forearm and the nonaffected lower extremity. While the subject raised the pelvic off the table, a manual isometric resistance was provided on the inner aspect of the knee of the affected limb, and the subject was asked to match the therapist’s resistance.

The subject was encouraged to activate his core muscles similar to the first technique. This exercise rhythmically stabilized the affected hip and activated the core stabilizers at the same time. Isometric resistance was provided for 6 seconds and was repeated for 3 sets of 10 repetitions while the pelvic is lifted off the plinth for 60 seconds.

We also used the DNS “hanging position” with one arm support to activate the posterior chain of the lower extremity as shown in figure 9. In this position, the subject’s weight is supported on the affected lower extremity while maintaining a “foot centered” position to achieve optimal support on the affected lower extremity. The non-affected lower extremity is extended on the treatment table. The subject held a body blade to engage core and scapular stabilizers further, while the clinician applied a minimal resistance to hip external rotation.
to activate the glutei muscles and the whole posterior chain. At the same time, the subject is asked to try to lengthen the whole trunk as if he was reaching with the head toward the front wall. This ensured the trunk core muscles are activated. The resistance on the lateral aspect of the knee was maintained for 6 seconds before asking the subject to relax. Three sets of 10 repetitions were performed per session.

Fig. 9. DNS “hanging position” activating the posterior chain while holding a body blade

The DNS techniques used in this study were planned and conducted by two DNS practitioners co-authored this manuscript and modified by the main author of this manuscript; a physical therapist with 17 years of both clinical and academic experience. A thorough discussion between the treating clinicians assured that the modifications of the DNS techniques would not alter or defeat their purposes, rather, they would augment the desired effect.

Functional training

As subjects’ mobility, strength, and pain improved after the previous techniques, the focus was placed on advanced functional, athlete-style training at the end of each session. These exercises progressively strengthen and/or stabilize different muscle groups of the lower and upper kinetic chain in functional patterns, primarily in weight-bearing positions. [32] In these exercises, emphasis was placed on deep core muscles activation, strength, balance, stabilization of lower and upper kinetic chain, and attainment of proper body mechanics. Summary of the exercises performed with their description and/or rationale with their repetitions can be found in table 5. See appendix I for pictures of the exercises.

Results

Both subjects showed a reduction in pain intensity and improvement in PSFS scores. Subject 1 reported a decrease in pain intensity from 7/10 to 2/10 (86%). Similarly, subject 2 showed an 88% reduction in pain intensity (from 6/10 to 2/10). For PSFS, a 75% improvement in activity performance was shown in subject 1 as indicated by the total scores from 2.33 to 9.33 and a 64% improvement in subject 2 as shown in the increase in the total scores from 3.33 to 9.33.

By the end of the intervention, both subjects showed a clinically meaningful reduction in the difficulty of the activities they reported to be difficult at intake as assessed by the PSFS. This was reflected in the improvement in PSFS scores by 7 points in subject 1 and by 6 points in subject 2 which are more than the reported MCID values for the scale of 2.3. Subject 1 reported a GROC score of 6 (a great deal better) and subject 2 rated his progress as 5 (quite a bit better). Both subjects’ VAS scores before and after intervention are shown in figure 10, and PSFS scores in figure 11.

Discussion

In this case series, we applied an impairment-based, multi-modal rehabilitation program tailored to address the need of non-professional runners with FAI. Up to our knowledge, this is the first study to use manual therapy, DNS exercise therapy, and functional training in the treatment of runners with FAI. We hope that the proposed treatment provided in this case series will motivate researchers and clinicians to investigate this combined treatment on a larger scale of subjects and/or to investigate whether an impairment-based approach yields similar results as a generalized or a standardized treatment approach in runners with FAI.
### Summary of advanced functional training performed.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description and/or rationale</th>
<th>Sets X repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidestepping against band resistance</td>
<td>The subject walked three steps to the side against a band around his waist and return, leading with the affected limb to allow concentric activation of gluteus maximus muscle then turn around and lead with the non-affected limb to allow loading of the limb.</td>
<td>3x5 on each side</td>
</tr>
<tr>
<td>Side sliding on a fitter board</td>
<td>With a band resistance above the knees, the subject slides on the board against an adjusted bungee cords resistance.</td>
<td>3x10</td>
</tr>
<tr>
<td>Leg press against a semi-unstable surface on a Pilates reformer with resistance</td>
<td>While laying with a crossed leg on a Pilates reformer, the affected leg was put on a semi-unstable board and the subject was asked to push himself back to straighten the knee against an adjusted resistance. The subject was encouraged to keep his core muscles engaged.</td>
<td>3x10</td>
</tr>
<tr>
<td>Step-up on a semi-unstable surface holding a dowel</td>
<td>To activate and strengthen gluteus medius and maximus, the subject stepped up on a semi-unstable board holding a dowel to maintain trunk alignment and to activate core muscles. The therapist provided tactile stimulation to prevent hip/pelvic hiking.</td>
<td>3x5</td>
</tr>
<tr>
<td>Squat row on a BOSU ball with band resistance</td>
<td>The subject stood on the flat surface of the BOSU ball, held a band resistance in his hands, and in a functional squat position, was asked to pull the band toward his body.</td>
<td>3x10 while maintaining balance</td>
</tr>
<tr>
<td>Split squat on a Pilates reformer</td>
<td>With a band resistance above the knees and holding a dowel, the subject stood on a semi-unstable platform on a Pilates reformer and was asked to lunge forward against an adjusted resistance. This was performed to challenge strength and to activate the core.</td>
<td>3x10</td>
</tr>
<tr>
<td>Front raise single leg support with band resistance</td>
<td>From a functional squat position, the subject stood on the band with one foot and was asked to hinge forward at the hip while maintaining a straight trunk. He then was asked to lift the dowel against the resistance in front of him. This was to challenge the whole kinetic chain, dynamically stabilize hip and knee, activate the core, and improve strength.</td>
<td>6 seconds hold at the end position. 3x5</td>
</tr>
</tbody>
</table>

Fig. 10. VAS scores pre and post-intervention for both subjects
Although we cannot infer a cause and effect from case series and case reports, our subjects showed clinically meaningful outcomes which were reflected in their functional improvement as indicated by the PSFS, reduction in pain intensity as measured by VAS, and overall improvement as documented by the GROC after the intervention. The improvement in outcome with scores higher than the reported MCID values for the outcome measure indicates that our proposed treatment may be beneficial in improving short-term, patient-specific, self-reported measures in non-professional runners with FAI. MCID values may be necessary in case series and case report studies where this is a lack of a control group or comparative cohorts to report the improvement. We recommend that randomized-controlled trials be conducted to establish cause and effect relationships, including athletes, non-athletes, and/or control groups.

Our clinical improvement in the two subjects of this case series is consistent with the finding of Short et al. [33] who found a similar clinical improvement in pain and function in 5 patients case series treated with a comprehensive impairment-based program, similar to ours, but did not include DNS program, rather, their program targeted the hip in addition to the pelvic and lumbar spine. We feel that adding the DNS techniques to the intervention after hip injuries boosts the intervention’s effect and engages the subjects in more functional training positions.

We used the PSFS as a functional outcome measure in this case series. Besides being a widely used self-reported outcome measure, we chose this tool because it records the patient’s perceived level of disability in the patient’s own words. Hence, it directly addresses the patient’s needs, actively engages the patients in treatment planning, and matched our purpose of conducting this study which was to perform an impairment-based treatment approach to directly address the dysfunction associated with runners diagnosed with FAI. Because the scale gives the patients the freedom to list difficult functional activities that they need to address, improvement after treatment not only shows the patient the benefit of the treatment they received but can also motivate the patient to maintain outcome gained and help to avoid re-injury by avoiding provocative factors.

The PSFS has wide applications in various musculoskeletal conditions and was found to be a valid, reliable, and responsive outcome measure in patients with acute and chronic low back pain, knee dysfunctions, cervical radiculopathy, chronic lateral epicondylitis, carpal tunnel syndrome, and chronic whiplash injuries. [34-39] Stratford et al. [40] reported that the MCID scores of the PSFS for 3 activities ranged from 0.8 points (small change) to 4.3 points (large change) in patients with chronic low back pain. Our subjects showed 6 and 7 points of change at discharge which is well beyond the change documented by Stratford et al. [40] Again, this may be due to the willingness of the subjects to work to improve the activities they perceived to be difficult and also may be due to the nature of our impairment-based treatment approach that directly
addressed their dysfunctions.

Keeping the developmental kinesiology of infants as the conceptual framework. The DNS exercises is a form of fundamental movements that provide specific functional training to maintain a proper dynamic movement of the extremities while ensuring that all joints are properly aligned during movement. Because FAI results from abnormal hip joint morphology, DNS exercises encourage optimal alignment of the joint, which DNS practitioners called “joint centration”. This is positioning the joint in a proper alignment to maximize joint congruency and achieve the best mechanical advantage for the surrounding muscles throughout the ROM. When joint centration is achieved, mechanical stress on the surrounding tissues will be minimal. [26] Using this concept, the 7-month oblique sit position we used and modified in this study along with the “hanging position” achieve the overall goal of the DNS approach, and we think they improve the hip joint congruency by improving joint centration, although further investigation of their effects is still needed to document whether such positions will change the morphology of the joint and to what extent.

We augmented the fundamental movement exercise with functional movements training which primarily involved core stability and neuromuscular control while improving muscle flexibility and strength. [41] According to Wright et al. [42] fundamental movement exercises can only improve the specific movement targeted in the exercise but not necessarily improve functional movement training, which is more general and involves integrating more body parts than fundamental movements. Therefore, our impairment-based physical program can have the benefit of both types of concepts in rehabilitation. We believe that DNS exercises can be viewed as a preparation for more complex functional training, ranging from a simple activity of daily living to more advanced sports activities. [43] DNS exercises can also be considered as a building block upon which complex functional training can be built and trained. [44]

It is important to highlight that all of our intervention techniques/exercises were performed in the same session over the whole period of intervention, i.e. the two subjects received stretching, manual therapy, DNS, and functional training in every session. Treatment was not divided into stages according to the intensity or the degree of FAI involvement. In their 6 patients case series of patients with a groin injury, Kachingwe and Grech [45] customized a program of stretching, mobilization/manipulation, neuromuscular re-education, and dynamic exercises to each patient based on the nature of the injury, level of performance of the athlete, and the expected time before the athlete is expected to return to play. The intervention was provided in stages according to their progress in rehabilitation. A similar approach was followed by Short et al. [33] Since these two studies and ours are case series and cause and effect cannot be drawn, we cannot conclude the superiority of one approach over another and we think we should wait for further research to decide.

FAI can be a mysterious and challenging clinical condition to diagnose and treat due to various differential diagnoses involved and the multifactorial nature of this condition. Although the exact cause is still unclear, a thorough clinical examination is necessary to treat subjects with FAI. Although conservative treatment approaches are not likely to change the abnormal osseous morphology associated with FAI, [46] a comprehensive physical therapy program can improve the musculoskeletal signs and symptoms, improve function, decrease pain, and improve overall sports performance in non-professional runners with FAI.

Although we do not have a documented record for the hip joint ROM post-treatment, it can be inferred that the two subjects improved in their ROM from the improvement in other outcome measures, especially their functional activities. Lack of post-treatment ROM is one of the limitations of this study. Other limitations may include the study design of a case series with only two subjects treated which will preclude generalization of the outcomes although we believe that an impairment-based treatment approach will be more accurate to address patients’ functional demands than a generalized or a standardized treatment approach. Also, we did not have a follow-up assessment beyond the discharge date and therefore we cannot establish the long-term effect of the provided treatment. We recommend similar research be conducted to determine the long-term effect of such a rehabilitation program on non-professional runners. One last limitation is the lack of blinding; the study participants and treating clinicians were aware of the assessment and treatment provided and, therefore, can be biased.
Conclusion

In this case series, two non-professional runners benefited from stretching, manual therapy, DNS, and advanced functional training exercises in terms of improving pain and function. Providing an impairment-based, multi-directional treatment approach is recommended based on the outcome of this case series with follow-up, large-scale studies are recommended to confirm or negate the outcome of the intervention of this case series.

Acknowledgements

The authors would like to thank the participants in this study.

Conflict of interest

The authors declare that they have no competing interests.

References


Appendix I

The functional training exercises performed

Fig. 1. Sidestepping against a resistance band

Fig. 2. Side sliding on a fitter board

Fig. 3. Leg press against a semi-unstable surface on a Pilates reformer with resistance

Fig. 4. Step-up on a semi-unstable surface holding a dowel

Fig. 5. Squat row on a BOSU ball with band resistance

Fig. 6. Split squat (forward lunge) on a Pilates reformer challenging balance and strength

Fig. 7. Front raise single leg support with band resistance
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Received: 2022-08-12    Accepted: 2022-09-23    Preprint 2022-10-02    Published: 2023-06-25