CLINICAL DECISION MAKING AND TREATMENT IN A RUNNER WITH HIP PAIN AND NEUROMUSCULAR CONTROL DYSFUNCTION: A CASE REPORT

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ABSTRACT

Background and Purpose: The incidence of running related injuries remains high despite numerous efforts to understand the mechanical contributors to the etiology of these injuries. In light of continued running injury, theories of neuromuscular control, or movement patterns, have been suggested as possible contributors to running related injuries. However, the clinical decision making determining when altered neuromuscular control strategies may be affecting a runner's symptoms has not been described. Therefore, the purpose of this case report is to describe the clinical reasoning within the ICF framework for a runner with hip pain and neuromuscular control dysfunction.

Case Description: A 47-year-old, experienced, female runner presented with posterior hip pain and radiating posterior thigh pain limiting her ability to participate in running and threatened her goal to run in an upcoming marathon. Several features of her examination indicated soft tissue muscular irritation of the posterior hip complex related to impaired balance and control of the lower quarter during functional movement and running activities consistent with a neuromuscular control dysfunction. Her initial Focus on Therapeutic Outcomes (FOTO) score was 69 with predicted change score of +7.

Outcomes: The subject was able to achieve her goals including a return to participation in her weekly running routine and competing in a marathon race. Objective examination features of range of motion, strength, and control of movement were all improved. Her reported function was greatly improved with a final FOTO score 98.

Discussion: The diagnosis and treatment of running related injuries remains a clinical challenge. This case report describes the examination and clinical reasoning in diagnosing neuromuscular control dysfunction and proposes a treatment progression to address this functional limitation. The decision making scheme is also structured to follow the International Classification of Functioning, Disability, and Health.

Level of evidence: 4

Key words: Hip, movement system, piriformis syndrome, running

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BACKGROUND AND PURPOSE

Running related injuries (RRI's) are quite common, even among recreational runners.¹ With a reported incidence of RRI as high as 79.3%,¹ multiple aspects of running mechanics have been investigated to attempt to identify modifiable factors which may contribute to injury. These include peak vertical ground reaction force,² vertical loading rate,^{2,3} degree and rate of pronation,^{4,5} knee abduction and adduction angles,⁶ and foot strike patterns.^{7,8} However, the evidence is unclear regarding the role that each of these factors play in the etiology of RRIs.

The observed inconsistencies regarding how these factors may affect the incidence of injury has led to different paradigms regarding the role that ground and joint reaction forces and muscle activity play in determining the control of the lower extremity during the task of running.⁹⁻¹² Nigg¹² has proposed a running paradigm of “muscle tuning” where impact forces serve as an input signal to the neuromusculoskeletal system to “pre-activate” the muscles of the lower extremity in order to control the joints and limb segments of the lower extremity and attenuate impact forces. This theory was recently refined to include the consideration of individual variation regarding the degree of movement within a typical pattern of running gait. This has been termed the “preferred movement path”.¹¹

The combined implication of these paradigms is that individuals will utilize unique muscular strategies to maintain a predetermined (“preferred”) movement path. Further, these muscular strategies may be different across individuals, yet result in similar kinematic patterns.¹¹ This raises a unique challenge for clinicians as the use of running gait analysis relies on kinematic assessment of runners' lower extremities. However, what is observed kinematically does not necessarily reflect the underlying kinetics or muscular strategies utilized by individual runners.¹³ Thus, clinicians may need to rely on other evaluation strategies or different elements of the examination to identify subjects' impairments when altered muscle activation patterns or neuromuscular control dysfunction are suspected in the etiology of a individual's symptoms.

Different movement screening methods have been developed to assist clinicians with the identification of potentially disadvantageous movement patterns

or neuromuscular control dysfunction (i.e. Selective Functional Movement Assessment,¹⁴ Functional Movement Screening™,¹⁵ the Lateral Step Down Test,¹⁶ Landing Error Scoring System,¹⁷ etc.). These tests and measures aim to identify gross movement patterns or limitations in movement that may be affecting function with other activities.¹⁵ If neuromuscular control dysfunction is identified with these tests, the clinician can begin to reason that there is a greater likelihood of similar deficits with higher level tasks either causing or contributing to pain and/or injury in the athlete.

Once neuromuscular control dysfunction is identified, it behooves the clinician to begin hypothesizing relevant causes underlying those deficits (i.e. strength, endurance, coordination, proprioception, flexibility, joint mobility, etc.). One proposition regarding neuromuscular control dysfunction is that the demand of a given task exceeds the strength or endurance capacity of the musculoskeletal system preventing adequate control of relevant motions necessary to complete the task.

For example, patellofemoral pain has been linked to strength deficits at the hip¹⁸ as well as neuromuscular control dysfunction of the gluteal musculature.^{19,20} Specifically, onset of muscle activity of the gluteus medius appears to be delayed in female runners with patellofemoral pain.²⁰ Noehren et al. hypothesized that this delay in muscle activity may contribute to the altered hip adduction and internal rotation observed in runners with patellofemoral pain.^{6,21}

If one continues to hypothesize how the musculoskeletal system may attempt to compensate for a delay in gluteus medius activity or a deficit in gluteal strength, it is possible that the individual may utilize increased force production from the piriformis or other hip abductors and external rotators²² to help control this motion of the hip. This increase in force production from the piriformis may lead to fatigue and accumulation of abnormal stress to this muscle resulting in irritation and/or pain in either the piriformis (as the force production of this muscle may increase) or the gluteus medius/minimus (as these muscles are attempting to control a load greater than they are capable of managing), or both.

Further, this shift in muscular strategy may go unnoticed with 2D gait analysis if the shared loading of

muscle forces is sufficient to maintain a given kinematic profile, or “preferred movement path”. Nonetheless, this shift would alter the kinetic distribution of forces across tissues in the hip. Thus, identification of other components of neuromuscular control may be helpful to infer neuromuscular control dysfunction in the etiology of hip pain in runners in addition to running gait analysis.

Clearly, the nature of many neuromusculoskeletal conditions can be quite complicated and the nuances of individual subject presentation can make the management of subjects (from examination and evaluation, to intervention planning and goal setting) very challenging. In light of this, the use of common language, documentation, and clinical reasoning schemes have been proposed.²³ In 2008, the American Physical Therapy Association endorsed the use of the International Classification of Functioning, Disability, and Health (ICF) as one such organizational scheme.²⁴

The ICF is an integrative model which seeks to consider the human experience of functioning as a resultant interaction between an individual's health condition and his or her personal attributes while also considering environmental and contextual influences.²⁵ In addition to this, the model also seeks to create a systematic and encompassing framework as a reference to navigate through the process of subject management.^{26,27} Therefore, the purpose of this case report is to describe the clinical reasoning within the ICF framework for a runner with hip pain and neuromuscular control dysfunction.

CASE DESCRIPTION

Subject History and Systems Review

The subject was a 47-year-old female experienced runner (Ht: 155.5 cm; Wt: 51.6 kg; BMI: 21.34) referred by her primary care provider with a medical diagnosis of right sided piriformis syndrome. Symptoms began approximately two months prior to initiating physical therapy. She described the onset of symptoms as having occurred after running a 15 mile trail race. She noted having had to drive eight hours the day prior to the race. She had some familiar sensation of tightness in the hip leading up to this race, but in the subsequent weeks following the race, she began to notice buttock pain and

symptoms down the leg which were preventing her from increasing her running mileage. She denied any other changes in her training regimen regarding running frequency, mileage, intensity, or terrain. She had been consistently using the same model of footwear and had not used any type of insert or orthotic.

Treatment had consisted of self-management of symptoms with stretching, and soft tissue foam rolling of the hips and thighs, but symptoms continued to increase as she attempted to further her training.

Relevant clinical history included multiple overuse type injuries including bilateral iliotibial band syndrome; right-sided Achilles tendinopathy, plantar fasciitis, and meniscectomy of the knee; and left-sided patellar tendinopathy and piriformis syndrome similar to her current symptoms. Her previous left-sided hip pain was reported to be less severe than her current symptoms and spontaneously resolved with stretching and a brief period of reduced running mileage. No other health conditions or medical problems were identified by the subject upon questioning.

Her primary goal was to be able to resume her training regimen and progress her running distance in preparation for a scheduled marathon four months from the date of her initial presentation.

CLINICAL IMPRESSION #1

From her clinical history of multiple previous overuse injuries, her primary participation restrictions, activity limitations and environmental factors were determined and are described in Figure 1. These limitations and her reported symptoms led to the inclusion of multiple diagnoses within the hypothesis list of potential health conditions.

The onset and location of her pain and the history of multiple soft tissue injuries placed piriformis muscle irritation as a primary consideration in differential diagnosis, but additional symptom generators were considered including gluteal muscles, sacroiliac joint, the lumbar spine, and adverse neurodynamics. Given the subject's history of multiple overuse type symptoms, the hypothesis that some chronic issues may be present with her running pattern was generated. This was thought to increase the likelihood

Figure 1. Integration of examination features within the International Classification of Function (ICF) framework of patient management. Adapted from Atkinson, 2011.

of neuromuscular control dysfunction being present with examination.

EXAMINATION

At her initial visit, pain was located in the right buttock. Symptoms were rated 1/10 at rest and would reach 4/10 after periods of prolonged sitting or after runs exceeding five miles in distance. As symptoms increased some radiation into the posterior thigh was noted by the subject.

Functional limitations included a need to frequently reposition due to discomfort with sitting and reduced tolerance to running, hopping, and lifting. Her intake score on the Focus on Therapeutic Outcomes (FOTO, Inc.) hip inventory was 69 compared to a risk adjusted score of 54 with a predicted change score of +7.

A functional movement assessment was utilized to assess gross movement patterns which revealed deficits in total motion in standing forward flexion, extension and rotation (Table 1). Categorical assessment of these motions has previously been shown to be reliable.²⁸ However, gross visual estimations of quality and quantity of motion were utilized as opposed to categorical groupings to assist with assessment of change of quality of motion. The reliability of the methodology utilized in this case report has not been studied.

Single leg balance with eyes open was appreciated as symmetric as she was able to hold the test position greater than 30 seconds with similar stance quality as assessed by trunk sway, knee and ankle excursion and ability to hold the opposite hip at

Table 1. *Examination measures*

	Initial Visit	Final Visit
FOTO	69	98
NPRS	1/10 (at rest); 4/10 (at worst)	0/10 (at rest); 2/10 (at worst)
Functional Movements		
Multi-segmental Flexion	Fingers to mid-tibias	Fingers to floor
Multi-segmental Extension	~30°	~30°
Multi-segmental Rotation	R: ~80° L: ~80°	R: ~90° L: ~90°
Single Leg Balance	R: >30 sec L: >30 sec	R: >30 sec L: >30 sec
Single Leg Balance (EC)	R: <10 sec L: >10 sec	R: >10 sec L: >10 sec
Functional Squat	Early heel rise, forward knee position, poor frontal plane control, limited posterior weight shift, unable to achieve 90 degrees knee flexion	Early heel rise, forward knee position, good frontal plane control, able to achieve beyond 90 degrees knee flexion
Hip Passive Range of Motion		
Flexion	R: ~120° L: ~120° Perceived increase in resistance to motion noted on the right	R: 130° L: 125° Perceived increase in resistance to mid-range motion on the right
Extension	R: ~10-15° L: ~10-15°	R: ~10-15° L: ~10-15°
Internal Rotation (supine)	R: 30° L: 30°	R: 40° L: 40°
External Rotation (supine)	R: 35° L: 35°	R: 60° L: 50°
Internal Rotation (prone)	R: 30° L: 30°	R: 40° L: 40°
External Rotation (prone)	R: ~45° L: ~45°	R: 45° L: 30°
Flexibility Tests		
Hamstring 90/90	R: ~70° L: ~70°	R: ~70° L: ~70°
Piriformis	Symmetric motion, but reproduction of primary symptoms at end range position on the right	Symmetric motion, but increase stretch sensation on the right with no provocation of symptoms
Ely's	Limited bilaterally, but symmetric	Limited bilaterally, but heel to buttock distance is increased by 5 inches on the right
Ober's	Limited bilaterally, but symmetric	Limited bilaterally, but symmetric
Hip Strength (MMT)		
Flexion	R: 5 L: 5	R: 5 L: 5
Adduction	R: 5 L: 5	R: 5 L: 5
Abduction	R: 4 L: 4 Fatigue noted affecting ability to move through full ROM within 15 repetitions on the right	R: 4+ L: 4+ Increased sensation of fatigue following 15 repetitions on the right compared to the left; strength and ROM is maintained
Internal Rotation	R: 4 L: 4	R: 5 L: 5
External Rotation	R: 4 L: 4	R: 5 L: 5

FOTO=Focus on Therapeutic Outcomes; NPRS=Numeric Pain Rating Scale; EC=eyes closed; MMT=manual muscle test; ROM=range of motion; ~ = indicates that motion was visually estimated by the examiner

90 degrees flexion and maintain her hands positioned on her hips.

Side-to-side differences were noted during single leg balance with eyes closed (EC) as she was unable to maintain the test position for greater than 10 seconds on the right side while on the left she maintained the test position for greater than 10 seconds in one trial. Static-dynamic balance was also assessed in a single leg stance position while swinging the opposite leg from hip extension to 90 degrees of flexion up to 20 times. Increased pelvic motion during swing

and reduced hip extension was observed, bilaterally. However, provocation of symptoms occurred during right stance. Dysfunctional movement was also observed during a squat as evidenced by early heel lift, minimal posterior weight shift, anterior knee position, and reduced knee flexion range of motion.

Further breakdown of impaired movement included assessment of hip range of motion and flexibility using standard goniometric measurements or visual estimation. Overall limitations in range of motion were present, bilaterally. End range tightness was

appreciated during hip flexion and piriformis flexibility testing and provocation of symptoms occurred with piriformis flexibility testing (Table 1). Manual muscle testing revealed symmetric mid-range isometric strength with decreased strength present bilaterally for hip abduction, internal rotation, and external rotation (Table 1). Endurance testing included repetitive concentric hip abduction with the subject reporting increased fatigue on the right leg compared to the left over the same number of repetitions.

Palpation only assessed whether the subject reported tenderness and whether that tenderness was similar to her reported symptoms. No attempt was made to identify trigger points or myofascial restriction as the reliability of manual assessment has been questioned.²⁹ Palpation revealed primary symptoms located in the center of the buttock between the inferior-lateral sacral angle and greater trochanter over the course of the piriformis muscle belly. She had no tenderness to palpation or mobility assessment of the lumbo-sacral region or along the iliac crest. Sacral thrust test was also negative.

CLINICAL IMPRESSION #2

After examination, a list of specific impairments of body structure/function was created including limited hip and lumbar range of motion, limited flexibility, reduced hip abduction endurance, decreased single limb dynamic balance and kinesthetic awareness with coordination/control during lower extremity functional squat and dynamic leg motions (Table 1). Furthermore, evaluation of these specific impairments made it possible to hypothesize underlying contributors and potential causes of these impairments, similar to diagnosing an underlying health condition.

As lumbar motion did not provoke her symptoms, no tenderness was present with palpation or segmental mobility assessment of the lumbar spine, and piriformis flexibility test reproduced her primary symptoms, it was reasoned that her symptoms were being generated from muscular dysfunction of the posterior hip as opposed to possible lumbar or sacroiliac dysfunction. Additionally, she demonstrated deficits with hip abduction endurance and corrective balance strategies at the hip. Symptoms were provoked

during dynamic balance and underlying limitations in multi-segmental motion of the hip and lumbar spine. And, she demonstrated a dysfunctional squat. Thus, it was hypothesized that her symptoms were likely a result of neuromuscular control dysfunction about the hip region. This was further supported by overall loss of rotational motion of the hip and specific flexibility deficits of the rectus femoris (Ely's test) and tensor fascia latae and iliotibial band (Ober's test) suggesting length changes of the hip musculature. Also, given her history of multiple overuse type injuries, it was reasoned that these deficits may have been long standing and present prior to her current symptoms.

Running gait was not assessed, therefore, it is unknown whether altered running mechanics were present. However, the above findings supported the initial hypothesis of neuromuscular control dysfunction, and treatment was initiated to address those impairments identified during her examination.

INTERVENTION

The subject's primary activity limitation was with the task of running, which threatened her primary goal of participation with an upcoming marathon. The treatment plan was organized to allow her to continue with the activity of running and permit gradual progression towards her ultimate participation goal.

Exercise prescription was aimed at addressing her primary impairments of body structure/function namely reduced hip muscle strength and endurance, difficulty with balance, and neuromuscular control.

Her initial home program consisted of seated hip external rotation against resistance to facilitate hip external rotation strength in a position that would eliminate the influence of the piriformis muscle.²² Side-lying hip abduction to address the reported increased fatigue during hip abduction strength testing, and single leg balance with leg swings to address pelvic control during stance. As she reported aggravation of her symptoms with running distances greater than five miles, she was instructed to limit her running to no greater than five miles at a time. She was also instructed to monitor her symptoms, and if she were to have symptoms when running at what distance she began to notice them. Furthermore, she

Figure 2. A proposed progression of increasing dynamic components of exercise to challenge components of neuromuscular control. Single leg balance is completed in running stance position with stance knee flexed approximately 30 degrees and opposite hip flexed to near 90 degrees. Single leg balance with leg swings is completed with the stance knee flexed to near 30 degrees and the opposite leg swings from slight extension to 90 degrees of hip flexion with focus on pelvic control and knee stability. Walking lunges are completed with emphasis on controlling both the eccentric and concentric components of the exercises focusing on knee position remaining over the stance foot. Reverse lunges are completed by reaching backwards and completing the eccentric lowering of the body on one leg only.

was to note any other specific activities which aggravated her symptoms.

Visit #2

At her next appointment, two weeks later, she reported having had to cease running as her symptoms were aggravated by this activity. She noted that over the prior 10 days of no running and consistency with her home exercise program that she had less discomfort in the buttock and could tolerate sitting for longer times with fewer symptoms into her leg. Given the increase in her symptoms with continued efforts at running, she was instructed to refrain from running for the following week and to replace her typical running workouts with an updated home program including the above mentioned exercises with the addition of single leg balance with rotation, half kneeling balance, and walking lunges (Figure 2). Balance exercises were included to begin working on proprioception and neuromuscular control through the hip. Walking lunges were included to mimic running technique. Specific

instructions including slow and controlled motion during eccentric lowering of the front leg were given in an attempt to facilitate carry over from static exercises to more dynamic exercises.

Visit #3

A week later she noted having independently attempted a plyometric workout which resulted in an acute increase in her symptoms resulting in a return of posterior leg discomfort and increased buttock pain. Physical examination findings showed loss of hip flexion (right = 115 degrees; left = 125 degrees) and internal rotation (right = 25 degrees) motion. Palpable tenderness was also increased in the gluteal muscles and the piriformis with tenderness most pronounced into the gluteus medius and minimus.

Given the increase in her symptoms, measurable loss of range of motion, and increased muscular tenderness with palpation, dry needling was incorporated into her treatment regimen. It was reasoned that the

increase in muscular tenderness may be the result of acute change in activity resulting in an applied load which exceeded the muscular capacity to complete the plyometric tasks she attempted. This novel load may have contributed to the progression of latent trigger points to active trigger points causing an increase in pain in the hip and referral to the posterior thigh.

Dry needling was performed addressing the gluteus medius and minimus as this was the area of greatest tenderness and the gluteus minimus has a stronger referral pattern to the posterior thigh than does the piriformis.³⁰ Two-three needles (Myotech, Shanghai Kangnian Medical Device Company, Shanghai, China) were used for each muscle. Needles were manipulated in an up and down motion in attempts to elicit a twitch response. Only these muscles were treated to help differentiate between the gluteus medius/minimus and the piriformis as potential sources of her current pain. This resulted in a within session improvement of 10 and 15 degrees for passive hip flexion and internal rotation, respectively. She was instructed to continue with her home program and to continue to refrain from running and plyometrics.

Visit #4

At her next visit (one week later), she noted much improvement in her resting symptoms and tolerance to prolonged symptoms, and absence of posterior leg discomfort. However, some continued discomfort into the buttock was present. Hip internal rotation was pain free, and it was end range external rotation which reproduced her buttock symptoms at 55 degrees. Thus, an additional treatment of dry needling was performed.

Dry needling was performed again to the gluteus medius/minimus, but also included the piriformis. By adding treatment of the piriformis, while keeping previous treatment of the gluteus medius/minimus the same as her previous visit, clearer insight regarding her remaining symptoms was desired to discern between involvement of the gluteals and the piriformis. She demonstrated an increase of 10 degrees in passive external rotation motion following treatment.

As her symptoms appeared to be improving from a combination of rest and treatment, progression toward returning to a running program was made. Her home program was advanced to include further

dynamic control of the stance leg in the form of a reverse lunge to increase the vigor of her previous lunge exercise by moving from double leg support to single leg support (Figure 2), and to mimic the single leg eccentric control required during running.

Visit #5

The subject had refrained from running for one month and her primary goal of participating in a marathon was being jeopardized. Upon arrival, she noted complete absence of any posterior leg symptoms and buttock pain and no provocation of symptoms with any daily activities or her home exercise program. She demonstrated symmetric single leg balance, no provocation of symptoms with single leg balance in conjunction with contralateral leg swings, and improved control of motion with reverse lunges. Given these findings, no provocation of symptoms with previously symptomatic exercises, and her goal of participating in a marathon in three months' time, it was determined that an accelerated return to run program would be incorporated and consideration was given to the use of a body weight support (BWS) running system (Figure 3) to compliment a graded return to running program to allow more rapid increase in running volume.

A two-dimensional running analysis was completed to assess her tolerance to overground running and for qualitative gait assessment.³¹ Lower extremity control appeared symmetric with no concerning dynamic valgus, hip drop, or excessive pronation. Tibial angle demonstrated a mild posterior incline in conjunction with a clear rearfoot strike pattern. Cadence was measured as 170 steps per minute (spm).

Cadence manipulation was completed using an approximate 5% increase to 178 spm to attempt to reduce the load being placed upon the hip musculature.³² She then completed two sets of a five minute walk/jog routine without provocation of symptoms and thus was instructed to begin a return to running program at home. She was to utilize a metronome to maintain a cadence of 178 spm during these runs.

In order to allow more rapid increases in her running volume and to attempt to create carry-over from her neuromuscular control exercises to her running pattern, it was agreed to use the next several clinic appointments to progress her running volume via the use of a BWS system.

Figure 3. Photograph of the body weight support system utilized in this case report. The harness is fastened around the subject's legs with elastic cords attached to the support frame which is mounted around the treadmill.

Visits #6-12

These seven visits were scheduled once weekly and consisted of gradual progression of her overall running distance using the BWS system. Unloading was selected according to manufacturer recommendations

to have the support bars placed 12 inches above the greater trochanter which resulted in 26.2 lbs of her body weight supported by the system. She progressed her running time by 10 minutes each week. This progression continued until two weeks prior to the scheduled marathon. Her home running program was progressed in a similar fashion by completing two overground running days each week with incremental increases in total running time of five minutes with each subsequent run (Table 2). Time increases were selected such that a consistent increase would occur throughout the subject's running progression while staying below any increase in running volume exceeding 30%.³³

OUTCOMES

The primary outcome utilized for this study was her ability to participate in and complete a scheduled marathon. At her final follow-up visit, three weeks after this race, she reported having completed the full marathon with a time of 4:00:39 where she was able to run the entire distance other than walking through a few aid stations.

She noted overall status as 80% at three weeks following the marathon after some increased soreness and feelings of tightness following the race. She felt that her symptoms were improving with her home program and were not limiting her running. Her FOTO score improved by 29 points compared to an age predicted physical change score of +7.

Impairment measures of hip range of motion, strength, and functional movements were all improved at her final visit (Table 1). Goniometric measures of hip range of motion are considered to be acceptable measures to track clinical change and the differences measured

Table 2. Running progression during final phase of treatment

Week	Day 1	Day 2	Day 3 (BWS)
1	20 minutes	25 minutes	50 minutes
2	30 minutes	35 minutes	60 minutes
3	40 minutes	45 minutes	70 minutes
4	50 minutes	55 minutes	80 minutes
5	60 minutes	65 minutes	90 minutes
6	40 minutes	40 minutes	100 minutes
7	80 minutes	90 minutes	As tolerated (without BWS)
8	60 minutes	60 minutes	Race

BWS=Body weight support

exceeded the reported standard error of measure.³⁴ Manual muscle testing has been reported as reliable and is a common method employed by physical therapists to track gross improvement in strength.³⁵ Changes in strength were detected in this case and accompanied with a noticeable qualitative improvement for abduction and rotation in prone. Although a categorization scheme was not utilized in this study to assess change in functional movements, the qualitative and quantitative measures were improved. This in combination with her reduction in symptoms suggests a change in these motions occurred although this cannot be stated as the psychometric properties of these measurements have not been determined. Lastly, a reassessment of her running gait completed three weeks after her marathon revealed a cadence of 176 spm, while the kinematic profile of the lower extremity was similar to her previous analysis.

DISCUSSION

The etiology of RRI is multifactorial and requires sports physical therapists to take a holistic and comprehensive approach to subject management to facilitate examination and evaluation as well as treatment planning. Further, consideration should be given to any underlying health conditions as well as primary impairments to make hypotheses regarding the source of a subject's symptoms in order to curtail treatment selection and to allow complete amelioration of symptoms. Without inference into the underlying cause of a subject's pain, recurrent issues may develop. Thus, the primary aim of this case report was to highlight the clinical reasoning process in establishing a hypothesis of muscular irritation due to neuromuscular control dysfunction in an experienced runner. This reasoning process is also integrated within the suggested ICF model of subject management.

The approach to this case began with utilizing the ICF model and considering the subject's primary activity limitations and participation restrictions. By determining her primary limitations as occurring with the task of running resulting in reduced participation with social group runs and possibly prohibiting her from participating with a scheduled marathon, mutual goals were established and treatment was curtailed towards improving her ability to complete these activities.

From determination of her primary limitations, the subjective history focused on discerning salient external factors that may have impacted her plan of care. These included internal and external modifiers (Figure 1). It was upon consideration of the multiple reports of previous overuse type injuries in an experienced runner who reported no obvious training errors that the hypothesis of neuromuscular control dysfunction as an underlying impairment affecting her health condition of muscular pain and irritation was generated.

This process of hypothesis generation has been described as forward reasoning.³⁶ With subsequent questioning, additional components of the subject's history were also consistent with muscular irritation including the insidious onset, the location of symptoms, and the posterior leg pain with absent neurological symptoms. To test the hypothesis of these muscular symptoms being the result of neuromuscular control dysfunction, examination and evaluation of impairments of body structure and function were completed with findings supporting this hypothesis.

Given the subjects continued participation with running and high level of reported function, examination began with assessment of functional motion. She demonstrated gross deficits in multi-segmental motions in both the sagittal and transverse planes (limited standing forward flexion and extension and composite rotation < 90 degrees) along with aberrant motion during functional squats and deficits with single leg balance. These deficits supported the primary hypothesis of neuromuscular control dysfunction. Further, the absence of pain or reproduction of symptoms with multi-segmental flexion and extension were findings which would not be expected if her symptoms were lumbar in nature.

She demonstrated slight deficits in range of motion from normative values,³⁷ but these deficits were present bilaterally. Further, she had gross flexibility deficits in muscles which either controlled multi-planar motion or were biarticular in their attachment (i.e. the piriformis, hamstrings, rectus femoris, and IT band). The deficits in range of motion and flexibility of multiplanar and biarticular muscles may have been caused by these larger muscles compensating for stability, or control, deficits from more intrinsic musculature at the hip and/or knee.¹⁴ With

these deficits being bilateral, the underlying cause behind these motion deficits was likely not due to an increase in muscular tone in the presence of pain on the involved limb. Thus, it was reasoned that these bilateral deficits were due to a developed tone resultant from the neuromuscular control dysfunction detected with multi-segmental and functional motions which supported the primary hypothesis.

Lastly, it was important to rule out the lumbar spine and SI joint involvement. As lumbar segmental mobility and sacral thrust tests were negative, multi-segmental motion did not produce any pain in the back or near the SI joint, and other tests were supportive of neuromuscular control dysfunction, it was reasoned that it was possible to infer neuromuscular control dysfunction as the best explanation of her symptoms. And, treatment addressing neuromuscular deficits demonstrated a return of lumbar and hip ROM without specific interventions addressing the lumbar spine.

Initial treatment focused on addressing noted impairments of body structure and function, through hip strengthening and balance exercises. Due to underlying neuromuscular control dysfunction, dynamic components to balance exercises were incorporated (i.e. leg swings during single leg balance). As the primary hypothesis was that her symptoms were a result of neuromuscular control her treatment was progressed by increasing the challenge of balance and control instead of adding resistance to the selected exercises (Figure 3).

For example, single leg balance with leg swings was progressed to a walking lunge with a pause in single leg stance position. This was then progressed to a reverse lunge requiring her to maintain single leg stance through a larger excursion of hip and knee range of motion while maintaining balance. This progression was selected also to attempt to mimic aspects of her primary activity limitation (i.e. running).

After several weeks of this training, and allowing the irritability of her symptoms to reduce by restricting her running, it was hoped that a foundation of neuromuscular control of the lower extremity could be built such that when she did resume running, she would be able to do so without aggravating her symptoms. This seems to have been the case as she

was able to progress through an accelerated running program without provocation of pain.

As symptoms resolved it was deemed appropriate to examine her running gait. This revealed an interesting aspect of her clinical presentation as numerous components of her clinical examination demonstrated difficulty with neuromuscular control, but her running gait analysis showed no adverse motions at the hip or knee. Here the authors would like to suggest that neuromuscular control dysfunction may be present even in the absence of visible movement faults.

A recently proposed running injury paradigm ("the preferred movement path")¹¹ suggests that muscle activity is used to ensure that skeletal motion remains on a certain path while the degree of that movement can vary between individuals and depending on the conditions of the task. As muscle activity can vary to maintain this path, the control strategy being utilized by an individual may still be "altered", but the observed kinematics may look normal. It is hypothesized that this was occurring in the above case.

As the subject demonstrated multiple control deficits with lower level tasks including single leg balance, squats, and multi-segmental motion, it was reasoned that it was likely that similar deficits with control would be present during running. However, as her gait analysis showed no overt qualitative faults, it was hypothesized that she had developed a control strategy utilizing alternative muscle combinations.

Specifically, given that she had evidence of reduced gluteal endurance she may have developed a strategy where she utilized increased piriformis muscle force to control hip adduction²² leading to overuse and pain in that muscle. Or, the increased utilization of the piriformis muscle may have allowed her to reduce the load to the gluteus medius and minimus and could partially explain the reduced endurance of these muscles. This reduced endurance may have predisposed her to irritation of these muscles as she attempted to increase her mileage. Whether the pain generating muscle was the piriformis, the gluteus medius, gluteus minimus, or some combination of all three is not known with certainty, but an altered muscular recruitment strategy as outlined above could explain an injury to any of them.

To treat this, a two-fold approach was taken to reduce the load being placed on the hip musculature. First, her step rate was increased by approximately 5%. This was done to address potential gait faults of posterior tibial inclination, foot inclination, and heel-to-COM distance.³⁸ By reducing these aspects of her gait, vertical ground reaction forces may also be reduced and thus propagate less loading to the involved hip muscles.³⁹ Further, step rate increases have also been shown to directly reduce the muscle force requirements of the gluteus medius, gluteus minimus, and piriformis.³² She was instructed to incorporate this increase in step rate for all of her runs outside of the clinic.

The second approach taken to reduce the load to the hip muscles was to utilize BWS treadmill running. The use of BWS during running has been shown to reduce vertical ground reaction forces and rates of loading⁴⁰ as well as intra-muscular pressures of the lower leg.⁴¹ Thus, this was utilized to further reduce the load to the hip musculature. Utilization of this device was done for her weekly long runs to accelerate the building of her running volume in preparation for her upcoming marathon race. The amount of unloading was held constant and the time of running was progressed with each week (Table 2). This was done to allow physiological adaptation of the muscles to the accumulation of reduced loads over the duration of her runs as opposed to gradually transitioning her back to tolerate running under full body weight conditions.

The subject was able to progress through the combined running program of step-rate modification and BWS treadmill running without provocation of symptoms and was able to increase her running mileage such that she was able to successfully complete her primary goal of participating in a marathon race.

LIMITATIONS

It is important to note that the primary hypothesis of muscular irritation of the piriformis muscle was not diagnostically confirmed, but was rather a conclusion based on interpretation of available examination data on her movement quality and its potential impact on the movement system during the task of running. Only one sacroiliac joint test was completed, which may have left any contributing

dysfunction there undetected. And, core muscle function was not assessed and thus we are not able to determine what contribution these muscles may have had on the subject's presentation.

Inherent to case report methodology and the fact that no control was used for comparison, it is not possible to state if any of these interventions were the cause of her improvements. Further, it cannot be stated with certainty which component of the intervention plan led to her improved status. This case report only serves to present and highlight the reasoning process employed to arrive at the treatment strategy utilized.

Finally, it cannot be stated if the intervention actually resulted in a changed muscular strategy during running or assessment of functional motion. However, improved quality of motion was observed upon re-evaluation. This implies that improved movement control was present. Further study using musculoskeletal modeling techniques investigating estimates of muscle force production and EMG analysis would be required to elucidate what types of muscular activation and force strategies occurred resulting in the changed quality of motion.

CONCLUSION

The diagnosis and treatment of RRIs remains a clinical challenge. This case report highlights how features of the examination may assist in diagnosing neuromuscular control dysfunction as a relevant feature of the movement system and how that can lead to symptom provocation during specific movement tasks. Recognition of neuromuscular control dysfunction may then afford focused treatment progression to address functional limitations and may lead to successful return to activity.

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