Application of Regional Interdependence in Treating an Adolescent Athlete with Low Back Pain: A Case Report

Ari Kaplan, PT, DPT, SCS, CSCS, CertMDT

Association of Clinical Excellence, Wilmington, DE
ATI Physical Therapy, Bear, DE

ABSTRACT

Background: Descriptions of treatment of adolescent athletes with non-specific low back pain is sparsely cited in the literature. However, physical therapy is often recommended. **Case Description:** The patient was an 18-year-old high school athlete with low back pain. Interventions consisted of direct treatment (local) at the lumbar spine, and also a focus on improving anterior and rotational hip mobility (global approach). **Outcomes:** The patient was treated for a total of 7 visits with an Oswestry Disability Index improvement from 16% to 0%. **Discussion:** This case report describes the clinical reasoning and interventions of a regional interdependence approach in an athlete where hip deficits were found and were believed to be resulting in altered lumbar mechanics. The resolution of symptoms and full return to activity in a limited number of treatments may suggest the hip to be a contributor of symptom provocation in teenage athletes.

Key Words: physical therapy, lumbar pain

INTRODUCTION

Low back pain is the cause for seeking treatment in nearly 50% of all patients presenting to outpatient physical therapy.[1,2] This does not preclude adolescents, who show a prevalence that is exceedingly high. Estimates cite an effect as great as 70% to 80% of this population by age 20.[3] Recently, clinical prediction rules and treatment-based classifications have been developed to improve the care of patients with back pain.[4-8] They aim to treat a patient through symptom presentation as opposed to focusing on the anatomical diagnosis. While classifying patients has shown improvements in low back pain care,[9] Stanton et al[8] have shown that 50% of individuals will not clearly fit into a classification and half of that 50% (25%) will not fit into any category, resulting in difficulty deciding on the proper treatment. Additionally, past studies have excluded patients under the age of 18 and have not examined athletes as a specific population. The treatment categories also only focus on a specific intervention delivered to the lumbar spine: manipulation, directional preference exercises, stabilization exercises, and traction.[6]

There is a dearth of literature on back pain in the adolescent athlete, with much of this limited focus solely on spondylogenic lesions. Spondylogenic lesions can be illusive in their detection as special testing shows sensitivity and specificity that is poor and therefore often requires advanced imaging, such as magnetic resonance imaging.[10,11] As insurance companies deny greater proportions of advanced imaging, immediately searching for these issues may no longer be an option. Additionally, Fredrickson et al[12] found that 6% of adults showed a spondylogenic lesion, without associated pain in the past. This may be that some of these lesions may not be the source of an athlete's pain.

Clinicians have recently been considering applying the concept of regional interdependence, where one area of the body influences another area.[13] For example, much research has examined the hip's influence on the patellofemoral joint in anterior knee pain, noting that poorly controlled gluteal muscles correlate with patellofemoral pain.[14] Research is beginning to emerge on the effects of treating multiple areas of the body for a diagnosis of lumbar spinal stenosis and showing it to be superior to conventional treatments directed solely at the lumbar spine.[15-17]

In golf, there is research supporting the influence of other regions of the body on lumbar spine injury. Kim et al[18] found that a loss of hip rotation in the lead limb correlates with low back pain in professional golfers. They stated that the kinetic energy normally dissipated during the follow-through was transferred from the lead hip to the lumbar spine, resulting in compensatory excess rotational motion and stress.

Baseball shows high injury rates with most research having looked at the pitcher's shoulder and elbow during healthy and abnormal throwing.[19,20] Fleisig et al[19] have documented the increase in force on the shoulder and elbow with disruptions to the kinetic chain. Recently Shimamura et al[21] examined lumbopelvic motor control in collegiate baseball players. Fifty-two perfect of right-handers and 50% of left-handers were found to have discrepancies between their ability to control active hip rotation through their full available passive range of motion, despite no strength deficits in the gluteus medius and maximus muscles. The study did not link the lack of control to pain or injury. We are unaware of any published research that has investigated the effect of poor kinetic chain movements leading to back pain in adolescent pitchers.

To our knowledge, no literature has applied regional interdependence to treat a teenage positional player in baseball, other than the pitcher's shoulder. The purpose of this case report was to describe the examination procedures and treatment decision making progression for an adolescent baseball player with low back pain who plays both the outfield and pitches.

CASE DESCRIPTION

History

The patient was an 18-year-old right-handed male who played high school hockey and baseball who was referred to physical therapy by a sports medicine physician with a diagnosis of low back pain and a spondylogenic lesion not ruled out. He was experiencing the pain for the prior month with an insidious onset. He denied past trauma to the hips and back.

The patient's past medical history was unremarkable and he noted no previous episodes of low back pain. His symptoms were primarily in the middle of his low back, but at times it could travel into either the right or left side and into the lower thoracic spine as well. He rated this pain at rest at a 1/10, but it could increase to a 6/10 with prolonged sitting. His pain increased to a 6/10 when he lifted weights, played ice hockey, or when playing baseball. The pain was typically sharp in nature when lifting weights or playing

baseball, but dull with prolonged sitting in class. He denied any numbness, burning, or tingling through to lower extremities.

Examination and Evaluation

The patient completed an Oswestry Disability Index (ODI) prior to physical examination. The ODI is a low back functional outcome survey, scored from 0 to 100 with lower scores representing lower disability levels. It has shown both good reliability and validity.[22,23] The minimally clinically important difference (MCID) is 6%.[24] The patient's score on the ODI was 16%.

The patient was evaluated by the author, who considered a local and global approach in identifying multiple contributions of symptoms. His postural assessment revealed an excessive lordosis, most notably at the lumbosacral junction. His active range of motion revealed minimal limitations in flexion and side bending bilaterally, but a 75% limitation in lumbar extension compared to normal with 6/10 pain throughout the movement. Palpation of the patient's lumbar region revealed hypertonicity of the paraspinals in the lumbar and low thoracic region. Joint mobility testing using posterior-anterior (PA) glides of the lumbar spine was deferred due to guarding and pain with light palpation, but thoracic spine was found to be generally hypomobile with PA glides.

Special testing revealed normal neural testing with (-) straight leg raise and (-) slump testing. The FABER (flexion, abduction, and external rotation) test was (+) for mobility deficits with his knees bilaterally reaching 14" above the table, but it did not recreate lumbar symptoms. The FADIR (flexion, adduction, and internal rotation) test was (-), as was prone instability testing.

The examiner then evaluated the patient from a regional interdependence standpoint. The evaluating therapist used the Selective Functional Movement Assessment (SFMA). This tool is based on 10 multi-segmental movements that aim to identify mobility and stability deficits. Once the multi-segmental deficits are identified, the movements are further broken down with a joint-by-joint approach to identify specific impairments. The SFMA has been found to have high intra- and interrater reliability with experienced practitioners.[25] Appendix A shows a SFMA.

Using goniometric measurements and special testing, the patient being evaluated was found to have deficits at the hips and lumbar spine. His Thomas test was (+) bilaterally, R > L with bilateral abduction and external rotation at the hip, indicating tension in the antero-lateral hip region. Additionally, passive hip external rotation measured in a prone position was 25° bilaterally.

The treating therapist screened the thoracic spine, hips, knees, ankles, cervical spine, and shoulder as part of the SFMA evaluation and found no other impairments in the regions (Table 1).

Diagnosis and Prognosis

Upon completion of the examination, the therapist concluded that the patient's low back pain was likely a result of regional interdependence impairment. The origin of dysfunction stemmed from poor anterior and rotatory hip mobility, which was resulting in abnormal kinematics through the lumbar spine during rotational activities. This was seen functionally with painful swinging of a baseball bat or hockey stick, as well as sagittal plane dominated motions such as running.

At this point, it could not be ruled out whether a spondylogenic lesion was present, and therefore hyperextension treatments, such as repeated extension in standing or when lying prone were avoided. Due to caution of avoiding the possibility of a pars interarticularis stress fracture, it was also believed to be advantageous to avoid lumbar manipulations.

This ruled out the possibility of 2 treatment categories as described by Fritz et al's[6] treatment-based classification. Hicks et al's[7] subgrouping for instability was also inconsistent with this patient's symptoms. The findings for this patient in relation to the subgrouping were

- average straight leg raise > 91 (No),
- (+) prone instability (No),
- aberrant movement tested (No), and
- age < 40 (Yes).

Finally, there were no signs of a (+) crossed straight leg raise, and although the patient did appear to get worse with extension-based activities, there were no neural symptoms to suggest that traction may be beneficial.[26] Therefore, we proceeded with the diagnosis of low back pain secondary to a regional interdependence impairment, with caution of spondylogenic lesion if symptoms did not improve.

INTERVENTION

Treatment Sessions 1 and 2

The treating therapist's initial manual interventions were aimed at improving

Table 1. Initial Evaluation Summary of Findings

Range of Motion	Lumbar Flexion	25% restriction
	Lumbar Extension	75% restriction with hinge at L3/4 and 6/10 pain
	Lumbar Side Bending	25% restriction
	Thoracic Rotation	No restriction
	Passive Prone Hip External Rotation	25° bilaterally
	Hamstring	65° measured at hip angle
Joint Mobility	Lumbar	Guarded: unable to accurately assess
	Thoracic	Hypomobile through middle thoracic; normal upper and lower
	Hips	Normal bilaterally all directions
Special Testing	Straight Leg Raise	(-) Bilaterally
	Slump	(-) Bilaterally
	Prone Instability	(-)
	Flexion, Abduction, External Rotation	(-) for pain, but restricted with the knees 14" above the table bilaterally
	Flexion, Adduction, Internal Rotation	(-) Bilaterally
	Thomas Test	(+) Bilaterally, right > left with excessive hip abduction and external rotation
Palpation	Lumbar/Thoracic	Hypertonicity and pain at thoracolumbar junction and lumbosacral junction
	Hip and Thigh	Hypertonicity without pain rectus femoris and tensor fascia latae

lumbar and thoracic soft tissue mobility, decreasing hypertonicity and thereby leading to improvement in pain levels. An initial goal was to reduce pain levels through both a local and regional approach. The literature has shown motor control impairments or muscle atrophy in the lumbar spine correlate with both acute injury and chronic pain.[27,28] Reducing symptoms at the source of the pain was hypothesized by the author to reduce the ongoing motor control dysfunction and allow an opportunity to re-educate proper mechanics.

The exercise interventions focused on returning hip mobility and re-educating the transverse abdominis (TA) and multifidi. Literature has shown that the TA may show a delay in activation when performing functional tasks.[29,30] To address this, the author used basic movements such as an abdominal crunch, with a preactivation of the TA.

The patient additionally addressed hip mobility through foam rolling, hip flexor stretching (Figure 1), and then reinforced this with balance activities in positions where the hip flexors were lengthened and therefore inefficient to be used as stabilizers (Figure 2).[31] The goal of these activities were to decrease the need for hip flexor activation in preparation for later progressions in a standing position during running and swinging a baseball bat or hockey stick. The patient's impairments were bilateral and therefore treated bilaterally with a goal of creating functional mobility and symmetry. If the clinician or patient noted increased difficulty or greater restriction on one side, repetitions were added to the more involved side.

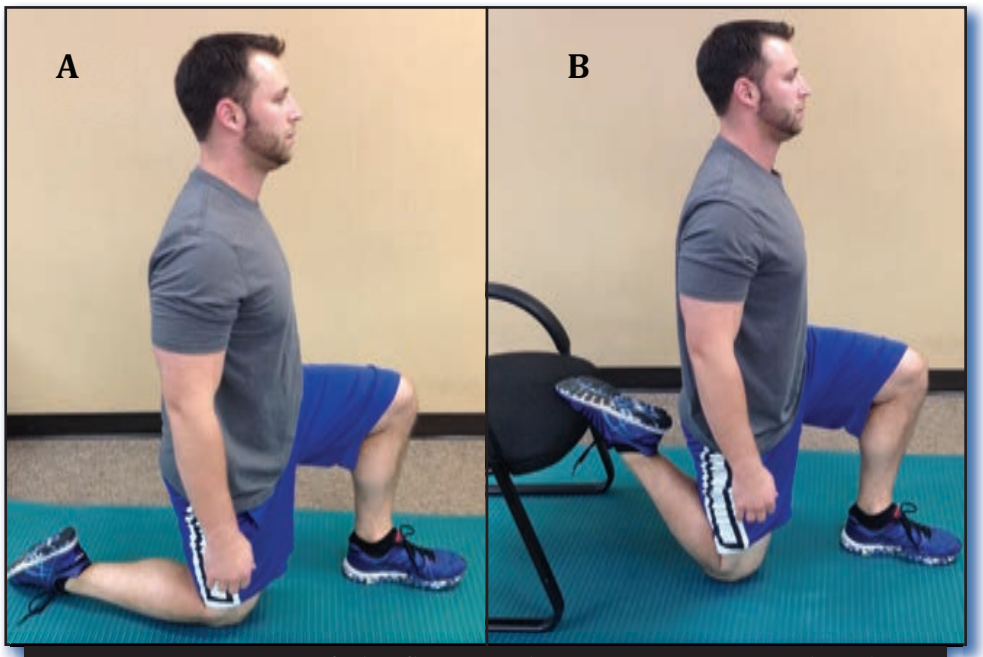

Figure 1. Demonstration of a hip flexor stretch. Focus is on posterior pelvic tilting to achieve pelvic neutral, while activating gluteals and lengthening the iliopsoas and rectus femoris. A, demonstrates a focus on iliopsoas. B, increases tension on rectus femoris by adding greater knee flexion. Caution is taken to avoid creating an excessive lordotic curve.

Treatment Session 3

The patient returned for his third treatment session 12 days following initial evaluation. He reported that he played in 2 hockey games in the previous 3 days with no symptoms remaining after the first game and only minimal symptoms that dissipated in about 1 hour following the second game. His Global Rating of Change (GROC) was a 4. The GROC is a 15-point Likert Scale used to objectively assess a patient's subjective recovery level. It ranges from -7, a very great deal worse, to 0, about the same, to 7, a very great deal better. A 4 represents moderately better.[32]

Patient re-evaluation showed an improvement in lumbar extension to only 25% limitation with decreasing pain vs 75% at initial evaluation. These results led the physical therapist to believe the patient's symptoms were not likely from spondylogenic origin. While lumbar extension continued to improve, his Thomas test, while improving, was slow despite a strict alliance with foam rolling and stretching of the hip flexors, quadriceps, and tensor fascia latae (TFL). A review of the golf literature would suggest that if a patient does not recover hip mobility, the rotational forces of swinging are likely to be transferred from the hips to the lumbar spine, which may place the athlete at an increased risk for re-aggravation of symptoms.[18,33] Therefore, the physical therapist elected to increase attention to returning hip mobility, using a soft tissue with movement technique to the TFL, vastus lateralis (VL), and rectus femoris (Figure 3).

The patient was placed in a Thomas test position and alternated flexion and extension of the knee to address the rectus femoris and VL, while the physical therapist applied pressure to hypertonic tissues. The patient then internally and externally rotated the hip while the therapist directed pressure to the TFL. While the TFL is a uniarticular muscle, its distal attachment of the iliotibial (IT) band extends below the tibiofemoral joint. Placing the athlete in a position that lengthens both the IT band at the knee and the TFL at the hip may be more advantageous to improving mobility so the Thomas position was selected.

The patient began to progress past balancing in a half-kneeling position, to rota-

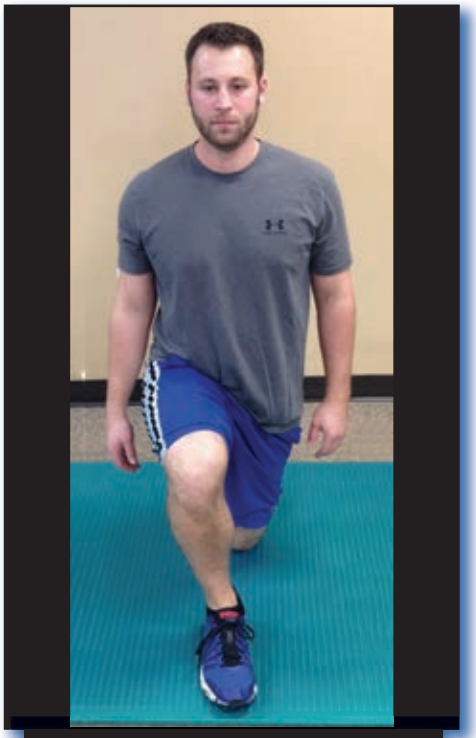

Figure 2. Demonstration of a stabilization progression. The iliopsoas and rectus femoris are placed in an inefficient position to contract by placing them in a lengthened position on the posterior leg. The gluteals are contracted and act as stabilizers. The base of support is narrowed to increase difficulty.

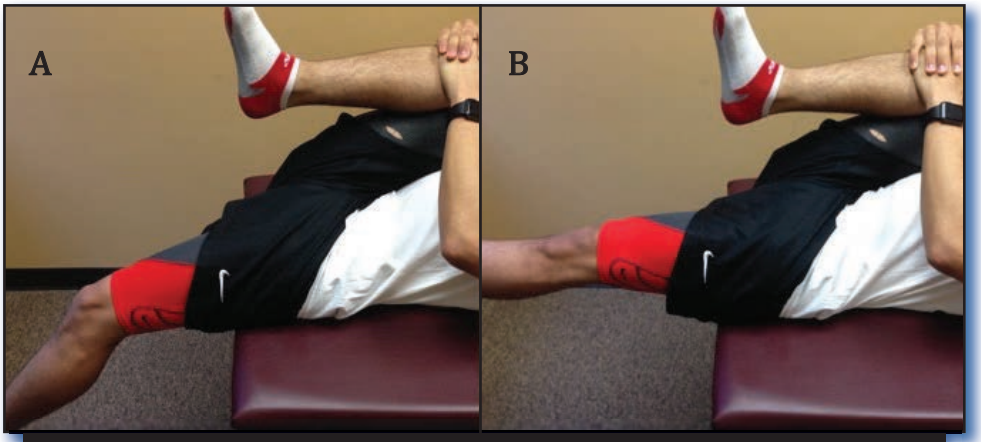

Figure 3. The Thomas Test position can be used to both measure and treat an anterior thigh musculature mobility deficit. Pressure was applied to the area of the palpated trigger points while the athlete moved the knee through flexion and extension. This can also be used to bias the tensor fascia latae by placing pressure through the tensor fascia latae and having the patient actively move the hip through external and internal rotation. A, the stretched position. B, the shortened position.

Figure 4. Demonstration of a stabilization progression. The iliopsoas and rectus femoris are placed in an inefficient position to contract by placing them in a lengthened position on the posterior leg. The gluteals are contracted and act as stabilizers. The thoracic spine is then rotated to improve coordination of thoracic spine motion on a stable lumbar spine and hip. A, rotation to the right. B, rotation to the left. The patient rotates side-to-side, focusing on maintaining stability at the lumbar spine and lower body with the upper body moving.

tional activities in half kneeling. This was believed to require the patient to begin simulating sport-like movements, while still in an inefficient position for the iliopsoas and rectus femoris to act as stabilizers. During this treatment, the patient focused only on initiating thoracic active range of motion rotation in this position, while maintaining a narrow base of support (Figure 4).

Quadruped reaching activities were also added to engage the multifidi and gluteal activation through a full range of hip extension. This was verbally cued carefully to avoid hip extension leading to lumbar hyperextension.

The patient also began hitting off a tee. He was preparing to transition from hockey to baseball for his high school spring sports season.

Visit 4 and 5

The patient continued to progress with his ODI improving from 16% at evaluation to 6% by visit 5. His GROC improved to a 5, quite a bit better. He noted that this would be even better, but he felt slightly tight during an all-day baseball practice. The weather was very cold and his back seemed to be fine except when he was not moving as much. He thought the tight feeling was due to the cold and not his injury.

The treating physical therapist found only a 10% deficit in rotation and lumbar extension at the beginning of treatment. Minimal remaining soft tissue deficits were found at the hip, lumbo-sacral, and thoraco-lumbar junction. All joint mobility showed a normal spring and endfeel. His gluteus maximus, medius, and minimus showed trigger points that were addressed through trigger point release and contract-relax stretching. After addressing these impairments, he showed no deficits in hip or lumbar range of motion and these motions were painfree.

His functional activities were progressed at visit 4 initiating half-kneeling chopping with resistance (Figure 5). At visit 5, this was progressed to include both half kneeling and standing to simulate swinging, while preventing movement through the lumbar spine. Various single leg activities were added with the goal of engaging gluteus maximus to provide strength and gluteus medius and minimus as stabilizers: Single Leg Romanian Dead Lift (RDL) and Single Leg Rotation. He also progressed through further return-to-sport activities in the clinic, such as multi-directional lunging and step-ups.

Visit 6

The patient cancelled his initial sixth visit appointment noting that he was not feeling well; however, he rescheduled this appointment for 2 days later. He had now been symptom-free with all activities of daily living, including sitting in class and full participation in baseball. A recheck of symptoms was planned along with a Functional Movement Screen (FMS) in preparation for a possible transition to a home exercise program. The FMS has been shown to have high interrater reliability.[33] It is comprised of 7 multi-segmental movements of the body with a maximum score of 21. A score of 15 or higher has been shown to be a normal injury risk, while 14 or below is an elevated risk.[35,36]

One month after initial evaluation when the patient arrived for visit 6, his personality appeared altered and he seemed to be generally fatigued. When the treating therapist inquired, the patient noted that he had donated blood 2 days prior. After donating blood, he became light-headed, resulting in a fall where he hit his head.

The treating therapist performed a concussion screen on the patient and noted altered balance and ocular-motor move-

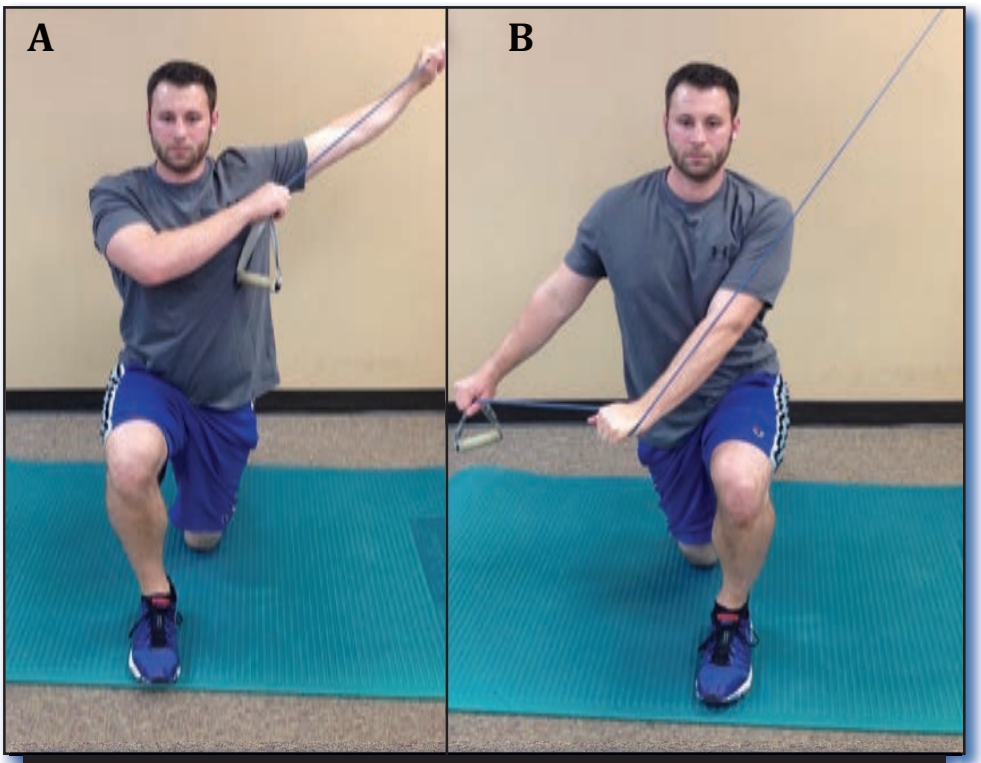

Figure 5. An external load is added, requiring stabilization to avoid loss of balance. The hip flexors are in an inefficient position to contract, preventing them from becoming stabilizers and therefore requiring stabilization from the gluteals and deep core musculature. This is used as a progression to chopping in standing and swinging a bat, racket, club for sports requiring swinging. A, the starting position. B, the ending position.

ments, as well as multiple subjective complaints consistent with a concussion. The patient noted that he did not want to bring up the symptoms to anyone and had not mentioned them to his parents, coaches, athletic trainer, or teachers. The referring sports medicine physician and school athletic trainer were contacted to note the findings and hold him from participation in sports. The referring physician diagnosed the athlete with a concussion and held further physical therapy appointments and sports participation.

Visit 7

The patient returned to physical therapy, under the physician's orders,1 month following the concussion (2 months since initial evaluation), after completing the required return-to-sport progression. The patient reported having competed in multiple practices and games without concussive or low back symptoms. His GROC was a 7, indicating a very great deal better. His ODI was a 0%, which indicates no disability remained. The patient completed the FMS with a score of 17/21, placing him at low-risk for reinjury.[35,36] A home exercise program focusing on hip flexor stretching, core exercises with the hip flexors in an insufficient position (chops in kneeling), and single leg RDLs for gluteal activation was prescribed. The patient was then discharged from physical therapy.

OUTCOMES

The patient was seen for 7 visits over an 8-week period and demonstrated a full resolution of all symptoms as measured by functional outcomes. A GROC of 7 is the highest obtainable score and is consistent with the ODI results. His ODI of 0% signifies a full recovery with no remaining disability and a 16% decrease from initial evaluation far exceeds the MCID of 6%.[24]

DISCUSSION

The purpose of this case report was to describe clinical reasoning and outcomes using regional interdependence in an adolescent athlete with low back pain. Initial interventions were aimed at reducing symptoms locally, with progression of treatment addressing the kinetic chain involved in sports. Treatment addressed areas of poor mobility, most notably the hips to decrease the strain through the lumbar spine.

Lead hip mobility has been noted to be an issue in professional golfers,[18,34] but has not been described for batters in baseball. The author believes the correlation of the lead hip and back is due to the abrupt end-feel of the lead hip when a golfer is decelerating after striking the ball. This has been well-documented in pitchers' shoulders as they attempt to decelerate when there is a decreased total arc of motion through the loss of internal rotation mobility.[20] When describing this phenomenon to patients or health care professionals, the author uses the analogy of a large airplane landing on a long vs short runway. On a long runway the plane would having no issue stopping. If however, that same plane is required to land on the shorter runway of a jet craft carrier, then there would not be enough room to decelerate and a problem is inevitable. The inadequate distance during landing is analogous to having inadequate motion in the shoulder or lead hip.

Another common finding in athletes is an anterior pelvic tilt, which has been correlated to increased activation of the erector spinae, decreased activation of the gluteals, and delayed onset of the gluteals. This can be addressed through stabilization exercises, which have been shown to improve both the delay and lack of activation.[37,38] To address the mobility impairments that may be present at the anterior hip, we prefer to use foam rolling or another form of soft tissue mobilization, followed by stretching in the half-kneeling position. This requires control of the pelvis while also addressing iliopsoas and rectus femoris mobility.

Half kneeling is also used to retrain normalized core stabilization. The literature has shown that when a muscle is placed in a lengthened position, it is inefficient at generating force.[31] Because the kneeling leg is lengthened at both the rectus femoris and the iliopsoas, it puts these muscles at a mechanical disadvantage to stabilize the core. The athlete receives instant feedback in the form of loss of balance or loss of pelvic alignment when stability is lost. This is believed to functionally retrain local core musculature initially.

Further progression can include more dynamic movements where an external load is used through chopping in half kneeling. Finally, the athlete returns to chopping in standing and swinging a bat.

The findings of this case report support the use of a regional interdependence

approach to back pain in the athletic population. However, due to the limitations inherent in case reporting, we cannot draw a cause and effect conclusion. A larger case series, with multiple athletes, would be beneficial in demonstrating the effects of treatment through regional interdependence. Additionally, higher-level research should compare treatment using regional interdependence with other current standards of care, including treatment-based classification, repeated motion testing, and core stabilization training.

The author believes that the current findings would not contradict current treatment-based classification as suggested by Fritz et al,[6] but instead begins to fill the gap in findings where 25% of the subjects were not included in a group.[8]

It should also be noted that the patient presented to physical therapy with a script that read, "possible spondylogenic lesion." In these cases, the author elects to proceed with caution if repeated extension testing or manipulation is being considered, which may preclude some treatments common in adults from comparison in this population. Palpation and special testing for spondylogenic lesions is poor, limiting our ability to rule out and continue with these forms of treatment.[10,39]

CONCLUSION

This case report described the clinical reasoning and treatment for an adolescent athlete with back pain who was treated with a regional interdependence approach. The outcomes show significant improvement in mobility and functional status over a limited number of treatments. This suggests a potential benefit of including a regional interdependence approach in athletes with back pain. Further research needs to be performed in adolescents with low back pain, comparing other leading interventions prior to conclusions about the effectiveness of this approach.

REFERENCES

1. Di Fabio RP, Boissonnault W. Physical therapy and health-related outcomes for patients with common orthopaedic diagnoses. *J Orthop Sports Phys Ther*. 1998;27(3):219-230.
2. Jette AM, Delitto A. Physical therapy treatment choices for musculoskeletal impairments. *Phys Ther*. 1997;77(2):145-154.
3. Jones GT, Macfarlane GJ. Epidemiology of low back pain in children and adolescents. *Arch Dis Child*. 2005;90(3):312-316.
4. Delitto A, Erhard RE, Bowling RW. A treatment-based classification approach to low back syndrome: identifying and staging patients for conservative treatment. *Phys Ther*. 1995;75(6):470-485, discussion 485-489.
5. Flynn T, Fritz J, Whitman J, et al. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. *Spine*. 2002;27(24):2835-2843.
6. Fritz JM, Cleland JA, Child JD. Subgrouping patients with low back pain: evolution of a classification approach to

(Continued on page 262)

Appendix 1. Selective Functional Movement Assessment (SFMA)

The SFMA is a full-body assessment to determine movements which demonstrate limited motion, pain, or both. The initial test is made up of 10 multi-segmental movement patterns. The patterns found to be dysfunctional or painful are then further broken down with a joint-by-joint approach to determine patient limitations.

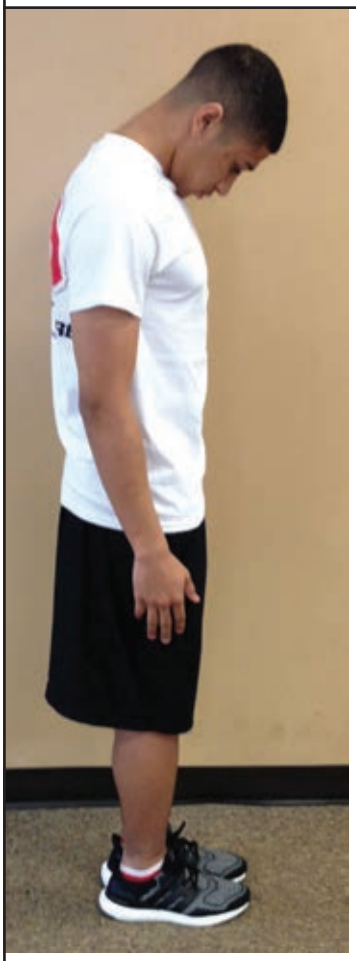

Figure A1. Cervical Flexion: Patient actively flexes neck. Functional movement is seen when the chin makes contact with the sternum.

Figure A2. Cervical Extension: Patient actively extends neck. Functional movement is seen when the head reaches near horizontal.

Figure A3. Cervical Rotation-Lateral Bend: Patient actively rotates neck to one side. The chin is then flexed downward towards the clavicle. Functional movement is seen when the chin contacts the clavicle. The test is repeated on the opposite side.

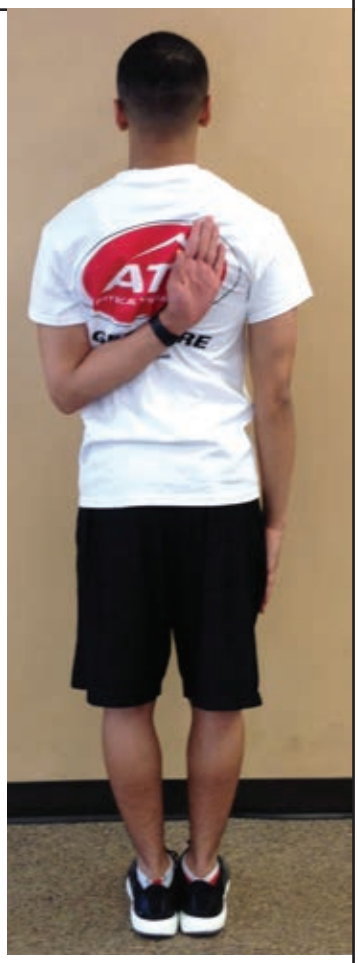

Figure A4. Upper Extremity Pattern 1: The hand reaches behind the back to the contralateral scapula to target shoulder extension and internal rotation. Functional movement is seen when the hand is able to reach the scapula. The test is repeated on the opposite side.

(Continued on page 261)

Figure A5. Upper Extremity Pattern 2: The hand reaches behind the neck to the contralateral scapula to target shoulder flexion and external rotation. Functional movement is seen when the hand is able to reach the scapula. The test is repeated on the opposite side.

Figure A6. Multisegmental Flexion: While standing with the feet together, the patient actively bends forward to touch his/her toes. A functional pattern is demonstrated when the toes are touched, the knees are kept straight, and a uniform curve of the spine is seen.

Figure A7. Multisegmental Extension: While standing with the feet together and the arms flexed above the head, the patient actively bends backwards as far as he or she is able. A functional pattern is demonstrated when the anterior pelvis moves beyond the front of the toes, the spine of the scapula moves posterior to the heels, and a uniform spinal curve is maintained.

Figure A8. Multisegmental Rotation: While standing with the feet together and the arms relaxed to the side, the patient actively rotates as far as he or she is able. A functional pattern is demonstrated when the pelvis rotates 50°, the shoulders rotate 50°, and there is no pelvis or spine deviation to the side.

Figure A9. Single Leg Stance: While standing with the feet together, the patient flexes one hip to 90° while standing on the opposite foot. This position is held for 10 seconds. It is then repeated again with the eyes closed. A functional test is seen when the patient is able to maintain both positions for 10 seconds without loss of balance or significant sway. The opposite side is then tested.

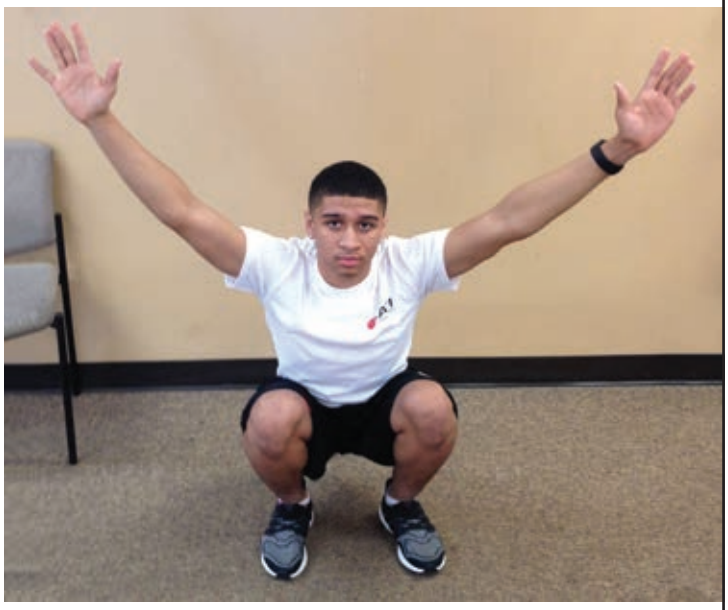

Figure A10. Overhead Deep Squat: The patient stands with the feet shoulder width apart and pointing straight forward. The arms are placed overhead. The patient descends downward into a squat as low as they can go. A functional test is seen when the thighs pass below horizontal, the knees remain in line with the hips and feet, and the trunk does not flex forward past the angle of the tibia.

physical therapy. *J Orthop Sports Phys Ther*. 2007;37(6):290-302.
7. Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. *Arch Phys Med Rehabil*. 2005;86(9):1753-1762.
8. Stanton TR, Fritz JM, Hancock J, et al. Evaluation of a treatment-based classification algorithm for low back pain: a cross-sectional study. *Phys Ther*. 2011;91(4):496-509.
9. Brennan GP, Fritz JM, Hunter SJ, Thackeray A, Delitto A, Erhard RE. Identifying subgroups of patients with acute/subacute "nonspecific" low back pain: results of a randomized clinical trial. *Spine*. 2006;31(6):623-631.
10. Masci L, Pike J, Malara B, Phillips B, Bennell K, Brukner P. Use of the one-legged hyperextension test and magnetic resonance imaging in the diagnosis of active spondylolysis. *Br J Sports Med*. 2006;40(11):940-946.
11. Standaert CJ, Herring SA. Expert opinion and controversies in sports and musculoskeletal medicine: the diagnosis and treatment of spondylolysis in adolescent athletes. *Arch Phys Med Rehabil*. 2007;88(4):537-540.
12. Fredrickson BE, Baker D, McHolick WJ, Yuan HA, Lubicky JP. The natural history of spondylolysis and spondylolisthesis. *J Bone Joint Surg Am*. 1984;66(5):699-707.
13. Wainner RS, Whitman JM, Cleland JA, Flynn TW. Regional interdependence: a musculoskeletal examination model whose time has come. *J Orthop Sports Phys Ther*. 2007;37(11):658-660.
14. Powers C. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther*. 2010;40(2):42-51.
15. Backstrom KM, Whitman JM, Flynn TW. Lumbar spinal stenosis-diagnosis and management of the aging spine. *Man Ther*. 2011;16(4):308-317.
16. Whitman JM, Flynn TW, Childs JD, et al. A comparison between two physical therapy treatment programs for patients with lumbar spinal stenosis: a randomized clinical trial. *Spine*. 2006;31(22):2541-2549.
17. Whitman JM, Flynn TW, Fritz JM. Nonsurgical management of patients with lumbar spinal stenosis: a literature review and a case series of three patients managed with physical therapy. *Phys Med Rehabil Clin N Am*. 2003;14(1):77-101.
18. Kim SB, You J, Kwon O, Ti CH. Lumbopelvic kinematic characteristics of golfers with limited hip rotation. *Am J Sports Med*. 2014;43(1):113-120.
19. Fleisig GS, Barrentine SW, Zheng N, Escamilla RF, Andrews JR. Kinematic and kinetic comparison of baseball pitching among various levels of development. *J Biomech*. 1999;32(12):1371-1375.
20. Wilk KE, Marcina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotation motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med*. 2011;39(2):329-335.
21. Shimamura KK, Cheatham S, Chung W, et al. Regional Interdependence of the hip and lumbo-pelvic region in division II collegiate baseball pitchers: a preliminary study. *Int J Sports Phys Ther*. 2015;10(1):1-12.
22. Davidson M, Keating JL. A comparison of five low back disability questionnaires: reliability and responsiveness. *Phys Ther*. 2002;82(1):8-24.
23. Frost H, Lamb SE, Stewart-Brown S. Responsiveness of a patient specific outcome measure compared with the Oswestry Disability Index v2.1 and Roland and Morris Disability Questionnaire for patients with subacute and chronic low back pain. *Spine*. 2008;33(22):2450-2457.
24. Fritz JM, Irrgang JJ. A comparison of a modified Oswestry low back pain disability questionnaire and the Quebec back pain disability scale. *Phys Ther*. 2001;81(2):776–788.
25. Glaws KR, Juneau CM, Becker LC, Di Stasi SL, Hewett TE. Intra and inter-rater reliability of the selective functional movement assessment (SFMA). *Int J Sports Phys Ther*. 2014;9(2):195-207.
26. Fritz JM, Weston L, Matheson JW, et al. Is there a subgroup of patients with low back pain likely to benefit from mechanical traction? Results of a randomized clinical trial and subgrouping analysis. *Spine*. 2007;32(26):E793-E800.
27. Benneck GJ, Kulig K. Multifidus atrophy is localized and bilateral in active persons with chronic unilateral low back pain. *Arch Phys Med Rehabil*. 2012;93(2):300-306.
28. Lynch AD, Logerstedt DS, Axe MJ, Snyder-Mackler L. Quadriceps activation failure after anterior cruciate ligament rupture is not mediated by knee joint effusion. *J Orthop Sports Phys Ther*. 2012;42(6):502-510.
29. Hodges PW, Richardson CA. Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. *J Spinal Disord*. 1998;11(1):46-56.
30. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. *Spine*. 1996;21(22):2640-2650.
31. Rassier DE, MacIntosh BR, Herzog W. Length dependence of active force production in skeletal muscle. *J Appl Physiol*. 1999;86(5):1445-1457.
32. Kamper SJ, Maher CG, Mackay G. Global rating of change scales: a review of strengths and weaknesses and considerations for design. *J Man Manip Ther*. 2009;17(3):163-170.
33. Minick KI, Kiesel KB, Burton L, Taylor A, Plisky P, Butler RJ. Interrater reliability of the Functional Movement Screen. *J Strength Cond Res*. 2010;24(2):479-486.
34. Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, Andrews JR. Low back pain in professional golfers: the role of associated hip and low back range-of-motion deficits. *Am J Sports Med*. 2004;32(2):494-497.
35. Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, Landis JA. Use of a functional movement screening tool to determine injury risk in female collegiate Athletes. *N Am J Sports Phys Ther*. 2010;5(2):47-54.
36. Kiesel K, Plisky PJ, Voight ML. Can serious injury in professional football be predicted by a preseason functional movement screen. *N Am J Sports Phys Ther*. 2007;2(3):147-158.
37. Kim T, Woo Y, Kim Y. Effect of abdominal drawing-in maneuver during hip extension on the muscle onset time of gluteus maximus, hamstring, and lumbar erector spainae in subjects with hyperlordotic lumbar angle. *J Physiol Anthropol*. 2014;33:34.
38. Oh JS, Cynn HS, Won JH, Kwon OY, Yi CH. Effects of performing an abdominal drawing-in maneuver during prone hip extension exercises on hip and back extensor muscle activity and amount of anterior pelvic tilt. *J Orthop Sports Phys Ther*. 2007;37(6):320-324.
39. Collaer J, McKeough M, Boissonnault, W. Lumbar isthmic spondylolisthesis detection with palpation: Interrater reliability and concurrent criterion-related validity. *J Man Manip Ther*. 2006;14(1):22-29.