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# TABLE OF CONTENTS

## VOLUME 11, NUMBER 4

<table>
<thead>
<tr>
<th>Page Number</th>
<th>Article Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORIGINAL RESEARCH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>507</td>
<td>The Efficacy of an Eight-week Core Stabilization Program on Core Muscle Function and Endurance: A Randomized Trial.</td>
<td>Hoppes CW, Sperier AD, Hopkins CF, Griffiths BD, Principe MF</td>
</tr>
<tr>
<td>520</td>
<td>A New Clinical Muscle Function Test For Assessment of Hip External Rotation Strength: Augustsson Strength Test.</td>
<td>Augustsson J</td>
</tr>
<tr>
<td>527</td>
<td>Comparison of Range of Motion, Strength, and Hop Test Performance of Dancers With and Without a Clinical Diagnosis of Femoroacetabular Impingement.</td>
<td>Kivlan BR, Garcia CR, Christoforetti JJ, Martin RL</td>
</tr>
<tr>
<td>536</td>
<td>The Effect of Conservatively Treated ACL Injury on Knee Joint Position Sense.</td>
<td>Relph N, Herrington L</td>
</tr>
<tr>
<td>544</td>
<td>Specific and Cross-Over Effects of Foam Rolling on Ankle Dorsiflexion Range of Motion.</td>
<td>Kelly S, Beardsley C</td>
</tr>
<tr>
<td><strong>CASE REPORT / SERIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>575</td>
<td>Using the Selective Functional Movement Assessment and Regional Interdependence Theory to Guide Treatment of an Athlete with Back Pain: A Case Report.</td>
<td>Goshtigian GR, Swanson BT</td>
</tr>
<tr>
<td>627</td>
<td>Evaluation and Treatment of a Patient Diagnosed with Adhesive Capsulitis Classified as a Derangement Using the McKenzie Method: A Case Report.</td>
<td>Bousier A, Swanson BT</td>
</tr>
<tr>
<td><strong>CLINICAL COMMENTARY / LITERATURE REVIEWS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>636</td>
<td>Intervention at the Foot-Shoe-Pedal Interface in Competitive Cyclists.</td>
<td>FitzGibbon S, Vicenzino B, Sisto SA</td>
</tr>
<tr>
<td>650</td>
<td>Pertinent Dry Needling Considerations for Minimizing Adverse Effects: Part One.</td>
<td>Halle JS, Halle R</td>
</tr>
</tbody>
</table>
CORRIGENDUM


It has come to the attention of the authors of this paper that incorrect data was reported for hip angles in Table 1. Please see the corrected Table 1 for updated data. The authors report having rerun the statistical analysis using the updated data, and the results and conclusions of this research study are unchanged, that is, no significant differences exist between muscular activity in HS and FFS conditions for hip angles. The authors and the editorial staff of IJSPT regret these errors.

<table>
<thead>
<tr>
<th>Table 1. Comparison of hip, knee, and ankle joint angles across 20 strides of rearfoot strike and forefoot strike running.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hip Angle</strong></td>
</tr>
<tr>
<td>HS</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Min</td>
</tr>
<tr>
<td>Max</td>
</tr>
<tr>
<td>ROM</td>
</tr>
<tr>
<td><strong>Ankle Angle</strong></td>
</tr>
<tr>
<td>HS</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Min</td>
</tr>
<tr>
<td>Max</td>
</tr>
<tr>
<td>ROM</td>
</tr>
</tbody>
</table>

Abbreviations: RFS, rearfoot strike; FFS, forefoot strike; E/I, eversion/inversion

* Indicates a significant difference (P < .05) between joint angles in RFS and FFS running
ABSTRACT

Background: While studies that have examined the prevalence of musculoskeletal injuries in alpine skiing and snowboarding exist, there has been no discussion of how neurocognitive deficits may influence such injuries. Recent authors have identified a possible link between Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) testing results and the prevalence of musculoskeletal injury in athletic populations. However, no study has specifically examined this in the alpine skiing and snowboard athletes who sustain injury and those that do not.

Hypothesis/Purpose: The purpose was to review injury data and ImPACT test results within the local ski/snowboard population to determine if there was a difference in components of ImPACT test scores between injured and non-injured athletes. It was hypothesized that differences would exist in component scores on ImPACT testing between injured and non-injured athletes.

Study design: Retrospective cohort study

Methods: Injury records and baseline ImPACT testing scores for 93 athletes aged 14-17 participating in a local ski and snowboard club during the 2009-2012 seasons were gathered retrospectively. Injuries documented for the lower and upper extremity included ligament sprains, muscle strains, contusions, dislocation/subluxation, fractures and concussions. Athletes who sustained any of these listed injuries were categorized within the injured athlete group. Each component of ImPACT test scores was compared between gender and for injury status within skiing and snowboarding disciplines using a series of two-way analysis of variance tests.

Results: There was no difference between non-injured and injured females as well as non-injured and injured males in reaction time and visual motor speed (VMS), however there was an interaction between gender and injury status on composite reaction time and visual motor speed, or VMS. The composite reaction time for females was 4.7% faster with injury while males without injury had a composite reaction time that was slower by 5.8%. Females had a 4.1% higher mean VMS score with injury while males had a 14.4% higher VMS score without injury.

Conclusion: Future research may consider prospectively examining neurocognitive testing scores and injury prevalence within the disciplines of snowboarding and both alpine and freestyle skiing.

Levels of Evidence: Level 3

Key Words: Musculoskeletal injury, neurocognitive deficits, neurocognitive testing

1 Memphis Grizzlies, Memphis, TN, USA
2 Howard Head Sports Medicine, Edwards, CO, USA
3 La Crosse Institute for Movement Science, Strzelczyk Clinical Biomechanics Laboratory, Department of Health Professions, Physical Therapy Program, University of Wisconsin-La Crosse, La Crosse, WI, USA
4 Ski and Snowboard Club Vail, Vail, CO, USA

Acknowledgement

We thank Kim Greene from Vail Valley Medical Center for her contribution in providing ImPACT data records for this study. No outside funding was received for the completion of this study.

The study protocol was approved by the Institutional Review Board at Vail Valley Medical Center. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article.

CORRESPONDING AUTHOR

John Faltus,
Memphis Grizzlies,
191 Beale Street, Memphis TN 38103
E-mail: jfaltus@grizzlies.com
INTRODUCTION
Musculoskeletal injuries in skiing and snowboarding are common and have been well documented.\textsuperscript{1,2,3,4,5} The prevalence of the types of injuries with these sports varies. Hand, wrist, shoulder and ankle injuries occur at a higher rate in snowboarding whereas knee injuries are more prevalent in skiing.\textsuperscript{1,2,3,4,5} It can be assumed that the elements of both sports which often require quick changes in direction involving high limb acceleration during very high-risk maneuvers performed on varied surfaces with changing climate conditions may greatly factor into the incidence of injury. Much of the current literature identifies both neuromuscular and biomechanical mechanisms contributing to such musculoskeletal injuries, specifically regarding non-contact knee injury mechanisms, because these risk factors are thought to be modifiable.\textsuperscript{5,6,7}

Neurocognitive testing has become a standard, objective means for assessing changes in cerebral and cortical function associated with concussions and have been used to assist with return-to-play decisions. The reliability and validity of ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing, ImPACT Applications, Inc., Pittsburgh, PA) has been shown in several studies using athletic samples.\textsuperscript{8,9,10} Independent studies have demonstrated good reliability of the ImPACT test overall with ICC ranges from .70-.85.\textsuperscript{8,10} With regards to the specific components of the total ImPACT score, self-reported symptoms represent the least reliable index while motor processing speed has been reported to be the most reliable.\textsuperscript{5,10} Regarding test validity, Maerlender et al\textsuperscript{11} reported that the cognitive domains represented from ImPACT testing were shown to have good construct validity compared to neuropsychological tests that are sensitive to cognitive functions associated with mild traumatic brain injury.\textsuperscript{11}

Recent authors have investigated a possible link between neurocognitive deficits identified from ImPACT tests and lower extremity injury risk.\textsuperscript{12,13} Specifically, composite reaction time $>.545$ s doubled the risk for injury in collegiate football athletes.\textsuperscript{13} It is reasonable to assume that deficits in neurocognitive function may contribute to the occurrence of musculoskeletal injury given recent evidence. A history of concussions in NFL athletes was associated with higher odds of sustaining a musculoskeletal injury.\textsuperscript{14} Furthermore, college athletes were found to have increased odds of musculoskeletal injury following return to sport after concussion.\textsuperscript{15,16} Deficits in cortically driven reaction time, processing speed, and visual and verbal memory may indicate a diminished capacity for neuromuscular control and predispose an athlete to subsequent injury.\textsuperscript{12,13} Maintaining dynamic control during complicated, high velocity athletic movements is contingent on both cortically programmed muscle pre-activation and reflex-mediated muscle contraction. Although many peripheral and segmental reflexive pathways exist, ultimately the cerebral cortex is responsible for planning and regulating all of these motor control processes.\textsuperscript{14} Neurocognitive tasks, such as those measuring reaction time, processing speed, visual memory, and verbal memory are indirect measures of cerebral performance.\textsuperscript{17} Situational awareness, arousal, and attention are resources that an individual may use to influence those areas of neurocognitive function, and these in turn affect the integration of vestibular, visual, and somatosensory information needed for neuromuscular control.\textsuperscript{12,17,18,19}

The purpose was to review injury data and ImPACT test results within the local ski/snowboard population to determine if there was a difference in components of ImPACT test scores between injured and non-injured athletes. It was hypothesized that differences would exist in component scores on ImPACT testing between injured and non-injured athletes.

METHODS
Data for this retrospective cohort study included ImPACT testing scores and injury reports for athletes from a local ski and snowboard club during three competitive seasons. The components of the ImPACT assessment were evaluated as well as the elements of each respective component score which included reaction time (average response speed), verbal memory (attentional processes, learning, and memory within the verbal domain), visual memory (visual attention and scanning, learning and memory), VMS, or visual motor speed (visual processing, learning and memory, and visual-motor response speed), and cognitive efficiency index (CEI). The CEI component of this test examines the interaction between speed and memory and is determined from
the symbol-matching task within the ImPACT test. During this component, speed is measured from the number of items correctly identified while accuracy is the number of items correctly identified from the memory portion of this symbol-matching task. The test scores were collected from a local hospital that administered baseline neurocognitive tests. Injury records were collected directly from the local ski and snowboard club. This study protocol was approved by the Vail Valley Institutional Review Board.

Charted records for male and female athletes aged 14-17 participating in the disciplines of alpine skiing, freestyle skiing, and snowboarding during the 2009-12 competitive seasons (October-April) were examined. Records for athletes in this cohort that did not contain the baseline ImPACT testing prior to each competitive season were excluded. Out of roughly 450 athletes, the records for 134 athletes who met the inclusion criteria were included in the data analysis (Table 1). There were 93 documented injuries within this cohort. Injuries documented for the lower and upper extremity included ligament sprains, muscle strains, contusions, dislocation/subluxation, fractures and concussions. Athletes who sustained any of these listed injuries were categorized within the injured athlete group. Athletes who did not sustain an injury but met inclusionary criteria for this study were categorized as non-injured athletes. Informed consent for injury documentation and record keeping was obtained from each athlete and his or her respective legal guardian prior to participation during each season.

Neurocognitive function assessment was performed prior to each competitive season by administering the ImPACT test. ImPACT is computer software that assesses neurocognitive function and concussion symptoms through a series of six neurocognitive tests. According to the ImPACT Applications, Inc. Technical Manual, these six tests evaluate word recognition, design memory, visual processing and memory, and working memory/visual response speed. From these six tests, five composite scores are produced in the areas of verbal memory, visual memory, reaction time, visual motor speed (VMS) and impulse control. Testing was conducted in a quiet, controlled environment. Following test completion, scores were stored in a secure electronic database in the local hospital’s medical records maintained by the director of ImPACT testing. Composite scores from each component (RT, VMS, Verbal, Visual and CEI) were determined from each athlete documented along with injury records, in both paper and electronic form, by the local ski and snowboard club coaching staff and were then used to examine the research question. Testing validity was determined based upon comparison to criterion values for each composite score. Previously established standards for whether a baseline test is invalid include an impulse control composite score greater than 30, processing speed composite score less than 25, reaction time scores greater than .80, verbal memory composite score below 70 and visual memory composite score below 60. Additionally, the ImPACT Applications, Inc. Technical Manual states that the ImPACT report software will automatically generate an indication that a completed baseline test has questionable validity if certain criteria, based upon previously mentioned composite score standards and/or low percentage of correct answers in word and design recognition tasks, are met.

**STATISTICAL METHODS**

Two-way analysis of variance tests with two between factors (gender – male/female) and injury status (injured/non-injured) were applied separately to each component variable from neurocognitive testing: reaction time, visual motor speed, verbal memory, visual memory and cognitive efficiency index. Alpha was set a priori to 0.05 for each of these tests. Post hoc comparisons were performed as warranted.
RESULTS

Of the 93 injuries documented, the majority of these injuries occurred in the lower extremity followed by concussions/head injuries, and upper extremity injuries (Table 2). In regards to testing validity criterion that will be discussed later in this manuscript, ten total athletes (five from injured group and five from uninjured group) scored below the criterion point for verbal memory composite scoring. Eighteen total athletes (7 from injured group and 11 from uninjured group) scored below the criterion point for visual memory composite scoring. Also, two subjects from the uninjured group scored at equal to or slightly greater than this criterion for reaction time. Data which did not meet these criteria was excluded from analysis.

For reaction time, there was no difference based on gender (F(1,89)=1.97, p = .164) or injury status (F(1,89)=0.7, p = .763). There was a 2.5% mean difference in reaction time between females and males, with females being slower in reaction time. Reaction time means based on injury status was nearly identical (less than 1% difference between genders). There was a significant interaction between gender and injury status on mean reaction time (F(1,89)=5.08, p=0.027). Follow up tests indicated that the composite reaction time for females was 4.7% lower with injury (t(42)=-1.27, p=0.210) while the composite reaction time for males was greater by 5.8% (t(42)=2.09, p=0.045) (Figure 1).

VMS scores were not different between gender (F(1,89)=0.48, p=0.490) or injury status (F(1,89)=1.55, p = .216). VMS mean scores between genders with nearly the same (less than 1% difference between genders). Based on injury status VMS differed by 4.1% with injury yielding slightly higher scores. There was a significant interaction between gender and injury status on VMS scores (F(1,89)=5.65, p = .027). Follow up tests indicated that the females had a 4.1% higher mean VMS scores with injury (t(42)=0.80, p=0.426) whereas the males had a 14.4% higher VMS score without injury (t(47)=-2.55, p=.014) (Figure 2).

Verbal memory scores were not different between gender (F(1,89)=0.51, p = .476) or injury status (F(1,89)=0.84, p = .363). Mean verbal scores based on gender was 84.7±12.5 for males and 83.5±11.3

<table>
<thead>
<tr>
<th>Table 2. Injury by Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
</tbody>
</table>

Figure 1. Mean and standard deviation for reaction time (RT) for injured and non-injured males and females.

Figure 2. Mean and standard deviation for visual motor speed (VMS) for injured and non-injured males and females.
for females. Similarly, the means on injury status for verbal scores were only 2.1% different with injury being slightly larger. There was also no interaction between gender and injury status for verbal scores (F(1,89)=0.05, p = .822). Means for verbal scores changed based on injury status was smaller by 2% while males were smaller by 3.5%.

Visual memory scores were not different between gender (F(1,89)=1.46, p = .231) or injury status (F(1,89)=0.17, p = .679). Mean visual scores were 4.6% higher in females compared to males. Injury status similarly had little influence on mean visual scores with 73.4 ± 13.9 for females and 73.1 ± 16.4 for males. There was also no interaction between gender and injury status for verbal scores (F(1,89)=0.10, p = .750). Mean visual scores were 5.2% lower with injury for females and nearly 2% lower for males.

CEI scores were not different between gender (F(1,89)=0.41, p = .526) or injury status (F(1,89)=0.02, p = .882). Female and male mean CEI values differed by 5% while injury status had little influence on mean CEI scores (2.7% difference). There was also no interaction between gender and injury status for verbal scores (F(1,89)=0.77, p = .383). Mean CEI scores were 8.9% higher for females with injury while males had a 6.4% greater CEI with injury.

DISCUSSION
The current study investigated whether there was a difference in each component of ImPACT testing based on gender and injury status. Results indicated interaction between gender and injury status on composite reaction time and VMS (Figures 1 and 2). There was no difference in ImPACT scores and injury prevalence in the adolescent ski and snowboard population based the results of the current study.

While lower extremity injuries accounted for 34% of total injuries in the data collection, concussions were also a commonly documented injury in this ski and snowboard population (Table 2). The occurrence of concussion injuries in this population as well as possible effects on neurocognition must be considered given recent attention provided to this topic in the literature. There appears to be a relationship between age, gender and concussion outcomes including symptoms to component scores from ImPACT testing and postural stability. Iver-son et al demonstrated decreased performance on specific components of the ImPACT test, specifically verbal memory, visual memory, visual motor speed and reaction time after sustaining a concussion. Diminished performance in these component score categories may indicate delayed neurocognitive recovery and could impact physical performance as well. Deficits in neurocognitive measures such as sustained auditory attention, visual motor processing speed, reaction time and postural stability may hinder physical performance and could lead to increased risk of musculoskeletal injuries and concussion.

High school athletes appear to take longer to recover from concussion injury than collegiate athletes. Iver-son et al reported that 37% of concussed high school athletes were still clinically symptomatic on two or more neurocognitive measures reported on the ImPACT test including verbal memory, visual memory, and reaction time at 10 days after a concussion compared to impairments in visual motor speed that resolved in five days after sustaining a concussion in collegiate athletes. Covassin et al suggested that high school athletes had a poorer performance than college athletes on verbal and visual memory scores on the ImPACT test after sustaining a concussion injury. Their results suggest that on average, neurocognitive impairments may persists for 10-21 days after a concussion for high school athletes compared to 5-7 days for neurocognitive recovery in collegiate athletes. Meehan et al reported on a study of 2041 high school athletes and found that up to 23% of concussed athletes continued to demonstrate difficulties on cognitive tasks three weeks after injury. Given the high percentage of concussion injuries in the study, special consideration of neurocognitive deficits in these ski and snowboard athletes with a history of concussion and the possible effect of these deficits on performance must be further examined, especially if compromised neurocognitive function may contribute to elevated injury risk.

Previous authors have identified delayed reaction time with injuries in the lower extremity with a defined prediction value (≥.565) based upon ImPACT reaction time composite scores. This prediction value represents the reaction time composite score.
in milliseconds for determining injury risk. In the case of the studies referenced, athletes who had a delayed reaction time, greater than 0.57 milliseconds, were found to be at greater risk for musculoskeletal injury. In comparison to the results, injured female and male athletes had an average reaction time of 0.61 and 0.62 ms, respectively. Non-injured female and male athletes had an average reaction time of 0.64 and 0.58 ms, respectively. These findings may indicate that a reaction time of 0.57 ms may not be a good predictor of injuries in the ski and snowboard population. Furthermore, interaction effects between genders and both injured and non-injured populations should be further investigated across different sports. The predictive nature of other composite scores within ImPACT has not been established.

Baillargeon et al provided evidence that sports concussion may specifically affect working memory processes in all age groups. However, adolescents displayed more cognitive impairments than children and adults after sustaining a sports related concussion. Previous authors have also demonstrated that gender may have an effect on recovery from a concussion. Covassin et al reported that after sustaining a concussion, female collegiate athletes demonstrated significantly worse on visual memory compared to males. Similarly, it has been reported that concussed female athletes had slower reaction times and more post-concussion symptoms compared to males. Gender differences in cognitive function after a concussion may be attributed to hormone differences specifically estrogen and progesterone, weak musculature, anatomic differences and cerebrovascular organization. With regards to gender, the study showed interaction effects between injured females and non-injured males in the categories of reaction time and visual motor speed. Injured female athletes in our study scored lower by 4.7% in the reaction time category. However, a history of concussion was not considered in this category during analysis.

Neurocognitive testing is an important component in both the assessment and management of sports-related concussion. Typically, baseline testing is used as a comparative measure to determine an athlete’s readiness to return to sport when neurocognitive function is assessed following a concussion. ImPACT was the neurocognitive testing platform used for baseline testing in this study and has been shown to be a valid measure for examining deficits in reaction time, processing speed, working memory, attention and concentration. In addition, ImPACT has shown specificity and sensitivity in identifying neurocognitive deficits following a concussion. For the purposes of this study, ImPACT scores were used solely to investigate possible differences between baseline scores and in-season injury occurrence.

Despite studies indicating the usefulness of ImPACT in identifying neurocognitive deficits following a concussion, the validity of baseline testing has and should be further examined. As previously mentioned, some of the athletes who initially met the inclusion criteria in this study had invalid test scores, likely due to either delayed or slower response times to tasks or completing the test too quickly. Subsequently, the data that did not meet validity criteria were excluded. There are some factors that must be considered when performing computerized neurocognitive assessment testing. Athletes may also intentionally score lower on baseline testing in order to score higher on follow-up testing should they sustain a concussion injury during the competitive season and possibly return to competition sooner. In addition, despite that ImPACT is widely used and accepted, reliability and validity of scores between age groups requires further investigation. It was determined that the age group of 14-17 would be used for this study due to it being the largest cohort within the local ski and snowboard club as well as consideration given to the cognitive development of adolescents who may not score as drastically than on testing during earlier adolescent years. A reliability study investigating the use of ImPACT within a similar cohort found that online baseline ImPACT testing is a stable measure of neurocognitive performance for high school athletes across a one-year time period. Furthermore, it was recommended that high school athletes complete updated baseline testing every two years to account for any changes in neurocognitive performance. While it was difficult to control for all the previously mentioned variables, data for athletes who did not complete baseline testing prior to the start of their competitive season was excluded from this study. Invalid
testing scores based upon generated ImPACT results for the cohort in this study were also excluded from data collection. In some of these cases, seasonal athletes had completed ImPACT testing at home prior to relocation to the training center. Lack of attention focused on testing due to cell phone music or television use while completing neurocognitive testing likely resulted in invalid scores.

Athletes presenting with various neurocognitive deficits may benefit from a rehabilitative program which integrates training strategies focused on improving reaction time, processing speed and ability to maintain postural stability in an environment which challenges balance and motor control. A rehabilitation program that addresses the neurocognitive deficits in a snowboard athlete has been outlined. The dynamic and aerial nature of disciplines within both snowboarding and alpine skiing as well as environmental factors must also be considered. While the results of our study did not find difference in reaction time with increased injury risk, it may be prudent to integrate reactionary training activities into pre-season conditioning and in-season strength and on-hill sessions to address any potential neurocognitive deficits that may exist. Furthermore, it may be useful for athletes to be evaluated for movement impairments, which may potentially increase their risk for musculoskeletal injury. Functional movement screening tools have been effectively used to identify compensatory movement patterns and increased injury risk in the athletic population. Strength and conditioning programs which combine elements of neurocognitive training and corrective exercise designed to address movement impairments may provide robust outcomes in both improving neurocognitive function and movement efficiency in the athletic population. The results of the study do not specifically indicate differences in neurocognitive testing components and injury risk, but rather interaction affects between genders. However, neurocognitive deficits recognized on ImPACT can be addressed in training programs, which consider both the musculoskeletal and neurocognitive components of injury in both genders in the ski and snowboard population. Further research is needed to determine whether this aforementioned training approach can improve neurocognitive function and decrease injury risk in the ski and snowboard population.

A limitation of this study is that athletes between the ages of 14-17 were utilized. Data for athletes younger than 14 or older than 17 was not included in the analysis and, thus limited the cohort size. Findings from this study cannot necessarily be generally applied to ski and snowboard athletes outside of the inclusionary age group. Previous research has also suggested that computer based neurocognitive testing such as the ImPACT test may not be as reliable and valid for younger athletes secondary to changes in cognitive function that occur with brain development. Computer based neurocognitive testing such as the ImPACT test are often utilized for efficiency and may provide better measurements of cognitive function related to reaction time and the speed of information processing. Furthermore, computerized neurocognitive testing also allows athletes to serve as their own control and the data can be compared to a baseline score if the test was taken prior to a concussion or data can also be compared to normative samples. However, normalized samples are often based on the older athletes and may be less generalizable to younger athletes. McCrory suggested that cognitive maturation may be greatest in those under the age of 15 years and then plateaus to an adult level of performance. This may suggest that comparing neurocognitive testing to baseline cognitive performance may be problematic with athletes less than 15 years of age. This may also support the need for more frequent baseline testing of younger athletes because their baseline function changes with age. Concussions and/or musculoskeletal injuries from seasons prior to 2009-12 were not considered as exclusionary criteria primarily due to lack of documentation records of these conditions prior to the 2009 season. This could be a limitation of this study as well since a plausible argument could be made that prior concussions and/or musculoskeletal injury could influence the likelihood of future injury as has been suggested in previous research. Additional research would be needed to support this theory as it applies to the population in this study. Lastly, another limitation of this study is that it is a retrospective study with a convenience sample. Future research should consider including ski and snowboard athletes from both the amateur and professional ranks, both within and outside of the age groups included in this study, in a prospective manner where both ImPACT results and
injury data can be compared from season to season within disciplines as opposed to a group of seasons collectively.

CONCLUSION
In summary, the current findings indicate an interaction between gender and injury status in the categories of reaction time and visual motor speed. More research is needed to determine whether a correlation between neurocognitive deficits and musculoskeletal injury exists in the ski and snowboard population. Future research should compare ImPACT results and injury data between seasons and among a wider range of age groups and disciplines. Further investigation is needed to determine if interaction effects exist between genders and both injured and non-injured athletes within neurocognitive testing in various sports.

REFERENCES


ABSTRACT

Background: Body armor is credited with increased survival rates in soldiers but the additional axial load may negatively impact the biomechanics of the spine resulting in low back pain. Multiple studies have found that lumbar stabilization programs are superior to generalized programs for patients with chronic low back pain. It is not known if such programs produce objective changes in trunk muscle function with wear of body armor.

Hypothesis/Purpose: An eight-week core stability exercise program would result in a larger improvement in physical endurance and abdominal muscle thickness than a control intervention. The purpose of this study was to assess the effectiveness of an eight-week core stability exercise program on physical endurance and abdominal muscle thickness with and without wear of body armor.

Study Design: Randomized controlled trial

Methods: Participants (N = 33) were randomized into either the core strengthening exercise group or the control group. Testing included ultrasound imaging of abdominal muscle thickness in hook-lying and standing with and without body armor and timed measures of endurance.

Results: There were statistically significant group by time interactions for transversus abdominis muscle contraction thickness during standing, both with (p = 0.018) and without body armor (p = 0.038). The main effect for hold-time during the horizontal side-support (p = 0.016) indicated improvement over time regardless of group. There was a significant group by time interaction (p = 0.014) for horizontal side-support hold-time when compliance with the exercise protocol was set at 85%, indicating more improvement in the core stabilization group than in the control group.

Conclusion: Performing an eight-week core stabilization exercise program significantly improves transversus abdominis muscle activation in standing and standing with body armor. When compliant with the exercises, such a program may increase trunk strength and muscle endurance.

Levels of Evidence: Therapy, Level 2b

Key Words: Body armor, lumbar stabilization, transversus abdominis

1 U.S. Army-Baylor University Doctoral Program in Physical Therapy, Fort Sam Houston, TX, USA
2 Center for Performance & Clinical Research, Walter Reed National Military Medical Center, Bethesda, MD, USA

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CORRESPONDING AUTHOR
Carrie W. Hoppes, PT
828 East Arcadia Drive
Pittsburgh, PA 15237
E-mail: cwh27@pitt.edu
INTRODUCTION
Back pain is a significant concern in the military due to attrition from a unit during deployment or training as well as increased medical costs. Back pain has been identified as the leading non-battle injury that occurred in the theater of operations during Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF).\textsuperscript{1} Low back pain was the primary complaint of 53% of soldiers in OIF/OEF who presented to a military pain management center,\textsuperscript{1} a leading cause of medical evacuation in OIF/OEF,\textsuperscript{2} and the second most frequent reason for health care visits of active duty military personnel.\textsuperscript{3} From 2004 to 2007, only 13% of 1,410 consecutive soldiers medically evacuated to Germany for two weeks of rehabilitation for back pain returned to their deployed unit.\textsuperscript{4} Not just a condition affecting the U.S. military, the need for medical consultation and treatment due to low back pain was 2.4 times greater for men in the Finnish military than in age-matched controls not in the military.\textsuperscript{5}

Deployed military personnel often carry more than 45 kg of gear and equipment while on foot patrols.\textsuperscript{6} The Kevlar® vest alone weighs 9.5 kg in its minimum configuration and 14 kg in its standard configuration.\textsuperscript{7} Body armor (Figure 1) is standard military issued equipment that is vital to the safety of personnel, however, it may cause increased pain and disability due to increased load carriage. There is a positive correlation between increased musculoskeletal pain and soldiers who wore body armor for more than four hours each day.\textsuperscript{8} Additionally, many soldiers reported that they attributed their back pain to wearing body armor rather than specific job-related tasks or physical training with their units.\textsuperscript{8} Reports of low back pain were also higher with loads of 45% body weight in active duty Marines.\textsuperscript{8} Wear of body armor and carrying a ruck sack, ammunition, and weapons can comprise such a load. Postural adaptations, such as increased trunk flexion and forward head posture, are contributing factors to back pain\textsuperscript{8,10} and may be exacerbated by wearing body armor, especially if such postures are unable to be counteracted by adequate core stability.

There is evidence to suggest that the recurrence of back pain can be reduced with core stabilization exercise programs.\textsuperscript{11-15} Among individuals who had acute low back pain, those who performed multifidus-specific exercises had a 30% injury recurrence rate compared to the control group of 84% after one year.\textsuperscript{11} Additionally, improving core strength has been shown to help prevent injury among firefighters by 42% and reduced lost time from injuries by 62%.\textsuperscript{16} The ability to quantitatively measure muscle thickness under loading would be valuable to clinicians in order to assess the effectiveness of core stabilization treatment programs and could aid in return to work decisions as abdominal muscle thickness has been shown to correlate with strength.\textsuperscript{17} Ultrasound (US) imaging has been used to measure abdominal muscle thickness with subjects in multiple positions\textsuperscript{18} or with the muscles under load.\textsuperscript{19} Imaging the abdominal muscles with and without wear of body armor may provide the clinician with a greater understanding of how the core muscles perform under increasing functional demands.

There is limited available literature on core stabilization effects on muscle activation with wear of body armor in the military population. The purpose of this study was to assess the effectiveness of an eight-week core stability exercise program on physical endurance and abdominal muscle thickness with and without wear of body armor. It was hypothe-
sized that there would be a difference in core muscle engagement when standing with body armor as compared to lying supine or standing unloaded. Additionally, it was hypothesized that an eight-week core stability exercise program would result in a larger improvement in physical endurance and abdominal muscle thickness than a control intervention.

**METHODS**

**Participants**
Participants were all active duty U.S. service members who responded to recruiting advertisements in the Army Medical Department Center and School at Joint Base San Antonio, Texas. Study inclusion criteria consisted of greater than 18 years of age, able to perform standard physical training, and no conditions that may have affected standing balance. Exclusion criteria included presence of low back pain and inability to perform the prescribed core stability regimen. The study protocol was approved by the Institutional Review Board of Brooke Army Medical Center. All participants provided informed consent prior to study enrollment. Demographic characteristics for all participants are listed in Table 1.

A parallel group, randomized controlled trial was conducted. It was determined that a sample size of 16 participants in each group (using an effect size of 45 seconds based on the extensor endurance test) was needed to achieve 80% power with alpha set at 0.05. Allowing for attrition, thirty-six active duty men and women over the age of 18 were enrolled from July 2012 to February 2013.

**Procedures**
During the initial appointment, participants were screened for the absence of low back pain and to ensure they were otherwise physically appropriate to participate in the study. Lumbar range of motion was observed and a bilateral quadrant test was performed to ensure pain-free, active motion within a normal physiological range and with provocation (positioning into combined extension and rotation). Participants were randomized into either the core strengthening exercise group or the control group. The randomization process was performed using a random number generator and allocation concealment was preserved until the moment of group assignment.

Participants were evaluated initially and after eight weeks. Previous research has determined that initial changes in muscle strength are related to neural factors, such as increased neural innervation. After three to five weeks of strength training both increased neural innervation and hypertrophy of muscles account for strength gains, however, hypertrophic changes are the primary means of strength gains after that time. Therefore, the time frame of eight weeks was used to capture both neural and hypertrophic changes that could occur in muscle strength.

The measures during the pre- and post-intervention assessments included ultrasound imaging of abdominal muscle thickness with and without wear of body armor and timed physical endurance tests. Examiners were blind to the participants’ group assignment.

**Ultrasound Imaging**
Ultrasound imaging was used to measure the muscle thickness of the transversus abdominis (TrA) and internal oblique (IO) at rest and with the TrA preferentially contracted. The imaging took place at both the initial and final assessments. The subject’s left side was imaged just superior to the iliac crest.

| Table 1. Baseline demographics for the control and exercise groups |
|-------------------|-----------------|
|                  | Control Group   | Exercise Group  |
| Sex              | 8 Male, 10 Female | 8 Male, 8 Female |
| Age*, years      | 27 ± 5          | 29 ± 5          |
| Weight*, kg      | 70.53 ± 15.42   | 70.86 ± 10.83   |
| Height*, m       | 1.73 ± 0.11     | 1.73 ± 0.12     |
| BMI*, kg/m²      | 23.27 ± 2.88    | 23.66 ± 2.59    |

*Values are mean ± SD
to standardize data collection. In order to measure the muscles consistently, the anterior fascia of the TrA was aligned with the edge of the US imaging screen. The US technician read directly from a script to ensure that all participants received standardized instructions. During imaging, the US technician cued the participant with one of three methods (the abdominal drawing in maneuver, cutting off the flow of urine, or closing the anal sphincter) in order to preferentially activate the TrA. The method that best activated the TrA was used for that participant at both initial and final assessments and was used while doing all of the prescribed exercises for participants in the core strengthening exercise group. Three trials of each position were imaged (hook-lying, standing, and standing with body armor) as previously described by Hoppes et al. This method has shown high intrarater reliability (ICC (3,3) = 0.90 to 0.98) but poor to fair interrater reliability (ICC (2,1) = 0.39 to 0.79) when measuring abdominal muscle thickness on the same day. The longitudinal reliability of this method is not known. Therefore, the same examiner, who had undergone approximately 3-4 hours of hands-on training with the US machine and protocol, performed all US imaging. The order of US imaging was randomized for each participant to prevent order effects such as fatigue.

In the hook-lying position, participants were supine with their knees bent and feet flat to minimize lordosis. In standing, participants lined up the base of each of their fifth metatarsals inside a 30 cm tile on the floor. The time from initiation of standing or standing with body armor until US imaging was approximately two minutes. The body armor used was the same model worn by service members currently engaged in combat operations (Point Blank Enterprises, Inc., Pompano Beach, FL). The manufacturer modified the body armor under the direction of the research team in order to allow access to the abdomen for US imaging while maintaining the structural integrity and weight distribution caused by the Ballistic Panels, Small Arms Protective Inserts, and Enhanced Small Arms Protective Inserts. All inserts were training grade but still possessed the same weight and size as the combat-grade inserts.

The percent change in thickness for each muscle was determined based on the average of three trials for each position according to the equation below and multiplied by 100%.

$$\Delta t = \left( \frac{t_{TrA\text{ contracted}}}{t_{Total\ AB\ contracted}} \right) - \left( \frac{t_{TrA\ resting}}{t_{Total\ AB\ resting}} \right)$$

This equation calculates the relative change in the proportion of the TrA relative to the total lateral abdominal muscle thickness, with higher values indicating more change in the TrA thickness and lower values indicating more change in IO and external oblique thickness.

**Physical Testing**

Participants completed a series of three timed endurance tests; the order of which was randomized for each participant to prevent order effects. Examiners did not count aloud or provide verbal encouragement during the test. The three timed physical endurance tests were the horizontal side support, extensor endurance, and flexor endurance. The participants were asked to hold each static position until they were either too fatigued to continue or until 240 seconds had elapsed. A rest period of no less than two minutes was provided in between each endurance test.

The extensor endurance test was used to measure the endurance of the erector spinae muscle group, including the lumbar multifidus. This test, also known as the Biering-Sorensen test, has predictive and discriminative validity for nonspecific low back and has high reliability. During this test of extensor muscle endurance, participants were required to lie prone on a treatment table with the upper half of their body positioned off the edge and resting on the pull-out head rest while they were supported by straps in three locations (ankles, knees, and greater trochanters). The participants were instructed to hold their torso in neutral alignment, parallel to the floor, after the pull-out head rest was removed. If they deviated greater than ten degrees from neutral they received one verbal cue to realign, and if they faltered again, the test was terminated.

The horizontal side support, which purports to measure the endurance of the TrA muscle, started with the participant laying on their right side with legs
extended and their feet stacked so their body was aligned. Participants were instructed to lift their hips from the ground and support themselves on their right elbow so that their body maintained a straight line. They were also instructed to hold their left arm across their chest with the left hand placed on the right shoulder. The same position was repeated on the left side. If this position could not be maintained, the participant was verbally prompted to maintain the position, if this could not be achieved, the test was terminated. The horizontal side support is known to have good to excellent interrater agreement for both the right (ICC 0.89-0.91) and left (ICC 0.82-0.91) sides.27 A minimal clinically important difference has not been established for the horizontal side support (or side bridge test), but McGill et al. have proposed ratios between extensor, flexor, and lateral flexor core muscle groups in healthy adults.20

The flexor endurance test measured abdominal muscle strength. This was a modification of a commonly performed exercise in Army physical training, known as the bent-leg raise.28 During this test, participants were supine and lifted both legs 15 cm off the surface of the table. If they deviated greater than 5 cm they were prompted to return to the original position. If they faltered again, the test was terminated.

**Intervention**

Upon completion of the initial assessment, the intervention group (N = 16) was assigned a core stabilization exercise regimen to perform five days per week for eight weeks. The core stabilization regimen used in this study was adapted from the Prevention of Low Back Pain in the Military (POLM) program.29 The regimen consisted of seven exercises, each performed for one minute (Appendix A). The program called for slow activation of the deep core muscles using the abdominal drawing-in or similar maneuver with little to no trunk movements. All exercises were performed with body weight and fewer repetitions than traditional exercise programs. At the initial session, the intervention group was given a pamphlet of detailed instructions, verbal and tactile feedback while first performing the exercises, and a DVD with a model performing the proper technique for each exercise. The pamphlet included a training log so the participants and examiners were able to track performance of the exercises. After four weeks, the core stabilization group was contacted by phone to determine compliance with the exercise program. At this time, participants were offered verbal reinforcement of the exercises if necessary. When the participants returned for the eight-week follow up, the US imaging and endurance tests were repeated. The training log was collected from each participant but the participants were allowed to keep the pamphlet and exercise DVD.

Upon completion of the initial assessment, the control group was instructed to continue their previous individual workout routines and to avoid starting any new exercise programs. They were not participating in organized physical training with their units and were not participating in the POLM program. At the eight-week follow up, the US imaging and endurance tests were repeated.

**STATISTICAL METHODS**

Descriptive statistics (mean and standard deviation) were calculated for demographic variables as well as US imaging and physical testing measurements. Six 2 x 2 mixed model analyses of variance were conducted on muscle thickness as a function of time and group using IBM SPSS Statistics 22 (Chicago, IL). The within-participants independent variable was time with two levels (baseline and after eight weeks). The between-participants independent variable was group with two levels (control and core strengthening exercise). The Greenhouse-Geiser test was interpreted as a safeguard against type I error. An intention to treat analysis was used, with baseline data on dropouts carried forward to estimate eight-week status.

**RESULTS**

A total of 34 people were enrolled and 33 (17 men, 16 women; average age 28 ± 4.9 years) completed the study (Figure 2). A statistically significant group by time interaction for TrA activation was found during standing, both with \( F(1,31) = 6.25, p = 0.02 \) and without body armor \( F(1,31) = 4.70, p = 0.04 \). The change in thickness of the contracted TrA muscle in the exercise group while standing and standing with a load was significantly greater than the control group after the eight-week core stabilization program (Figure 3).
The exercise group increased their TrA activation by an average of 24.6% while standing and 35.5% while standing with body armor (Table 2). Although the other muscle contraction thicknesses were not significantly different between the groups after eight weeks, the IO muscle showed a similar trend to the TrA.

Time by group interactions for endurance hold-times were not statistically significantly different. However, there was a main effect for horizontal side-support ($F(1,31) = 6.54, p = 0.02$) which indicated an improvement in ability to hold the position regardless of group. Moreover, there was a significant group by time interaction ($F(1,31) = 7.05, p = 0.01$) for the horizontal side support hold-time when compliance with the exercise protocol was set at greater than 85% (Figure 4). Six subjects in the intervention group, or one-third, achieved 85% or greater compliance with the core stabilization exercise regimen. Those compliant with the exercise protocol increased their ability to hold the horizontal side support from 85.9 ± 41.9 to 112.3 ± 57.7 seconds (mean ± standard deviation).

**DISCUSSION**

The results of this study suggest that performing an eight-week core strengthening exercise program significantly improves TrA muscle activation, assessed by a change in muscle thickness in standing and
standing with increased load. For the military population, the implication of this finding may be to offset the physical detriments caused by wearing body armor as activation of the core musculature may reduce excessive mobility and loading of the spine. This study was not designed to serially assess muscle thickness, so it is not known if muscle thickness varies with time in standing. Unpublished thesis work using surface electromyography of the internal and external oblique muscles found no change in muscle activation with 30 minutes of prolonged standing. Therefore, the authors do not think that standing would change the measures of muscle thickness over time and the overall implications of the current study.

Not only may an eight-week core stabilization program increase core muscle activation but such a program may also increase core muscle endurance. Although both the control and exercise groups showed significant improvement in performing the horizontal side support, the exercise group showed statistically greater improvements after eight weeks if the participants had higher compliance with the exercise program. Multiple studies have found that lumbar stabilization programs are superior to generalized programs for patients with chronic low back pain. The eight-week core stabilization program used in this study was found to have a positive effect, though limited, on core endurance. Future studies should explore if such changes in core endurance translate to decreasing the incidence of low back pain and injury related to wearing body armor in the military population.

One limitation of the current study was the compliance rate with the exercise program. Only one participant demonstrated 100% compliance with the exercise program. The lack of compliance by other participants with the prescribed exercises may have negatively affected the endurance test results. For example, when compliance was set at greater than 85%, the length of time the participants were able to hold the horizontal side support significantly increased for the exercise group after eight weeks. The increased endurance hold-time indicates more improvement in the core strengthening group than in the control group when the participants performed the stabilization program as indicated. It is possible that similar results would also occur with the other endurance tests if compliance was higher.

Additionally, there was variability in the measure of the mean percent muscle activation during TrA contraction at baseline and after an eight-weeks for the control and exercise groups, as evidenced by the standard deviations reported in Table 2. This variability

| Table 2. Mean percent muscle activation with standard deviation during transversus abdominis (TrA) contraction at baseline and after eight weeks for the control and exercise groups. |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|
|                               | Control Group   | Control Group   | Exercise Group  | Exercise Group  |
|                               | Initial         | Final           | Initial         | Final           |
| TrA in Hook-lying             | 83.16 (47.44)   | 88.21 (52.97)   | 69.68 (35.14)   | 91.04 (45.12)   |
| TrA in Standing               | 57.44 (32.63)   | 47.58 (36.86)   | 42.15 (21.24)   | 66.74 (39.43)   |
| TrA in Body Armor             | 73.74 (46.39)   | 63.17 (38.87)   | 45.45 (36.07)   | 80.71 (46.06)   |

Figure 4. Average difference in endurance test hold-time for the compliant exercise group (greater than 85% adherence to the core strengthening regimen) and the control group. Horizontal side support (HSS), extensor endurance (EXT), and flexor endurance (FLEX).
may be due to consistency of US transducer placement between the pre- and post-intervention assessments. The authors attempted to limit systematic error by conducting US imaging training, using standardized protocols, and referencing anatomical landmarks. Measurement variability introduced by systematic error would certainly negatively impact the ability to record true changes in muscle activation over time. Figure 3 depicts the difference in percent activation of the TrA in three positions (hook-lying, standing, and standing with body armor) for the exercise group and the control group after 8 weeks. In this figure, the exercise group showed increased activation while the control group showed a trend toward decreased activation. This change in the control group may reflect measurement variability as discussed previously or it may reflect true change. As many of the participants were in academic training programs during the study, they may have become more sedentary over the 8 weeks. These changes were not statistically or clinically different than the baseline measurements.

A third limitation was that while all the participants were active duty personnel, most did not wear body armor regularly, which could limit generalization of the results to other types of U.S. military personnel. There was also no long term follow up with the participants, which would be helpful in determining if the exercise program has long term effects regarding injury prevention. Future studies should incorporate trials of the eight-week exercise program with soldiers who train with body armor regularly or who are deployed, and should include long-term outcome assessments regarding injury rates.

**CONCLUSIONS**

The results of the current study demonstrate an increase in core muscle activation while wearing body armor and a limited increase in core muscle endurance following an eight-week core stabilization exercise program. Future research is required to determine if this program could be used to decrease the low back pain and injury rates associated with wearing body armor in the military population, in turn leading to decreased attrition rates and medical costs.

**REFERENCES**


30. Soliday KM. Effects of Prolonged Standing on Ground Reaction Force Control and Core Muscle Activation, Colorado State University; 2015.
## APPENDIX A

<table>
<thead>
<tr>
<th>Core Stabilization Exercise</th>
<th>Instructions Provided to Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal Drawing-In Maneuver Crunch</td>
<td><strong>Start Position:</strong> Lie on back with arms crossed over chest. <strong>Movement:</strong> Pull lower abdominal muscles up and into spine. Slowly curl trunk off the ground until just the base of shoulder blades are touching ground, hold for 10 seconds and then slowly curl trunk back down. Perform 6 repetitions in 1 minute.</td>
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| Right Horizontal Side Support | **Start Position:** Lie on right side with legs straight and feet stacked. Upper body should be supported with right elbow; cross left arm across chest (left hand on right shoulder). **Movement:** Pull lower abdominal muscles up and into spine. Lift right side off the ground so body weight is supported through right elbow and feet. Go up in 5 counts and down in 5 counts. Perform 6 repetitions in 1 minute. |
**Left Horizontal Side Support**

Start Position: Lie on left side with legs straight and feet stacked. Upper body should be supported with left elbow; cross right arm across chest (right hand on left shoulder).

Movement: Pull lower abdominal muscles up and into spine. Lift left side off the ground so body weight is supported through left elbow and feet. Go up in 5 counts and down in 5 counts. Perform 6 repetitions in 1 minute.

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**Prone Plank**

Start Position: Lie on stomach with legs straight and feet together. Upper body should be supported with elbows and forearms.

Movement: Pull lower abdominal muscles up and into spine. Lift entire body off the ground so body weight is supported through elbows/forearms and toes. Pull shoulders down and back (don’t slump). Hold for 15 seconds in “up” position then slowly return to start. Perform 4 repetitions, 15 seconds each.
**Supine Shoulder Bridge**

Start Position: Lie on back with knees bent 90 degrees, feet flat on the ground.

Movement: Pull lower abdominal muscles up and into spine. Lift buttocks off the ground in a straight line (knees, hips, shoulders) supporting weight with shoulders and feet. Straighten right leg and hold for 5 seconds; then slowly bend right knee (5 seconds) and place right foot flat on the ground. Repeat with left leg. Slowly lower buttocks back to start position to complete one repetition. Perform 4 repetitions in 1 minute.

**Quadruped Alternate Arm and Leg**

Start Position: On all fours, knees under hips and wrists under shoulders.

Movement: Pull lower abdominal muscles up and into spine. Simultaneously stretch out right arm and left leg for a 3 second count, hold for 5 seconds (do not arch back), then slowly return to start position. With each repetition, alternate opposite arm and leg. Perform 4 repetitions in 1 minute.
Hip Flexor Squat ("Wood-Chopper")

Start Position: Stand with feet shoulder width apart, arms overhead (hands clasped).

Movement (2-count): Pull lower abdominal muscles up and into spine.

ONE: Squat down, move arms down between knees, keep heels on the floor, stick out buttocks. Do not allow knees to go in front of toes.

TWO: Stand up, moving arms overhead, coming up onto toes. Do not arch back. End at start position on the last rep.

Perform repetitions of 2-count exercise for 1 minute.
ABSTRACT

Introduction: Dynamic clinical tests of hip strength applicable on patients, non-athletes and athletes alike, are lacking. The aim of this study was therefore to develop and evaluate the reliability of a dynamic muscle function test of hip external rotation strength, using a novel device. A second aim was to determine if gender differences exist in absolute and relative hip strength using the new test.

Methods: Fifty-three healthy sport science students (34 women and 19 men) were tested for hip external rotation strength using a device that consisted of a strap connected in series with an elastic resistance band loop, and a measuring tape connected in parallel with the elastic resistance band. The test was carried out with the subject side lying, positioned in 45° of hip flexion and the knees flexed to 90° with the device firmly fastened proximally across the knees. The subject then exerted maximal concentric hip external rotation force against the device thereby extending the elastic resistance band. The displacement achieved by the subject was documented by the tape measure and the corresponding force production was calculated. Both right and left hip strength was measured. Fifteen of the subjects were tested on repeated occasions to evaluate test–retest reliability.

Results: No significant test–retest differences were observed. Intra–class correlation coefficients ranged 0.93–0.94 and coefficients of variation 2.76–4.60%. In absolute values, men were significantly stronger in hip external rotation than women (right side 13.2 vs 11.0 kg, \(p = 0.001\), left side 13.2 vs 11.5 kg, \(p = 0.002\)). There were no significant differences in hip external rotation strength normalized for body weight (BW) between men and women (right side 0.17 kg/BW vs 0.17 kg/BW, \(p = 0.675\), left side 0.17 kg/BW vs 0.18 kg/BW, \(p = 0.156\)).

Conclusions: The new muscle function test showed high reliability and thus could be useful for measuring dynamic hip external rotation strength in patients, non–athletes and athletes. The test is practical and easy to perform in any setting and could therefore provide additional information to the common clinical hip examination, in the rehabilitation or research setting, as well as when conducting on–the–field testing in sports.

Level of evidence: 3

Keywords: Dynamic test, hip external rotation, muscle strength, reliability
INTRODUCTION
Adequate hip strength is important throughout life. The ability of the elderly individual to perform chair rises and stair and level walking, for example, is dependent on sufficient levels of hip strength.1 Also, hip strength is important to a wide range of athletic and sporting activities (e.g., soccer, gymnastics, weight lifting).2 Moreover, impaired hip muscle strength – particularly of the hip external rotators and abductors – have been associated with various musculoskeletal disorders, both in the hip region, such as femoroacetabular impingement (FAI),3 as well as distal to the hip (patellofemoral pain and iliobibial band syndrome, for example).4,5 Additionally, the role of hip strength in the etiology of anterior cruciate ligament (ACL) injuries has received increased attention in recent years.6,7 In a recent prospective study, hip external rotation and abduction strength were found to be significantly lower in ACL injured athletes compared with noninjured athletes.8 The authors concluded that measures of pre-season hip abduction and external rotation strength independently predicted future ACL injury status in competitive female and male athletes.8 Also, studies have reported deficits in isokinetic hip strength following ACL reconstruction.9-14 Further, several studies have been performed on gender differences in the relationship between hip strength and lower extremity injuries over the past decade.15-17 Taken together, information about hip muscle performance through strength testing is of paramount importance in orthopedic practice, sports medicine, sports, as well as in research.

When it comes to clinical tests of hip strength, no particular type of test could be considered as the gold standard measure. Manual hip muscle strength testing is commonly used for the assessment of muscle strength. In the absence of severe weakness, however, it is relatively inaccurate and unreliable.18 Further, isometric handheld dynamometry is used as an assessment tool in the clinic and also in research for the measurement of hip strength.19 This test method may have drawbacks in terms of difficulties to accurately maintain the placement of the dynamometer, and at the same time stabilize the subject. This is especially true when the “break test” procedure is used, where the examiner applies resistance, trying to force the hip to “break” its hold.20 Further, it was recently noted that isometric hip strength assessment using handheld dynamometry was subject to intertester bias when testers were of different sex and strength.21 Taken together, there appears to be a lack of clinical muscle function tests that measure hip strength dynamically and, furthermore, where the examiner is not directly involved, i.e., applies resistance. Since most physical activity during work, sports and leisure time is dynamic in its nature, dynamic strength tests could seem to be more valid than isometric ones. The aim of this study was therefore to develop and evaluate the reliability of a dynamic muscle function test of hip external rotation strength, using a novel device. A second aim was to determine gender differences in absolute and relative hip strength using the new test.

METHODS

Subjects
Fifty-three sport science students (34 women and 19 men) volunteered to participate in the study. Table 1 displays the subject demographics. All subjects were healthy and active in various sports training, on either a recreational or competitive level, with asymptomatic back, hip and knee function. Subjects that reported any musculoskeletal disorders of the trunk or lower extremities, or any neurological conditions were excluded. Information regarding the study was given to all subjects and informed consent was obtained. Approval for the study was granted from the Regional Ethics Committee.

Development of the test device
A device was developed that consisted of a strap (Arno, Sweden) connected in series with an elastic resistance band loop (model medium rubber band, Refit, Sweden), and a measuring tape, cut off at 50 cm length (model 150 cm, Profi, Germany) connected in parallel with the elastic resistance band (Figure 1). Using the trial and error method
for solving problems, the elastic resistance band loop was doubled for appropriate resistance and proper length (approximately 14 cm). The strap was attached to the elastic resistance band with a quick link (Swedol, Sweden). The first part of the measuring tape was permanently fastened on the strap on one side of the rubber band, using a rivet. The middle part of the measuring tape was attached to the strap on the other side of the rubber band with a clip so that it could run along the strap, as the rubber band extended.

Experimental set-up
The test was carried out with the subject side lying, positioned in 45° of hip flexion and the knees flexed to 90°, with the device firmly fastened proximally across the knees. The subject’s shoulders, hips and feet were aligned (Figure 2). With the top leg, the subject then exerted maximal hip external rotation force against the device, thereby extending the elastic resistance band (Figure 3). The displacement achieved by the subject was documented in mm by the tape measure. Both right and left hip strength was measured, and the test administered in random order to each subject. One practice trial and two experimental trials with one minute of rest between trials were performed. The best value of the two experimental trials was recorded. Before the testing session, each subject performed a five minute warm-up that incorporated movements for the lower extremity including squats, forward lunges, lateral squats and toe raises. All hip strength measurements were obtained by a single examiner, a physical therapist that had 25 years of experience of muscle strength testing. Because of logistical factors, the examiner conducting the test was not blinded as regards to the results of the test.

Conversion of elastic resistance band displacement to force
The extension of an elastic resistance band is proportional to the force, thus there is a linear relationship between the applied force and the resulting extension, known as Hooke’s law.22 Thus in order to investigate the corresponding force production, based on the distance achieved by the subjects, the elastic resistance band loop was hanged from a stand. At the lower end a 5 kg weight plate (Eurosport Fitness,
Sweden) was placed and the length of the rubber band was measured using the tape measure. More weight plates were then added in increments of 2.5 kg. The starting weight (5 kg) resulted in less displacement than what the weakest of the subjects achieved and the end weight was 17.5 kg which resulted in slightly greater displacement than the result of the strongest subject. A load-versus-displacement plot showed a strong linear relationship, i.e. the increase in length corresponded to a progressive increase in the elastic resistance. Using the plot, it was possible to return interpolated results for any given value.

Test occasions
Fifteen of the subjects (10 women and five men) were tested on repeated occasions (seven days apart) to evaluate test–retest reliability. All testing of the subjects was performed using the same procedure for both occasions.

Statistical methods
The results are presented as means with SDs. To estimate the test–retest reliability of the test of hip strength, intraclass correlation coefficient (ICC) with the two–way random effects model of the measurements with 95% confidence interval (CI) were used. Further, within–subject variation was determined using typical error expressed as a coefficient of variation (CV). A paired samples t–test was used to detect significant test–retest differences. Differences in performance between the women and the men for the test of hip strength were analyzed using independent–samples t–test. The significance level was set at \( p < 0.05 \).

RESULTS
Descriptive characteristics of the subjects are presented in Table 1. The hip external rotation strength test results on the different test occasions are presented in Table 2. No significant test–retest differences were observed in the scores of the subjects that were tested on repeated occasions (right side 11.9 ± 2.2 vs 12.1 ± 2.3 kg, \( p = 0.126 \)), left side 11.7 ± 2.1 vs 12.2 ± 2.4 kg, \( p = 0.109 \)). ICCs ranged 0.93–0.94, CIs 0.80–0.98 and CVs 2.76–4.60%. Gender differences in hip strength are shown in Table 3. In absolute values, men were on average significantly stronger in hip external rotation than women (right side 13.2 ± 1.7 vs 11.0 ± 2.0 kg, \( p = 0.001 \)), left side 13.2 ± 1.4 vs 11.5 ± 2.0 kg, \( p = 0.002 \)). On average, there were no significant differences in hip external rotation strength normalized to body weight (BW) between men and women (right side 0.17 ± 0.02 kg/BW vs 0.17 ± 0.03 kg/BW, \( p = 0.675 \)), left side 0.17 ± 0.02 kg/BW vs 0.18 ± 0.03 kg/BW, \( p = 0.156 \)).

DISCUSSION
The main findings of this study were that the new clinical muscle function test for assessment of dynamic hip external rotation strength showed high reliability and proved to be applicable on young healthy subjects, active in various sports training, on either a recreational or competitive level. In clinical practice, reliable evaluation tools that measure dynamic hip strength have been lacking. In this study a novel way to measure muscle strength in the hip using an elastic resistance band loop and a measuring tape was therefore developed. The test can be readily used for example by an orthopaedist or a physiotherapist in the clinic, or an athletic trainer.

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**Table 2. Hip External Rotation Strength Test Results in Kilograms for the Right and Left Side on the Different Test Occasions (n=15). Expressed as Mean (± SD).**

<table>
<thead>
<tr>
<th></th>
<th>Right side</th>
<th>Left side</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st test</td>
<td>11.9 (±2.2)</td>
<td>11.7 (±2.1)</td>
</tr>
<tr>
<td>2nd test</td>
<td>12.1 (±2.3)</td>
<td>12.2 (±2.4)</td>
</tr>
<tr>
<td>ICC</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.80–0.98</td>
<td>0.81–0.98</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.76</td>
<td>4.60</td>
</tr>
<tr>
<td>t-value</td>
<td>0.126</td>
<td>0.109</td>
</tr>
</tbody>
</table>

**Table 3. Gender Differences in Hip Strength. Expressed as Mean (± SD).**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women</th>
<th>Men</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right side</td>
<td>Left side</td>
<td>Right side</td>
<td>Left side</td>
<td>Right side</td>
<td>Left side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absolute (kg)</td>
<td>Absolute (kg)</td>
<td>Relative (kg/BW)</td>
<td>Relative (kg/BW)</td>
<td>Absolute (kg)</td>
<td>Absolute (kg)</td>
<td></td>
</tr>
<tr>
<td>HER</td>
<td>11.0 (±2.0)</td>
<td>11.5 (±2.0)</td>
<td>0.17 (±0.03)</td>
<td>0.18 (±0.03)</td>
<td>13.2 (±1.7)*</td>
<td>0.17 (±0.02)</td>
<td></td>
</tr>
</tbody>
</table>

*Different from women, \( p < 0.05 \).

**Abbreviations:** SD, standard deviation; ICC, intraclass correlation coefficient; CV, coefficient of variation.
or a strength and conditioning coach in a gym, as it is simple, non-expensive and does not require laboratory equipment. Further, this quick and easy test could be systematically implemented in different research projects allowing for large groups of athletes and patients to be followed prospectively. This would in turn improve the possibilities to answer questions such as the effect of strength training during FAI-rehabilitation and the role of hip muscle strength in the etiology of ACL injuries. Also, the new hip external rotation strength test could be used as a complement to the common strength tests (e.g., thigh muscle strength tests) performed before return to sport after ACL reconstruction.

Studies have been performed on the properties of elastic bands used in exercise programs,25-27 noting that elastic rubber bands provide consistent, linear, and predictable increase in force with elongation. In the present study, all subjects were measured using the same rubber band. Because the rubber band was doubled and of a heavy-duty type it was only moderately stretched during testing. Therefore, the amount of degradation to the rubber band compound was probably negligible. A rubber band will, however, change its mechanical properties over time especially if heavily used. So for purposes of testing it should be replaced on a regular basis. It is also important to choose a rubber band that is strong enough to be only moderately and not maximally stretched during testing, thereby extending the band's longevity and precision.

Researchers, orthopedists, physiotherapists and strength and conditioning coaches have a variety of modes available for strength testing.28 Strength testing using elastic bands seems to fall into the isotonic category even though the resistance is not constant. The isotonic subcategory term ‘variable resistance’ is used when the resistance throughout the range of motion is varied, for example by an irregularly shaped camwheel or a lever arm.29 This definition – ‘isotonic variable resistance’ – would apply also for rubber bands where the level of resistance varies according to the force/extension relationship.

Values of reliability for the isotonic, variable resistance hip muscle function test were high (ICC 0.93–0.94 with narrow CIs, CV 2.76–4.60%) and of the same order of magnitude or higher as those for isokinetic30 (ICCs ranging from 0.55 to 0.76) and isometric21 (ICCs ranging from 0.82-0.91) modes of hip strength testing. In clinical practice and when conducting on-the-field testing in sports the new dynamic hip strength test might therefore be the preferred choice over isokinetic or isometric measurements.

Although it was not the main aim of the study, gender differences in hip strength were analyzed using both absolute and body weight normalized strength data to compare strength differences between women and men. In the present study, the women displayed 85% of the men’s absolute hip strength. There were, however, no significant differences in mean hip external rotation strength normalized for body weight between men and women. This result is in contrast with Cowan and Crossley31 who observed lower hip external rotation strength relative to body weight in young and healthy females compared with males. A possible explanation for this contradictory finding is that the subjects’ isometric rather than isotonic strength was measured in the study by Cowan and Crossley.31

The relatively large sample size is a strength of this study, and the high reliability values for the test are encouraging. The generalizability of the present study, however, is limited to healthy, active young adults. Further studies on e.g., patients with different knee and hip injuries, using the newly developed muscle function test of dynamic hip external rotation strength, are therefore desirable. Also, the question of the validity of the new measurement should be addressed. A criterion validity test comparing the new device with “gold standard” would have been desirable. However, no isotonic “gold standard” test of hip strength exists today in the clinical setting. When it comes to the movement of the new test and the position of the subject, it is identical to the so called Clam exercise in which the subject is in sidelying with both legs flexed to 45° at the hip and 90° at the knee, typically with an elastic rubber band around the thighs to provide resistance. In a recent study that assessed which hip exercises are best for activating the gluteal muscles, Selkowitz et al.32 noted that gluteal muscle activation (especially the gluteus maximus) was among the highest during the Clam exercise. This in turn validates the new
test of hip strength, in that it actually measures the strength of the hip muscles.

In a paper on closed and open kinetic chain tests of muscle strength, Augustsson and Thomeé\textsuperscript{33} stated that the purpose of assessment should determine which mode of test be used: to identify specific deficiencies or problem areas, open kinetic chain testing would be preferred, whereas a closed kinetic chain test may be better suited for assessing functional performance. In the present study, the test comprised of a side lying hip external rotation motion performed in an open kinetic chain. Because of its “non-functional” nature, it is not clear how the test corresponds to dynamic weight bearing movement performed in a closed kinetic chain. Strength measured such as in the present study, however, is able to isolate a specific muscle or muscle group and would therefore be the preferred choice as a diagnostic test of muscle function.

**CONCLUSION**

The novel muscle function test of dynamic hip external rotation strength showed high reliability and could be a useful device for measuring strength in different populations (e.g., athletes and patients) for both clinical and research purposes. Furthermore, the test is cost effective, easy to use, and could provide additional information to the common clinical hip examination as well as when conducting on-the-field testing in sports.

**REFERENCES**


ABSTRACT

Background: Dancers commonly experience anterior hip pain caused by femoroacetabular impingement (FAI) that interrupts training and performance in dance. A paucity of literature exists to guide appropriate evaluation and management of FAI among dancers.

Purpose: The purpose of this study was to determine if dancers with clinical signs of FAI have differences in hip range of motion, strength, and hop test performance compared to healthy dancers.

Study Design: Quasi-experimental, cohort comparison.

Methods: Fifteen dancers aged between 18-21 years with clinical signs of FAI that included anterior hip pain and provocative impingement tests were compared to 13 age-matched dancers for passive hip joint range of motion, isometric hip strength, and performance of the medial triple hop, lateral triple hop, and cross-over hop tests.

Results: No statistically significant differences in range of motion were noted for flexion (Healthy = 145° ± 7°; FAI = 147° ± 10°; p = 0.59), internal rotation (Healthy = 63° ± 7°; FAI = 61° ± 11°; p = 0.50), and external rotation (Healthy = 37° ± 9°; FAI = 34° ± 12°; p = 0.68) between the two groups. Hip extension strength was significantly less in the dancers with FAI (224 ± 55 Newtons) compared to the healthy group (293 ± 58 Newtons; F(1,26) = 10.2; p = 0.004). No statistically significant differences were noted for flexion, internal rotation, external rotation, abduction, or adduction isometric strength. The medial triple hop test was significantly less in the FAI group (354 ± 43 cm) compared to the healthy group (410 ± 50 cm; F(1,26) = 10.3; p = 0.004). Similar results were observed for the lateral hop test, as the FAI group (294 ± 38 cm) performed worse than the healthy controls (344 ± 54 cm; F(1,26) = 7.8; p = 0.01). There was no statistically significant difference between the FAI group (2.7 ± 0.92 seconds) and the healthy group (2.5 ± 0.75 seconds) on the crossover hop test.

Conclusion: Dancers with FAI have less strength of the hip extensors and perform worse during medial and lateral hop triple tests compared to healthy dancers. Clinicians may use this information to assist in screening of dancers with complaints of hip pain and to measure their progress for return to dance.

Level of Evidence: 3B, non-consecutive cohort study

Key words: Dancers, femoroacetabular impingement, functional performance, hop test.
INTRODUCTION
The hip region is the second most commonly injured area of the body among dancers.1 The injury rate for the hip joint in dancers is 0.77 injuries per 1000 hours of dance.1 Dancers with pain in the hip region often describe the symptoms in the proximal, anterior aspect of the thigh and groin region.2 Femoroacetabular impingement (FAI) is a common cause of anterior hip pain in dancers. FAI occurs as the femoral head/neck region contacts the acetabular margin resulting in potentially damaging stresses to the capsule, synovium and labrum of the hip joint. In the general population, FAI is often associated with abnormal proximal hip morphology.3 Although dancers experience symptoms of FAI more frequently than non-dancers, abnormal hip morphology has not been found to be a common cause of FAI in this population. In dancers, FAI has been attributed to the extremes of range of motion required for common dance maneuvers,4 an inability to adequately handle the muscular demands of dance,5 and a rigorous training schedule.6 Despite the prevalence of anterior hip pain among dancers, a paucity in the literature exists to establish appropriate parameters in the evaluation and management of FAI among dancers.

Screening procedures to identify risk factors associated with musculoskeletal injury to the spine and lower extremities of dancers have been utilized by sports medicine clinicians.1 These musculoskeletal screens include assessments of range of motion, flexibility, and strength. Although existing screening procedures may help identify risk characteristics for potential injury, none of these procedures have been shown to aid in the detection of intra-articular hip pathology, specifically FAI. Furthermore, none of the current screens have included a dynamic assessment of the dancer's ability to leap and land. Leaping and landing is an important component of many dance disciplines and is repetitively performed during dance performance and training.2 Thus, an ideal screening tool for dancers may include functional tests that assess the dancer's leaping and landing abilities.2 Recently, researchers have shown good reliability of hop tests including the medial triple hop, lateral triple hop, and cross-over hop tests performed on dancers with non-specific hip pain.2 The distance traveled during the medial triple hop test was shown to be significantly less in the symptomatic limb of subjects with non-specific hip pain compared to the non-symptomatic limb.2 Further study is warranted to investigate if these hop tests are useful measures to be included in screening for symptoms related to femoracetabular impingement as well as during assessment of athletes to determine the readiness to return to dance activities. Determining how dancers with clinical signs of FAI perform on hop tests compared to healthy, non-symptomatic dancers may be an important step toward developing functionally specific screening measures for preventing and managing the symptoms associated with FAI in dancers. The purpose of this study was to determine if dancers with clinical signs of FAI have differences in hip range of motion, strength, and hop test performance compared to healthy dancers. The hypotheses were that healthy dancers would demonstrate greater muscular strength, less range of motion, and significantly greater performance on each respective hop test compared to the dancers with FAI. The information gained from this study may help to define tests and measures to screen for FAI and establish baseline values to help determine when a dancer may be appropriate to return to dance activity.

METHODS:
Subject Recruitment
Female dancers between the ages of 18–22 years who were enrolled in a collegiate performing arts program and participating in a minimum of eight hours of dance training in ballet, jazz, tap, lyrical, or modern dance disciplines were recruited for this research study. All participants read and consented to participate in this IRB approved study. Dancers that volunteered to participate in the study were categorized into either an FAI group or a healthy dancer group based on the combination of subjective complaints and physical exam. Inclusion criteria for the FAI group were: a subjective report of groin pain and provocation of familiar symptoms with the anterior impingement test (combination of flexion, adduction, and internal rotation of the hip joint) and the FABER (combination of the flexion, abduction and external rotation) test. The dancers categorized in the healthy dancer group were enrolled in the same
collegiate dance program without any complaints of lumbar or lower extremity pain including anterior hip pain, and who presented with negative anterior impingement and FABER tests. These criteria were selected based on previous research that reported excellent sensitivity (0.97) for the combination of an absence of groin pain and negative findings with the anterior impingement and FABER tests for ruling out FAI.8

Data Collection
Height, weight, age, a visual numeric pain rating scale (0-10) of the hip region during dance activity, and self-reported functional rating for the hip joint (Hip Outcome Score Activities of Daily Living and Sports Scales) were collected to describe and compare the sample populations. The subject’s hip range of motion and strength was measured followed by performance of the medial triple, lateral triple, and cross-over hop tests. All data collection was performed by the primary investigator (BRK) who has 15 years experience as an outpatient physical therapist with advanced certification in Sports and Orthopedic Physical Therapy.

Range of Motion
Passive range of motion of the hip joint for flexion, external rotation, and internal rotation was performed as described by Holm et al.9 The range of motion measures employed in this study have shown good intra-rater reliability (ICC=0.82-0.90).9 Internal and external rotation range of motion was assessed with the subject prone with their knees flexed to 90 degrees. An angle formed by an imaginary vertical line and the shaft of the tibia was quantified with a standard goniometer (Baseline Standard 12-inch goniometer, Fabrication Enterprises, White Plains, NY) to determine internal and external rotation motion. Hip flexion was measured in the supine position. With the knee joint in full flexion, the femur was moved towards the ipsilateral shoulder until an endpoint was noted without compensation from the pelvis. The hip flexion angle was determined by the angle formed between the bisection of the trunk and an imaginary line connecting the greater trochanter to the lateral femoral epicondyle. All range of motion measures were repeated three times and averaged for data analysis. The order in which range of motion measures were taken was randomized.

Isometric Hip Strength
Next, isometric muscle testing of the hip was performed. Muscle testing was performed with a hand-held dynamometer (Microfet 3, Hoggan Medical Industries, West Jordan, UT) for strength of hip flexion, extension, abduction, adduction, internal rotation, and external rotation.10,11 The dynamometer was placed just proximal to the malleoli for each respective motion as the subject applied maximal force into the pad of the dynanometer. The order in which strength measures were taken was randomized. Hip internal rotation, external rotation, and extension were performed with the subject in a prone position with the non-testing hand of the examiner stabilizing the pelvis. Hip adduction was performed in sidelying on the ipsilateral limb and the opposite limb supported. Hip abduction was performed from sidelying on the contra-lateral limb and the examiners non-testing hand stabilizing the pelvis. Hip flexion was performed with the patient in a supine position, with the knee fully extended. Intra-rater reliability has been previously reported as good for muscle testing in these positions (ICC=0.77 – 0.97).10,11 Three trials of muscle tests were performed with a rest time of 30 seconds between trials. The average of three trials for each direction was used for data analysis.

Hop Testing
The subjects then completed the medial triple hop test, lateral triple hop test, and cross-over hop test in random order as previously described by Kivlan et al.2 To perform the medial triple hop test, the subject stood on the designated limb and was asked to perform three consecutive hops in the medial direction (Figure 1). The total distance traveled was recorded. The lateral triple hop test was performed in similar fashion, only the subject hopped in a lateral direction (Figure 2). The crossover hop test measures the time required to hop on a single limb six meters across a line 15cm in width. The subject must clear the 15cm line with each subsequent hop as they hop in diagonal fashion as fast as possible to the end of the line (Figure 3). Each subject performed six trials for each hop test with a 30-second rest between tri-
als to minimize the effects of fatigue during repeated trials of hop testing. The average of the final three trials was used for data analysis. The hop tests used in this study have been previously studied on dancers with hip pain and have demonstrated excellent test-retest reliability (ICC = 0.89-0.96).^2\)

**Statistical Methods**

All data were entered into a commercially available statistical software program (SPSS 21.0; Chicago, IL) for data analysis. Descriptive statistics were computed and compared with a multivariate analysis of variance to describe subject characteristics with regard to height, weight, pain rating, and self-reported function for each group. A multivariate analysis of variance compared functional performance measures that included range of motion, strength, and hop performance between the FAI group and the healthy group of dancers, with an a priori alpha set at 0.05.

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**Figure 1.** The subject hops medially for three consecutive hops to perform the medial triple hop test. The total distance traveled is measured in centimeters. The average of 3 trials was used for data analysis.

**Figure 2.** The subject hops laterally for three consecutive hops to perform the lateral triple hop test. The total distance traveled is measured in centimeters. The average of 3 trials was used for data analysis.

**Figure 3.** The subject performs the cross-over hop test by hopping as fast as possible on the involved limb diagonally over the entire distance of a 6-meter line. The total time required to hop to the end of the line is recorded in seconds.
RESULTS

Subject Characteristics

There were 15 dancers that volunteered for the study that met the inclusion criteria for the FAI group and an additional 13 dancers that volunteered to be part of the healthy control group. Table 1 displays the characteristics of the subjects in the FAI group versus the healthy dancers. There were no statistical differences between the groups with regards to height, weight, or age (p>0.05). There was a significant difference in self-reported pain and function between the groups. The FAI group had lower daily function and sports function as per the Hip Outcome Score Activities of Daily Living and Sports scales and greater pain during dance compared to the healthy dancers.

Functional Performance Measures

The results of the multivariate analysis of variance revealed that there was a statistically significant difference in functional performance measures among dancers with FAI versus healthy dancers. (F(12,15) = 2.71, p = 0.036; Wilks Lambda = 0.32, partial η² = 0.68)

Range of Motion

Table 2 displays the ranges of motion values for the hip joint of the healthy dancers and the dancers with FAI. The univariate analysis revealed that there were no statistically significant differences in range of motion values for flexion (Healthy = 145° ± 7°; FAI = 147° ± 10°; p = 0.59), internal rotation (Healthy = 63° ± 7°; FAI = 61° ± 11°; p = 0.50), or external rotation (Healthy = 37° ± 9°; FAI = 34° ± 12°; p = 0.68) between the two groups.

Strength

Table 3 displays the strength values of the hip joint for the healthy dancers versus the dancers with FAI. Hip extension strength was significantly less in the dancers with FAI (224 ± 55 Newtons) compared to the healthy group (293 ± 58 Newtons; F(1,26) = 10.2; p = 0.004). There was no statistically significant difference between the FAI group and the healthy group in strength values for hip flexion, internal rotation, external rotation, abduction, or adduction.

Hop Tests

Table 4 displays the hop test performances of the healthy dancers versus dancers with FAI. The

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Table 1. The characteristics of the subjects in the FAI group versus the healthy dancers. (Reported as Mean + Standard Deviation)

<table>
<thead>
<tr>
<th></th>
<th>Healthy (n=13)</th>
<th>FAI (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>18.9 ± 1.3</td>
<td>19.6 ± 1.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.6 ± 1.4</td>
<td>164.9 ± 6.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.8 ± 6.2</td>
<td>59.0 ± 8.4</td>
</tr>
<tr>
<td>Pain (0-10)</td>
<td>0.8 ± 1.9</td>
<td>2.6 ± 1.6</td>
</tr>
<tr>
<td>Hip Outcome Score ADL subscale (0-100%)</td>
<td>94.4 ± 6.4*</td>
<td>85.8 ± 9.4*</td>
</tr>
<tr>
<td>Hip Outcome Score Sports subscale (0-100%)</td>
<td>94.8 ± 7.7*</td>
<td>81.4 ± 15.8*</td>
</tr>
</tbody>
</table>

FAI= Femoroacetabular impingement, *=Significant difference between groups (p<0.05)

Table 2. Ranges of motion values for the hip joint of the healthy dancers and the dancers with FAI. (Reported as Mean + Standard Deviation)

<table>
<thead>
<tr>
<th>Range of Motion (Degrees)</th>
<th>Healthy (n=13)</th>
<th>FAI (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>145±7°</td>
<td>147±10°</td>
</tr>
<tr>
<td>External Rotation</td>
<td>63±7°</td>
<td>61±11°</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td>37±9°</td>
<td>34±12°</td>
</tr>
</tbody>
</table>

FAI= Femoroacetabular impingement

Table 3. Isometric strength values of the hip joint for the healthy dancers versus the dancers with FAI. (Reported as Mean + Standard Deviation)

<table>
<thead>
<tr>
<th>Force (Newtons)</th>
<th>Healthy (n=13)</th>
<th>FAI (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>214±42N</td>
<td>196±29N</td>
</tr>
<tr>
<td>Extension</td>
<td>293±58N*</td>
<td>224±55*</td>
</tr>
<tr>
<td>Abduction</td>
<td>134±42N</td>
<td>122±24N</td>
</tr>
<tr>
<td>Adduction</td>
<td>121±44N</td>
<td>115±34N</td>
</tr>
<tr>
<td>External Rotation</td>
<td>99±26N</td>
<td>89±21N</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td>87±26N</td>
<td>73±22N</td>
</tr>
</tbody>
</table>

FAI= Femoroacetabular impingement, *=statistically significantly different at p<0.05

Table 4. Hop test performances of the healthy dancers versus dancers with FAI. (Reported as Mean + Standard Deviation)

<table>
<thead>
<tr>
<th>Hop Test Performance</th>
<th>Healthy (n=13)</th>
<th>FAI (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial triple hop</td>
<td>410±50cm*</td>
<td>354±43cm*</td>
</tr>
<tr>
<td>Lateral triple hop</td>
<td>343±54cm*</td>
<td>394±38cm*</td>
</tr>
<tr>
<td>Cross-over hop</td>
<td>2.5sec±0.7cm*</td>
<td>2.7sec±0.9cm*</td>
</tr>
</tbody>
</table>

FAI= Femoroacetabular impingement, cm= centimeters, sec= seconds, *=statistically significantly different at p<0.05
The medial triple hop test was significantly less in the FAI group (354 ± 43cm) compared to the healthy group (410 ± 50cm; F(1,26) = 10.3; p = 0.004). Similar differences were seen for the lateral hop test, as the FAI group (294 ± 38cm) performed worse than the healthy controls (344 ± 54cm; F(1,26) = 7.8; p = 0.01). There was no statistically significant difference between the FAI group (2.7 ± 0.92 seconds) and the healthy group (2.5 ± 0.75 seconds) for the crossover hop test (F(1,26) = 0.212; p = 0.65).

DISCUSSION
The purpose of this research project was to determine if dancers presenting with clinical signs of FAI have different patterns of hip range of motion and strength and perform differently with functional performance tests when compared to healthy, non-symptomatic dancers. It was hypothesized that healthy dancers would demonstrate greater muscular strength, less range of motion, and significantly greater performance on each respective hop test compared to the dancers with FAI. The original hypotheses proved to be only partially upheld.

Range of motion of the hip joint was not significantly different among the group of dancers with FAI versus the group without symptomatic FAI. This finding differs from what has been previously reported in studies of non-dancer populations with FAI. In non-dancer populations, a relative loss of hip flexion and internal rotation is commonly associated with FAI. There were no observed differences in the FAI group versus the healthy group with regards to hip range of motion values. However, our results did show that both dancer groups had relative increased values for external rotation and less internal rotation range of motion. Regardless whether they had symptomatic FAI or not. Previous work suggests dancers exhibit a relative increased external rotation and decreased internal rotation range of motion compared to healthy age-matched controls. The results of the current study suggest that range of motion of the hip joint would have limited value as a screening measure to differentiate a dancer that has FAI from a healthy dancer. This is consistent with the findings of Gamboa et al. that showed that hip range of motion measures were not risk factors of lower extremity injury in dancers. However, considering the demands of hip joint motion required during common dance maneuvers, range of motion measures of the hip joint may still be valuable to identify abnormal values from those established in the current study that may suggest hypomobility or hypermobility of the hip joint specific to the needs of a dancer.

It was also hypothesized that dancers with FAI would have diminished strength of the hip musculature. Previous research has shown decreased average cumulative strength of the hip flexors, extensors, internal rotators, external rotators, adductors, and abductors, as well as the knee flexors and extensors to be a common characteristic of injured dancers. Subjects with FAI have been previously shown to have hip strength deficits of 28% for adduction, 26% for flexion, 18% for external rotation, and 11% for hip abduction. The results of the current study showed that hip extension was the only direction that demonstrated a significant deficit of hip strength. A 24% deficit of hip extension strength was observed among the dancers with FAI compared to healthy dancers. Diamond et al. reported a 23% deficit in hip extension strength among active adults with symptomatic FAI versus healthy controls, but the study was not sufficiently powered. Contrary to the original hypothesis, hip abduction and rotation strength was not significantly less in the group of dancers with symptomatic FAI compared to controls similar to what has been shown through previous investigations. Collectively, these findings may be further evidence of the apparent differences of dancers with FAI versus a non-dancer population with FAI.

The deficits noted with hip extension strength among the dancers with FAI may help to further explain the deficits also noted on the medial and lateral triple hop tests. Compared to males, females produced higher knee extensor moments relative to hip extensor moments during landing tasks. This relative reduction of hip extensor moment has been attributed to decreased strength of the hip extensors. Based on these previous findings, one could hypothesize that weakness of the hip extensors observed in the FAI group could limit the efficiency of the subjects to absorb landing forces and may explain why the medial triple hop and lateral triple hop tests were significantly less in dancers with FAI versus healthy
The medial and lateral triple hop tests were approximately 410cm and 343cm, respectively, in the group of healthy dancers. Dancers with FAI hopped less far by approximately 50cm for the medial triple hop test and the lateral triple hop test. Clinicians may use this information to understand normal hop distances and distances that may be expected in dancers that have clinical signs of FAI. This could lead to further studies that establish minimal hop distances that may be used to help detect intra-articular hip disease and determine a safe return to dance activity.

The results of this study build on a previous investigation that compared performance of the medial triple hop, lateral triple hop, and crossover hop tests on the involved versus the uninvolved side among a group of dancers with complaints of unilateral hip pain. Previous work showed an average deficit of 17.84cm between the symptomatic and non-symptomatic side during the medial hop test. The current study demonstrated a significant difference of approximately 50cm between the performances on the medial hop test by injured dancers when compared to healthy dancers. In the previous study, however, the lateral hop test did not demonstrate a significant side-to-side difference. The current study demonstrated a significant difference that was similar to that of the medial triple hop test when comparing dancers with FAI to healthy, age-matched dancers. Therefore, the lateral triple hop test may also have value in screening for FAI in female dancers that was not demonstrated in the previous study when comparing the injured to uninjured sides. The crossover hop test, similar to the previous study, did not demonstrate a difference between symptomatic and nonsymptomatic groups. Therefore, one may conclude that the crossover hop test has limited utility discerning dancers with hip pathology, specifically FAI. It would appear that dancers are still able quickly change direction while hopping and accomplish the test without notably affecting performance despite apparent hip pathology. Based on these findings, repeated hops in a medial or lateral direction may best exhibit greater differences among injured and non-injured hips than a timed test that requires change of direction.

Screening measures for the hip joint are needed for dancers as articular cartilage lesions and labral tears are common. Thirty-five percent of dancers that have evidence of an intra-articular lesion on magnetic resonance imaging of the hip joint do not report pain. Dancers that report pain tend to exhibit a higher threshold and tolerance for pain compared to non-dancers. Dancers also distinguish poorly between pain that is customary and related to dance performance and pain that is associated with a potential injury. Thus, pain alone cannot be a reliable indicator for intra-articular hip pathology. The results of this study identify differences of strength and functional performance measures in dancers with FAI versus those without FAI. This information may help in the future study and development of screening measures to aide in the early detection of FAI. Further research is needed to see if deficits in hip extension strength and/or hop test performance are actual risk factors for developing intra-articular hip pathology in dancers.

**Limitations**

There are limitations to this study that deserve consideration when interpreting the results. First, the generalizability of the results should be applied to only highly trained dancers. The population studied in the current study included elite dancers with proficiency in multiple disciplines of dance who were participating in advanced dance training at the collegiate level. The dancers with FAI from this study did not demonstrate strength and range of motion deficits that have been commonly associated with a diagnosis of FAI in the general population. Further, non-dancers are often diagnosed with FAI based on radiological evidence of abnormal hip morphology. In dancers, FAI may occur in the absence of abnormal anatomical morphology of the hip joint, thus radiographic evaluation may not be helpful in determining a diagnosis. Therefore a diagnosis FAI was based on subjective complaints and special clinical tests. Few physical examination tests have been studied adequately in unbiased population samples to direct clinical decision making without further study. However, the most current research supports the inclusion criteria used in the current study as a subjective complaint of groin pain in combination with provocation of symptoms with the anterior impingement test and the FABER test has sensitivity of 0.97, making this specific combination of signs and tests excellent to rule out FAI. One must also consider that the functional
testing procedures employed in this study may also have been influenced by fatigue. To minimize the impact of fatigue from repeated strength and functional testing, large rest:work ratios were adopted from previous studies that demonstrated excellent inter-rater reliability. Finally, the objective findings of this study cannot be interpreted as having the ability to predict femoroacetabular impingement. The results of this study, however, illustrate certain characteristics of strength, range of motion and functional performance that are common deficits in dancers with FAI. It is unknown if these characteristics precede the onset of the symptoms among the dancers. Therefore, it cannot be determined if the deficits of hip extension strength and medial and lateral triple hop test performance observed in the current study will predict an occurrence of symptoms related to FAI. The results do however demonstrate factors that may be included in a prospective study in order to help determine contributory factors for the development of FAI among dancers.

CONCLUSIONS
The results of this study provide evidence for the use of the medial triple hop and lateral triple hop tests in the assessment of dancers with suspected FAI. Clinicians may expect dancers with FAI to have less strength of the hip extensors and perform worse during medial and lateral hop tests on their symptomatic side compared to healthy dancers. There were no apparent differences in range of motion patterns between the dancers with FAI and the healthy dancers. Clinicians may use this information to assist in screening for dancers with complaints of hip pain and to measure their progress during assessment for return to dance.

REFERENCES


ORIGINAL RESEARCH

SPECIFIC AND CROSS-OVER EFFECTS OF FOAM ROLLING ON ANKLE DORSIFLEXION RANGE OF MOTION

Shane Kelly, MSc1
Chris Beardsley, MA (Hons)2

ABSTRACT

Background: Flexibility is an important physical quality. Self-myofascial release (SMFR) methods such as foam rolling (FR) increase flexibility acutely but how long such increases in range of motion (ROM) last is unclear. Static stretching (SS) also increases flexibility acutely and produces a cross-over effect to contralateral limbs. FR may also produce a cross-over effect to contralateral limbs but this has not yet been identified.

Purpose: To explore the potential cross-over effect of SMFR by investigating the effects of a FR treatment on the ipsilateral limb of 3 bouts of 30 seconds on changes in ipsilateral and contralateral ankle DF ROM and to assess the time-course of those effects up to 20 minutes post-treatment.

Methods: A within- and between-subject design was carried out in a convenience sample of 26 subjects, allocated into FR (n=13) and control (CON, n=13) groups. Ankle DF ROM was recorded at baseline with the in-line weight-bearing lunge test for both ipsilateral and contralateral legs and at 0, 5, 10, 15, 20 minutes following either a two-minute seated rest (CON) or 3 × 30 seconds of FR of the plantar flexors of the dominant leg (FR). Repeated measures ANOVA was used to examine differences in ankle DF ROM.

Results: No significant between-group effect was seen following the intervention. However, a significant within-group effect (p<0.05) in the FR group was seen between baseline and all post-treatment time-points (0, 5, 10, 15 and 20 minutes). Significant within-group effects (p<0.05) were also seen in the ipsilateral leg between baseline and at all post-treatment time-points, and in the contralateral leg up to 10 minutes post-treatment, indicating the presence of a cross-over effect.

Conclusions: FR improves ankle DF ROM for at least 20 minutes in the ipsilateral limb and up to 10 minutes in the contralateral limb, indicating that FR produces a cross-over effect into the contralateral limb. The mechanism producing these cross-over effects is unclear but may involve increased stretch tolerance, as observed following SS.

Levels of Evidence: 2c

Key Words: Flexibility, self-massage, self-myofascial release

CORRESPONDING AUTHOR

Shane Kelly, MSc
Right to Dream Academy
Atimpoku, Volta Region, Ghana, Africa.
Phone: +233 0505405562 or +44 7597385507
E-mail: shanekellyhealth@gmail.com

1 School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, United Kingdom.
2 Strength and Conditioning Research Limited, Holborn Viaduct, London, United Kingdom
INTRODUCTION

Flexibility is an important physical quality. Many factors contribute to flexibility such as joint structure, muscle length, age, and activity level. In this study, flexibility will be defined as the range of motion (ROM) available at a joint, where ROM describes the degree of angular motion. Although the overall role of flexibility in determining injury risk is unclear, there is evidence to suggest that restricted ankle dorsiflexion (DF) ROM, is a contributing factor for some lower extremity injuries and is commonly seen after ankle sprains, fractures, and Achilles tendon injuries. This may be because restricted ankle DF ROM limits the forward translation of the tibia over the foot during gait, possibly leading to dysfunction and an altered gait pattern. Such changes may increase the risk of developing patellofemoral pain syndrome, patellar tendinopathy, lateral ankle sprains, plantar fasciopathy, and medial tibial stress syndrome. Furthermore, drop or jump landings in subjects with a reduced ankle DF ROM result in greater peak landing forces. Decreased ankle DF ROM is also associated with increased knee valgus. Both greater peak landing forces and increased knee valgus are associated with increased anterior cruciate ligament injury risk. Increasing ankle DF ROM may therefore help reduce incidence of lower limb dysfunction and lower musculoskeletal injury risk.

Self-myofascial release (SMFR), is a form of manual therapy in which the individual applies a manual treatment to themselves with foam rolling (FR) being the most commonly used practice. The literature indicates that FR improves flexibility for approximately 10 minutes post-treatment but the mechanism or mechanisms by which SMFR exerts its effects are currently unclear and many possible explanations exist. Such mechanisms can be differentiated into mechanical and neurophysiological types. Within mechanical models, it is theorized that the material properties of fascia are affected by the pressure exerted through SMFR, thereby altering its viscoelastic properties. Many possible mechanisms exist including thixotropy, piezoelectricity, fascial adhesions, cellular responses, fluid flow, fascial inflammation, and myofascial trigger points. Within neurophysiological models, it is theorized that the mechanical pressure from SMFR influences a state of tissue relaxation through afferent signal input to the central nervous system via stimulation of the Golgi reflex arc and other mechanoreceptors. In contrast to such potential mechanisms of SMFR, acute increases in flexibility produced by static stretching (SS) are most likely caused by increases in stretch tolerance. It remains possible that SMFR may also be effective through a similar mechanism, particularly as manual therapies in general are typically reported as having a number of pain-relieving effects.

The cross-over effect was first observed by Scripture et al. It describes how resistance training in an ipsilateral limb produces strength gains in the contralateral limb and indicates that strength training produces a central adaptation and not just a local one. Munn et al reviewed the literature and concluded that unilateral strength training produces modest increases in contralateral strength and similar findings have been shown on contralateral limbs in respect of acute fatigue. There is also a cross-over effect in relation to flexibility, as static stretching of the ipsilateral limb produces acute increases in ROM in the contralateral limb, as well as other limbs across the upper and lower body. Static stretching of the ipsilateral limb may also affect force production in the contralateral limb. Such findings indicate that SS likely produces its cross-over effects by means of a global improvement in stretch-tolerance. In contrast to SS, there has been little exploration of the cross-over effect of flexibility in SMFR. Nevertheless, Jay et al found that SMFR using FR reduced delayed onset muscle soreness, suggesting the presence of a cross-over effect of analgesic effects, which raises the possibility that similar cross-over effects might be observable in relation to flexibility.

Therefore, it was the purpose of this study to explore the potential cross-over effects of SMFR by investigating the effects of a FR treatment of 3 bouts of 30 seconds to the ipsilateral limb on changes in ipsilateral and contralateral ankle DF ROM and to assess the time-course of those effects up to 20 minutes post-treatment.

METHODS

Subjects

A convenience sample of 26 (16 male and 10 female) recreationally active, university students were
recruited through email and posters (Table 1). Recreationally-active was defined as performing exercise approximately two to three times per week\(^\text{28}\) as this is the population that is believed to use and therefore benefit from SMFR,\(^\text{29}\) thereby improving external validity. Participants were included if they were healthy and free from ankle injuries in the six months preceding the testing.

### Experimental approach

A randomized controlled between-subjects design was used. The between-subjects design was selected in order to provide a ‘true’ control group, and thereby reduce the impact of the familiarization of the testing protocol.\(^\text{30}\) Participants were randomly assigned to either FR or CON group using a computer-generated model for randomization in order to comply with risk of bias in trials.\(^\text{31}\) Subjects were asked to refrain from strenuous exercise for at least three hours prior to testing as this may affect flexibility.\(^\text{32}\) Upon arriving at the laboratory, the subjects signed consent forms, after which sex, age, height and weight were recorded. Subjects then carried out a warm up of 10 double-leg heel raises to the floor. Previous similar studies have included warm ups,\(^\text{28,17}\) although others have not\(^\text{33}\) and the nature and extent of the warm-up may affect the results observed.\(^\text{17}\) Nevertheless, a warm up is more likely to mimic what happens in real life\(^\text{32}\) and therefore improves external validity.

Immediately after the warm up, a baseline measurement of DF ROM for both ankles for subjects in both groups was measured using the weight-bearing lunge test (Figure 1). The weight-bearing lunge test has been shown to have high inter-rater ($r = 0.99$) and intra-rater ($r = 0.98$) reliability.\(^\text{34}\) Several previous studies have used this test successfully.\(^\text{34,28,33}\) Subjects stood with their foot approximately 10cm back, perpendicular to the wall. They were then instructed to look forward and to flex their knee until it reached the wall.

![Figure 1. Weight Bearing Lunge Test with tester holding theraband under subjects heel.](image)

The knee was to touch the wall, travel over the midline of the foot and the heel was to stay firmly on the ground for it to be considered a successful attempt.\(^\text{28,33}\) The subject was then instructed to either slide their foot forward or back depending whether their knee failed or successfully touched the wall in the previous test. A ruler attached to the ground measured the distance of their big toe from the wall at the point where the knee was just making it to the wall with the heel on the ground.\(^\text{28,33}\) To ensure no elevation of the heel took place, a theraband was put under the heel and tension was applied by the same experimenter.\(^\text{28}\) If the heel came off the floor, the theraband would snap back and would be deemed a failed attempt.

Immediately after the baseline ankle DF ROM measurements, subjects in the CON group remained

<table>
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<tr>
<th>SEX</th>
<th>AGE (YRS)</th>
<th>HEIGHT (CM)</th>
<th>WEIGHT (KG)</th>
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</thead>
<tbody>
<tr>
<td>FOAM ROLLING</td>
<td>Male: n = 8</td>
<td>24.8 ± 2</td>
<td>174 ± 7.1</td>
</tr>
<tr>
<td></td>
<td>Female: n = 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTROL</td>
<td>Male: n = 8</td>
<td>24.4 ± 1.7</td>
<td>174 ± 5.6</td>
</tr>
<tr>
<td></td>
<td>Female: n = 5</td>
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in a long sitting resting position for two minutes while subjects in the FR group carried out the FR intervention, which involved foam rolling the calf musculature of the dominant leg (leg used to kick a ball) for three bouts of 30 seconds, with 10-second rest intervals between bouts, for a total time of two minutes. Subjects were instructed to place the top of their calf musculature of their dominant leg onto the roller, to place their other leg on top, to raise their buttocks off the floor, place as much force through the roller as possible, and roll down slowly in kneading like motions until they reached the Achilles tendon insertion (Figure 2). Subjects were instructed to roll back up to the top and repeat until 30 seconds had elapsed, using a slow pace (approximately three seconds down and one second up) in order to reduce variance in rolling technique. Subjects were instructed to focus on the lateral aspect of the calf for the first set, the middle aspect for the second set and the medial aspect for the third set to ensure that the entire calf area was treated. A foam roller (The Grid Roller - Escape Fitness, Cambridgeshire, UK) made from a hard, hollow uniform cylinder enclosed with a layer of ethylene vinyl acetate foam was used. This type of foam roller was used as harder foam rollers are thought to elicit a greater benefit in ROM through increased pressure on the tissue. Each subject in the FR group sat in a long sitting resting position between ROM measurements to control for any effect moving around may have on flexibility. After the two-minute rest (CON) or the foam rolling intervention (FR), ankle DF ROM was measured for both legs, dominant leg first. Identical measurements were taken at 0, 5, 10, 15 and 20 minutes.

**STATISTICAL ANALYSIS**

Normality of the data was firstly established using the Shapiro-Wilk Test, where skewness and kurtosis were identified through histogram presentation. The Shapiro-Wilk Test was used given its power and appropriateness given the small sample size. Mauchly’s test of sphericity was used to ensure there was homogeneity of variance between conditions. If the laws of sphericity were violated the Greenhouse Geisser correction was used. A two-way repeated measures analysis of variance (ANOVA) was used to explore the hypotheses over time where an alpha level of 0.05 was set, representing significance. If a significant (p < 0.05) effect was found, analysis was continued with a one-way ANOVA and post-hoc testing involving pairwise comparisons with Bonferonni corrections, as suggested by Munro. SPSS version 22 (SPSS Inc., Chicago, IL, USA) was used to carry out all of the statistical analysis.

**RESULTS**

**Between groups**

No statistically significant differences (p > 0.05) between groups for ankle DF ROM at baseline for either leg were identified. Significant main effects for time (p=0.00; F (5,20) = 59.28; partial $\eta^2 = 0.937$), and significant interaction effects for time*group (p=0.00; F(5,20) = 43.40; partial $\eta^2 = 0.916$), time*leg (p=0.00; F(5,20) = 15.27; partial $\eta^2 = 0.792$) and time*leg*group (p=0.00; F(5,20) = 8.38; partial $\eta^2 = 0.677$) were found. However, follow-up analysis using pairwise comparisons with Bonferonni corrections revealed that all individual between-group effects were not statistically significant (all p > 0.05) (Table 2).

**Within groups**

Within the FR group, a significant main effect for time for the dominant leg and for the non-dominant leg were identified (p=0.00; F(3.91, 93.935) = 48.66; partial $\eta^2 = 0.670$). Pairwise comparison of different time points for the dominant leg showed significant (p < 0.05) differences for all time-points compared to baseline ROM, which suggests that FR improved ROM up to 20 minutes (Table 2). Similarly, pairwise comparison of different time points for for the non-dominant leg showed significant (p < 0.05) differences at 0, 5 and 10 minutes compared to baseline ROM.

**Figure 2. Foam Rolling of the plantar flexors.**
ROM, suggesting a cross-over effect that lasted for approximately 10 minutes (Table 2).

**DISCUSSION**

Although no significant differences were noted in the between-group analysis, there were significant within-group effects in the FR group. The within-group effects suggest that FR improves ankle DF ROM for at least 20 minutes in the ipsilateral limb and up to 10 minutes in the contralateral limb, indicating that FR produces a cross-over effect into the contralateral limb. The mechanism producing these cross-over effects is unclear but may involve increased stretch tolerance, as observed following SS.

The change in ankle DF ROM on the dominant leg in the weight-bearing lunge test was small (1.12cm/8.79%) and even smaller in the non-dominant leg (0.72cm/5.55%) immediately post-rolling and therefore the clinical impact in healthy populations is questionable. Nevertheless, in a rehabilitation setting, where ankle DF ROM may be limited, small changes could be beneficial and so have a greater clinical relevance. Additionally, a longer intervention may provide greater improvements in Ankle DF ROM, a potential area for future research. The cross-over effect has potential applications where ROM is restricted on one side of the body as a result of injury, post-operation immobilization or neurological conditions. In such cases, SMFR treatment of the healthy limb may have benefits through the cross-over effect into the injured limb, although longitudinal trials are necessary to find out whether the cross-over effect persists beyond a single treatment.

**Time course of effects**

The findings of this study are broadly in line with earlier studies that have investigated the time course of the acute effects of FR on flexibility. In general, it has been found that acute increases in flexibility can be observed for at least 10 minutes post-treatment but not longer than 30 minutes. MacDonald et al reported that there was no difference in the acute effects at two and 10 minutes and Halperin et al similarly found no differences between measurements taken at one and 10 minutes. Jay et al found that increases in flexibility were recorded at 10 minutes but not at either 30 or 60 minutes. Finally, Škarabot et al found no differences between time points up to 20 minutes. Adding to these findings, the current study reported significant differences at all post-intervention time-points for the ipsilateral leg compared with baseline ROM, which suggests that FR improved ROM up to 20 minutes in the treated leg. However ROM was trending towards baseline levels following the 10 minute mark. Whether measurements taken at 30 or 60 minutes in the present study would have demonstrated a return to baseline is unclear. Additionally, it is important to note that a range of factors could affect differences in reported results between trials, including the population, the measurement method used for joint ROM, the muscle group being treated, and the nature, intensity, volume and method of application of the SMFR tool.

**Cross-over effects**

In this study, a crossover effect of flexibility from the ipsilateral limb to the contralateral limb was

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<tr>
<th>Table 2. Differences in ROM scores from Baseline at the various timepoints given in centimetres (cm) and percentage (%)</th>
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<tbody>
<tr>
<td><strong>Baseline</strong></td>
</tr>
<tr>
<td><strong>FOAM ROLLING</strong></td>
</tr>
<tr>
<td>Dom (12.77cm)</td>
</tr>
<tr>
<td>Non-Dom (12.88cm)</td>
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<tr>
<td><strong>CONTROL</strong></td>
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<tr>
<td>Dom (12.9cm)</td>
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<tr>
<td>Non-Dom (12.8cm)</td>
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* = Statistical difference (p<0.05) noted when compared to baseline ROM.
Key: Dom = dominant leg; Non-Dom; non-dominant leg
observed immediately, 5 and 10 minutes post rolling. In one previous investigation, Jay et al\textsuperscript{27} reported a reduction in delayed onset muscle soreness in the contralateral limb after SMFR of the ipsilateral limb but did not suggest any mechanism by which such cross-over effects might have occurred. Investigating SS applied to an ipsilateral limb, Chaouachi et al\textsuperscript{24} found increased flexibility in the contralateral limb and suggested that changes in the somatosensory perception of tissue length and tension occurred, which likely required cortical involvement. Similarly, Behm et al\textsuperscript{25} observed global effects of an acute bout of SS by testing upper and lower body flexibility after bouts of lower and upper body SS, respectively. Behm et al\textsuperscript{25} also investigated changes in electromyography amplitude after SS and reported no alterations despite the increased ROM, which they interpreted as suggesting no influence on neural drive. Consequently, they also concluded that the mechanism by which SS produced these global effects on flexibility was enhanced stretch tolerance.

As previous studies have indicated that FR interventions may possess an additive effect on increasing ROM when combined with SS,\textsuperscript{33} it is plausible that the force applied during rolling may serve to increase parasympathetic nervous activity through the stimulation of mechanoreceptors.\textsuperscript{39} As this would be a global response, it could allow the contralateral limb to gain and may further explain the cross-over effects seen in this study. In support of this possibility, a recent study reported reduced electromyography amplitude during a lunge following a bout of roller-massage in which the authors suggested suppression of H-reflexes may be an explanation for the reduction in electromyography amplitude.\textsuperscript{40}

**Limitations**

This study was limited in several important respects. Firstly, the current sample size was not chosen based upon a power analysis, although it was comparable in size to similar studies. Since the observed improvements in ROM were relatively small, the study may not have been sufficiently powered to detect a significant difference between groups.\textsuperscript{35} Secondly, the subjects and the sole examiner were not blinded to the groups in which the subjects were placed, which increases the risk of bias and type I error.\textsuperscript{35} Thirdly, the warm-up of heel raises to the floor is a shortening contraction without a lengthening following it, this may have affected the flexibility of the muscle and therefore results also. Future studies should address this when planning their methodology. Fourthly, the number of attempts to achieve maximal ROM may have affected flexibility due to tissue ‘creep’\textsuperscript{41} or improvements in stretch tolerance.\textsuperscript{42} In this respect, a strength of the current study was the use of the control group, where the effect of repeated measures can be seen to be minimal, with the largest increase in ROM being just 0.14cm from baseline, which is very small in comparison with the 1.12cm improvement observed in the treatment group. Lastly, although a significant effect was found for the FR group over time, the clinical relevance of such findings is uncertain and further research is required to determine the role of foam rolling within the clinical environment.

**CONCLUSION**

An acute bout of FR in the ipsilateral leg produced significant increases in ankle DF ROM for at least 20 minutes in the ipsilateral limb and up to 10 minutes in the contralateral limb, indicating that FR produces a cross-over effect into the contralateral limb. The mechanism producing these cross-over effects is unclear but may involve increased stretch tolerance, as observed following SS. Although the absolute increase in ankle DF ROM was small and may not be clinically meaningful for healthy populations, the cross-over effect has potential applications where ROM is restricted on one side of the body as a result of injury, post-operation immobilization or neurological conditions. In such cases, SMFR treatment of the healthy limb may have benefits through the cross-over effect into the injured limb.

**REFERENCES**

4. Bell DR., Padua DA, Clark MA. Muscle Strength and Flexibility Characteristics of People Displaying


33. Skarabot J, Beardsley C, Štirn I. Comparing The Effects Of Self-Myofascial Release With Static...


CASE SERIES
REHABILITATION OF SUBACROMIAL PAIN SYNDROME
EMPHASIZING SCAPULAR DYSKINESIS IN AMATEUR ATHLETES: A CASE SERIES

Katherinne F. Moura, PT, MSc
Renan L. Monteiro, PT, MSc
Paulo R.G. Lucareli PT, PhD
Thiago Y. Fukuda, PT, PhD

ABSTRACT

Study design: Case series

Background and Purpose: Scapular dyskinesia has been associated with several shoulder injuries. Recent literature has suggested that a greater activation of the scapular muscles can play an important role in reducing subacromial impingement in patients with shoulder pain. Thus, the purpose of this case series was to describe a rehabilitation program that emphasizes scapular dyskinesia correction for those with clinical evidence of subacromial pain syndrome.

Case Descriptions: The four amateur athletes in this series showed clinical evidence of subacromial pain syndrome and scapular dyskinesia and each underwent a treatment protocol consisting of three phases. Phase 1 emphasized pain relief, scapular control, and recovery of normal range of motion (ROM), Phase 2 focused on muscular strengthening, and Phase 3 emphasized sensory motor training.

Outcomes: All subjects demonstrated decreased pain, improved sports performance and function, increased muscular strength for shoulder elevation and external rotation, and increased ROM for internal rotation. Improvement in serratus anterior (SA) activation was also noted.

Discussion: The results of this case series suggest that subjects with clinical tests positive for subacromial pain syndrome can show significant improvement with an intervention focused on scapular dyskinesia correction. SA activation can play an important role in this process given that all subjects presented with better recruitment after rehabilitation, as measured by electromyography.

Levels of Evidence: Level 4
Key Words: Impingement, serratus anterior, trapezius

CORRESPONDING AUTHOR
Thiago Y. Fukuda
Instituto Trata, Rua Martinico Prado, 26 Cj 141, CEP 01224-010
Bairro Higienópolis, São Paulo – SP, Brazil
Phone: (55 + 11) 96400-4144
E-mail: fukuda@institutotrata.com.br

1 Physical Therapy Sector, Santa Casa of São Paulo - ISCMSP, São Paulo-SP, Brazil
2 Nove de Julho University, São Paulo-SP, Brazil
3 Trata Institute – Knee and Hip Rehabilitation, São Paulo-SP, Brazil
BACKGROUND AND PURPOSE
Subacromial pain syndrome is defined as any non-traumatic shoulder problem, usually unilateral, with localized pain around the acromion, which usually worsens during or after lifting of the arm.1 The following terms are commonly linked to subacromial pain syndrome: bursitis, tendinosis calcarea, supraspinatus tendinopathy, partial tear of the rotator cuff, biceps tendinitis and rotator cuff tendon degeneration. Interest in the etiology, diagnosis, and treatment of subjects with shoulder pain continues to increase.1 While there is available information for subacromial pain syndrome,2-6 there is limited research regarding appropriate rehabilitation programs for those subjects that present clinical evidence of scapular dyskinesis. As clinicians become more aware of scapular influence on shoulder injuries, information is needed to help guide rehabilitation focusing on scapular control.

The scapula is highly dependent on muscle activation for mobility and stability due to minimal stability offered by the bony structures.7,9 The combination of the actions of the upper and lower trapezius fibers with the serratus anterior (SA) and the rhomboid muscles provides dynamic scapular stability. The main function of the upper trapezius (UT) is to generate the clavicular retraction needed to avoid excessive internal rotation of the scapula.10 The main function of the lower trapezius (LT) is to rotate the scapula upward during arm elevation.8,9 The rhomboids assist the LT in stabilizing the scapula by controlling medial and lateral sliding. The SA is the muscle that contributes to all normal components of the three-dimensional movement of the scapula (upward rotation, posterior tilt, and external rotation) during arm elevation, while stabilizing its medial border and lower angle, and it is also responsible for scapula protraction.8,9

Scapular dyskinesis refers to dysfunctional movement of the scapula and describes the loss of control of optimal scapular mechanics.8 Scapular dyskinesis is not considered an injury and is not always directly related to a specific injury.9 However, this change reduces the shoulder function, stressing the acromioclavicular joint, subacromial space, muscle activation, arm positioning and movement, which can lead to the onset of symptoms.9 The final result of most of these etiological factors is a protracted scapula, which can lead to a decrease in the subacromial space, decreased rotator cuff strength due to poor stabilization of the scapula, and increased stress in the anterior glenohumeral ligaments.8,9

Dyskinesis can be evaluated and classified as “yes” or “no” with an agreement of 79%, moderate inter-rater reliability (ICC of 0.41), and good sensitivity (76%).9,11 Scapular dyskinesis can also be classified as: Type 1 or inferior angle prominence, which is associated with excessive anterior tilt; Type 2 or medial border prominence, which is associated with excessive scapular internal rotation; and Type 3 or superior border prominence, which is associated with elevated scapula.11 This method also has a moderate interrater reliability (ICC of 0.44), but with an interrater agreement of 61% and low sensitivity (between 10%-54%).11 Therefore, the yes/no classification has been the most commonly recommended method for use in research.8,9,11-13

Some authors describe scapular dyskinesis as the cause-effect of several disorders of the shoulder complex,9,14 thus scapular rehabilitation should be included in the treatment of subjects with these disorders. Currently, the treatment described in the literature is based on exercises that increase soft tissue flexibility and range of motion (ROM). Others have also suggested strengthening exercises for the periscapular muscles without overload of the hyper-active muscles.9,10,15,16

However, there is a need for further investigation and descriptions of rehabilitation programs focused on scapular dyskinesis correction during treatment of patients with subacromial pain syndrome. The program outlined in this case series emphasized scapular control and muscular performance. Thus, the purpose of this case series was to describe a rehabilitation program that emphasizes scapular dyskinesis correction for those with clinical evidence of subacromial pain syndrome.

CASE DESCRIPTION
This research received approval from The Institutional Review Board of Santa Casa of São Paulo – SP, Brazil, and all participants gave informed, written consent prior to participation. Four amateur athletes with report of unilateral subacromial pain syn-
drome and clinical evidence of scapular dyskinesis were evaluated at baseline and after six weeks of treatment. The demographic data, relevant history, and primary symptoms of each subject are shown in Table 1. Evaluation consisted of an assessment of glenohumeral internal rotation deficit – GIRD, pain and level of function as assessed with the visual analogue scale (VAS), the Constant score, and the Athletic Shoulder Outcome Rating Scale (ASORS). A visual assessment of the scapular dyskinesis was performed according to methods used in previous studies. The Yes/No categorical classification for scapular dyskinesis was used due to better reliability. The following special tests for scapular dyskinesis were performed: the scapular assistance test (SAT) and the scapular retraction test (SRT). Beside the visual test, at least one of these two tests had to be positive for the confirmation that subacromial pain syndrome was related to scapular dyskinesis.

In addition, the Yocum, Neer, Hawkins, and Jobe tests for subacromial pain syndrome; the apprehension test and Fukuda tests for glenohumeral instability were administered. Based on the study conducted by Michener et al., these tests were clustered aiming to increase diagnostic accuracy. An evaluator who was not part of the treatment sessions conducted all tests and questionnaires. It is important to highlight that no patients presented radiological signs of decreased glenohumeral or acromioclavicular joint space or morphological changes in the acromion shape.

Isometric strength was measured using a handheld dynamometer (Lafayette Instruments, Lafayette, IL, USA) for shoulder elevator, internal and external rotator muscles. The strength tests were performed according to Donatelli et al. and Marcondes et al. methods. A reliability pilot study that was conducted with 10 healthy subjects (20 shoulders) demonstrated ICC values of 0.8 for elevation and 0.7 for internal and external rotation (over three repetitions), which are considered good reliability. To evaluate the internal and external rotator strength, patients were positioned in supine with the shoulder in the scapular plane (around 40 degrees of abduction and flexion), elbow flexed at 90 degrees and neutral rotation. The dynamometer was positioned 2 cm below the styloid process in the ventral face of the wrist (for internal rotation) and dorsal face (for external rotation). To assess the strength of shoulder elevation, the patient was in a sitting position, shoulder in scapular plane and neutral rotation with the elbow extended. The dynamometer was positioned on the dorsal surface of the wrist. The tests were performed twice, with an interval of one minute between each test.

**Table 1. Subject Demographics**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, y</th>
<th>Gender</th>
<th>Relevant history</th>
<th>Complaints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>Female</td>
<td>Student, amateur tennis player, unilateral anterior shoulder pain, and scapular dyskinesis on the right side (dominant arm)</td>
<td>Anterior and lateral shoulder pain with irradiation (occasional) to the hand, duration of symptoms: 4 years</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>Male</td>
<td>Amateur soccer player, bodybuilder, unilateral anterior shoulder pain, and scapular dyskinesis on the left side (non-dominant arm)</td>
<td>Anterior shoulder pain during sports-specific activity and daily-life activities, duration of symptoms: 2 months</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>Female</td>
<td>Student, bodybuilder, traumatic shoulder dislocation (6 years ago), general joint laxity, unilateral anterior shoulder pain and anterior instability, and scapular dyskinesis on the right side (dominant arm)</td>
<td>Anterior shoulder pain, apprehension for dislocation during overhead activities, duration of symptoms: 6 years</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
<td>Male</td>
<td>Amateur archer, unilateral anterior shoulder pain, and scapular dyskinesis on the left side (non-dominant arm)</td>
<td>Anterior shoulder pain during elevation and arm support on left side during sports-specific activity, duration of symptoms: 4 months</td>
</tr>
</tbody>
</table>
average between these tests was used for statistical analysis. Strength data, measured in kilograms, were normalized to body mass, also measured in kilograms using the following formula: (kg strength/kg body weight) x 100.27, 28

To assess the muscular activation during shoulder elevation in scapular plane, the electromyography (EMG) activity was recorded using an 8-channel EMG system (EMG System do Brasil® Ltda) and surface electrodes with 10-mm diameter Ag/AgCl discs set at an inter-electrode distance of 2 cm, following skin preparation (shaving and cleansing with 70% alcohol) to reduce electrode impedance (typically 10 kΩ or less).29 The EMG signals were converted into a digital format using a 16-bit analog-to-digital converter (EMG System do Brasil®) and an input range of -12 to +12 volts. For signal processing, a high-pass filter with frequency of 500 Hz. Analysis was performed during arm elevation at 120 degrees, with a resistance of around 50% of 1-maximal repetition (1-MR). The root mean square (RMS) of the EMG signal was captured in the UT, LT, and SA of the involved limb for six seconds with the arm elevated and six seconds in the initial position (12 seconds total). A metronome was used to control duration of movement. The patients performed three trials, with a rest time of 30 seconds between each repetition. All data were normalized in relation to maximal isometric voluntary contraction (MVIC).10,28 The electrodes were positioned according to SENIAM criteria.16,29,30

To assess the maximal voluntary isometric contraction (MVIC) of the UT, the subject was seated with the arm in 90 degrees abduction, neutral shoulder rotation and with the head rotated 45 degrees toward the non-test side. The patient was then asked to perform shoulder abduction against a fixed resistance imposed by straps on the distal humerus, while manual resistance was applied to the back of the head in the anterolateral direction.31 The LT was tested in the prone position, with the arm placed diagonally overhead in line with the fibers of the LT. Resistance was applied against further elevation.32 For the SA, the patient was seated with the arm flexed to 135 degrees and resistance was applied against further flexion.29,33 The subjects performed three 10-second MVICs. There was a one minute pause between each MVIC.

Rehabilitation protocol
The treatment protocol (Table 2) was developed for those with report of subacromial pain syndrome and clinical evidence of scapular dyskinesis. It was asked that subjects not perform sports activities until discharged, returning gradually at Phase 3 of the protocol. Phase 1 consisted of pain control, ROM, and education in scapular control (Figure 1). Pain control was performed as needed according to therapist experience, using manual techniques as trigger point treatment or joint mobilization, or modalities, combined with therapy.1,34,35 In this phase, the subjects were instructed to keep shoulders down during the exercises to reduce UT activation. Once a patient noted diminished pain and decreased UT activation with improved control of the scapular movement, the patient could progress to Phase 2.

Phase 2 focused on periscapular muscular strengthening and initiation of sensory motor training (Figure 2). All exercises were dosed at 3 sets of 15 repetitions throughout the protocol, and this intermediate dosage was chosen in order to focus on muscular strength and endurance. Once muscle strength and scapular control were considered acceptable, i.e. performing the exercises without excessive anterior tilt of the scapula, the subject could progress to next phase.

Phase 3 emphasized advanced sensory motor training. Proper scapular alignment and stabilization were encouraged at all times during activity (Figure 3).5,7,16,32,36,37 All subjects attended two treatment sessions per week for six weeks and progressed through all protocol phases.

OUTCOMES
Special test results, pain level, and functional scores are included in Table 3. The results of the strength assessment, ROM, and muscular activation (EMG) are provided in Table 4. All subjects attended two treatment sessions per week and progressed through the three phases of the proposed protocol in accordance with the outlined criteria.

Each subject generally progressed well through the treatment program. The analysis of the EMG data showed a pattern of consistently increased SA activity among all subjects, however this pattern did not
Table 2. Rehabilitation protocol for treatment of scapular dyskinesis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Progression criterion</strong></td>
<td>• Anterior shoulder pain</td>
<td>• Significant decrease or absence of pain complaint</td>
<td>• Good control and muscular strength</td>
</tr>
<tr>
<td></td>
<td>• Scapular dyskinesis</td>
<td>• Scapular conscious</td>
<td></td>
</tr>
<tr>
<td><strong>Pain</strong></td>
<td>• Myofascial release</td>
<td>If necessary:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Physical agents (combined therapy or laser therapy)</td>
<td>• Myofascial release</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Physical agents (combined therapy or laser therapy)</td>
<td></td>
</tr>
<tr>
<td><strong>Scapular awareness (Scapular consciousness)</strong></td>
<td>• Sitting, arms in neutral position, pull their shoulder blades back and down</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ROM</strong></td>
<td>• Sleeper stretch for posterior shoulder capsule</td>
<td>If necessary:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sleeper stretch for posterior shoulder capsule</td>
<td></td>
</tr>
<tr>
<td><strong>Muscle strength</strong></td>
<td>• Punch exercise (supine, with the arm flexed to 90° and the elbow extended, punch the ceiling -protracts and retracts the scapula)</td>
<td>• Punch with dumbbells</td>
<td>• Low row exercise (arm extension in shoulder neutral rotation and the elbows extended with elastic resistance)</td>
</tr>
<tr>
<td></td>
<td>• Wall push-up plus exercise (standing with hands on wall, protraction and retraction of the scapula) and progress to knee push up plus exercise (support on hands and knees, elbow extended, protraction and retraction of the scapula)</td>
<td>• One-handed knee push up plus exercise (support in one hand and knees, protraction and retraction of the scapula) and progress to standard push-up plus (support on hands and feet, elbow extended, protraction and retraction of the scapula)</td>
<td>• Rotator Cuff exercise (arms internal / external rotation at 90° elevation in scapular plane with elastic resistance)</td>
</tr>
<tr>
<td></td>
<td>• Modified prone Cobra (arms in neutral position, arm extension with external rotation)</td>
<td>• Modified prone Cobra exercise (arms in neutral position, arm extension with external rotation with dumbbells)</td>
<td>• In all exercises (except Punch and Push-up plus) perform scapular retraction and depression</td>
</tr>
<tr>
<td></td>
<td>• In all exercises (except Punch and Push-up plus) perform scapular retraction and depression</td>
<td>• Prone horizontal abduction exercise (arms abducted at 90°, horizontal abduction with external rotation in prone with dumbbells)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Prone V-raise exercise (arms abducted at 120°, horizontal abduction with external rotation in prone with dumbbells)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Prone row (arms in neutral position, arm extension with the elbows flexed to 90° in prone)</td>
<td>• 3 X 15 reps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Rotator cuff exercise (arm internal / external rotation at 45° of abduction with roll under arm with elastic resistance)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>3 X 15 reps</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• In all exercises (except Punch and Push-up plus) perform scapular retraction and depression</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 3 X 15 reps</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Progression of the load as tolerated</td>
<td></td>
</tr>
<tr>
<td><strong>Sensory motor training</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Punch with oscillation flexibar</td>
<td>• Standard push-up plus the Swiss ball or balancer (Hands on the unstable surface)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Modified prone Cobra exercise on the swiss ball with dumbbells</td>
<td>• Prone horizontal abduction exercise on the swiss ball with dumbbells</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Prone V-raise exercise on the swiss ball with dumbbells</td>
<td>• Prone horizontal abduction exercise on the swiss ball with dumbbells</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• In all exercises (except Punch and Push-up plus) perform scapular retraction and depression</td>
<td>• In all exercises (except Punch and Push-up plus) perform scapular retraction and depression</td>
<td>• 3 X 15 reps</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Abbreviations: ROM - Range of motion
a Load: 70% of the 1-repetition maximum
b Maximum resistance that enabled 10 repetitions
exist with regard to the UT and LT because two subjects (1 and 2) decreased activation of the UT and LT, while the other two subjects (3 and 4) showed an increase in activation.

It should be noted that subject 1 reported a decrease in shoulder pain and improvement in scapular control in the first two weeks. However, in the third week, the subject presented with UT pain during daily activities followed by excessive muscle tension, which influenced progress in the protocol. After this period, the protocol was completed with 16 sessions (8 weeks), without pain complaints, and with return to normal functional and sporting activities.

**Figure 1.** Phase 1. A) Punch exercise. B) Knee push-up plus exercise. C) Wall push-up plus exercise. D) Modified prone Cobra.

Subject 2 progressed to Phase 2 in just one week and complied with all steps of the protocol. Table 1 shows that this subject had a short duration of symptoms, which may have favored a faster progression through the protocol. After 12 treatment sessions (6 weeks), the patient resumed normal functional and sports activities without complaints.

Subject 3 had bilateral anterior instability of the shoulder associated with a history of recurrent dislocation of the right shoulder and positive provocative tests for glenohumeral instability. The protocol was completed after 12 sessions (6 weeks), but the patient still presented with apprehension sign. However, functional and sporting activities were resumed without complaints.

Subject 4 was an amateur archer with subacromial impingement in the left shoulder (arm providing support to the bow), precluding him from participating in sport. After 12 sessions (6 weeks), the subject showed significant clinical improvement, returning to sports training.

DISCUSSION
This case series describes a rehabilitation program focusing on treatment of scapular dyskinesis used with amateur athletes who presented with clinical evidence of subacromial pain syndrome. Over a six-week period, the four subjects who participated in this program noted decreased pain, increased strength and ROM, as well as improvement in function and sports performance. Moreover, all subjects showed increased SA muscle activation, as observed by surface EMG.

As noted in Table 3, after treatment, all subjects reached good and excellent scores in terms of function and sports performance, which allowed the return to sport-specific training. Sports performance was assessed by the ASORS questionnaire, which was chosen because it is valid for assessing active adults or athletes with shoulder injuries. Level of function was assessed by the Constant score, which was validated for several shoulder injuries. It has an interrater error ranging from 0% to 8%. The minimal clinically important difference (MCID) is unknown for both questionnaires. However, the MCID for the VAS (0-10 cm) was estimated at 1.4 cm, specifically for shoulder injuries. All patients demonstrated total pain relief (down to zero in VAS), as well as improved muscle strength of the arm elevators (19%-43%) (Table 4). It is important to highlight that, in the first evaluation, the patients’ shoulder internal rotators (IR) were stronger than the external rotators (ER) at a ratio of 1.2:1, which changed to 1:1 over the course of the treatment. These findings
Table 3. Results of clinical tests and functional and pain scales for the initial evaluation and re-evaluations (discharge from therapy)

<table>
<thead>
<tr>
<th>Patient/Special Tests</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Involved</td>
<td>Uninvolved</td>
</tr>
<tr>
<td>Patient 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yocum</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Hawkins - Kennedy</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Neer</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Jobe</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Apprehension test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fukuda test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAT</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>SRT</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>VAS (0-10)</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>CONSTANT (0-100)</td>
<td>73 (regular)</td>
<td>82 (good)</td>
</tr>
<tr>
<td>ASORS (0-100)</td>
<td>28 (poor)</td>
<td>80 (good)</td>
</tr>
<tr>
<td>Patient 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yocum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hawkins - Kennedy</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Neer</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jobe</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Apprehension test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fukuda test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SRT</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>VAS (0-10)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>CONSTANT (0-100)</td>
<td>90 (excellent)</td>
<td>100 (excellent)</td>
</tr>
<tr>
<td>ASORS (0-100)</td>
<td>96 (excellent)</td>
<td>100 (excellent)</td>
</tr>
<tr>
<td>Patient 3</td>
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<td></td>
</tr>
<tr>
<td>Yocum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hawkins - Kennedy</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Neer</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Jobe</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Apprehension test</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fukuda test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAT</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>SRT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VAS (0-10)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>CONSTANT (0-100)</td>
<td>77 (regular)</td>
<td>83 (good)</td>
</tr>
<tr>
<td>ASORS (0-100)</td>
<td>92 (excellent)</td>
<td>96 (excellent)</td>
</tr>
<tr>
<td>Patient 4</td>
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<td>Yocum</td>
<td>+</td>
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<td>Hawkins - Kennedy</td>
<td>+</td>
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</tr>
<tr>
<td>Neer</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Jobe</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Apprehension test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fukuda test</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SRT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VAS (0-10)</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>CONSTANT (0-100)</td>
<td>76 (regular)</td>
<td>91 (excellent)</td>
</tr>
<tr>
<td>ASORS (0-100)</td>
<td>70 (good)</td>
<td>86 (good)</td>
</tr>
</tbody>
</table>

Abbreviations: SAT - Scapular Assistance Test; SRT - Scapular Retraction Test; VAS - Visual Analog Scale; ASORS - Athletic Shoulder Outcome Rating Scale

a 0- to 10-cm scale, where 0 means "no pain" and 10 means "worst imaginable pain"

b 0 to 100 points, where below 70 points is "poor", 70-79 is "regular", 80-89 is "good" and 90-100 is "excellent"

c 0 to 100 points, where below 50 points is "poor", 50-69 is "regular", 70-89 is "good" and 90-100 is "excellent"
Table 4. Muscle strength using handheld dynamometer, range of motion using goniometer, and EMG data

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th></th>
<th>Patient 2</th>
<th></th>
<th>Patient 3</th>
<th></th>
<th>Patient 4</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Patient</td>
<td>Change, %</td>
<td>Before</td>
<td>After</td>
<td>Patient</td>
<td>Change, %</td>
</tr>
<tr>
<td>Muscle strength(^a), %</td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Arm elevation</td>
<td>16.9</td>
<td>19.1</td>
<td>13.1</td>
<td>42.2</td>
<td>43.5</td>
<td>3.05</td>
<td>24.3</td>
<td>33.1</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>32.7</td>
<td>37.8</td>
<td>15.6</td>
<td>68.5</td>
<td>70.9</td>
<td>3.5</td>
<td>43.8</td>
<td>39.7</td>
</tr>
<tr>
<td>External rotation</td>
<td>26.0</td>
<td>31.8</td>
<td>22.5</td>
<td>61.9</td>
<td>68.1</td>
<td>10.1</td>
<td>26.5</td>
<td>39.9</td>
</tr>
<tr>
<td>Range of motion, degrees</td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Internal rotation</td>
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<td>94.0</td>
<td>64.9</td>
<td>62.0</td>
<td>67.0</td>
<td>8.1</td>
<td>62.0</td>
<td>87.0</td>
</tr>
<tr>
<td>External rotation</td>
<td>93.0</td>
<td>104.0</td>
<td>11.8</td>
<td>99.0</td>
<td>92.0</td>
<td>(-) 7.1</td>
<td>95.0</td>
<td>94.0</td>
</tr>
<tr>
<td>Surface EMG(^b), %</td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
<td></td>
<td></td>
<td>Patient</td>
<td></td>
</tr>
<tr>
<td>Upper trapezius</td>
<td>17.9</td>
<td>12.6</td>
<td>(-) 29.8</td>
<td>50.5</td>
<td>35.6</td>
<td>(-) 29.5</td>
<td>15.1</td>
<td>81.7</td>
</tr>
<tr>
<td>Lower trapezius</td>
<td>25.2</td>
<td>9.8</td>
<td>(-) 61.2</td>
<td>71.5</td>
<td>51.5</td>
<td>(-) 28.0</td>
<td>24.0</td>
<td>59.9</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>35.3</td>
<td>68.6</td>
<td>94.6</td>
<td>49.6</td>
<td>70.0</td>
<td>41.0</td>
<td>33.9</td>
<td>43.4</td>
</tr>
</tbody>
</table>

Abbreviation: EMG (electromyography)
\(^a\)Normalized in relation to body mass index
\(^b\)Normalized in relation to maximal isometric voluntary contraction

appear to contradict previous theoretical ideas\(^6\) that the dynamic stabilization of the shoulder depends on a proper balance between ER and IR, where the ER should have at least 65% of the IR strength.

An increase in ROM for internal rotation was observed, which probably occurred due to stretching (sleeper stretch) of the posterior shoulder structures. This finding corroborates with those of other authors who reported that this deficit in internal rotation is closely related to posterior capsule tightness and to scapular dyskinesis, leading to labral lesions and subacromial impingement, among others.\(^5,21\)

There was increased SA activation in all subjects after treatment, which may also have contributed to improvement of symptoms and the diminished scapular dyskinesis. This finding corroborates the opinion of several authors who believe that the SA is a very important muscle because it is involved in the three scapular movements required for arm elevation and because it commonly demonstrates lower activation in subjects with shoulder injuries.\(^5,8-10,37\) The fact that most of the patients showed increased SA activity may have influenced the patient's progress with regard to symptoms, even though this increase was not accompanied by a reduction in UT activity or an increase in LT activity.\(^11,13\) A possible explanation for the lack of change in the UT / LT relationship is that subjects may have had more scapula anterior tilt than upward deficit. However, the clinical tests currently available are inconclusive in terms specificity of different types of scapular dyskinesis.

Various authors have suggested that neuromuscular control and strengthening of the periscapular muscles is important in the treatment of scapular dyskinesis in patients with shoulder injuries. A study by Baskurt et al\(^15\) on patients with subacromial impingement syndrome showed the efficacy of proprioceptive neuromuscular facilitation exercises for scapular muscles. These results agree with the findings of De Mey et al,\(^36\) who associated this clinical improvement with the reduction in relative UT activation and the increase in SA activity, even if these exercises leave the UT/LT relationship unchanged.\(^40\) Finally, the results of a systematic review suggest that a rehabilitation program for subjects with shoulder dysfunction should focus on strengthening the periscapular and rotator cuff muscles, joint mobilization techniques, and posterior capsule stretching.\(^4\)

The treatment protocol described and utilized in the present study emphasized improvement in scapular movement and scapular dyskinesis with the use of exercises divided into three phases according to the level of difficulty based on previous studies.\(^5,7,15,16,32,37\) A number of authors agree that patterns of scapular dyskinesis can be caused by excess UT activation combined with reduced LT and SA activation and that the appropriate treatment would then be selective activation of the hypoactive muscles and reduc-
tion in the hyperactive muscles. However, the present study showed a pattern of SA activation accompanied by a directly proportional relationship between UT and LT activity. These results help to understand how the treatment focusing on scapular dyskinesis can lead to symptom relief, since the dyskinesis may be associated with several shoulder pathologies (such as subacromial impingement, rotator cuff tear, multidirectional instability, among others). The authors of this study strongly believe that the treatment of shoulder injuries should not be focused only on the lesion, but rather on the movement dysfunction. It is important to highlight that other authors already have shown that the presence of rotator cuff tear or degeneration as well as labral injury are not necessarily related to pain.

The limitations of the present case series include the small number of patients treated and the absence of a control group, which do not allow the generalization of the results. Another limitation is the use of surface EMG, because this technique may have allowed interference or cross-talk from other muscle groups. However, EMG is the most common technique used in the literature to evaluate muscle activity. It is important to highlight that the SENIAM criteria for electrode placement and procedures were adopted to minimize all potential interferences. Nevertheless, this study is relevant because it proposes and examines a treatment protocol for scapular dyskinesis to improve shoulder pain in active subjects. Future clinical trials with greater subject numbers and a control group are needed to confirm these results.

CONCLUSION
The results of this case series indicate that amateur athletes with clinical evidence of subacromial pain syndrome associated with scapular dyskinesis patients responded well to a rehabilitation program that emphasized scapular control, upper trapezius relaxation, correction of muscular imbalance, and sensory motor training. The results suggest that subjects with clinical evidence of subacromial pain syndrome can show significant improvement in terms of pain relief, function, and muscular performance after a rehabilitation program intended to address scapular dyskinesis. Further research is necessary to determine the short- and long-term effectiveness of this approach in the management of shoulder injuries.

REFERENCES


ABSTRACT

Background: Partial meniscectomy does not consistently produce the desired positive outcomes intended for meniscal tears lesions; therefore, a need exists for research into alternatives for treating symptoms of meniscal tears. The purpose of this case series was to examine the effect of the Mulligan Concept (MC) “Squeeze” technique in physically active participants who presented with clinical symptoms of meniscal tears.

Description of Cases: The MC “Squeeze” technique was applied in five cases of clinically diagnosed meniscal tears in a physically active population. The Numeric Pain Rating Scale (NRS), the Patient Specific Functional Scale (PSFS), the Disability in the Physically Active (DPA) Scale, and the Knee injury and Osteoarthritis Outcomes Score (KOOS) were administered to assess participant pain level and function.

Outcomes: Statistically significant improvements were found on cumulative NRS (p ≤ 0.001), current NRS (p ≤ 0.002), PSFS (p ≤ 0.003), DPA (p ≤ 0.019), and KOOS (p ≤ 0.002) scores across all five participants. All participants exceeded the minimal clinically important difference (MCID) on the first treatment and reported an NRS score and current pain score of one point or less at discharge. The MC “Squeeze” technique produced statistically and clinically significant changes across all outcome measures in all five participants.

Discussion: The use of the MC “Squeeze” technique in this case series indicated positive outcomes in five participants who presented with meniscal tear symptoms. Of importance to the athletic population, each of the participants continued to engage in sport activity as tolerated unless otherwise required during the treatment period. The outcomes reported in this case series exceed those reported when using traditional conservative therapy and the return to play timelines for meniscal tears treated with partial meniscectomies.

Levels of Evidence: Level 4

Key Words: Knee pain, meniscus, mobilization with movement
BACKGROUND AND PURPOSE
Meniscal tears are the second most common knee injury in sport, contributing to significant time loss for athletes. Common symptoms of meniscal tears include: clicking, catching or locking, joint line tenderness, a feeling of "giving out" or instability, pain with squatting or pivoting motions, pain at end range of flexion and/or extension, and a loss of range of motion. Sustaining a meniscal tear is thought to lead to knee joint space narrowing and altered joint biomechanics, which if not addressed, may lead to osteoarthritis (OA).

Arthroscopic surgery is the "gold standard" for diagnosing meniscal tears, but the most frequently used advanced diagnostic tool is magnetic resonance imaging (MRI); MRI has been found to have a specificity of 76%, sensitivity of 96%, and a diagnostic accuracy of 88%. Meniscal tears are also commonly diagnosed clinically using a battery of special tests. McMurray's (specificity 95%, Sensitivity 21%), Apley's (Specificity 90%, Sensitivity 13%) and Thessaly's test (Specificity 97.7%, Sensitivity 90.3%) are the most commonly used special tests for clinical diagnosis, with Thessaly's test having the highest diagnostic accuracy (94-96%) when performed at 20 degrees of knee flexion. Clinicians can also expect high diagnostic accuracies (>88%) from McMurray's and Apley's tests; when used as a testing battery, McMurray's and Apley's tests are comparable to MRI findings alone.

One method for improving the accuracy of the clinical exam is to create a more detailed clinical testing battery. Lowery et al. identified five components of a standard clinical examination which, when used as a battery, yielded a clinical composite score (CCS) superior to the accuracy of MRI for the detection of meniscal tears. The battery included: a history of catching or locking in the knee, pain with passive terminal knee flexion, pain with passive terminal knee extension, joint line tenderness and a positive McMurray's test. When all five signs were present in patients, a positive predictive value (PPV) of 92.3%, a specificity of 99% and a sensitivity of 11.2% were identified for the detection of meniscal tears (Table 1). The PPV and specificity decreased to 81.8% and 96.1% respectively, while sensitivity increased to 17% in the presence of four signs. When three of the five signs were present, the PPV was 76.7%, specificity 90.2%, and sensitivity 30.8%; even with only three signs present, accuracy remained comparable to that of MRI findings. Despite the frequent use of MRI for diagnosing meniscal tears, a detailed patient history combined with a battery of reliable special tests can produce a diagnostic accuracy of 90%, slightly superior to the diagnostic accuracy of MRI alone. Accurate diagnosis of meniscal tears is the gateway to producing quality outcomes in patients with meniscal tear symptoms. However, following up an accurate diagnosis with the proper course of treatment should be the primary focus of any experienced practitioner.

The standard of care for partial tears in the non-vascular portion of the meniscus is arthroscopic partial meniscectomy; this surgical procedure accounts for as many as 50% of all orthopedic surgeries in the United States. Partial meniscectomy is said to provide symptom relief, correct biomechanical dysfunction that occurs as a result of the injury, and delay the onset of OA. However, partial meniscectomies do not correct biomechanical dysfunction, and have actually been identified as the leading cause of OA in the knee. Furthermore, post-surgical outcomes have only reported limited success in radial tears of the posterior medial horn. Despite its prevalent use, partial meniscectomy patient outcomes have been found to be no different to those of patients who receive a sham surgery. Patient-reported symptoms 12-months after surgery and the number of patients requiring follow-up surgery were not significantly different between the two groups. When indicated, meniscal repair surgery is a preferred alternative to partial meniscectomy due to the preservation of the meniscus, which is thought to enhanced joint stability. However, reported failure rates for meniscal repair procedures can range from 8.9% to 42% and depending on the location of the tear, a repair may not be indicated in patients without a concomitant anterior cruciate ligament (ACL) tear. Additionally, the risk for follow-up surgery is higher for meniscal repair, 20.7%, than meniscectomy, 3.9%. In light of the evidence, it is important for clinicians to exhaust conservative treatment options prior to surgery in the management of meniscal tears.
The Mulligan Concept (MC) “Squeeze” technique is a manual therapy intervention designed to treat limited range of motion and localized joint line pain, which are symptoms often found in the presence of meniscal tears. Despite the theorized benefit of this technique in patients with meniscal tears symptoms, limited formal investigations of the efficacy of this treatment exist and the mechanism of action is unknown. Therefore, the purpose of this case series was to examine the effect of the MC “Squeeze” technique in symptomatic, physically active patients who met the criteria for a clinical diagnosis of a meniscal tear.

**CASE SERIES DESCRIPTION**

A multi-site a priori study was designed by four clinicians (mean clinical experience = 6 years ± 2.94 SD) to treat patients presenting with meniscal tear symptoms. Five participants (age = 19.6 ± 3.2, four males and one female) actively competing in a variety of sports at either high school or collegiate levels (Table 2) presented with clinical symptoms of meniscal tears. All participants were treated with the MC "Squeeze" technique until they reached discharge criteria; outcome measures were collected throughout the course of treatment. No other treatment intervention was applied and participant activity-level was not modified during the course of treatment. The Institutional Review Boards at all four data collection sites approved the collection of medical information from the participants in this study. Participants signed written informed consent acknowledging possible publication of their outcomes.

**CLINICAL IMPRESSION #1**

Participants were included in the case series if they presented with at least three of the following: positive McMurray’s test, pain with terminal knee flexion, pain with terminal knee extension, and a history of clicking and/or popping; yielding a high CCS. Participants were excluded if they

<table>
<thead>
<tr>
<th>Table 1. Clinical composite score findings for the detection of meniscal tears (Lowery et al., 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Sensitivity</td>
</tr>
<tr>
<td>% Specificity</td>
</tr>
<tr>
<td>PLR</td>
</tr>
<tr>
<td>% PPV</td>
</tr>
</tbody>
</table>

PLR=Positive Likelihood Ratio; PPV= Positive Predictive Value
Clinical Composite Tests = history of clicking and popping, joint line pain, pain with terminal knee flexion, pain with terminal knee extension, and a positive McMurray’s test.

<table>
<thead>
<tr>
<th>Table 2. Demographic data for participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>
had a potential ACL injury, indicated by a positive Lachman's test, because ACL tears have been found to reduce the diagnostic accuracy of the meniscal clinical composite score.\textsuperscript{11} In addition to the CCS, two tests involving a rotational force, Thessaly's at 20 degrees and Apley's compression and distraction test, were used because they have been identified to accurately assist in the clinical diagnosis of meniscal tears.\textsuperscript{12} Participants were required to present with a positive finding in at least one of these rotational special tests. Participants were also excluded if they presented with the following conditions during the initial exam: knee contusions, fractures, knee dislocations, increased pain with manual therapy, knee ligament instability, and non-mechanical causes of pain (e.g., hyperalgesia). The co-morbidities were considered precautions to manual therapy for the purpose of this study.

**EXAMINATION**

Examination included a thorough history and a comprehensive clinical exam relating to the chief complaint. The participants reported the following signs that met the inclusion criteria of: history of clicking and popping (n=2), joint line pain (n=5), pain with terminal knee flexion (n=5), pain with terminal knee extension (n=4), positive McMurray's test (n=4), positive Thessaly's test at 20 degrees of knee flexion (n=4), and/or positive Apley's compression/distraction test (n=3; Table 3). Based on the evidence

<table>
<thead>
<tr>
<th>Sign/Symptom</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
<th>Participant 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of Popping or Clicking</td>
<td>Positive</td>
<td>Positive</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Joint Line Tenderness</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Terminal Knee Extension</td>
<td>Positve</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Terminal Knee Flexion</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>McMurray's Test</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Thessaly’s Test (@ 20°)</td>
<td>Not Performed</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Apley’s Compression Test</td>
<td>Positive</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Other Initial Exam Symptoms</td>
<td>Edema, ROM Restriction, unable to weight bear</td>
<td>Edema and ROM Restriction</td>
<td>ROM Restriction</td>
<td>Edema and ROM Restriction</td>
<td>ROM Restriction</td>
</tr>
</tbody>
</table>
supporting the diagnostic accuracy of Thessaly's test\textsuperscript{15} and a battery of special tests,\textsuperscript{16-19} participants who met the inclusion criteria were provisionally diagnosed with meniscal tears.

**CLINICAL IMPRESSION #2**

Once participants were included in the study based on the clinical exam (Table 3), all five were treated with the MC “Squeeze” technique. The number of treatments (mean = 5 ± 1.73) and the duration of treatment in days (mean = 14.2 ± 5.68 days) were not standardized. Participants were treated until they reported a Patient Specific Functional Scale (PSFS) score of 10, a Numeric Pain Rating Scale (NRS) score of one or less, and a DPA scale score below 23 (Table 4). Participants were also progressively released to participate in physical activity as tolerated based on the clinician's individual sport-specific return to play criteria, which did not necessarily correlate to being discharged from the study. The participant could remain in the study after returning to sport activity until they reached the standardized discharge criteria.

**OUTCOME MEASURES**

The following outcomes were collected at intake: Numeric Pain Rating Scale (NRS), the Patient Specific Functional Scale (PSFS), the Disablement in the Physically Active Scale (DPA), and the Knee injury and Osteoarthritis Outcomes Score (KOOS). The NRS and PSFS were collected pre- and post- each treatment, while the DPA and KOOS were only collected at intake and discharge. All outcomes scales were found to be internally and externally valid, as well as reliable.\textsuperscript{31-36}

The NRS was used to quantify participant reported pain. The NRS score was conducted verbally and documented as an average (cumulative NRS) of current pain, best pain within 24 hours, and worst pain within 24 hours at intake, pre-treatment, and discharge.\textsuperscript{31} Immediate post-treatment pain changes (current NRS) were recorded using participant reported current pain post-treatment. The NRS scale was scored on an 11-point scale, with 0 representing no pain and 10 representing severe pain.\textsuperscript{31} The reported minimal clinically important difference (MCID) for the NRS is a decrease of 2 points or 33%.\textsuperscript{32}

The PSFS was used to quantify functional ability. The PSFS score was documented during intake, pre- and post-treatment, and after discharge. The participant was asked to identify a single activity to perform in the clinic that was limited due to injury. After identifying the activity, the participant verbally rated the severity of the limitation on an 11-point scale, with 0 representing being unable to perform the activity and 10 representing being able to perform the activity at the level before injury.\textsuperscript{32} The reported minimal detectable change (MDC) is a change in 2.5 points when using an individual activity in patients with a lower limb injury.\textsuperscript{34}

The DPA scale was used to quantify disablement across impairment, functional limitation, disability, and health-related quality of life.\textsuperscript{35} The DPA was collected at intake and discharge. Responses on the DPA are based on a scale ranging from 1 (no problem) to 5 (severe

<table>
<thead>
<tr>
<th>Participant</th>
<th>Total Treatments</th>
<th>Days to Discharge</th>
<th>Average NRS</th>
<th>Current NRS</th>
<th>PSFS</th>
<th>DPA</th>
<th>KOOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intake</td>
<td>Discharge</td>
<td>Intake</td>
<td>Discharge</td>
<td>Intake</td>
<td>Discharge</td>
<td>Intake</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>21</td>
<td>3</td>
<td>0*</td>
<td>2</td>
<td>0*</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>18</td>
<td>5.33</td>
<td>0*</td>
<td>5</td>
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<td>6</td>
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<td>5.33</td>
<td>0.33*</td>
<td>5</td>
<td>1*</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2</td>
<td>4.33</td>
<td>0*</td>
<td>5</td>
<td>0*</td>
<td>4</td>
</tr>
</tbody>
</table>

Average Numeric Pain Rating Scale (NRS)= the patients average score of current, best and worst pain over 24 hours; Current NRS=patients reported pain at time of treatment; PSFS= Patient Specific Functional Scale; DPA= Disability in the Physically Active Scale; KOOS= Knee injury and Osteoarthritis Outcomes Score

*= MCID Achieved in first treatment
**= MCID Achieved by discharge
***= Normal range prior to treatment
problem) across 16 items; total possible scores range from 0 to 64 points. A normal, healthy score is less than or equal to 34. An MCID is a decrease of 9 points for an acute injury and 6 points for a chronic injury. The KOOS was used to assess five dimensions: pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life. The KOOS was collected at intake and discharge. Responses within each dimension of the KOOS are based on a scale ranging from 0 to 4; a total score of 100 indicates no symptoms present. Each dimension of the KOOS was scored separately and a composite score of the average of all 5 categories (KOOS5) was used in the analysis of the data presented in this case series. An MCID for each subsection is a change of 8-10 points, however, an MCID value has not been established for the KOOS5 composite score.

INTERVENTION

The MC “Squeeze” technique was administered according to Mulligan Concept principles. All treatment started with the participant supine and the involved knee in 90 degrees of flexion, or flexed to the participant's pain-free limit, for better access to the joint line. The clinician placed the medial border of one thumb over the site of maximum joint line pain and swelling, and with the other thumb reinforced the first to create an overlap grip position (Figure 1). Next, the participant extended their knee to their maximal pain-free range, while the clinician maintained hand position, releasing the grip force on the joint line as the joint space closed (Figure 2). After maximal knee extension was reached, the participant actively returned their knee towards full flexion as the clinician increased the force with the overlapping thumb towards the center of the joint. The clinician continued to hold the pressure at the joint line for two seconds as the participant applied overpressure by pulling the tibia with both hands to their end range of knee flexion (Figure 3). The participants were allowed to experience localized discomfort from the overlap grip to tolerance, but the localized discomfort was not to be exacerbated with movement. Each treatment consisted of three sets of ten repetitions of the MC “Squeeze” technique. All participants were treated until discharged. The discharge criteria consisted of a PSFS score of 10, an NRS score of
one or less, and a DPA scale score below 23. No additional care was provided beyond the MC “Squeeze” technique. Participants were not restricted from any activities of daily living, and those deemed able by the clinician (based on clinical presentation) were allowed to participate as tolerated in their specific sport activity.

OUTCOMES

DATA ANALYSIS

Paired t-tests were performed on the cumulative NRS score, current NRS pain score, PSFS, DPA Scale, each dimension of the KOOS, and KOOS5 (an average of all dimension scores) to determine the effect of the interventions from initial exam to discharge. Mean differences from the initial visit scores and 95% confidence intervals (CIs) were calculated for all outcomes measures. Cohen’s d was calculated to determine the effect size, or maximum likelihood, of each outcome measure. For Cohen’s d, an effect size of 0.2 to 0.3 was considered a “small” effect, 0.5 a “medium” effect, and 0.8 to infinity a “large” effect. All data was analyzed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA).

NRS

The use of the MC “Squeeze” technique produced a statistically significant improvement in cumulative NRS scores (t(4) = 10.796, p ≤ .001, 95% CI: 3.21 to 5.43, Cohen’s d = 4.39) from initial exam to discharge. A statistically significant improvement in current NRS pain scores (t(4) = 7.303, p ≤ .002, 95% CI: 2.48 to 5.52, Cohen’s d = 3.07) was also found from initial exam to discharge, 14.2 ± 5.68 days after initial exam (Table 5). The Cohen’s d values resulted in a large effect size, indicating the change in NRS scores can very likely be attributed to the treatment intervention. All five participants reported a decrease in pain immediately after a single treatment; four participants met or exceeded the MCID (decrease of 2 points or 50%) on the NRS after the first treatment (mean change = 3.75 ± 1.89). All participants also reported a cumulative NRS score of less than 1 by discharge. Four participants reported cumulative NRS scores of 0, while one participant reported a cumulative score of 0.33 at discharge.

PSFS

The use of the MC “Squeeze” technique produced a statistically significant positive change in PSFS scores (t(4) = -6.74, p ≤ .003, 95% CI = -9.32 to -3.88, Cohen’s d = 3.01) from initial exam to discharge 14.2 ± 5.68 days after initial exam (Table 5). The Cohen’s d value resulted in a large effect size, indicating the change in PSFS scores can likely be attributed to the treatment intervention. Of particular importance, all participants reported an increase of at least 3-points by discharge, meeting the MDC for PSFS. All participants reported a PSFS score of 10 by discharge, indicating a complete restoration of function (Table 4).

DPA SCALE

The use of the MC “Squeeze” technique produced a statistically significant improvement in DPA Scale scores (t(4) = 3.817, p ≤ 0.019, 95% CI = 4.96 to 31.44, Cohen’s d = 1.44) from initial exam to discharge,

<table>
<thead>
<tr>
<th>Outcomes Scales</th>
<th>Mean Change</th>
<th>p-value</th>
<th>95% Confidence Interval</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRS- Average</td>
<td>4.32</td>
<td>0.00*</td>
<td>3.21 to 5.43</td>
<td>4.39</td>
</tr>
<tr>
<td>NRS-Current</td>
<td>4</td>
<td>0.002*</td>
<td>2.48 to 5.52</td>
<td>3.07</td>
</tr>
<tr>
<td>PSFS</td>
<td>6.6</td>
<td>0.003*</td>
<td>-9.32 to -3.88</td>
<td>3.01</td>
</tr>
<tr>
<td>DPA</td>
<td>18.2</td>
<td>0.019*</td>
<td>4.96 to 31.44</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Table 5. Statistical and clinical significance for pain, function, and disability scales

Average Numeric Pain Rating Scale (NRS)= the patients average score of current, best and worst pain over 24 hours; Current NRS=patients rating of pain at time of treatment; PSFS= Patient Specific Functional Scale; DPA=Disability in the Physically Active Scale

*= Statistically significant difference
14.2 ± 5.68 days after initial exam (Table 5). While only three participants reported a score that met the MCID for acute injuries (9 points), the other two participants began with scores below 23, which is within the normal range. The two participants who did not meet the MCID still improved by 7 and 8 points respectively. All participants’ scores on the DPA Scale were below 23 at discharge, which indicated that their perception of disability had likely returned to their pre-injury state (mean change = 18.2 ± 10.66; Table 4).

KOOS
The use of the MC “Squeeze” technique produced statistically significant improvement in KOOS5 (t(4) = -7.342, p ≤ 0.002, 95% CI = -39.36 to -17.62, Cohen’s d = 1.36) scores in each of the five dimensions, along with large effect sizes, from initial exam to discharge 14.2 ± 5.68 days after initial exam (Table 6). Of particular importance, all participants reported a minimum of 8-10 point increase on each of the five dimensions of the KOOS, meeting the MCID. There is currently no published MCID values for the KOOS5, but the mean change was a total increase of 28.56 ± 8.7 points for each participant on the KOOS5 from initial exam to discharge.

DISCUSSION
The results of this case series indicate improved patient outcomes when utilizing the MC “Squeeze” technique in participants who were classified as having a meniscal tear based on the meniscal pathology clinical composite score. Meniscal tear diagnosis was determined by a clinical evaluation consisting of a thorough history and a comprehensive clinical assessment relating to the chief complaint. The criteria for clinical diagnosis was determined to be accurate based on the evidence supporting the diagnostic accuracy of Thessaly’s test and a battery of special tests. A clinical examination has been determined to have a similar, and in some cases better, diagnostic accuracy than MRI alone, concluding that MRI is only necessary in cases lacking a definitive clinical diagnosis.

<table>
<thead>
<tr>
<th>KOOS Sub-Scale</th>
<th>Mean Change</th>
<th>Significance (p)</th>
<th>95% Confidence Interval</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td>27.06</td>
<td>0.036*</td>
<td>-51.98 to -2.93</td>
<td>2.89</td>
</tr>
<tr>
<td>Pain</td>
<td>32.22</td>
<td>0.013*</td>
<td>-53.06 to -11.39</td>
<td>1.89</td>
</tr>
<tr>
<td>ADL’s</td>
<td>23.22</td>
<td>0.014*</td>
<td>-38.94 to -7.72</td>
<td>1.93</td>
</tr>
<tr>
<td>Sports</td>
<td>49</td>
<td>0.014*</td>
<td>-81.38 to -16.62</td>
<td>1.77</td>
</tr>
<tr>
<td>QOL</td>
<td>11.2</td>
<td>0.037*</td>
<td>-21.31 to -1.09</td>
<td>0.79</td>
</tr>
<tr>
<td>Composite</td>
<td>28.56</td>
<td>0.002*</td>
<td>-39.36 to -17.76</td>
<td>1.36</td>
</tr>
</tbody>
</table>

KOOS= Knee injury and Osteoarthritis Outcomes Score; ADL= Activities of Daily Living; QOL= Quality of Life
* = Statistically significant difference

The treatment timelines in this case series varied due to each participant’s availability, however, all participants were discharged within six treatments (Table 4) delivered over an average of 14.2 days (± 5.68 SD). Additionally, the improvements reported by each participant were found to be statistically and clinically significant across all outcomes measures used in this case series. The use of the MC “Squeeze” technique also produced immediate benefits for the participants, as four of the five participants reported experiencing clinically significant improvements in pain after the first treatment (Table 4). Of particular importance to the athletic population, each of the participants continued to engage in sport activity as tolerated during the treatment period. Participants #1 and #4 returned from non-weight bearing status to limited activity after just one treatment and returned to full activity by the third treatment.
Participant #2 returned to full activity after two treatments. Participants #3 and #5 maintained full activity for the duration of treatment.

The outcomes reported in this case series exceed those reported in the use of traditional conservative therapy. The use of progressive resistive exercises (PREs) and non-steroidal anti-inflammatory drugs for treating meniscal pathology typically require more treatment sessions over a longer period of time (i.e., 12 weeks). The outcomes of this case series also surpass the return-to-play timelines for meniscal tears treated with partial meniscectomies. In a previous study, only 80% of participants who underwent partial meniscectomy returned to full sport activity after six months of rehabilitation.

Despite less than desirable outcomes in many cases, the "gold standard" of care continues to be partial meniscectomy; however, there are also recommendations to exhaust conservative treatment options prior to considering surgery. While more research is still needed, the positive results reported in this case series provide support for the MC "Squeeze" technique as an alternative non-operative treatment option for patients with presenting with meniscal pathology.

Several limitations exist in this case series, beginning with not controlling for each participants' activity during the course of treatment and the lack of arthroscopy for the confirmation of meniscal tears; however, given that most diagnoses are not made with arthroscopy and rely on clinical diagnosis, it is important to study the treatment of meniscal pathology patients who are classified through a clinical exam. Other limitations include the lack of a control or comparison treatment group and the collection of long-term (e.g., 6-months post-discharge) outcome measures. Additionally, according to the Mulligan Concept, it is common to first apply an internal rotation accessory glide of the tibia when treating patients with general knee pain, and to progress to medial/lateral glides of the tibia, to provide the greatest reduction in symptoms. Thus, the patient outcomes reported in this case series may have been further improved by determining which MC technique was best for each individual participant. However, as the MC "Squeeze" technique is recommended for the management of meniscal tear symptoms. Finally, while the outcomes using the MC "Squeeze" technique were positive, the application of the technique was provided by clinicians who were novices in utilizing this specific technique. Expert MC practitioners could have possibly exceeded the clinical outcomes produced in this study; the impressive results produced by novices, however, provides evidence for the potential efficacy of using this technique. Future research is needed to compare the MC "Squeeze" technique to other interventions for short- and long-term benefit. If the technique is found to be beneficial, investigation would also be needed to better understand the underlying physiological mechanism of the treatment.

CONCLUSION
Meniscectomy and meniscal repair surgery are currently common practice; however in this case series, use of the Mulligan Concept "Squeeze" technique produced statistically and clinically significant improvements in participants who were clinically diagnosed with a meniscal tear. The MC "Squeeze" technique may produce positive results in an athletic population seeking conservative treatment of meniscal pathology. The use of this manual therapy technique may also satisfy recommendations to exhaust conservative treatment interventions before seeking surgical intervention. Further research is needed to determine physiological mechanism and long-term effect of the treatment.

REFERENCES


ABSTRACT

Background: Despite the multidirectional quality of human movement, common measurement procedures used in physical therapy examination are often uni-planar and lack the ability to assess functional complexities involved in daily activities. Currently, there is no widely accepted, validated standard to objectively assess movement quality. The Selective Functional Movement Assessment (SFMA) is one possible system to assess complex functional movements. The purpose of this case report is to illustrate the application of the SFMA as a guide to the examination, evaluation, and management of a patient with non-specific low back pain (LBP).

Case Description: An adolescent male athlete with LBP was evaluated using the SFMA. It was determined that the patient had mobility limitations remote to the site of pain (thoracic spine and hips) which therapists hypothesized were leading to compensatory hypermobility at the lumbar spine. Guided by the SFMA, initial interventions focused on local (lumbar) symptom management, progressing to remote mobility deficits, and then addressing the local stability deficit.

Outcomes: All movement patterns became functional/non-painful except the right upper extremity medial rotation-extension pattern. At discharge, the patient demonstrated increased soft tissue extensibility of hip musculature and joint mobility of the thoracic spine along with normalization of lumbopelvic motor control. Improvements in pain exceeded minimal clinically important differences, from 2-7/10 on a verbal analog scale at initial exam to 0-2/10 at discharge.

Discussion: Developing and progressing a plan of care for an otherwise healthy and active adolescent with non-specific LBP can be challenging. Human movement is a collaborative effort of muscle groups that are interdependent; the use of a movement-based assessment model can help identify weak links affecting overall function. The SFMA helped guide therapists to dysfunctional movements not seen with more conventional examination procedures.

Level of Evidence: Level 4

Keywords: Functional movement, low back pain, Selective Functional Movement Assessment
BACKGROUND AND PURPOSE
Non-specific low back pain (LBP) is a diagnosis frequently encountered in outpatient orthopedic settings that presents a challenge for both patients and healthcare professionals. LBP is the most commonly reported musculoskeletal complaint among American adults with greater than one in four reporting symptoms in the previous three months. Studies have shown that by age fifteen, the incidence of LBP is as high as 36% among adolescents and even more prevalent in those who participate in sports. The majority of these cases lack an underlying pathoanatomic diagnosis and are classified as non-specific LBP.

Despite emphasis on movement and function in physical therapy (PT), traditional examination and evaluation procedures tend to be heavily geared toward measurements of motion in a single plane or isolated assessment of strength of one muscle in order to attempt to identify a patho-anatomic source of pain, lacking the qualitative evaluation of movement patterns as a whole. When considering the composition of musculoskeletal examination, the American Physical Therapy Association’s Guide to Physical Therapy practice includes only gross range of motion and strength and lacks specific outcome measures of movement quality. Only one study has looked at the psychometric properties of the Selective Functional Movement Assessment (SFMA) and it has been shown to have almost perfect intra-rater reliability and good inter-rater reliability among experienced clinicians when used as a movement-based diagnostic tool that provides clinicians with a standard to identify movement dysfunction in patients with known musculoskeletal injury. This objective system assists the healthcare professional in applying a qualitative approach, in parallel with quantitative measurements, in order to guide treatment of musculoskeletal pain and associated movement dysfunction using targeted interventions. The SFMA is rooted in the theory of Regional Interdependence which views all regions of the body as being “musculoskeletally linked”. Accordingly, seemingly unrelated impairments in remote regions may be the cause of a patient’s reports of pain but may go unidentified if the examination is focused on isolated localized movements alone. The SFMA consists of a series of ten functional movements designed to assess fundamental movement patterns of individuals with known musculoskeletal pain. These ten whole body functional movements are then further assessed via algorithms of impairment-based assessments called “breakouts” that dissect each pattern to identify the source of the dysfunction. The system is intended to help identify meaningful impairments, some of which may initially appear unrelated to the primary complaint, in order to facilitate the development and implementation of an individualized plan of care (POC).

Although this tool is useful with any patient, those with non-specific LBP are particularly good candidates for being evaluated using the SFMA because they lack a clear diagnosis or clearly identified anatomic source for their pain. Van Tulder et al have shown that treatment plans for patients with chronic LBP that focus on a single pathological structure often result in poor outcomes. The SFMA can guide the PT to underlying movement dysfunction in remote regions of the system that may be the cause of, or contributory to, abnormal stress in the lumbar spine. Studies have successfully linked limitations in remote regions to symptoms elsewhere in the system, including limitations of hip mobility to LBP and foot dysfunction causing patellofemoral pain. These correlations suggest the need for a valid evaluative system capable of identifying these dysfunctions to improve outcomes and potentially decrease recurrence. The purpose of this case report is to illustrate the application of the SFMA as a guide to the examination, evaluation, and management of a patient with non-specific low back pain (LBP).

CASE DESCRIPTION

History
The subject signed an informed consent to allow use of his personal medical information for this case report. The subject was an 18 year-old male who had just finished his first year of college and was referred to outpatient PT by his primary care provider with a chief complaint was intermittent low back pain. He reported that the pain had been present for the prior two years, and had become worse in the last three months, including new onset of symptoms in the posterolateral left hip. The subject was an avid weight lifter and participated on his college soccer
team. At the time of evaluation he had decreased his lifting frequency from five days a week to two and had significantly adjusted his exercise routine due to his pain; however, he was still playing soccer two to three times a week. The subject reported increased pain and stiffness following weight lifting and sports which were reduced with Ibuprofen and activity modifications. He was otherwise independent in all activities of daily living despite some discomfort. The subject reported his primary goal was to be pain-free with activity so he could return to his full pre-season lifting schedule and full participation in collegiate-level soccer.

**Systems Review**
The systems review revealed that all systems were unimpaired except the musculoskeletal system. The subject demonstrated limited gross spine and hip range of motion (ROM) and slightly decreased hip strength bilaterally. (Table 1)

**Clinical Impression 1**
The subject’s general complaints of LBP for two years and recent left hip pain could be the result of many possible diagnoses; however, he did not present with any red flag signs and therefore had not undergone any diagnostic imaging at the time of evaluation. Based on his complaints, the working differential diagnoses included facet joint dysfunction, intervertebral disc pathology, lumbar strain, sacroiliac joint dysfunction, hip muscular strain, impingement, and/or hip bursitis. The subject was referred to PT to identify and treat the source of his LBP. Based on history, it was suspected that the subject may have had muscle imbalances in the lumbo-pelvic region leading to LBP with activity.

**EXAMINATION**

**Tests & Measures**
Significant results from initial exam and discharge can be seen in Table 2. The subject was assessed via the SFMA top-tier patterns in order to identify functional movement deficits. A detailed explanation of the administration and interpretation of the SFMA top-tier movements can be found in Appendix A. Results of the SFMA top-tier screening revealed dysfunctional/non-painful movement (DN) in six of the ten motions. He was limited in multi-segmental patterns (including flexion, extension, and rotation), cervical and upper extremity (UE) patterns as well as ability to perform a deep squat. Dysfunctional movement in these patterns can suggest mobility limitations, stability dysfunction or both. Mobility limitations can

<table>
<thead>
<tr>
<th>Table 1. Results of systems review at initial examination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiovascular/Pulmonary</strong></td>
</tr>
<tr>
<td>Not Impaired</td>
</tr>
<tr>
<td>Heart Rate: 76 beats/min</td>
</tr>
<tr>
<td>Respiratory Rate: 12 breaths/min</td>
</tr>
<tr>
<td><strong>Integumentary</strong></td>
</tr>
<tr>
<td>Not Impaired</td>
</tr>
<tr>
<td>No presence of scar</td>
</tr>
<tr>
<td>Skin color and texture within normal limits</td>
</tr>
<tr>
<td><strong>Affect, Cognition, Learning Style, Communication</strong></td>
</tr>
<tr>
<td>Not Impaired</td>
</tr>
<tr>
<td>Alert and oriented times 3</td>
</tr>
<tr>
<td>Requests pictures for home exercise program</td>
</tr>
<tr>
<td>English speaking, college educated</td>
</tr>
<tr>
<td><strong>Neuromuscular</strong></td>
</tr>
<tr>
<td>Not Impaired</td>
</tr>
<tr>
<td>Lower extremity myotomes, transfers, locomotion, balance,</td>
</tr>
<tr>
<td>coordination all within normal limits.</td>
</tr>
<tr>
<td>Did not test dermatomes or deep tendon reflexes</td>
</tr>
<tr>
<td><strong>Musculoskeletal</strong></td>
</tr>
<tr>
<td>Impaired</td>
</tr>
<tr>
<td>Hip Strength: 4/5 on L and 4+/5 on R in all planes</td>
</tr>
<tr>
<td>Spinal AROM: 25% limited/painful in all planes</td>
</tr>
<tr>
<td>All other uni-planar AROM within functional limits all</td>
</tr>
<tr>
<td>planes</td>
</tr>
<tr>
<td>L = left; R = right; AROM = active range of motion</td>
</tr>
</tbody>
</table>


be categorized as tissue extensibility or joint mobility dysfunction. Stability dysfunctions are more complex and also referred to as a “motor control dysfunction” within the SFMA system. Stability is affected by multiple factors or systems including, but not limited to, the central and peripheral nervous systems, the proprioceptive system, postural alignment, structural integrity, and muscular inhibition, rather than focusing solely on the absolute strength of the stabilizer muscles. Mobility and stability limitations frequently coincide, as the body may sacrifice mobility in one region in an attempt to achieve a compensatory “pseudo-stabilization” in another. Based on top-tier results, therapists performed abbreviated versions of SFMA assessments at initial examination and discharge.

**Table 2. Results of SFMA and other special tests at initial examination and discharge**

<table>
<thead>
<tr>
<th>Selective Functional Movement Assessment (SFMA)</th>
<th>Initial Evaluation Results</th>
<th>Discharge Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>Cervical Flexion</td>
<td>FN</td>
<td></td>
</tr>
<tr>
<td>Cervical Extension</td>
<td>FN</td>
<td></td>
</tr>
<tr>
<td>Cervical Rotation</td>
<td>DN</td>
<td>DN</td>
</tr>
<tr>
<td>Upper Extremity (LRA)</td>
<td>FN</td>
<td>FN</td>
</tr>
<tr>
<td>Upper Extremity (MRE)</td>
<td>DN</td>
<td>DN</td>
</tr>
<tr>
<td>MSF</td>
<td>DN</td>
<td></td>
</tr>
<tr>
<td>MSE</td>
<td>DN</td>
<td></td>
</tr>
<tr>
<td>MSR</td>
<td>DN</td>
<td>DN</td>
</tr>
<tr>
<td>Single Leg Stance</td>
<td>FN</td>
<td>FN</td>
</tr>
<tr>
<td>Deep Squat</td>
<td>DN</td>
<td></td>
</tr>
<tr>
<td>Joint Mobility</td>
<td>Thoracic Spine (all levels): 2/6</td>
<td>Thoracic Spine (all levels): 3/6</td>
</tr>
<tr>
<td>Numeric Pain Rating Scale</td>
<td>- Best: 2/10</td>
<td>- Best: 0/10</td>
</tr>
<tr>
<td></td>
<td>- Worst: 7/10</td>
<td>-Worst: 2/10 (2 weeks prior)</td>
</tr>
<tr>
<td></td>
<td>- Current: 3/10</td>
<td>- Current: 0/10</td>
</tr>
<tr>
<td>Modified Thomas Test</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Patrick Test (FABER)</td>
<td>(-)</td>
<td>for hip pathology</td>
</tr>
<tr>
<td>(+) for limited ROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90/90 Straight Leg Raise Test (ROM)</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Straight Leg Raise Test (disc pathology)</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>Gaenslen’s Test</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>Hip Scouring Test</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>Slump Test</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td>Quadrant Test</td>
<td>(-)</td>
<td></td>
</tr>
</tbody>
</table>

FN = Functional/Non-painful, DN = Dysfunctional/Non-Painful, LRA = Lateral Rotation/Abduction, MRE = Medial Rotation/Extension, MSF = Multi-segmental Flexion, MSE = Multi-segmental Extension, MSR = Multi-segmental Rotation, ROM = range of motion.
of the SFMA breakouts over the course of the first two visits in order to narrow down the source of the movement dysfunction. Full details of each breakout is beyond the scope of this manuscript, however, specific follow-up testing using parts of each breakout was performed in order to assess mobility and stability impairments (Appendix B).

All special tests and measures were performed according to O'Sullivan and Magee. Using a verbal numeric pain rating scale, the subject reported his pain was a 7/10 at worst, 2/10 at best and a 3/10 at the time of examination. To identify regional sources of dysfunctional patterns, and whether they were due to mobility or stability issues, special tests for soft tissue extensibility of the hip were performed along with a joint mobility assessment of the spine. Special tests were positive for decreased soft tissue extensibility around the hip including the Modified Thomas Test and 90/90 Straight Leg Raise Test. The Modified Thomas Test was graded as a pass/fail, based on whether the test-leg angle at the knee was greater or less than 90° and was an indication that the quadriceps and hip flexors were contributing to limited hip mobility, in particular multi-segmental extension. FABER's Test was negative for pain provocation and was used to rule out pathology of the hip joint but was positive for ROM restriction. The 90/90 Straight Leg Raise Test was performed to assess posterior chain flexibility and was found to be positive for decreased hamstring extensibility determined by a knee angle less than 125° and was a likely contributor to limited multi-segmental flexion. Decreased joint mobility throughout the thoracic spine was noted to be 2/6 during accessory motion assessment using anterior-posterior glides at the spinous processes. Thoracic spine motion was evaluated due to its generally accepted influence on motion of the lumbar spine and lack of thoracic curvature noted with multi-segmental flexion. Isometric break manual muscle tests of the hips were performed bilaterally to assess stability and revealed asymmetrical strength with the right being one-half grade stronger than the left throughout all planes. This method of strength testing has been shown to be both reliable and valid. Postural analysis via visual assessment revealed increased thoracic kyphosis and forward shoulders as well as a moderately increased anterior pelvic tilt and lumbar lordosis in standing. Excessive anterior pelvic tilt remained during gait analysis but gait was otherwise unremarkable. Functional gait analysis has been found to be moderately reliable. Hip and sacroiliac (SI) joint pathologies were ruled out using the Hip Scouring Test and Gaenslen's Test, respectively. The Hip Scouring Test is a valid and reliable test to detect hip pathology such as impingement. Gaenslen's test has been shown to be reliable (test-retest k = 0.46) based on multiple studies as part of a battery of tests to identify SI joint lesions. Additionally, SI joint misalignment and leg-length discrepancy were ruled out by palpation and visual observation using the Weber-Barstow Method. The Slump Test, which is valid and reliable for adverse neural tension, was negative. Facet pathology was ruled out using the Quadrant Test despite literature indicating its poor diagnostic accuracy of this method. A Straight Leg Raise Test was also performed during hamstring length assessment and found to be negative, ruling out disc pathology. Palpation revealed tenderness and myofascial density throughout the bilateral erector spinae, quadratus lumborum, gluteus maximus and medius. Therapists assessed core stability using an alternating quadruped (bird dog) exercise; the subject had difficulty maintaining a neutral spine with dynamic motion suggesting underlying core stability deficits. After ruling out hip, SI, facet and disc pathology, the therapists hypothesized that the subject's pain was due to improper movement patterns as a result of the muscular and ROM imbalances identified during examination.

**Clinical Impression 2**
Examination findings confirmed the hypothesis that the subject had functional movement pattern dysfunctions contributing to his LBP. Based on SFMA and special test findings of decreased mobility in the hips, thoracic spine and shoulder girdle, therapists hypothesized that the lumbar spine was moving excessively as compensation for this lack of motion. His stability and mobility limitations were consistent with the joint-by-joint theory which argues that joints alternate in their primary role from stability to mobility and when a joint isn't able to carry out it's typical mobility or stability role, the next joint in the chain eventually will. The subject displayed
limited functional mobility at the hips, thoracic spine and shoulder which, according to this theory, function primarily as mobile joints while the lumbar spine serves primarily as a stable junction between the thoracic spine and pelvis. Therapists hypothesized that dysfunctional movements identified in basic SFMA patterns indicated a poor fundamental foundation for proper movement, causing excessive compensation at the lumbar spine.

Dysfunctional patterns could be the result of a true mobility deficit stemming from either limited soft tissue extensibility or joint mobility, or due to increased muscular tone as a result of an unstable segment. As seen in Appendix B, based on active and passive flexibility testing in supported postures with associated muscular end-feel and the results of special tests, it was believed the primary reason for decreased mobility at the hip was soft tissue extensibility and the thoracic spine limitations were due to impaired gross vertebral joint mobility. Based on the subject's inability to maintain and control pelvic tilt and lumbo pelvic positioning during exercise activities (for example an inability to maintain a neutral spine while performing quadruped stability exercises) the therapists believed based on clinical experience there were also underlying core stability deficits contributing to excessive stress at the lumbo pelvic junction. This may have resulted in his gross increase in tone as a means to restore or impose stability using the global musculature. However, it was decided this was a secondary dysfunction that would be addressed at a later point once proximal and distal mobility had been restored.

The therapists also believed that a major contributor to limited UE ROM was restricted thoracic spine extension as the subject was only limited in the functional (combined) pattern and had full motion for both shoulder extension and internal rotation assessed in isolation. The working hypothesis was that these limitations had caused this subject to load his lumbar spine in a hyperextended and unstable position when weight training, resulting in excessive pressure.

**Physical Therapy Diagnosis**

Based on findings from the examination, therapists determined the subject's primary PT diagnosis was impaired muscle performance (pattern 4C) due to chronic musculoskeletal dysfunction as well as a secondary diagnosis of impaired posture (pattern 4B). The ICD – 9 code was Lumbago (724.2).

**Prognosis**

The subject was a good candidate for PT due to his age, active lifestyle and motivation. In considering prognostic factors for recovery, chronicity was a negative factor, but the subject's young age was a positive factor. With improved mobility, stabilization exercises, postural modification and corrected movement patterns, it was anticipated that the subject's symptoms would subside, allowing him to meet his long-term goal of return to full activity with proper form and mechanics. Discharge criteria included being pain-free at rest and with exercise and attainment of a score of 14 or better on the Functional Movement Screen (FMS™) that indicated the subject was no longer at increased risk of injury with return to activity.

**INTERVENTIONS**

**Patient/client related instruction**

Therapists communicated to the subject that the plan of care (POC) was to alleviate symptoms first before progressing to mobility, then stability exercises. The subject was educated on what therapists hypothesized was contributing to his LBP. Therapists suggested to the subject that he avoid activities that caused pain and highly recommended he reduce the number of soccer games he was playing while continuing to adjust his weight training program. Finally, the subject was given an initial home exercise program (HEP) which included foam rolling for the hamstrings and quadriceps, a standing hamstring stretch, and half kneeling rear foot elevated hip flexor stretch to address soft tissue extensibility limitations present at the hip. Thoracic spine extension over a foam roller was incorporated to address general thoracic vertebral joint hypomobility. Finally, spine flexion/extension in quadruped was used to incorporate proprioceptive feedback during performance of controlled lumbo pelvic motions while also integrating diaphragmatic breathing for its role in stabilization of the spine. The subject confirmed he understood the POC, HEP and discharge criteria.
Procedural interventions

The subject was seen for 13 visits over nine weeks. Visits ranged from 45 minutes to one hour in duration and began with one to two visits per week initially, then one visit per week during the last three weeks. Interventions, based on categories put forth by the Guide to Physical Therapist Practice, included manual therapy, motor function training, and therapeutic exercises. Manual therapy techniques included soft tissue massage, spinal mobilization, high velocity manipulation of the spine, and passive ROM. Motor function training was incorporated into most exercises in the form of neuromuscular re-education for improved postural stabilization. Therapeutic exercises incorporated into the POC included flexibility, strength and power exercises, and breathing strategies.

Therapists initially prioritized pain relief in the lumbar region for the initial one to three weeks, theorizing that pain would disrupt normal movement patterns and cause continued dysfunction. Pain was treated using soft tissue massage to lumbar paraspinals and breathing techniques which were effective in minimizing pain. This same rationale was applied to the decision to attain full ROM of all limited patterns, which was the focus of weeks three to six, before performing stability exercises. Based on clinical experience the therapists believed attempting exercises with limited range would also result in altered movement patterns. Interventions carried out were from one of three categories including “resets” such as modalities or stretching to decrease pain or restore mobility, followed by a “reinforcement” exercise which incorporated newly gained ROM into a motion to protect the reset gains, and finally “reloading” movements which would integrate new gains into a functional pattern using therapeutic exercise. An example of this progression for the subject would be hamstring stretching as a mobility “reset”, followed by performance of toe touches with heels elevated to reinforce hamstring length and pattern a posterior weight shift, and finally “reloading” via completion of a proper deadlift with adequate posterior weight shift of the pelvis in order to strengthen within the corrected movement pattern.

To begin every treatment session, the subject was assessed using each of the SFMA top tier movements that were dysfunctional during the previous visit in order to guide treatment. Reports of pain were addressed with soft tissue massage, positioning and breathing techniques or spinal manipulation. Limited motion or soft tissue extensibility was addressed using sustained stretching including rear foot elevated hip flexor stretches and contract relax stretching for the hamstrings. Joint mobility restrictions were treated with high velocity spinal manipulation of the upper thoracic spine in supine or grade IV P-A glides of the vertebrae throughout the thoracic spine in prone.

Once mobility was normalized, as determined by a re-evaluation of special testing, limitations in lumbo-pelvic control during movement became more apparent; likely due to a loss of secondary stability that was being provided by tightness in hip musculature. This was addressed with static stability exercises such as planks which were progressed to dynamic core stability exercises that incorporated extremity movements while maintaining pelvic control such as 1/2 kneeling diagonal chops and lifts with resistance bands. Stability exercises were progressed based on neurodevelopmental sequencing beginning with a posture that provided more support, such as quadruped or 1/2 kneeling, to positions demanding more motor control and balance such as asymmetrical split-stance or single-leg stance. The therapists believed that if the subject could not display effective motor control in foundational (lower level developmental) positions, he likely would compensate in more complex (higher level developmental) patterns leading to continued stress on his back. Therefore a stability progression, with a goal of return to power lifting activities, began with cat-camel pelvic tilting to increase proprioceptive sense of a neutral spine. This neutral position was then progressed and strengthened dynamically with alternating upper and lower extremity motion in quadruped. The subject was then challenged to load his spine in this position by shifting his weight into a stability ball and maintaining a neutral pelvis and spine. Once he demonstrated good control of his pelvis with loading to the spine, he was progressed to double leg squatting and deadlifting with kettlebells, followed by asymmetrical lunging and single leg exercises in order to continue to strengthen his...
hips and promote core stability in more challenging positions. Once the subject could consistently perform these activities with a stable pelvis, and without excessive lumbar extension, he was progressed to powerlifting with a barbell and finally to sport-specific training for soccer.

Initially the therapists focused on restoring multi-segmental patterns for flexion and extension as these were most limited. These patterns were cleared for mobility issues and pain in the first five sessions using manual therapy techniques and as a result of the subject’s commitment to his HEP. These gains were maintained for all subsequent visits and stability exercises were progressed as previously described. Despite patterns being functional, the subject continued to demonstrate excessive lumbar lordosis with advanced exercises. As seen in Appendix C, focus was then shifted to UE movement patterns which were limited in the medial rotation and extension pattern, primarily on the right side. Based on clinical experience and the joint-by-joint theory it was hypothesized that limited motion was promoting compensation with excessive lumbar extension when under a barbell. Shoulder ROM improved in subsequent treatment sessions, and when combined with previously mentioned core stabilizing neuromuscular-reeducation exercises, the excessive lumbar compensation during power lifts was resolved. Appendix C shows all procedural interventions and progressions performed during each visit.

The subject was sent home to progress his activity over two weeks, then return for a reevaluation. At that time, the subject reported being pain-free with activity and was screened using the FMS™ (Table 3). The subject met his long-term goal of pain-free weight lifting as well as the therapist’s criteria for discharge based on FMS™ scoring and was discharged with an updated HEP after ensuring proper technique with deadlift and squat.

**OUTCOMES**

The subject of this case report showed significant improvements in pain (exceeding MCID), ROM (based on special tests and movement patterns), strength, and subjective motor control, achieving his long-term goal of a full pain-free return to weight lifting and soccer (Table 2). Additionally, he met both long-term goals set forth by therapists which included 5/5 symmetrical strength in bilateral hips and an FMS™ score ≥ 14 with no asymmetries or 0’s. Thoracic spine joint mobility (T1 – T12) went from a 2/6 to a 3/6 based on a P-A glide assessment and hip mobility improved bilaterally based on special tests. The subject received a designation of DN on nine of

<table>
<thead>
<tr>
<th>Functional Movement Screen</th>
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<tbody>
<tr>
<td>Screen</td>
</tr>
<tr>
<td>Deep Squat</td>
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<tr>
<td>Hurdle Step</td>
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<tr>
<td>In-line Lunge</td>
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<tr>
<td>Shoulder Mobility</td>
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<tr>
<td>Shoulder Clearing Test</td>
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<tr>
<td>Active Straight Leg Raise</td>
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<tr>
<td>Trunk Stability Push-up</td>
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<tr>
<td>Push-Up Clearing Test</td>
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<tr>
<td>Rotary Stability</td>
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<tr>
<td>Posterior Rocking Test</td>
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<tr>
<td>Total</td>
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</tbody>
</table>
The subject demonstrated improved form with deadlifting, with control of his pelvis and decreased lumbar lordosis. Outcomes at initial examination and discharge are detailed in Tables 2 and 3.

**DISCUSSION**

This case report outlines the application of the SFMA and theory of Regional Interdependence to guide initial examination, POC development, exercise selection and discharge criteria for a subject with LBP. Utilizing treatment principles suggested by the creators of the SFMA, this subject made significant improvements over the course of his nine week episode of care which allowed him to return to sports and weight lifting without pain. Emphasis placed on regaining mobility in his hips, mostly through his commitment to the HEP, appeared to be a major contributing factor to his decrease in symptoms. The effects seen after gains in mobility further supports the previously noted relationship between hip ROM restrictions and LBP. Once hip mobility was restored, emphasis was placed upon motor control to maintain stability at the lumbopelvic junction, which therapists believed may have been artificially created by the increased tissue tightness in his hips.
and thoracic spine as opposed to a true active stability. According to a supposition by Cook, limited hip motion has been assumed to cause back pain, however, instability in the back may in fact have facilitated “apparent hip tightness” that serves as a “secondary brace” to allow for continued function, even if it reduces mobility.\(^5\) This works in agreement with the joint-by-joint theory, wherein a possible instability at the lumbar spine may have created compensatory stability through increased tone at the joints above and below. It is difficult to determine which came first; therefore it was necessary to focus on maintaining a stable spine once mobility was restored.

The primary hypothesis was that improved motor control and core stability in addition to the subject’s newly acquired functional mobility, would allow him to return to athletics without risk of re-injury. To accomplish this, therapists sought to establish basic functional movement patterns which serve as the foundation for higher movement skills such as weight lifting and soccer.\(^6\) The goal of targeting movement pattern interventions was to attempt to resolve total body impairments, such as those identified by the SFMA. The SFMA helped to guide therapists away from the tendency to treat one pathological structure in a region such as the back, and instead identify non-painful impairments in regions adjacent to the site of pain that required intervention. We believe that this approach may help avoid falling into a continued cycle of recurring dysfunction and chronic pain by identifying the cause of pain rather than dealing with local symptoms.

The SFMA and FMS™ provide a means to both assess painful movement and screen pain-free movement. The two systems as a whole identify subtle impairments in movement patterns of the active individual, the correction of which theoretically results in decreased recurrence of injury. Currently only one study has looked at psychometric properties of the SFMA and it demonstrated poor to good reliability among novice evaluators and very good reliability in experienced users.\(^29\) However, responsiveness to change and validity of the SFMA has yet to be explored. Further investigation of the application of the SFMA and associated outcomes in various musculoskeletal injuries is needed. Validation of the SFMA as a clinical outcome tool has the potential to function as an adjunct to the current medical/patho-anatomic examination model, with the potential to serve as a standard for the assessment of functional movement patterns.

**LIMITATIONS**

Typical of case reports, the single subject design limits the relevance of these results when considering similar patients. Interventions based upon the SFMA proposed intervention system can vary greatly between therapists, as there is no definitive treatment prescription related to specific findings, and therefore intervention choices are dependent upon practitioner judgement, experience, and personal equipoise. As a result, each PT may have different approaches for interventions. Therefore it is not known if other treatments for this patient would have resulted in similar outcomes.

**CONCLUSIONS**

This case report demonstrates the effective use of the SFMA as a method or system used to qualitatively analyze movement at initial examination, and throughout the treatment process, and to direct subsequent intervention choices. In this case, the SFMA helped therapists to recognize dysfunctional movements that were present in subsequent regions that were not seen with more conventional examination procedures. While the ability to establish a cause-and-effect relationship is limited in this single subject, in this instance the SFMA presented an effective framework for the evaluation and treatment of an athlete with non-specific low back pain.

**REFERENCES**


APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA

- The SFMA is meant to be used for a patient with pain, unlike the FMS™ which is a pain-free screen. It uses movement to provoke symptoms and demonstrate dysfunction.

- The assessment consists of ten basic movements that are standardized for classification. Patterns are broken down into respective “breakouts” for clarity and perspective.

- Breakouts include active and passive movements, weight-bearing and non-weight-bearing positions, multiple and single-joint functional movement assessments and unilateral and bilateral challenges.

- When performing the assessment the examiner should avoid excessive instructions for form in order to evaluate how the patient moves naturally.

- Any additional movements deemed to be compensation outside the specified movement pattern is graded as dysfunctional.

- Any movement pattern that results in labored breathing is graded as dysfunctional.

- Any movements that provoke pain should be further assessed with caution as pain is known to alter motor control. Pain modulating therapies/modalities should be used and movements reassessed.

- Top-tier movements and breakout tests are graded with 4 possible notations based on subjective assessment:

  1. **Functional/Non-painful (FN)** – meets specified criteria and patient reports no pain
     - Further investigation of that pattern not recommended
     - Consider using FMS™ to assess pain-free functional movement patterns

  2. **Functional/Painful (FP)** – meets specified criteria but patient reports pain
     - Confirmation of patterns which can provoke pain can be used as a marker
     - Pattern can be broken down to sub-movements; proceed to treat symptoms

  3. **Dysfunctional/Non-painful (DN)** – does not meet criteria but patient reports no pain
     - Breakdown movement uncomplicated by pain
     - Further examine using breakout algorithm for that pattern to identify if the dysfunction is due to mobility or stability and whether the limitations stem from soft tissue extensibility or joint mobility

  4. **Dysfunctional/Painful (DP)** – does not meet criteria and patient also reports pain
     - Need to determine if poor movement is causing pain or pain is causing poor movement
     - Treat symptoms first before addressing movement with exercises
APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA (CONTINUED)

Cervical Patterns

Cervical Flexion

Instructions: Stand erect with feet together, toes pointing forward. Touch chin to chest with mouth closed.

Criteria:
1. Chin touches sternum with mouth closed

Evaluating: available cervical flexion including occipital-axis mobility

Breakout: Active supine cervical flexion → passive supine cervical flexion → active atlanto-occipital supine cervical flexion

Cervical Extension

Instructions: Stand erect with feet together, toes pointing forward. Patient instructed to extend neck back as far as they can.

Criteria:
1. Head reaches > 10° of parallel

Evaluating: available cervical spine extension

Breakout: supine cervical extension

Cervical Rotation (R + L)

Instructions: Stand erect with feet together, toes pointing forward. Patient rotates the head as far as possible, then flexes the neck moving chin to collarbone.

Criteria:
1. Chin touches mid-clavicle

Evaluating: amount of available cervical spine rotation and lateral flexion in a pattern which combines both movements.

Breakout: active supine cervical rotation → passive cervical rotation → supine C1-C2 passive cervical rotation
APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA (CONTINUED)

Upper Extremity Patterns

Medial Rotation-Extension (MRE) Pattern (R + L)

Instructions: Stand erect with feet together, toes pointing forward. Reach back and up spine with arm to try and touch opposite shoulder blade.

Criteria:
1. Touches inferior angle of contralateral scapula

Evaluating: internal rotation, extension and adduction of shoulder complex

Lateral Rotation – Abduction (LRA) Pattern (R + L)

Instructions: Stand erect with feet together, toes pointing forward. Reach behind head and down spine to touch opposite shoulder blade.

Criteria:
1. Touches spine of contralateral scapula

Evaluating: external rotation, flexion and abduction of the shoulder

UE Breakouts: Active pattern in prone → passive pattern in prone → supine reciprocal pattern
APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA (CONTINUED)

**Multi-Segmental Patterns**

**Multi-segmental Flexion (MSF)**

**Instructions:** Stand erect with feet together and shoes off, toes pointing forward. Bend forward to touch toes and come back to standing.

**Criteria:**
1. Touches toes and returns to standing position
2. Sacral angle is \( \geq 70^\circ \)
3. Presence of posterior weight shift (T-L junction over foot)
4. Uniform spinal curves

**Evaluating:** flexion of the hip and spine

**Breakout:** Single leg forward bend \( \rightarrow \) toe touch in long sitting \( \rightarrow \)

\( \rightarrow \) **Mobility Breakout:** Prone rocking OR Active straight leg raise \( \rightarrow \) Passive straight leg raise \( \rightarrow \) supine knee to chest

\( \rightarrow \) **Stability Breakout:** rolling patterns

**Multi-segmental Extension (MSE)**

**Instructions:** Stand erect with feet together, shoes off, toes pointing forward. Patient extends arms overhead with elbows in line with ears and bends backwards as far as possible.

**Criteria:**
1. ASIS clears toes
2. Maintains normal shoulder flexion \( (\geq 170^\circ) \)
3. Spine of scapula clears heels
4. Uniform spinal curves

**Evaluating:** extension of shoulders hips and spine

**Breakout:**

**Spine Extension:** backward bend without UE \( \rightarrow \) single leg backbend \( \rightarrow \) prone press up \( \rightarrow \) lumbar locked active extension \( \rightarrow \) lumbar locked passive extension

**Lower Body Extension:** standing hip extension \( \rightarrow \) prone active hip extension \( \rightarrow \) prone passive hip extension \( \rightarrow \) FABER \( \rightarrow \) Modified Thomas Test

**Stability Breakout:** rolling pattern
APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA (CONTINUED)

Multi-segmental Rotation (MSR) – (R+ L)

**Instructions:** Stand erect with feet together, shoes off, toes pointing forward. Rotate entire body as far as possible (hips, shoulders and head)

**Criteria:**
1. Pelvis rotation ≥ 50°
2. Trunk/Shoulder rotation ≥ 50°
3. No deviation of spine and pelvis
4. Limited knee flexion needed to achieve motion

**Evaluating:** rotational mobility of neck, trunk, pelvis, hips, knees and feet

**Breakout:**

- **Spine Mobility:** seated rotation  ➔ lumbar locked active rotation  ➔ lumbar locked passive rotation  ➔ prone on elbow rotation
- **Hip Mobility:** seated active hip rotation  ➔ seated passive hip rotation
- **Stability Breakout:** rolling pattern

Single Leg Stance (R + L)

**Instructions:** Stand erect with feet together and shoes off then lift knee to hip and hold for 10 seconds.

**Criteria:**
1. Maintains for 10 seconds
2. No loss of height (bending of knee)

**Evaluating:** ability to stabilize independently on each leg

**Breakout:** vestibular and core testing  ➔ ankle ROM assessment
APPENDIX A: SFMA INSTRUCTIONS, PATTERNS & CRITERIA (CONTINUED)

Overhead Squat

Instructions: Stand feet shoulder width apart with shoes off and feet pointed forward. Raise arms over head and squat as deep as possible keeping heels on floor and hands over head.

Criteria:
1. Maintains shoulder flexion
2. Maintains neutral thoracic spine (no flexion)
3. Femur > than parallel to floor
4. No sagittal plane deviation of lower extremities

Evaluating: bilateral symmetrical mobility of the hips, knees, ankles and shoulders as well as thoracic spine extension.

Breakouts: hands behind head squat → assisted squat → half-kneeling dorsiflexion → supine knees to chest

* Note: all patterns are meant to be performed with shoes off*
APPENDIX B

**Multi-Segmental Flexion**

- **DN** - doesn’t reach toes; PSIS don’t clear heels posteriorly

  - **Long Sit Toe Touch**
    - **DN** - Doesn’t reach toes in supported position

  - **Active ROM – Straight Leg Raise**
    - **DN** - hip angle < 70°

  - **Passive ROM – 90/90 Straight Leg Raise**
    - **DN** - knee angle < 125°

  - **Supine Knee to Chest**
    - **FN** - pulls thighs to chest

- **Posterior Chain Tissue Extensibility Dysfunction and/or Hip Stability Dysfunction**

- **Intervention Plan**
  - Restore soft tissue extensibility in hamstrings first then address core stability

**Multi-Segmental Extension**

- **DN – ASIS don’t clear toes anteriorly**

  - **Hip Mobility Assessment**
  
  - **Spine Mobility Assessment**

  - **Hip Extension AROM**
    - **DN** - bilateral inability to extend > 10° without excessive anterior pelvic tilt

  - **Hip Extension PROM**
    - **DN** - PT unable to passively extend bilateral hips > 10° without excessive anterior pelvic tilt

  - **Hip Mobility Special Testing**
    - Patrick's Test and Thomas Test both (+) bilaterally for restricted motion

  - **Bilateral Anterior Hip/Sacroiliac Joint Tissue Extensibility and/or Stability Dysfunction**

  - **Intervention Plan**
    - Restore soft tissue extensibility in hip flexors and joint mobility in spine first then address core stability

  - **Prone Press Up**
    - **DN** - ASIS don’t remain on table

  - **Spine Passive Intervertebral Motion**
    - **DN** - 2/6 grossly through thoracic spine

  - **Spine Tissue Extensibility and Joint Mobility Dysfunction**
## APPENDIX C: INTERVENTIONS

<table>
<thead>
<tr>
<th>Rx Day 1 (exam)</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam Rolling: quadriceps, hamstrings, hip flexors, glutes (1 minute each)</td>
<td>Standing rear foot elevated hip flexor stretch (2 x 1 min hold B/L)</td>
</tr>
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<table>
<thead>
<tr>
<th>Rx Day 2</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: MSF, MSE, MSR, B/L cervical rotation, B/L MRE, deep squat</td>
<td>STM erector spinae, multifidi, thoracic-lumbar (T-L) junction 15 minutes</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Rx Day 3</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: MSF, MSE, MSR, B/L cervical rotation, B/L MRE, deep squat</td>
<td>STM erector spinae, T-L junction, posterior rotator cuff 15 minutes</td>
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<thead>
<tr>
<th>Rx Day 4</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: MSF, MSE, MSR, B/L cervical rotation, B/L MRE, deep squat</td>
<td>STM erector spinae, posterior rotator cuff 10 minutes</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Rx Day 5</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: MSF, MSE, B/L cervical rotation, R MRE, deep squat</td>
<td>½ kneeling hip flexor stretch with anterior band pull (2 x 1 min hold B/L)</td>
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<tbody>
<tr>
<td>Rear foot elevated MSE (2x10)</td>
<td>Rear foot elevated MSE (2x10) (MSE cleared)</td>
</tr>
</tbody>
</table>
## APPENDIX C: INTERVENTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Rx Day 6</th>
<th>(MSE cleared)</th>
<th>Planks (3 x 30 seconds)</th>
<th>Squats to 18” bench (3x10)</th>
<th>RNT banded squats with anterior pull at knee (2 x 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: B/L cervical rotation, R MRE, deep squat</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Rx Day 7</th>
<th>(MSE cleared)</th>
<th>½ kneeling diagonal lifts with core activation with Cook band (2 x 10 B/L)</th>
<th>Posterior weight shift patterning with dowel (2 x 10)</th>
<th>Deadlift latissimus activation with barbell (1x5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: B/L cervical rotation, R MRE</td>
<td>STM posterior rotator cuff and pec minor 10 minutes</td>
<td>Banded MRE stretch in standing (10 x 15 second hold R)</td>
<td>TRX walkout shoulder extension (10 x 10 second hold)</td>
<td>Medial shoulder rotation mobility in extension with dowel (10 x 3 second hold)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rx Day 8</th>
<th>(MSE cleared)</th>
<th>½ kneeling rhythmic stabilizatio n for core control (2 x 10 B/L)</th>
<th>½ kneeling diagonal lifts and chops with Cook band (2x10 B/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: R MRE</td>
<td>Self soft tissue massage to posterior rotator cuff and pec minor with lacrosse ball 5 minutes</td>
<td>Horizontal adduction self stretch prone on table (5 x 15 second hold)</td>
<td>Banded MRE stretch in standing (10 X 15 second hold R)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rx Day 9</th>
<th>(MSE cleared)</th>
<th>Barbell squats with 75 lbs (3 x 8)</th>
<th>Sled push with core activation with 90 lbs (4 x 100 ft)</th>
<th>Split squats (3 x 8 B/L)</th>
<th>Barbells deadlifts with 115 lbs (3x6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: R MRE</td>
<td>STM posterior rotator cuff and pec minor 10 minutes</td>
<td>High velocity manipulation of T-spine in supine (T2 – T8)</td>
<td>✓</td>
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</table>

<table>
<thead>
<tr>
<th>Rx Day 10</th>
<th>(MSE cleared)</th>
<th>Single leg squats to 18” bench (3x8)</th>
<th>Barbells deadlifts with 115 lbs (3x6)</th>
<th>Single leg dead lift patterning with dowel (1x10)</th>
<th>Single leg dead lift to 6” box with 12kg kettlebell (3x6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: R MRE</td>
<td>Banded MRE stretch in standing (10 X 15 second hold R)</td>
<td>TRX walkout shoulder extension (10 x 10 second hold)</td>
<td>Medial shoulder rotation mobility in extension with dowel (10 x 3 second hold)</td>
<td>Single leg squats with core activation with 90 lbs</td>
<td>Single leg squats to 18” bench with 12kg (3x10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rx Day 11</th>
<th>(MSE cleared)</th>
<th>Horizontal shoulder adduction self-stretch</th>
<th>Sled push with core activation with 90 lbs</th>
<th>Single leg dead lift to 6” box with 12kg</th>
<th>Single leg squats to 18” bench (3x10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN: R MRE</td>
<td>✓</td>
<td>✓</td>
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</table>
## APPENDIX C: INTERVENTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Rx Day 12</th>
<th>DN: R MRE, B/L cervical rotation</th>
<th>STM scalene and upper trapezius 10 minutes</th>
<th>High velocity manipulation of T-spine in prone (T2 – T8)</th>
<th>Barbell shoulder extension stretch (2 x 6 for 5 second hold)</th>
<th>Core engage plank walkouts (2 x 10)</th>
<th>Squat Review</th>
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</thead>
<tbody>
<tr>
<td>Rx Day 13</td>
<td>DN: R MRE</td>
<td>FMS Screen</td>
<td>HEP review</td>
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</table>

STM = soft tissue massage; P-A = posterior-anterior; R = right, L = left, B/L = bilateral SFMA = Selective Functional Movement Assessment; DN = dysfunctional/non-painful; MSF = multi-segmental flexion, MSE = multi-segmental extension, MSR = multi-segmental rotation, MRE = medial rotation extension; ✓ = repeat of exercise above, FMS = Functional Movement Screen.
ABSTRACT

Study design: Case report

Background: Isolated, grade III lateral collateral ligament knee injuries are an uncommon traumatic injury with little guidance available in the literature for conservative management and prognosis for return to sport. The purpose of this case report is to describe the clinical decision-making in both differential diagnosis and physical therapy management of an isolated grade III lateral collateral ligament sprain in an adolescent multi-sport high school athlete.

Case Description: A 16 year-old male, high school, multi-sport athlete (cross country, wrestling, track and field) sustained a traumatic knee injury during a wrestling match when his involved lower extremity was forcefully externally rotated by his opponent. Initial clinical presentation revealed pain and increased laxity with varus stress testing of the left knee, which was subsequently identified via MRI as a complete lateral collateral ligament rupture (grade III). A conservative physical therapy program was developed targeting the active and neuromuscular subsystems, theorized to compensate for the lack of an intact lateral collateral ligament.

Outcomes: The subject attended 18 visits of physical therapy over a period of 12 weeks. His rehabilitation program focused on functional strengthening of the posterolateral corner, enhancement of neuromuscular control, and graded progression to sports specific drills. Return to play decisions were based on a combination of lower extremity functional performance measures, condition specific outcome measures and subjective performance on sports specific tasks. At discharge from physical therapy, he reported 0/10 pain, scored a 76/80 on the Lower Extremity Functional Scale, and was able to return to competitive track and field events.

Discussion: Few descriptions in the literature exist for the conservative management of isolated, grade III lateral collateral ligament injuries. A program of selective functional strengthening, proprioceptive training, and graded sport specific activities may allow these individuals to return to sport with conservative management.

Levels of Evidence: 4 (Single Case Report)

Key Words: Lateral collateral ligament, posterolateral corner, track and field
BACKGROUND AND PURPOSE
Knee injuries constitute a major area of disability in sport. Epidemiological studies report the incidence of knee injuries comprising up to 39% of all related sport injuries,¹ reaching as high as 73.9% in some studies.² The most commonly injured structures include the anterior cruciate ligament (ACL), medial collateral ligament (MCL), and menisci.¹,³,⁴ Lateral ligament injuries of the knee are far less common overall, representing 1.1% of knee injuries.¹ Moreover, the lateral collateral ligament (LCL) is rarely injured in isolation; rather, concomitant cruciate, meniscal, and potentially peroneal nerve involvement are commonly seen.⁵,⁶,⁷ This is observed both clinically and in cadaveric biomechanical models of injury.⁸,⁹ When seen in combination, injuries to the lateral side of the knee can also be a major source of failed cruciate ligament reconstructions when overlooked and not properly addressed during surgery.¹⁰

The LCL is a major passive stabilizer to the lateral aspect of the knee.¹¹,¹² Considered a component of the posterolateral corner (PLC), the LCL is a primary static restraint to varus stress at the knee.¹² It is a secondary restraint to tibial external rotation, along with the popliteus tendon, popliteofibular ligament, and posterolateral capsule as more primary static restraints.¹¹,¹² The LCL is most taut from 0°-30° of knee flexion and is most suited to resist varus forces within this range, which corresponds to the accepted position of clinical tests to isolate the integrity of this ligament.¹¹,¹³ The LCL is also able to resist varus force through additional ranges of knee flexion, as well as contributing to stability to tibial internal rotation.¹⁴

The LCL’s role in restricting tibial external rotation is most optimum when the knee is in full extension, as this position places the greatest force upon this ligament.¹⁰

Because isolated LCL injuries are rare, detailed descriptions of their conservative management in the literature are limited, and are often considered more broadly with injuries to the PLC. The literature generally supports conservative management of grade I and II injuries, with grade III injuries often managed surgically⁹,¹⁰,¹⁵–¹⁹ although there is not a strict consensus.⁹,²⁰ The majority of reports of conservative management of LCL injuries do not provide sufficient detail to replicate from a rehabilitation perspective, aside from two examples, both of which are also in the context of injuries to the posterolateral corner.¹⁹,²¹ The purpose of this case report is to describe the clinical decision-making in both differential diagnosis and physical therapy management of an isolated grade III lateral collateral ligament sprain in an adolescent multi-sport high school athlete.

CASE DESCRIPTION: HISTORY AND SYSTEMS REVIEW
The subject was a 16 year-old male high school athlete (1.60 m, 66 kg; BMI 25.8 m/kg²), who participated in year-round competitive sports, including cross-country, wrestling and multiple track and field events (100 m, shot put and discus). His injury occurred during a wrestling match, when his planted, left lower leg was forcefully externally rotated from a standing position by his opponent in a take-down maneuver. He was unable to continue the match secondary to pain and limited ability to bear weight. Radiographs of the left knee taken in the emergency room were negative for fracture. He was given crutches to limit weight bearing and placed in a knee immobilizer. Two weeks later, he was evaluated by a pediatric orthopaedic physician who discontinued the knee brace and crutches, ordered an MRI, and referred the subject to physical therapy. The preliminary diagnosis by the physician was a left knee ACL and LCL tear, which was made prior to obtaining the MRI results.

The initial physical therapy evaluation was performed 3.5 weeks post injury. The subject reported no previous orthopedic injuries with an unremarkable past medical history. His chief complaints were localized lateral knee pain with weight bearing, activity limitations related to inability to ambulate with a normal gait pattern, and perceived knee instability most noted with stair descent. The subject had been able to participate fully in school with minimal limitations. He denied paresthesias into the lower extremity. The subject's goals were to return to sports as soon as possible, targeting the spring track season, which was to begin in two months. He rated his pain as a 5/10 at worst on the verbal numeric rating scale (VNRS) and scored a 49/80 on the Lower Extremity Functional Scale (LEFS).²²

CLINICAL IMPRESSION #1
The subject’s described mechanism of injury and reported symptoms of instability with ambulation and stairs suggested ligamentous involvement. Priorities for the examination included determining presence of intra-articular joint effusion, baseline range of motion
and strength measures, analysis of function and gait, and special tests established for the ligamentous and intra-articular joint structures of the knee. From the subject's reported mechanism of injury, pain location and perceived instability of the affected knee, the examination was focused upon determining the integrity of the menisci, collateral and cruciate ligaments, and PLC.

**EXAMINATION**

The subject was tender with palpation to the lateral joint line and lateral femoral condyle. There was no appreciable knee effusion, with the subject exhibiting a negative ballottement test and score of zero on the stroke test. Knee AROM was pain free and measured via standard goniometry to be equivalent bilaterally at 0°-130°. Knee PROM was equivalent bilaterally as well, with 10 degrees hyperextension and a firm, painless end-feel into extension. He was unable to cross the left lower extremity over the right in sitting secondary to marked apprehension. Manual muscle testing to the left lower extremity revealed 4/5 strength of the knee flexors, knee extensors, and hip extensors. The subject demonstrated manual muscle testing of at least a 3/5 for the left hip abductor strength with the knee immobilized, but with complaints of lateral left knee pain and fear of movement into this plane of motion.

Analysis of the subject's gait revealed a number of compensations at the subject's ipsilateral hip that partially mitigated the demand for knee flexion in transitioning from terminal stance into initial swing. This included an increase in hip extension and posterior rotation of the pelvis into terminal stance and a concomitant mild ipsilateral hip hike into initial swing. As a result, the affected knee experienced a decreased knee flexion excursion during the transition from terminal stance through initial swing. Stair ascent was unaffected, though the subject was hesitant with weight acceptance on the affected leg with stair descent. The subject perceived discomfort at the lateral knee with terminal stance and was most apprehensive with weight acceptance in stair descent on the affected extremity.

Left knee ligamentous laxity was noted with varus stress test at both 30° and 0° of knee extension and graded as 2+ and 1+ respectively, though the subject exhibited negative anterior drawer and Lachman's tests. The posterior drawer test, posterior sag sign, and Dial test at both 30° and 90° were negative. The subject had a non-mechanical but painful McMurry’s test for the lateral meniscus, but this was confounded by the presence of varus stress at the knee that occurs with this test. A summary of the pertinent examination findings can be found in Table 1.

**CLINICAL IMPRESSION #2**

The results of the initial physical therapy examination were consistent with findings of an isolated LCL injury. Clinical testing of the medial collateral ligament, cruciates and other structures of the postero-lateral corner were negative, in addition to exhibiting a low likelihood of meniscal involvement. Additionally, varus testing at 30° of knee flexion revealed a marked (+2) instability, with only a very slight (+1) instability at 0° of knee flexion, also supporting an isolated LCL injury. Results from his MRI, two-days following his PT evaluation, confirmed a

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**Table 1. Summary of Pertinent Exam Findings**

<table>
<thead>
<tr>
<th>Examination Category</th>
<th>Clinical Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait</td>
<td>Decreased knee flexion at pre-swing, pain noted at terminal stance into pre-swing. Mild decreased stance time on left, compensatory ipsilateral hip hike into initial swing. No assistive device.</td>
</tr>
<tr>
<td>Strength</td>
<td>4/5 strength left knee flexors, knee extensors, hip extensors. At least 3/5 left hip abductors secondary to pain/apprehension to side-lying hip abduction. SLR without extensor lag</td>
</tr>
<tr>
<td>ROM</td>
<td>AROM Knee flexion 0-130 bilaterally. Extension PROM to 10° hyperextension bilaterally, pain free.</td>
</tr>
<tr>
<td>Special Tests</td>
<td>Stroke test 0. Negative ballottement. Positive varus stress test (1+ at 0° and 2+ at 30° of knee flexion) and positive Modified McMurry’s for lateral meniscus. Negative anterior drawer, posterior drawer, Lachman’s, posterior sag sign, Dial test at 30° and 90°.</td>
</tr>
<tr>
<td>Functional Performance</td>
<td>Inability to cross left leg to don shoes. Apprehension with weight acceptance with stair descent on left.</td>
</tr>
</tbody>
</table>

ROM = range of motion; AROM = active range of motion; PROM = passive range of motion
complete proximal to mid-substance tear of the lateral collateral ligament along with bone marrow edema at the lateral femoral condyle, which may represent an avulsion mechanism of injury (Figure 1). The imaging report noted intact structures of the posterolateral corner (including the iliotibial band, biceps femoris and popliteus tendons), menisci and cruciate ligaments. This confirmed the clinical findings of isolated LCL laxity present with varus stress testing and apprehension to movements producing a varus stress at the knee (e.g., side lying hip abduction and crossing the affected leg to don shoes).

The subject's observed gait deviations were explainable by what is known about the biomechanical function of the LCL. The LCL contributes primarily to varus knee stability within the first 30˚ of knee flexion.18 The subject's deviation seen during terminal stance into pre- and initial swing is consistent with the joint stability conferred by this ligament during these phases of the gait cycle, as the knee transitions from full extension and rapidly flexes into swing. Others have described gait deviations in this phase with injuries to the PLC involving the LCL.18,21 The absence of a varus deformity or varus thrust during gait may have been due to the integrity of the remaining structures of the PLC.

**INTERVENTION**

The subject was seen for a total of 18 visits over a period of 12 weeks. The subject exhibited full left knee ROM, so the initial program design emphasized improving the strength and neuromuscular control of the active components of the PLC thought to compensate for the lack of the passive LCL restraint, while being mindful of protecting the knee from motions that would stress the joint from forces the LCL would normally restrain early in the rehab process.19 The authors were initially cautious of exercises and activities that may generate varus and/or tibial external rotation stresses to the knee, particularly in light of the hesitancy seen with side-lying hip abduction and assuming the figure-four position. The authors adapted previous work describing conservative PLC injury management, as no rehabilitation protocols for isolated LCL injuries were found in the literature.19

Rehabilitation goals initially focused on normalizing gait, developing strength and neuromuscular control in the sagittal plane, proprioceptive activities, and progression to sports-specific training. Milestones were established for first gaining good control in the sagittal plane, with subsequent progression to frontal plane and finally rotary activities. The intervention plan was developed with the subject's goal of participating in

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**Figure 1.** Consecutive coronal fat suppressed proton density (PD) weighted images of the left knee demonstrate complete tear of the LCL proximally (arrow) associated with bone marrow edema (arrowhead) of the lateral femoral condyle at the femoral attachment of the LCL. Bone marrow edema may be due to avulsion injury from the proximal portion of the LCL.
the spring track season for the 100m, shot put and discus events. Optimal conservative management would ideally allow the subject to first be able to participate in the 100m sprint, as this is primarily a sagittal plane activity. The shot put and discus involve a progressive demand for multi-planar stability, especially with the rotary component of the discus throw. The authors hypothesized return to these activities would come later in the rehabilitation process.

The rehabilitation program was divided into four distinct phases, correlating to what has been described in the literature (Table 2). Based on the subject’s evaluation findings (normalized knee extension ROM, knee flexion > 120°, performing a straight leg raise without a quadriceps lag, and absent knee effusion) he was deemed appropriate to begin in Phase II relative to those previously outlined. He was initially seen two times per week, with tapering frequency to once per week as he progressed to sport practice and independence with his home exercise program. Table 2 presents each rehabilitation phase with selected exercise interventions, remaining activity and participation restrictions and accomplishment of milestones. Progression between phases was based on a combination of rehabilitation milestones, continued participation restrictions, and periodic clinical evaluation by the subject’s orthopedic physician and physical therapist.

**Phase II: Weeks 3-5 (Visits 1-6)**

Table 2 presents each rehabilitation phase with selected exercise interventions, remaining activity and participation restrictions and accomplishment of milestones. Progression between phases was based on a combination of rehabilitation milestones, continued participation restrictions, and periodic clinical evaluation by the subject’s orthopedic physician and physical therapist.

**Table 2. Rehabilitation phases for the conservative management of an isolated LCL tear**

<table>
<thead>
<tr>
<th>Phase II-Weeks 3-5</th>
<th>Selected Intervention</th>
<th>Milestones on Phase Completion</th>
<th>Precautions/Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modalizes (e.g., ice) as needed, knee ROM and mobilization techniques, lower extremity strengthening exercise</td>
<td>Painfree ADL’s, no knee effusion, full knee ROM, 4+/5 strength to the involved lower extremity</td>
<td>Precautions with varus and tibial ER stress</td>
</tr>
<tr>
<td></td>
<td>Double limb proprioception activities</td>
<td>Normalized gait and reciprocal stair negotiation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bridge progression (Figure 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Static and dynamic squats, lateral resisted walk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase III-Weeks 6-9</td>
<td>Continue previous phase interventions</td>
<td>Painfree ADL’s, no knee effusion, full knee ROM, 5/5 strength to the involved lower extremity</td>
<td>Knee soreness rules for running/activity progression</td>
</tr>
<tr>
<td></td>
<td>Running program</td>
<td>LEFS &gt; 68/80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agility ladder, sagittal to frontal plane progression</td>
<td>Timed 6m hop – 100%, Triple hop – 90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Static unidirectional lunges, progression to dynamic and multi-directional</td>
<td>Completed running program</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Double-limb chops</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weighted (lateral) walk with obstacle stepover</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bilateral/unilateral straight-leg deadlift</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase IV-Weeks 10-15</td>
<td>Lateral sprinting, progress to full effort</td>
<td>Painfree ADL’s, no knee effusion, full knee ROM, 5/5 strength to the involved lower extremity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mountain climbers</td>
<td>LEFS &gt; 75/80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single-limb chops</td>
<td>Timed 6m hop &gt; 90%, Triple hop &gt; 90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discus throw progression</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storks/Bilateral straight-leg deadlifts on angles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dosage of exercises were up to 3 sets of 10 to 15 repetitions each at 10 repetition maximum intensity, agility ladder at 50 sec to 1 minute bouts.

LCL = lateral collateral ligament; ROM = range of motion; ADL = activities of daily living; LEFS = Lower Extremity Functional Scale.
lack of an intact LCL, such as the lateral hamstrings. Exercises in this phase consisted of a combination of bridging activities (Figure 2). A bridging exercise progression was chosen to initiate strengthening of the hamstring complex (semimembranosus, semitendinosus and the long and short heads of the biceps femoris). Through inclusion of the bridge on a physioball, the authors were also able to incorporate a static, support phase (bridge with single limb support) and involve the popliteus with its role in tibial internal rotation in the early phase of knee flexion (bridge with knee flexion). Squats were progressed from supported (wall squats) to unsupported, and from stable to unstable surfaces as a means to introduce double limb proprioceptive activities. Stairs were addressed with focus on eccentric quad control and proper lower extremity alignment. This was initially approached cautiously early on secondary to pain with excessive tibial external rotation. Lateral stepping activities and static single limb balance/proprioception exercises were also incorporated.

Midway through this phase the subject reported a perceived return to normalized gait, no difficulty with stair descent, and was without marked pain during the school day. By the end of this phase, his pain was rated at 3/10 at worst on the NPRS. His sports medicine physician initiated a consultation with an orthopedic surgeon in order to determine if he was a surgical candidate. Surgery was deferred due to his progress with physical therapy, but would be considered in the future if recurring knee instability limited his function. He was subsequently cleared to run with return to sport decisions to be made based upon his performance in physical therapy.

**Phase III: Weeks 6-9 (Visit 7-14)**

This phase was characterized by strengthening in functional movement patterns designed to simulate sports specific tasks, a progressive running program and graded agility, neuromuscular control, and plyometric activities. The guiding treatment principle reflected the authors' hypothesis of first gaining adequate lower extremity sagittal plane control, prior to introducing activities requiring control in the frontal and transverse planes, as well as multi-planar activities. The authors also developed and utilized a subjective rating scale for perceived effort when introducing novel activities in order to help grade a gradual return to sport simulation. In order to grade the subject's perceived effort and relate to potential symptoms, the subject rated on a 100-point percentage scale (where 0% was no effort and 100% was full, maximum effort) his effort with an activity, in addition to reporting any perceived pain and instability.

![Figure 2](image-url). Bridging exercise progression example (rehabilitation guidelines phase II). (A) Bilateral physioball bridges, (B) Bilateral physioball curls, and (C) Single leg physioball bridge kicks.
at his knee. The subject was instructed to gradually increase effort, with any signs of instability or pain at higher efforts ceasing activity at that level. This was used in addition to the knee soreness rules to help guide treatment progression decisions.26

Exercises in this phase included lunges, straight-leg deadlifts, and step-down exercises progressed in height with feedback given for proper form. The deadlifts were chosen to help focus on hamstring strengthening in a closed chain, and progressed from bilateral to unilateral support, with the goal of targeting the hamstrings as active support to the LCL deficient knee. Lateral walks were progressed with increasing resistance to challenge the frontal plane stability of the knee, as well as, increasing periods of single limb support by integrating stepping over obstacles. We also utilized a diagonal upper extremity flexion exercise (i.e., chops) for beginning to integrate the throwing motion of the shot put (Figure 3). This was also progressed from double limb to single limb support. Both agility and plyometric activities were integrated during this phase as well. An agility ladder was used to begin more dynamic training, as well as progressing to bounding activities to mimic and train for more explosive movements required in sprinting. The subject was familiar with this activity as it was part of his usual training regimen in track practices. The subject was instructed to gradually increase effort, with any signs of instability or pain at higher efforts ceasing activity at that level.

During this phase, the subject began a return to running progression. Our criteria for running were maintaining the absence of knee effusion, pain-free jogging in the clinic without perceived apprehension and the performance of symptom-free bounding activity in the clinic. He was able to jog comfortably for short distances in the clinic with good mechanics. Walk-run intervals were used to gradually increase his running tolerance on the treadmill. Intervals were gradually increased from two minutes up to 10 minutes of total run time in the clinic. At the end of this phase, the subject was able to run continuously for 20 minutes, sprint short distances comfortably, and perform shot put simulations and bounding to full perceived effort. Functional lower extremity testing at the end of this phase on the timed 6m hop and triple hop were 100% and 90% of the uninvolved limb, respectively.27,28

![Figure 3. Example exercises for rehabilitation phase III (functional strength). (A) Straight-leg deadlift, bilateral (B) Stork reach, (C) Straight-leg deadlift, unilateral (D) Chop, (E) Resisted lateral step-over; (F) Forward bounding.](image-url)
discus throw continued to elicit perceived instability on his affected lower extremity.

At that point, it was recommended that he be allowed to compete in both the shot put and sprints, based on his hop test performance and ability to demonstrate pain free performance in the clinic. Because he continued to experience symptoms with walk-through simulation of the discus throw, the subject was not cleared to participate in this event. His physician cleared him for participation in sprints and shot put, though discus participation was not allowed at this time. His home exercise program focused on double and single leg deadlifts, bounding, mountain climbers, and single leg chops, as well as running for conditioning two to three days per week.

Phase IV: Weeks 10-15 (Visit 15-18)
This final phase represented a gradual continued return to full sport activity, focusing on sport-specific drills for the discus and exercises directed at improving single limb multi-plane control. He began participating in sprinting and shot put at team practices and competing in weekly meets for these events during week 11. Exercises were progressed in this phase by increasing the speed of movement with the chop exercise and performing stork and single limb straight-leg deadlifts at angles deviating from pure sagittal plane motion to introduce a controlled rotary stress. Perturbation training with lunges and single limb proprioception/balance activities on a variety of surfaces were added in addition to integrating lateral sprinting for dynamic knee control.

Discus specific drills were completed by progressing from a walk-through speed increasing towards full speed using the subjective rating of perceived effort utilized for the bounding activity as described in Phase III. Verbal feedback for form was given to help with landing mechanics during the activity. Towards the end of this phase, discus throws were comfortable up to a reported 50% effort in the clinic with good observed form. At this point he was cleared to participate in discus in practice, with instructions to replicate gradual increase in effort with throws based on his perceived knee stability and continued absence of pain. Once he was able to throw at his rated 100% effort comfortably in practice, he then was allowed to participate in the discus event in competition. His last visit occurred following participating in all three events at the track championships at the end of the season.

OUTCOMES
The subject was able to return to full track competition and practice for the 100m and shot put during the beginning of Phase IV of his rehabilitation program, successfully competing in all three events at the end of Phase IV. Although functional measures including hop testing and LEFS scores met commonly accepted criteria for return to sport at the end of Phase III, he continued to experience apprehension with the discus throw. Additional treatment, with focus on functional strengthening and balance and proprioception with gradually increasing effort in discus throw simulations resulted in the ability to compete without perceived limitations.

DISCUSSION
Isolated, high-grade LCL injuries are rare in their occurrence making their rehabilitation challenging, from recognition of the salient clinical features of their presentation, intervention design, and prognosis. Two published examples of isolated LCL injuries have been reported in the literature. Patel describes a radiographically confirmed, isolated grade III LCL rupture in a 34 year-old male, with the injury occurring during a yoga pose from placing his leg behind his head. This subject also presented with no knee effusion and tested as a grade II laxity with varus stress testing. Interestingly, his mechanism of injury was similar to the movement of crossing one’s legs to don shoes, an activity with which the subject of this case report was initially markedly apprehensive. Others have described this position as favoring palpable integrity of the LCL. A second study retrospectively analyzed the management and outcomes of radiographically confirmed isolated Grade III LCL injuries in nine professional football players over a 10-year period. Interestingly, five of these players returned to competition within six weeks, with conservative management and bracing, whereas four of these were treated operatively and did not return to play until the following season. Those managed surgically had a lower overall duration of remaining playing years in the National Football League. Unfortunately, the conservative
The International Journal of Sports Physical Therapy | Volume 11, Number 4 | August 2016 | Page 604

management strategy used in the NFL study was not described in enough detail to allow for reproduction. This does indicate, however, that in elite level athletes, return to play can be realistically achieved with bracing in the short-term, and that, conservative management allowed these individuals to continue to play subsequent seasons in the league. It is unclear as to what criteria were used to decide on surgical intervention in that subset of isolated Grade III LCL injuries.

This case report highlights a previously raised issue with the difference between a radiographic grading scale and that seen with attempting to grade ligamentous instability clinically with the LCL.20,30 For lateral sided knee injuries, it has been shown that the clinical grading scales based upon results of special tests are not an accurate measure of instability.31 For complete disruption of the LCL in particular, varus openings of 2.7mm are to be expected with varus stress leading these authors to argue that the clinical grading scale is an inaccurate measure of instability.31 This has been previously supported clinically with the Bushnell study20 and in the case report of a complete disruption in the subject during yoga,29 when these individuals tested a grade II, with MRI showing a complete LCL disruption in isolation. This is consistent with the clinical presentation of the subject in this case report, which may be due to the partial redundancy of structures at the PLC that resist varus stress. Had the subject in this case report continued to exhibit symptoms of instability with activity and been unable to return to sport, he may have benefited for a referral for possible surgical intervention. Current recommendations for surgery would involve the use of an autogenous semitendonosis tendon graft for anatomic reconstruction.30

The subject's management strategy was based on a combination of interventions previously reported for the non-operative management of PLC injury, including functional strengthening of structures thought to compensate for the deficient ligament, and sports specific drills utilizing increasing subjective effort as a progression method. He began physical therapy after the acute phase of injury without needing to address basic impairments such as ROM or edema management, as would be required in Phase I in various protocols.19 He was able to progress through the gait normalization phase with verbal feedback and the use of simple non-weight bearing and weight bearing activities focusing on quadriceps and hamstring strength and developing proprioception. The subject was initially protected from activities involving varus and tibial external rotation stesses, based on his apprehension with these activities initially and from what is known about the biomechanical function of the LCL.

Later phases of the subject's rehabilitation relied on functional strengthening of structures of the PLC, continued balance and proprioception, and sports-specific drills. A graded introduction of activities producing varus and rotary stress were also included in this phase. The authors initially hypothesized a timeline of return to sport of first 100m sprints, followed by shot put and finally the discus. This was based on the requirement of increasing stability demands of these activities at the knee, from more pure sagittal plane (sprinting) to progressive increases in multi-planar stability demands as seen with the shot put and discus. The subject had returned to both sprinting and shot put early in Phase IV, though continued with perceived apprehension with the discus. The discus in particular involves over 540 degrees of full body rotation, with the in-circle throwing motion divided into five distinct phases.32 Proper throwing technique involves periods of both single-limb and double-limb phases, involving rapid pivoting on the lower extremities.33 For a right-handed thrower, the left leg is subjected to both a rotary and varus stress at high-speeds. This certainly involves a demanding degree of rotary stability at the knee, which the subject was last to fully develop adequately to allow for participation without symptoms. His ability to participate in these events, including the discus event, is indicative of the redundancy of the active, passive and neuromuscular control subsystems of the knee that can allow one to function without an intact LCL.

The authors do acknowledge several limitations to this study, which limit the generalizability of the study's outcomes. The very nature of a single case report limits the applicability to a larger population. A longer-term follow-up with the subject after discharge could not be completed, therefore it cannot be determined if the success of this program translated to continued functional success beyond this
course of physical therapy. Aside from a longer-term outcome, it is also not known if the lack of an intact LCL would predispose this individual to either an acute lower extremity injury via the increased stress on the cruciate ligaments seen in LCL deficiency, or potentially to further chronic injury of the affected knee (e.g., medial compartment degeneration), which has been demonstrated in animal models. These caveats need to be considered when considering the outcomes presented in this case report.

**CONCLUSION**

This case report describes the identification of and conservative management of an isolated, high-grade LCL injury in a multi-sport high school athlete. By taking a functional strengthening and sports-specific drill progression approach, the subject was able to successfully return to competitive sports. This case report provides guidelines for the successful conservative management of and timeline for recovery from these injuries.

**REFERENCES**


ABSTRACT

Background and Purpose: Screening for referral, regardless of setting, is the responsibility of all physical therapists. A serious condition that sports physical therapists may encounter is upper extremity (UE) deep venous thrombosis (DVT), which can result in the important and sometimes fatal complication of pulmonary embolism.

Case Description: A 22 year-old male right-hand dominant collegiate pitcher was referred for physical therapist evaluation and treatment secondary to acute right UE pain and swelling. The athlete described the onset of these symptoms as insidious, denying any form of trauma. The athlete had undergone testing, which included UE Doppler ultrasound of the bilateral UE veins and a computed tomography (CT) scan of the chest without contrast; both of which were deemed negative. He was subsequently diagnosed with thoracic outlet syndrome and referred to the team physical therapist. After examination, the physical therapist hypothesized the athlete was presenting with a possible vascular compromise. Findings leading to this decision were: 1) insidious onset, 2) inability to account for the athlete's pain with ROM, strength, neurological, or provocation testing, 3) significant swelling of the right UE (arm and forearm), 4) increased discomfort with palpation in the supraclavicular region, and 5) history of strenuous UE use.

Outcomes: The athlete was referred back to the orthopedist. A venogram CT was ordered, which revealed an axillary and subclavian DVT and the presence of venous collaterals. The athlete was referred to a vascular surgeon who performed a right first rib removal. The athlete was able to complete post-operative rehabilitation and successfully return to competitive throwing the following spring.

Discussion: The delay in the initial diagnosis may have been due to the vague symptomology associated with venous complications and negative findings upon initial diagnostic testing.

Conclusion: This case report highlights the importance of subjective and physical examination findings and use of diagnostic testing for timely identification of an UE DVT. Ultimately, the physical therapist in this case was able to screen for referral, which led to the correct diagnosis and allowed the athlete to safely and successfully return to sport. Physical therapists should include effort thrombosis in their upper quarter differential diagnosis list for athletes who perform strenuous UE activity.

Level of evidence: 4

Keywords: Baseball, deep venous thrombosis, effort thrombosis, Paget-Schroetter syndrome, upper extremity thrombosis

CORRESPONDING AUTHOR

William R. VanWye, PT, DPT, ACSM-RCEP, CSCS
Doctor of Physical Therapy Program
Western Kentucky University
Medical Center Health Complex,
3318 Bowling Green, KY 42101
Work: 270-745-4925
E-mail: ray.vanwye@wku.edu
BACKGROUND AND PURPOSE
Screening for referral, regardless of setting, is the responsibility of all physical therapists. Although the level of involvement in the actual diagnosis of pathology has been debated, physical therapists must screen for conditions outside the scope of their practice and refer to the appropriate professional.1,2 During the initial examination, physical therapists are tasked with answering three questions: is the individual's pain coming from a potentially serious or life-threatening disorder; secondly, where is the individual's pain arising; and lastly, holistically, what has caused this condition to develop and persist? If the answer to the first question is yes, then a immediate referral must be made, leaving the last two queries to be answered by the appropriate provider.3

One serious condition sports physical therapists may encounter infrequently is upper extremity (UE) deep venous thrombosis (DVT). Early diagnosis is imperative since a delay in care could result in a potentially fatal complication such as pulmonary embolism (PE), which is found in up to one third of individuals who experience UE DVT. DVT and PE have an incidence of 1.17 per 1000 individuals resulting in over 28,000 deaths in the U.S. each year.4 UE DVT accounts for as high as 14% of all DVTs.5 Effort thrombosis is a form of UE DVT caused by strenuous and/or repetitive arm movements. Therefore, athletes who engage in strenuous UE activity are at increased risk for developing effort thrombosis. Arko and colleagues performed a retrospective analysis of athletes from various sports and of the 26 patients treated for vascular conditions, the majority of all vascular cases were effort thrombosis (46%), followed by injuries to axillary/subclavian artery (27%), popliteal artery (23%), and iliac artery (4%).6 Upper extremity effort thrombosis is often considered synonymous with Paget-Schroetter syndrome. This syndrome was first described in the mid to late 1800's when two clinicians (Paget and Schroetter) observed an association between repetitive arm movements and the development of a DVT.7 Therefore, the purpose of this case report is to demonstrate a sports physical therapist's differential diagnosis process for an athlete with insidious right UE swelling, ultimately resulting in the discovery of an UE DVT.

CASE DESCRIPTION
Subjective Examination and Review of Systems
A healthy 22 year-old male (1.78 meters in height, 79.5 kg) right-hand dominant collegiate pitcher reported waking with an insidious onset of significant swelling and pain (5/10) throughout his right UE. He had pitched the day before, with a pitch count of approximately 35, which was a typical outing for him as a middle relief pitcher. That same day, he was evaluated by a vascular surgeon via Doppler ultrasound of the deep veins of bilateral UE's and a computed tomography (CT) scan of the chest without contrast in order to screen for DVT and PE, respectively. Both were interpreted as negative. The following day, the athlete was evaluated by the team orthopedist who diagnosed him with thoracic outlet syndrome (TOS). The athlete was restricted from throwing and referred to the team physical therapist for evaluation and treatment.

Two days after the onset of symptoms, the athlete reported to the physical therapist. At evaluation, the athlete's chief complaint was supraclavicular right UE swelling and discomfort, rating his pain at 1/10. His disability was measured via the Quick-Dash, which is a self-report measure of activities of daily living (ADL) and sport specific activities. The athlete scored 0% disability in the ADL component and, due to his medical restriction from throwing, his sport component disability was 100%. The athlete's medical history and review of systems were unremarkable. The athlete's goal was to have his throwing restriction lifted in order to return to competitive pitching.

Clinical Impression 1
This case highlights the importance of a thorough subjective examination. Even though he had been screened medically and subsequently diagnosed with TOS, the athlete’s history did not appear consistent with a musculoskeletal condition. The physical therapist hypothesized this based on the following factors: chief complaint of right UE swelling, minimal pain, and insidious onset. Although it would have been plausible to associate the athlete's symptoms with his pitching, the physical therapist would have expected a more specific incident to account for the athlete's presentation. There was nothing
new or unusual about his activity level and he did not have any symptoms during or immediately after his last outing.

The physical therapist planned to begin the physical examination with a systems review consistent with the Guide to Physical Therapist Practice. In addition, the athlete had been diagnosed by the physician with TOS, which is a collection of signs and symptoms associated with irritation of the brachial plexus and subclavian vessels needing additional scrutiny. TOS is controversial due to varied definitions and presentations. It typically consists of vague neurogenic (~90% of cases) and/or vascular complaints. Interestingly, vascular involvement accounts for the minority of cases, however the majority of special tests assess for vascular changes making them limited in utility for screening or diagnosis. Therefore, TOS is considered a diagnosis of exclusion. With this consideration in mind, the physical therapist’s examination initially focused on ruling out more common musculoskeletal conditions of the upper quarter such as cervical spine or shoulder dysfunction. This included the use of established cervical spine and shoulder clusters. Wainner et al found clustering positive findings of positive upper limb tension test A (ULTT-A), Spurling’s test, the cervical distraction test, and finding limited cervical ROM less of than 60 degrees significantly increase the likelihood of an individual having cervical radiculopathy (+LR 30.3). In addition, the authors found the ULTT-A to be highly sensitive (Sn .95, -LR .12), thereby being capable of ruling out cervical radiculopathy. Similarly, Park and colleagues found clustering negative findings for the Hawkins-Kennedy Impingement Sign, the Painful Arc Sign, and pain or weakness with resisted shoulder external rotation moderately decreased the probability of subacromial impingement (-LR .17).

**Physical Examination**

Observation of the athlete with his shirt removed revealed swelling and discoloration evidenced by a reddish cutaneous tint throughout the right UE (Figure 1). Circumference measures were taken at the upper arm at the midpoint between the shoulder and elbow and the forearm at the maximum width, which both showed a 3.8 cm increase in diameter as compared to the left. Active and passive range of motion (ROM) of his cervical spine and bilateral UEs were within normal limits (WNL). His upper quarter neurologic screen was negative bilaterally, revealing 5/5 strength of myotomes C1-T1, WNL sensation to light touch of dermatomes C1-T2, and WNL reflexes. The aforementioned cervical spine and shoulder test clusters were all negative. The athlete reported his pain increased to 3/10 with palpation of the right supraclavicular region.

**Clinical Impression #2**

The physical therapist hypothesized the athlete was presenting with a possible vascular compromise. Findings leading to this decision were: 1) insidious onset, 2) inability to account for the athlete’s pain with ROM, strength, neurological, or provocation testing, 3) significant swelling of the right UE, 4) increased discomfort with palpation in the supraclavicular region, and 5) history of strenuous UE use. The physical therapist was unable to develop any other differential diagnosis possibilities. Therefore, the physical exam...
therapist did not initiate treatment due to these red flags. The athlete was immediately referred back to the team orthopedist for re-evaluation.

OUTCOMES

Table 1 displays an outline of the athlete's course of diagnostic testing. An arteriogram and D-dimer test were ordered, which were negative and positive, respectively. Due to the positive D-dimer, a venogram CT was ordered (Figure 2), which revealed a right axillosubclavian DVT with evident venous collaterals. Collateral flow is a naturally occurring process to address inadequate circulation, possibly due to pathology such as a DVT. Of note, there was a significant delay in the time from when the athlete's D-dimer was positive and the results of the venogram CT. After the positive D-dimer, the athlete's care was transferred from the team orthopedist to a shoulder specialist in a neighboring city. This may have led to the delay between the D-dimer and venogram CT. Positive findings from the venogram CT prompted immediate hospitalization of the athlete and initiation of anticoagulation therapy. The athlete was diagnosed with Paget-Schroetter syndrome. Ultimately a vascular surgeon assumed the athlete's care and determined surgical intervention was indicated. Subsequently, a right first rib resection was performed. The athlete received ongoing anticoagulation therapy for three months post-operatively. The athlete's recovery was unremarkable, and he completed his post-operative rehabilitation program and successfully returned to competitive pitching the following spring. Specifically, he made 26 appearances, pitching in 34 innings as a reliever.

<table>
<thead>
<tr>
<th>Timeline Post Onset</th>
<th>Diagnostic Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Duplex and real time ultrasound examination of the jugular, axillary, brachial, radial and ulnar veins of the right UE</td>
<td>Normal</td>
</tr>
<tr>
<td>Day 1</td>
<td>CT Scan of the chest without contrast</td>
<td>Normal</td>
</tr>
<tr>
<td>Day 10</td>
<td>Arteriogram of the right UE</td>
<td>Normal</td>
</tr>
<tr>
<td>Day 10</td>
<td>D-dimer</td>
<td>Abnormal</td>
</tr>
<tr>
<td>Day 31</td>
<td>Venogram CT demonstrating right subclavian and axillary deep vein thrombosis</td>
<td>Abnormal</td>
</tr>
</tbody>
</table>

UE = upper extremity

Figure 2. Venogram CT which demonstrates a right subclavian and axillary deep vein thrombosis. Dense collateral veins are readily visible (red arrows), indicating inadequate circulation due to a DVT.
DISCUSSION

Risk factors for athletes’ developing UE DVT include previous history of upper or lower extremity DVT, TOS, trauma, oral contraceptives, and strenuous and/or repetitive UE use. The latter (i.e., effort thrombosis) is associated with young active adults who are engaged in sports activities or whose professions require repetitive arm movements. It is believed that these activities cause trauma to the axillosubclavian vein, precipitating a DVT. Furthermore, pathophysiologic studies have led to the belief that effort thrombosis is an acute manifestation of a chronic condition.

Typically, the clinical presentation of effort thrombosis is consistent with the classic signs and symptoms of UE DVT, which includes unilateral upper quarter swelling, skin discoloration, and pain. However, it is not unusual for individuals to be asymptomatic. Previous cases of effort thrombosis in baseball players include signs and symptoms such as shoulder pain, soreness, stiffness, or tightness, decreased shoulder ROM, UE swelling, paresthesia, and skin discoloration. One case of effort thrombosis progressed to a PE with the athlete presenting with symptoms of shortness of breath and dizziness. In addition to these cases, a retrospective case series identified effort thrombosis in four right UE dominant elite baseball players, which included three pitchers and one catcher (mean age = 22). In each case, the thrombosis was thought to be related to repeated compression of the subclavian vein secondary to the extreme abduction and external rotation that occurs during the throwing motion. Initial symptoms included arm “tiredness” or “heaviness” and a gradual onset of UE swelling over a two to seven day period. Physical examination revealed venous engorgement of the arm, swelling of several centimeters throughout the UE, palpable cords, and skin discoloration. Diagnosis was confirmed in all cases by contrast venography. Each case showed evidence of venous thrombosis of the axillary or subclavian veins in close proximity to the intersection of the clavicle and first rib. All athletes underwent initial catheter-directed urokinase thrombolysis. They were subsequently treated with systemic anticoagulant therapy of heparin followed by warfarin sodium for three months. All underwent delayed transaxillary first rib resection ranging from one week to three months following their initial clinical visit. Rehabilitation included early ROM and strengthening exercises and progressed to a light tossing program at eight weeks post-operatively. By 12 weeks post-op, a graduated throwing program was implemented. All athletes resumed competitive baseball by the next season and athlete follow-up (36 to 84 months) revealed no recurrence of symptoms.

The athlete’s presentation in the current case report revealed similarities with the aforementioned cases such as a history of strenuous UE use and an insidious onset of acute right UE swelling, discomfort, and discoloration. However, other reported common signs and symptoms such as pain, disability, and upper quarter ROM and strength changes were absent. His medical intervention, rehabilitation, and the timing of his return to sport were all consistent with the aforementioned case series.

Screening for and diagnosing lower-extremity DVT has a well-established strategy, which incorporates clinical probability, D-dimer, and imaging tests. In contrast, there is less procedural certainty for diagnosing or excluding an UE DVT. A 2010 systematic review analyzed the accuracy of diagnostic tools for UE DVT. The authors found one study reporting the D-dimer test to be a valuable screening tool with a sensitivity of 100% (95% CI, 78–100%). D-dimer is a specific degradation product of endogenous fibrinolysis (i.e., clot breakdown). It is a blood test, often ordered to screen for blood clotting disorders. Although it is a useful screening tool for DVT, due to its lack of specificity, the D-dimer test is not diagnostic.

Ultrasonography for UE DVT has sensitivity ranging from 84-97% and specificity of 93-96%. MRI has been investigated for diagnosing UE DVT, but conclusive data for its accuracy is lacking. Contrast venography is the reference standard for the diagnosis of an UE DVT; however, it is invasive and requires the use of ionizing radiation. Therefore, duplex ultrasound is the initial imaging test of choice for diagnosing UE DVT secondary to being non-invasive and its high sensitivity and specificity for UE DVT. If suspicion for clot remains high despite a negative ultrasound, then venography may be required to confirm the diagnosis of UE DVT, as witnessed in this case.
In light of aforementioned research, it would appear prudent to begin testing of a suspected UE DVT with a D-dimer due to its high sensitivity.\(^2\) If the clinician is unable to rule out an UE DVT (i.e. the D-dimer test is positive), then proceeding to more advanced testing would be indicated in order to rule out a DVT. It is possible the sequence of testing in this case, and subsequent results, may have acted as a distractor that ultimately delayed the diagnosis and subsequent care. In retrospect, when the physical therapist referred the athlete back to his physician, he could have made more specific recommendations in accordance with the above information, possibly resulting in a quicker diagnosis. Overall, even though physical therapists are not responsible for making a medical diagnosis or ordering diagnostic tests, knowledge of the correct test sequence and psychometric properties could facilitate earlier diagnosis, as well as improve communication with providers who order diagnostics.

**CONCLUSION**

Ultimately, the physical therapist’s ability to screen for referral led to the correct diagnosis, which allowed the athlete to safely and successfully return to sport. The physical therapist accomplished this by correctly clustering subjective and physical examination findings. This included awareness of common risk factors for athletes who might develop an effort DVT, such as strenuous UE use and TOS. However, physical therapists should recognize that TOS is a diagnosis of exclusion. Available special tests for diagnosis or screening TOS focus on identifying vascular changes, which limits their usefulness since this occurs in the minority of cases. Physical therapists should include effort thrombosis in their upper quarter differential diagnosis list for athletes who perform strenuous UE activity. Lastly, clinicians would benefit from future research to develop a clinical prediction rule for screening and diagnosing UE DVT.

**REFERENCES**


ABSTRACT

**Background:** Ulnar collateral ligament (UCL) tears and associated Tommy Johns surgical intervention from excessive and poor quality pitching has increased immensely—with more college and professional pitchers undergoing the surgery in 2014 alone than in the 1990s as a whole. Faulty mechanics developed at young ages are often well-engrained by the late adolescent years and the minimal healing ability of the largely avascular UCL often leads to delayed safe return to sport.

**Purpose:** The purpose of this case study was to describe an innovative, multimodal approach to conservative management of a chronic UCL injury in a college-aged baseball pitcher. This innovative approach utilizes both contractile and non-contractile dry needling to enhance soft tissue healing combined with standard conservative treatment to decrease pain and improve sport performance as measured by the Disabilities of Arm, Shoulder and Hand (DASH), Numeric Pain Report Scale (NPRS), and return to sport.

**Study Design:** Retrospective Case Report

**Case Description:** A collegiate athlete presented to an outpatient orthopedic physical therapy clinic for treatment of UCL sprain approximately six weeks post-injury and platelet-rich plasma injection. Diagnostic testing revealed chronic ligamentous microtrauma. Impairments at evaluation included proximal stabilizing strength deficits, myofascial trigger points throughout the dominant upper extremity, improper pitching form, and inability to pitch in game conditions due to severe pain. Interventions included addressing strength deficits throughout the body, dry needling, and sport-specific biomechanical training with pitching form analysis and correction.

**Outcomes:** Conventional DASH and Sport-Specific scale on the DASH and the numeric pain rating scale improved beyond both the minimally clinically important difference and minimal detectable change over the 12 week treatment. At 24-week follow up, conventional DASH scores decreased from 34.20% disability to 3.33% disability while sport-specific DASH scores decreased from 100% disability to 31.25% disability. Although initially unable to compete due to high pain levels, the subject is currently completing his pitching role full-time with 1/10 max pain.

**Discussion:** The approach used in this case study provides an innovative approach to conservative UCL partial tear treatment. Dry needling of both contractile and non-contractile tissue in combination with retraining of faulty mechanics may encourage chronically injured ligamentous tissue healing and encourage safe return to sport.

**Level of evidence:** Level 4

**Keywords:** Baseball, biomechanics, dry needling, pitching, ulnar collateral ligament
BACKGROUND

Although a wide range of literature is available on the surgical repair of a fully torn ulnar collateral ligament (UCL), very little research has been published regarding the prognosis for conservative treatment in chronic partial UCL tears caused by long-term microtrauma and upper extremity repetitive overuse. Non-operative options for the large majority of UCL partial and complete tears are typically adequate for the non-athletic population. However, when considering conservative treatment of high-demand throwing athletes with chronic partial or complete tears, return to sport at similar intensity is unlikely. Bruce and Andrews published research assessing the benefits of a standardized, conservative four-month protocol focusing on upper extremity strength and range of motion. This protocol when implemented in isolation reveals only a 42% return to sport.

Due to the frequency of UCL injury, particularly in young athletes, a variety of risk factors have been associated with the potential for UCL damage. Pitch counts both per game and per season in young athletes have been significantly linked to future UCL injury. Players who pitch more than 100 innings per year experience a 3.5 times greater likelihood of upper extremity injury. Those individuals pitching more than eight months per year had a 500% increased likelihood for later surgery, indicating that shear number of pitches plays a larger role than pitch type. A variety of pitching limit protocols are now available based on pitches per game, week, season, and year to address the epidemic that UCL injury has become.

Dry needling of muscles is used to decrease myofascial trigger points their resultant pain; additionally it is an innovative approach to inducing microtrauma to the ligament, which is believed to encourage healing via re-stimulation of the inflammatory cycle. Studies performed by Lewit and Dunning have shown that trigger point dry needling of muscle tissue results in both immediate and long-term relief via the needle effect. Lewit has defined this needle effect as the “immediate analgesia produced by needling the pain spot.” Very little research exists regarding dry needling in combination with electrical stimulation as compared to dry needling alone, as the majority of research investigates the benefits of electroacupuncture. Dunning describes the utilization of electrical stimulation in conjunction with dry needling to muscle tissue has been shown to produce a local twitch response (LTR), which has been suggested and shown in small samples to reduce pain with decreased post-treatment soreness by inducing a spinal reflex resulting in a motor, efferent response of the alpha motor neuron pool. Needles are inserted at desired points along the muscle, and continuous electric pulses are generated between those needles using clipped on electrical stimulation.

Although dry needling of ligaments is less typically utilized when compared to trigger point dry needling (DN), utilizing dry needling to re-initiate the inflammatory process of a chronically injured tissue has shown promise in small studies. Similar in thought to the microfracture procedure that is utilized in surgeries of poorly vascularized tissues such as articular cartilage, small sterile perforations are made into the ligament to provide a newly “injured” environment and encourage new tissue formation in tissues that do not typically heal spontaneously. Although success rates of microfracture of bone in young patients ranges from 75-80%, very few studies have assessed the use or success rates of dry needling in this form, particularly for ligaments. A similar technique known as percutaneous needle tenotomy has been investigated in cases of delayed healing due to scar tissue resulting from avulsion fractures. This technique uses rapidly pistoning insertions to encourage neovascularization and the healing response, which Schoensee et al revealed full return to sport and full functional recovery. However, their sample size was small and the attempts discussed in the study focused on lower extremity injury. The theory behind this intervention is based on the idea that restoration of healing after needle insertion is natural and allows the body to “reset” the initial healing process, ideally disrupting the cyclic inflammatory process of chronically injured tissues. Dry needling of both superficial and deep non-trigger point regions has been shown to increase activity of pain inhibition systems in addition to decreasing limbic system activity. Based on basic understanding of tissue healing strategies utilizing both intrinsic and extrinsic responses and success in similar interventions such as microfracture, the rapid pistoning technique used...
in the needling intervention also ensures that all or most of the sensitized nerve endings are addressed in hopes of breaking the chronic pain cycle.8

Platelet rich plasma (PRP) injections are typically utilized in muscle and tendon injuries to encourage growth factors to surround the injury and promote healing utilizing a blood product.12 Literature review demonstrated that the majority of the research involving PRP focuses on tendon repair and healing with significantly less evidence existing concerning the benefits of PRP injections for ligament healing.12 A case series has been published regarding PRP injection to partially torn UCLs in which the subjects had failed two months of conservative treatment. Players receiving the injection demonstrated an 88% return to sport at 12 weeks, with a 70-week follow up revealing varying degrees of continued UCL injury.12 This case series, however, did not combine the PRP injection with form analysis and correction of faulty mechanics thus subjecting the subject to a potential return to sport in which the same forces that originally injured the UCL were reinitiated. Although this option may show some promise in allowing athletes to return to sport, multi-season re-injury rates were not studied.

Relatively little research exists regarding a combination of these approaches particularly in the high-level athlete with a goal of safe return to sport. Focus on the various tissues involved and their respective pain mechanisms allows both treatment of the local pain source as well as potential contributing factors, such as form retraining and neuromuscular re-education.13 Utilizing these well-established form techniques to address form dysfunction in combination with various novel soft tissue techniques, the goal was to maintain low pain levels and decrease likelihood of full UCL tear during the return to the complex, repetitive motions of pitching.

Pitching Mechanics

UCL injury in throwing athletes has been associated with decreased balance and lead leg strength.13,14 As a result of the decreased efficiency of the lower extremity during an athletic movement, it is thought that compensation occurs via excessive force throughout the upper extremity joints during the pitching motion in order to achieve identical velocity.13 In quantitative terms, a 20% decrease in kinetic energy from the hip and trunk musculature requires an additional 34% increase in the rotational velocity of the shoulder complex to transfer identical force to the hand and thus the ball.2 Based on this description by Bruce and Andrews, pitching as a whole should never be considered solely an upper extremity action. However, many individuals with UCL injuries are treated conservatively with a focus on scapular and shoulder stabilization exercises, rotator cuff and forearm strengthening, and restoration of full glenohumeral joint internal rotation motion without fully addressing the core and lower body.5,7 The general goal of physical therapy (PT) should be to optimize the efficiency of the entire kinetic chain, which could reduce shear force at the elbow joint and minimize the amount of micro-trauma with repetitive loading.13,14

Although the bony anatomy of the elbow allows for partial joint stabilization during functional motions, valgus restraint during 20-120° of elbow flexion primarily relies on surrounding soft tissue including the UCL.16 The UCL contains three bundles termed the anterior oblique ligament (AOL), the transverse ligament, and the posterior oblique ligament (POL). The AOL is the strongest of the three bundles and is the only bundle that provides significant stabilization and resistance of valgus forces while the elbow moves throughout the flexion range of 30-120°. The AOL originates at the anterior/inferior aspect of the medial epicondyle extending to its insertion just distal to the ulnohumeral joint at the sublime tubercle of the ulna as seen in Figure 1. The AOL typically requires forces of 260 N or greater before failure occurs. However,
medial shear forces during a typical throwing motion in a collegiate player frequently exceed 300 N.\textsuperscript{13,15}

The phases involved in baseball pitching have been extensively studied, analyzed, and critiqued in order to determine the form that minimizes general joint stress.\textsuperscript{14, 15, 16} Pitching has been dissected into six different widely accepted phases: windup, early cocking/stride, late cocking/stride, acceleration, deceleration, and follow through.\textsuperscript{17} The early cocking/stride phases through the beginning of the deceleration phase require relatively high valgus forces with maximal valgus force occurring at the end of arm cocking as seen in Figure 2.\textsuperscript{17} This valgus force must be countered by ligament stability, but dynamic stability relies largely on the flexor carpi ulnaris (FCU) and flexor digitorum superficialis (FDS).\textsuperscript{14, 19} In addition, as previously mentioned hip and knee stability and strength play a major role in stabilization of the lead leg to encourage efficient and adequate transfer of energy throughout the kinetic chain.\textsuperscript{14} Power generation from the larger muscle groups of the lower extremity—particularly from the hip abductors and rectus femoris to allow adequate stability and energy transfer from the lead leg is crucial to prevent overcompensation of the upper extremity and to minimize torque placed through the elbow.\textsuperscript{14, 15, 16} Even if an athlete continues to perform the throwing motion with adequate strength but without adequate endurance, these lower extremity and core muscles fatigue with high pitch counts and begin to increase reliance on both upper extremity strength and ligamentous stability for overall joint stabilization.\textsuperscript{13,14,15,16}

The purpose of this case study was to describe an innovative, multimodal approach to conservative management of a chronic UCL injury in a college-aged baseball pitcher. This innovative approach utilizes both contractile and non-contractile dry needling to enhance soft tissue healing combined with standard conservative treatment to decrease pain and improve sport performance as measured by the Disabilities of the Arm, Shoulder, and Hand (DASH), the numerical pain rating scale (NPRS), and return to sport.

**CASE DESCRIPTION**

**Examination**

The subject was a 20-year-old male baseball pitcher of athletic build beginning his junior year at a Division I college with no significant past medical history. The subject reported a slow onset of pain in April of 2015, which fully limited his participation in the sport approximately two weeks after initial pain onset associated after a game performance. The subject consulted with his team trainer and orthopaedic surgeon who diagnosed him with Grade I and “borderline” Grade II UCL sprain, indicating minor tearing of the anterior bundle of the UCL with very mild increase in joint space and laxity and edema within the trochlea using magnetic resonance imaging (MRI). The subject presented approximately six weeks after ceasing pitching activity and receiving one PRP injection to the injured UCL. Despite six weeks of limiting throwing, he continued to report 7-10/10 pain on the numeric pain rating scale (NPRS).

![Figure 2. The Six Phases of Pitching\textsuperscript{17} (Copyright 2009 American Orthopaedic Society for Sports Medicine, used with permission)](image-url)
during the early phases of throwing (primarily late cocking, early acceleration) and 1/10 pain with mild difficulty performing other activities of daily living such as turning door handles or opening jars.

Initial gross manual muscle testing revealed only mild strength deficits of the shoulder and wrist as seen in Table 1. Scapulothoracic testing revealed inability to recruit the middle and lower trapezius without significant compensation from the upper trapezius bilaterally. This strength limitation resulted in minor scapular dyskinesia throughout active performance of upper extremity elevation and abduction as the protracted scapulae were unable to rotate effectively through full range when starting in this position. Middle and lower trapezius were recruited through tactile and verbal cuing, and when activated the scapulae were able to complete full rotation bilaterally during the examination. Subsequent testing of the lower extremity, not initially performed due to focus on achieving full upper extremity strength, can be seen in Table 2. Range of motion examination data is presented in Table 3. The subject was mildly tender to palpation (1/10 on the NPRS) over

<table>
<thead>
<tr>
<th>Table 1. Upper Extremity Manual Muscle Testing</th>
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<tbody>
<tr>
<td><strong>Shoulder ER and IR</strong></td>
</tr>
<tr>
<td>Initial Evaluation</td>
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<tr>
<td>12-Week Follow Up</td>
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<tr>
<td>24-Week Follow Up</td>
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</table>

UT= Upper Trapezius

<table>
<thead>
<tr>
<th>Table 2. Lower Extremity Manual Muscle Testing</th>
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<tr>
<td><strong>Glute Max/Med</strong></td>
</tr>
<tr>
<td>Initial Evaluation</td>
</tr>
<tr>
<td>12-Week Follow Up</td>
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<tr>
<td>24-Week Follow Up</td>
</tr>
</tbody>
</table>

NT= Not Tested at Initial Evaluation
*Compensation in glute med testing (sidelying hip abduction) through tensor fascia latae

<table>
<thead>
<tr>
<th>Table 3. Range of Motion and Flexibility</th>
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<tbody>
<tr>
<td><strong>GH IR (R)</strong></td>
</tr>
<tr>
<td>Initial Evaluation</td>
</tr>
<tr>
<td>12-Week Follow Up</td>
</tr>
<tr>
<td>24-Week Follow Up</td>
</tr>
</tbody>
</table>

R= right, L= left, GH IR= Glenohumeral internal rotation, GH ER= Glenohumeral external rotation
the medial elbow. Special testing revealed a positive valgus stress test for increased laxity (Grade 4 indicating “slight hypermobility” on the manual grading of accessory joint motion scale) on the right when compared to the left with no associated pain.

**Outcome Measures**

The DASH outcome tool scores throughout treatment can be seen in Figure 3. The DASH is a 30-item self-report questionnaire utilized to determine arm pain and function in athletes and workers who require relatively high levels of ability and has been shown to be both valid and reliable.3,4,20 Scoring ranges from 1 (no difficulty) to 5 (unable) and includes reporting on various activities of daily living.18 A score of 100% would thus indicate 100% disability. The DASH also contains an optional four-item high performance sport-specific module in which the subject is questioned regarding their individual ability to participate in sport.3,4,20 Minimal detectable change and minimally clinically important difference for intercollegiate athletes utilizing the DASH have both been reported as 10 points.3,4,20 Baseline assessment revealed 100% disability in sport with 34.2% disability on the DASH.

**Functional Testing**

Although not initially assessed, functional pitching observation using UberSense® (www hudl com) slow motion video revealed altered pitching mechanics, particularly throughout the early and weight-transfer phases. This functional observation was initiated after MRI results revealed healing of the UCL ten weeks after initial evaluation. Figures 3-6 are images of the subject discussed in this case report captured through the UberSense® application. Major deviations found in the subject that differed from ideal form that may have contributed to the UCL trauma are summarized in Table 4.

**INTERVENTION AND OUTCOMES**

Physical therapy frequency was three times per week for five to six weeks followed by twice weekly for five to six weeks to ensure full healing of the UCL and to allow ample time for neuromuscular reeducation with body mechanics and safe return to high-level throwing. Rehabilitation was divided into three phases.

**Phase I: Upper Extremity Strengthening**

**Weeks 1-4**

Pain free range of motion and shoulder/scapular stabilization exercises were performed during this stage to maintain and eventually increase strength along
the upper extremity portion of the kinetic chain. After elbow pain at rest resolved, focus on the wrist flexors and pronators and supinators began. This portion of therapy, based around the “Thrower’s Ten” exercise set found in Appendix 2 is considered the typical conservative approach for UCL injury and lasted approximately six weeks. In typical UCL injury protocols, after full restoration of the strength of this musculature is complete the subject may begin functional exercise including a throwing program. Subsequently, the subject may return to sport after pain-free completion of the chosen return to throwing program or progression. In the subject of this case, despite full strength achievement throughout the upper body after approximately four weeks of intervention and ten total weeks of throwing cessation, pain free completion of a throwing program was not achieved.

**Phase II: Dry Needling Weeks 5-6**

Based on the assumption that continued pain was still stemming from chronically unhealed and inflamed tissue, dry needling was attempted five weeks after initial evaluation to initiate an additional acute

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**Figure 5.** *Late Cocking/Stride phase*

**Figure 6.** *Acceleration phase (a = early, b = mid)*
inflammatory response and secondarily inhibit nociception from local tissues.\(^8,9\) The first needling session was initiated approximately five weeks after physical therapy began. Trigger point dry needling of the flexor carpi radialis, flexor digitorum superficialis, and flexor digitorum profundus was performed to increase myofascial mobility to allow more efficient performance of the musculature by decreasing myofascial trigger points from chronic overutilization. The needles were retained in the target tissues, and connected to electrical stimulation (2 Hz via ITO ES-130 Three Channel Electro Stimulation Unit from Superior Medical Equipment in Wilmington, NC) to elicit a localized twitch response and remained in place for eight minutes to encourage post-synaptic pain modulation as previously discussed. When needling the injured non-contractile, avascular tissue, a pistoning technique was utilized with needles (0.23x15mm) placed in the proximal and lateral UCL, with placement based on the location of sprain indicated in original MRI. This technique was performed in hopes of re-initiating the extracellular healing cycle to allow improved healing time of the chronically injured and partially torn UCL which is often unable to adequately heal itself without signs of remaining laxity and dysfunction.\(^2\) The subject continued therapy two times per week, and underwent dry needling again one week later by the same protocol as described above. A follow-up MRI approximately three weeks after the second dry needling treatment revealed significantly decreased tears and laxity with no associated edema. Dry needling was discontinued after this point, as no palpable trigger points were present within the forearm musculature and the initial goal of dry needling for ligament healing had been achieved. As full ligament healing at this point had been accomplished, form analysis was performed at the end of week six to assess pitching mechanics.

### Phase III: Lower Extremity Strengthening and Form Analysis: Weeks 7-12

Approximately seven weeks after initial evaluation, the treatment focus shifted to target throwing mechanics and strengthening specific to the muscles of the kinetic chain utilized in a normal throwing motion. This focus was largely placed on mechanics, stability, and general strength throughout the lead (left) leg to provide increased general stability throughout the phases in which the most elbow valgus force typically occurs.\(^13, 14\) The acceleration phase has been shown to require adequate concentric rectus femoris strength to allow for hip flexion in addition to knee extension to increase angular momentum of the trunk through a properly stabilized lead leg.\(^15\) Providing a secure lead leg allows maximal hip flexion prior to ball release to decrease reliance on the upper extremity to create the force and associated velocity transmitted to the ball. Exercises to challenge stability included BOSU

<table>
<thead>
<tr>
<th>Table 4. <strong>Body Mechanics Analysis of the Subject During Pitching Motion</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Phase</strong></td>
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<tr>
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</tr>
<tr>
<td>Windup</td>
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<tr>
<td>Early Cocking/Stride</td>
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<tr>
<td>Late Cocking/Stride</td>
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<tr>
<td>Acceleration</td>
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The International Journal of Sports Physical Therapy | Volume 11, Number 4 | August 2016 | Page 621
(BOSU in Ashland, Ohio) lunges for proprioceptive training, double-leg squats with focus on decreasing anterior tibial translation, single-leg eccentric squats, stride drills focused on arm elevation at lead-leg strike, single-leg deadlifts with maintenance of core stability, and concentric and eccentric four-way resistance band hip strengthening to address any instability throughout the lower extremity and core in situations where the lead leg may not land in optimal positioning. Stride drills specifically focused on the early cocking phase in which the subject would repeatedly perform the wind-up to early cocking portion of the pitch to ensure that the lead foot was pointed directly towards home plate with the dominant upper extremity elevated to 90° abduction, 90° ER, and 90° elbow flexion to optimize energy transfer in later phases and decrease forces required through the upper extremity.

Outcomes
After only one week of education regarding pitching mechanics via verbal and visual feedback, the subject reported significantly lower pain levels as seen in Table 5. These pain levels surpassed both the minimal detectable change (3 points) and minimally clinically important difference for chronic musculoskeletal pain (1 point) on the NPRS. Education regarding form involved part-practice utilizing partial task completion, avoiding full speed pitching at this time in order to continue to promote proper mechanics and neuromuscular re-education prior to initiation of return to sport intensity levels. Re-education at half speed was required to overcome maladaptive motor patterns as the subject was repeatedly unable to perform proper pitching form with education, instruction, and self-observation alone.

Range of motion examination and strength examinations after this phase can be seen in the 12 and 24-week follow ups in Tables 1-3. The subject returned to sport at the start of the following season serving as the closing pitcher and has repeatedly pitched what is considered a full game for his position at six month after injury with no pain at full speed and significantly decreased DASH scores as seen in Table 6, surpassing both the minimal clinically important difference and minimal detectable change.

**DISCUSSION**
UCL injury is prevalent in young baseball athletes and surgery has become a common solution to this problem related to the long-term effects of micro-trauma occurring due to altered throwing mechanics and muscle fatigue as a result of excessive repetitions. Although many patients are able to return to sport after surgery, relying on the surgical fixation of

<table>
<thead>
<tr>
<th>Table 5. Subjective Pain Levels</th>
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<tbody>
<tr>
<td>Throwing Speed (mph)</td>
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<tr>
<td><strong>Initial Evaluation</strong></td>
</tr>
<tr>
<td><strong>After Dry Needling and Full UE Training</strong></td>
</tr>
<tr>
<td><strong>After 1 Week of Body Mechanics Retraining Implementation/12-Week Follow Up</strong></td>
</tr>
<tr>
<td><strong>24-Week Follow Up</strong></td>
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mph= miles per hour, NPRS= Numerical pain rating scale (verbal)

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<thead>
<tr>
<th>Table 6. Patient Reported Outcome Scores</th>
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<tbody>
<tr>
<td>Conventional DASH</td>
</tr>
<tr>
<td><strong>Initial Evaluation</strong></td>
</tr>
<tr>
<td><strong>12-Week Follow Up</strong></td>
</tr>
<tr>
<td><strong>24-Week Follow Up</strong></td>
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</table>

Conventional DASH= Disabilities of the Arm, Shoulder, and Hand (30 items of ADLs) DASH Sport Subscale= Four-item high performance module
the UCL may not fully address the underlying problem, and many individuals continue to utilize the mechanics that created the injury—increasing shear force through the medial elbow and eventually resulting in an exacerbation of symptoms. With advancements in the understanding of this injury, it is believed by the authors of this case report that implementation of pitching biomechanical retraining and kinetic chain optimization early in the rehabilitation process in combination with these innovative non-contractile dry needling techniques can encourage healing in largely avascular tissues as confirmed by diagnostic testing. Due to the timing of the injury, the subject discussed in this report missed approximately half of his sophomore season prior to starting physical therapy—but returned without limitation or pain in his junior year.

Symptoms were initially treated locally with the belief that nociception was being generated from the injured UCL tissue. This pain, by definition, should cease upon tissue healing. In this case report ligament healing confirmed by MRI post-dry needling interventions correlated with reduced pain complaints, although all pain was not fully abolished. Further analysis into other pain mechanisms was required to address other potential contributing factors and encourage safe return to sport. Particularly in a functional movement where such complex multi-joint coordination is required, even minor alterations in form as a result of pain can encourage improper motor strategies. Understanding the role various pain mechanisms may play is key to full resolution of symptoms, and combining the dry-needling technique to abolish nociceptive pain with biomechanics retraining to diminish central sensitization and pain associated with altered motor patterns was shown to be successful in the management of this subject.

Although the subject did present with significant strength deficits in the upper extremity, the subject did not show any improvement in pain levels with activity after completing the traditional four to six weeks of upper extremity strengthening, stabilization, and stretching. Dry needling of the UCL for re-stimulation of the healing process appeared to encourage healing of a typically very slow-healing connective tissue, resulting in only minimal chronic abnormalities upon follow-up MRI. Implementation of the emergic technique of dry needling of non-contractile tissue allowed further assessment of biomechanical analysis due to the potentially associated healing phase progression. The residual pain despite a “healed” ligament as evidenced by MRI led the physical therapists to believe that the UCL was not the only source of symptoms for this subject, and that he may in fact be experiencing referred pain from other structures, such as trigger points in the pectoral muscles. Addressing the initially faulty pitching mechanics that resulted in overload of the shoulder complex may have aided in offloading the work of the shoulder internal rotators during a pitching motion, and thus may have decreased the pain that may have been associated with these potential referral patterns.

Initiation of body mechanics education using visual feedback, verbal cuing, and part practice once UCL healing had been documented provided near-immediate reductions in pain during throwing. Progression of the performance of biomechanical throwing training to near full speed during whole task performance allowed the assessment of activity and determination of significantly decreased pain levels.

When individuals undergo surgical repair whether due to partial or full UCL tear, average return to prior level of competition has been reported as 11.6 months. Even after return to sport, researchers suggest that only 67% return to similar levels of competition postoperatively with 57% returning to the disabled list due to later injuries of the throwing arm, implying lack of attention to actual contributing factors and symptom sources. Ideally, if techniques such as non-contractile dry needling can be implemented to break up the chronic pain cycle post-injury, these full-body interventions can be utilized earlier in the therapy plan to significantly decrease the amount of sport cessation required for adequate healing and surgical intervention could be prevented. In future studies, early combination of upper extremity stabilization training combined with lower extremity and core stabilization exercises to optimize the kinetic chain in addition to dry-needling of both contractile and non-contractile tissues may greatly decrease pain levels, healing time, and time required for safe return to sport. Further, edu-
cation of proper throwing mechanics may prevent future damage to the UCL and prevent the need for surgical intervention, although further studies are needed to support this theory.

Limitations
This case report does have limitations in generalizability, as only one subject was assessed. No controls were utilized to assess healing times or return to sport measures with those who did not receive the aforementioned interventions. The outcome measures utilized in this report are standard to physical therapy, but no reliability or validity testing was performed on the individual completing those measures. No diagnostic testing was performed just prior to dry needling, and thus it is unclear whether or not the aforementioned healing and mildly decreased subjective pain report after dry needling occurred specifically due to the re-initiation of the inflammatory cycle or if the UCL damage had healed secondary to time or an additional three weeks of activity modification. However, due to the prolonged healing process of the UCL and delay of the needling technique until 14 weeks post-initial-injury, it is believed that the re-initiation of the healing cycle through the dry needling technique may have significantly impacted the healing of the tissue. Further research is necessary to determine long-term benefits of non-contractile and avascular dry-needling techniques, and follow-up should include completion of the sport season as long-term follow up was not performed in this report. More quantitative strength analysis may have provided more objective results, and focus on myofascial restrictions and impairments of the glenohumeral internal rotator muscles would have provided a more complete image of involved contributing factors.

CONCLUSION
The case presented is that of a college-aged male diagnosed with partial UCL tear. Poor response to initial treatment in this case resulted in reassessment of plan of care and source of symptoms, followed by alteration of interventions. Focus on the altered pitching mechanics that may have been a contributing factor to the UCL damage was incorporated. The subject reported a significantly decreased score on both the NPRS and DASH and was able to fully return to sport the following season without pain. Although the technique and benefits of dry needling particularly in non-contractile tissues continues to be a topic that is not fully understood, one theory suggests that re-initiation of the acute inflammatory process via intrinsic and extrinsic healing factors may impact healing time.8,9,10 This case report has demonstrated how a better understanding of healing and pain mechanisms may improve patient care by addressing both the adequate healing of the acutely injured tissue in addition to addressing the contributing factors to injury as a result of the complex pitching motion. Further research and larger sample sizes are necessary to better determine the impact that dry needling may have on soft tissue healing.

REFERENCES


### Appendix 1. Throwing Program Adapted from Andrews Sports Medicine

<table>
<thead>
<tr>
<th>Step 1</th>
<th>30’ Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-Up Throwing</td>
<td>30’ 25 Throws</td>
</tr>
<tr>
<td>Rest 15 min</td>
<td></td>
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<tr>
<td>Warm-Up Throwing</td>
<td>30’ 25 Throws</td>
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<thead>
<tr>
<th>Step 2</th>
<th>30’ Phase</th>
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</thead>
<tbody>
<tr>
<td>Warm-Up Throwing</td>
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</tr>
<tr>
<td>Rest 10 min</td>
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<tr>
<td>Warm-Up Throwing</td>
<td>30’ 25 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
<td></td>
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<tr>
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<thead>
<tr>
<th>Step 3</th>
<th>45’ Phase</th>
</tr>
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<tbody>
<tr>
<td>Warm-Up Throwing</td>
<td>45’ 25 Throws</td>
</tr>
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<td>Rest 15 min</td>
<td></td>
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<tr>
<td>Warm-Up Throwing</td>
<td>45’ 25 Throws</td>
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<table>
<thead>
<tr>
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<th>45’ Phase</th>
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<td>45’ 25 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
<td></td>
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<tr>
<td>Warm-Up Throwing</td>
<td>45’ 25 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
<td></td>
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<td>Warm-Up Throwing</td>
<td>45’ 25 Throws</td>
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<tr>
<th>Step 5</th>
<th>60’ Phase</th>
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<tr>
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<td>60’ 25 Throws</td>
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<tr>
<td>Rest 15 min</td>
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<tr>
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<td>60’ 25 Throws</td>
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<tr>
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</tr>
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<tr>
<td>Warm-Up Throwing</td>
<td>60’ 25 Throws</td>
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<tr>
<td>Rest 10 min</td>
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<tr>
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<tr>
<th>Step 7</th>
<th>90’ Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-Up Throwing</td>
<td>90’ 25 Throws</td>
</tr>
<tr>
<td>Rest 15 min</td>
<td></td>
</tr>
<tr>
<td>Warm-Up Throwing</td>
<td>90’ 25 Throws</td>
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<table>
<thead>
<tr>
<th>Step 8</th>
<th>90’ Phase</th>
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</thead>
<tbody>
<tr>
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<td>90’ 20 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
<td></td>
</tr>
<tr>
<td>Warm-Up Throwing</td>
<td>90’ 20 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
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<tr>
<td>Warm-Up Throwing</td>
<td>45’ 20 Throws</td>
</tr>
<tr>
<td>Rest 10 min</td>
<td></td>
</tr>
<tr>
<td>Warm-Up Throwing</td>
<td>45’ 15 Throws</td>
</tr>
</tbody>
</table>
Appendix 2.  *Thrower’s Ten UE Strengthening Program*\(^{22,23}\)

<table>
<thead>
<tr>
<th>Exercise Name</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. D2 Extension</td>
<td>Involved hand will grip tubing handle overhead and out to the side. Pull tubing down and across your body to the opposite side of leg. During the motion, lead with your thumb.</td>
</tr>
<tr>
<td>2. D2 Flexion</td>
<td>Gripping tubing handle in hand of involved arm, begin with arm out from side 45 degrees and palm facing backward. After turning palm forward, proceed to flex elbow and bring arm up and over the uninvolved shoulder. Turn palm down and reverse to take arm back to starting position. This exercise should be done in a controlled manner.</td>
</tr>
<tr>
<td>3. ER at 0° Abduction</td>
<td>Stand with involved elbow fixed at side, elbow at 90 degrees and involved arm across front of body. Grip tubing handle while the other end of the tubing is fixed to a stationary object. Pull out with arm, keeping elbow at side. Return tubing slowly and in a controlled manner.</td>
</tr>
<tr>
<td>4. IR at 0° Abduction</td>
<td>Standing with elbow at side, fixed at 90 degrees and should rotated out. Grip tubing handle while other end of tubing is fixed to a stationary object. Pull arm across body, keeping elbow at side. Return tubing slowly and controlled.</td>
</tr>
<tr>
<td>5. ER at 90° Abduction</td>
<td>Stand with shoulder abducted 90 degrees and elbow flexed 90 flexed. Grip tubing handle while the other end is fixed straight ahead, slightly lower than the shoulder. Keeping shoulder abducted, rotate the shoulder back, keeping elbow at 90 degrees. Return tubing and hand to start position.</td>
</tr>
<tr>
<td>6. IR at 90° Abduction</td>
<td>Stand with shoulder abducted to 90 degrees, externally rotated 90 degrees and elbow bent 90 degrees. Keeping shoulder abducted, rotate shoulder forward, keeping elbow bent at 90 degrees. Return tubing and hand to start position.</td>
</tr>
<tr>
<td>7. Shoulder Abduction to 90°</td>
<td>Stand with arm at side, elbow straight, and palm against side. Raise arm to the side, palm down, until arm reaches 90 degrees (shoulder level). Hold 2 seconds and lower slowly.</td>
</tr>
<tr>
<td>8. Scaption, IR</td>
<td>Stand with elbow straight and thumb up. Raise arm to shoulder level at 30 degree angle in front of body. Do not go above shoulder height. Hold two seconds and lower slowly.</td>
</tr>
<tr>
<td>9. Prone Horizontal Abduction</td>
<td>Lie on table, face down, with involved arm hanging straight to the floor, palm facing down. Raise arm out to side, parallel to floor. Hold 2 seconds and lower slowly.</td>
</tr>
<tr>
<td>10. Prone Horizontal Abduction Full</td>
<td>Lie on table, face down, with involved arm hanging straight to the floor, thumb rotated up (hitchhiker position). Raise arm out to the side slightly in front of shoulder, parallel to the floor. Hold 2 seconds and lower slowly.</td>
</tr>
<tr>
<td>11. Press-Ups</td>
<td>Seated on a chair or table, place both hands firmly on the sides of the chair or table, palm down and fingers pointed outward. Hands should be placed equal with shoulders. Slowly push downward through the hands to elevate your body. Hold the elevated position for 2 seconds and lower slowly.</td>
</tr>
<tr>
<td>12. Prone Rowing</td>
<td>Lying on your stomach, with your involved arm hanging over the side of the table, dumbbell in hand and elbow straight. Slowly raise arm, bending elbow and bring dumbbell as high as possible. Hold at the top for 2 seconds, then slowly lower.</td>
</tr>
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ABSTRACT

Background/Purpose: The McKenzie Method of mechanical diagnosis and therapy (MDT) is supported in the literature as a valid and reliable approach to the management of spine injuries. It can also be applied to the peripheral joints, but has not been explored through research to the same extent. This method sub-classes an injury based on tissue response to mechanical loading and repeated motion testing, with directional preferences identified in the exam used to guide treatment. The purpose of this case report is to demonstrate the assessment, intervention, and clinical outcomes of a subject classified as having a shoulder derangement syndrome using MDT methodology.

Case Description: The subject was a 52-year-old female with a four-week history of insidious onset left shoulder pain, referred to physical therapy with a medical diagnosis of adhesive capsulitis. She presented with pain (4-7/10 on the visual analog scale [VAS]) and decreased shoulder range of motion that limited her activities of daily living and work capabilities (Upper Extremity Functional Index (UEFI) score: 55/80). Active and passive ranges of motion (A/PROM) were limited in all planes. Repeated motion testing was performed, with an immediate reduction in pain and increased shoulder motion in all planes following repeated shoulder extension. As a result, her MDT classification was determined to be derangement syndrome. Treatment involved specific exercises, primarily repeated motions, identified as symptom alleviating during the evaluation process.

Outcomes: The subject demonstrated significant improvements in the UEFI (66/80), VAS (0-2/10), and ROM within six visits over eight weeks. At the conclusion of treatment, A/PROM was observed to be equal to the R shoulder without pain.

Discussion: This subject demonstrated improved symptoms and functional abilities following evaluation and treatment using MDT methodology. While a cause-effect relationship cannot be determined with a single case, MDT methodology may be a useful approach to the examination, and potentially management, of patients with shoulder pain. This method offers a patient specific approach to treating the shoulder, particularly when the pathoanatomic structure affected is unclear.

Level of Evidence: 4

Keywords: Adhesive capsulitis, McKenzie, Mechanical Diagnosis and Treatment

1 University of New England, Portland, ME, USA

The subject signed an informed consent allowing the use of medical information and photographs for this report and received information on the institution’s policies regarding the Health Insurance Portability and Accountability Act.

The authors acknowledge Taylor Dickerson, DPT, Cert. MDT, for assistance with case report conceptualization, and assistance during the treatment process.

CORRESPONDING AUTHOR
Ashley Bowser
University of New England, Department of Physical Therapy
716 Stevens Ave.
Portland, ME 04103
E-mail: abowser@une.edu
BACKGROUND/PURPOSE

It has been reported that the number of individuals with peripheral joint injuries far exceed those that require treatment for injuries of the spine. The prevalence of these peripheral joint injuries ranges from 6.7 to 46.7% per year in the general population, demonstrating the importance of finding effective evaluation and treatment methods. The literature reveals that most therapists commonly use specialized orthopedic testing procedures applied to a pathoanatomic model to diagnose shoulder injuries. However, arriving at a specific pathoanatomic diagnosis is challenging due to questionable reliability and validity of specialized orthopedic testing. De Winter et al reported that in the diagnosis of different shoulder injuries, including adhesive capsulitis, the kappa value for correct diagnosis was 0.45 (95% confidence interval 0.37,0.54), demonstrating only low-to-moderate reliability. Failure to correlate the exact anatomic structure with the patient's presentation can complicate the diagnosis and treatment process.

Traditional treatments delivered for adhesive capsulitis based on pathoanatomic findings include corticosteroid injections, nonsteroidal anti-inflammatory drugs, manipulations, and therapeutic exercise. The literature supports that exercise is much more effective than either modalities or medications. However, 40% of individuals treated with traditional therapies continue to experience pain and loss of ROM after discharge, suggesting that current treatment methods may be suboptimal. Assigning a sub-classification based on the tissue's mechanical response to loading, rather than pathoanatomic diagnosis, may offer a viable treatment approach to address the continued pain and stiffness in this population.

Application of the McKenzie method (MDT) has become widely accepted as a valid form of evaluation and treatment for the spine, and has demonstrated a high degree of inter-rater reliability when identifying a mechanical classification with trained therapists demonstrating approximately 92% agreement on classification. When these classifications were used to guide treatment, chronic pain and disability were improved in patients with spine injuries that received interventions based on directional preference.

It has been suggested that MDT assessment methodology could also be applied effectively to peripheral joints by classifying them into posture, dysfunction, or derangement syndromes. The McKenzie method is a mechanical sub-classification system based on the patient history and the response to repeated motions and positioning, rather than attempting to identify the exact pathoanatomic structure. An MDT trained therapist uses the assessment to classify the patient based on their responses during movement, with repeated motion testing used to determine the patient's mechanical classification and treatment.

Derangement syndrome is a classification not utilized by any other evaluation and treatment approach. It is defined as an internal disruption or displacement of tissue, which then mechanically deforms outer innervated structures. The resulting pain is then referred peripherally depending upon the degree of internal displacement. When the tissue is displaced to a lesser degree pain is intermittent; however, larger displacements may cause constant pain. Individuals with this syndrome can experience quick changes in symptoms and mechanical presentation as a result of repeated motions. A directional preference is found when movement(s) in a specific direction reduces the patient's report of pain. It must then be determined if this reduction is maintained over time, or if it will continue to re-occur. Conversely, motions that open the joint space may temporarily decrease pain, but may displace the tissue even further. Outcomes with this type of treatment have been very successful when applied to the spine. However, it appears that there are currently only two case reports that demonstrate the effectiveness of MDT on the shoulder complex.

The purpose of this case report is to detail the use of MDT principles in the assessment and treatment of an individual with shoulder pain. More specifically, this case report details the process used to identify a directional preference during evaluation, with subsequent treatment based on this response.

HISTORY AND REVIEW OF SYSTEMS

The subject was a 52-year-old female who reported pain and decreased ROM after striking her left shoulder on a refrigerator four weeks prior to the initial evaluation. Radiographs were negative, and
her orthopedic physician provided a diagnosis of adhesive capsulitis. She was subsequently referred to physical therapy for ROM and strengthening. The subject reported intermittent symptoms, made worse with overhead motions, twisting doorknobs, and opening jars. Significant functional limitations included: limited ability to perform her usual work hanging wallpaper, limited ability to perform volunteer work due to pain with lifting, and limited ability to care for her grandchildren.

A thorough systems review was conducted (Table 1). Overall, the subject reported good health, and denied any previous orthopedic injuries. Her main goal for therapy was to return to work, complete ADLs, and complete volunteer work without aggravating symptoms or needing assistance.

The subject provided written informed consent for participation in this case report, and for any photography or videography associated with this report.

**CLINICAL IMPRESSION 1**
Following the subjective history and systems review, it was hypothesized that the subject presented with left shoulder adhesive capsulitis, which is classified in the MDT system as a dysfunction. This was based upon her restricted left shoulder ROM in all directions with pain, consistent with ICD 10 criteria for adhesive capsulitis: reports of pain in the shoulder exacerbated by activity and feeling of stiffness, with examination criteria of reduced passive range of GH motion >30° in two planes. However, loss of ROM and pain are present with a variety of diagnoses; therefore a thorough evaluation was planned. Additionally, pain with elbow motions indicated possible involvement of the long head of the biceps tendon. Further tests/measures to rule in/out other possible conditions included the Crank test, Empty-Can Test, Hawkins-Kennedy Test, and Speed’s Test.

It was planned to evaluate the subject using McKenzie methodology. This approach involves identifying the body area involved, pain levels, how long the pain had been present, whether the symptoms were constant or intermittent, and if there were any positions or motions that changed the symptoms. After observation of posture, palpation, ROM/strength testing, and special testing, repeated motion testing commences. The evaluation focuses on identification of a concordant sign, defined as a movement or position that increases or reproduces the subject's symptoms consistently. The subject's report of how repeated motions in various directions affect the concordant sign determines the mechanical diagnostic classification, which in turn guides treatment.

### EXAMINATION
The subject completed the Upper Extremity Functional Index (UEFI), and received a score of 55/80, indicating moderate disability. She reported pain that ranged from 4-7/10 on the VAS. After observational analysis and palpation was conducted, a gross AROM and strength assessment was performed. Deficits were noted in AROM and strength of the left upper extremity (pain produced), leading to goniometric measurements of PROM and evaluation for end-feel and restrictions. PROM measurements can

<table>
<thead>
<tr>
<th>Table 1. Systems Review During Subject Examination.</th>
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<tbody>
<tr>
<td><strong>Cardiovascular/Pulmonary</strong></td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td><strong>Musculoskeletal</strong></td>
</tr>
<tr>
<td>Gross range of motion (ROM) impairments in left shoulder with pain.</td>
</tr>
<tr>
<td>5/5 Strength for all shoulder motions bilaterally; however, pain produced with abduction, internal rotation (IR), and external rotation (ER) on the left.</td>
</tr>
<tr>
<td>5/5 Strength for all elbow motions bilaterally; pain with left elbow flexion, extension, pronation, and supination</td>
</tr>
<tr>
<td><strong>Neuromuscular</strong></td>
</tr>
<tr>
<td>Normal</td>
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<tr>
<td><strong>Integumentary</strong></td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
</tr>
<tr>
<td>Normal</td>
</tr>
</tbody>
</table>
be seen in Table 2. All glenohumeral joint motions on the left presented with firm (capsular) end feel and pain. The following diagnostic tests were performed to evaluate for impingement, labral and/or muscular pathology: Crank Test (negative), Empty Can Test (positive), Speed’s Test (positive), and Hawkins-Kennedy Test (positive).

Repeated motion testing was performed as per MDT methodology. The subject performed two sets of 20 repetitions in shoulder flexion, shoulder external rotation, shoulder extension, and scapular retraction, and reported how the motions affected her symptoms during and after the test, with particular interest on change in the concordant signs (Table 3). Rapid improvements in ROM, pain, and her concordant signs were observed following scapular retractions and shoulder extension.

<table>
<thead>
<tr>
<th>Table 2. Passive Range of Motion Measurements (Initial Examination).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Joint</strong></td>
</tr>
<tr>
<td>Abduction</td>
</tr>
<tr>
<td>Flexion</td>
</tr>
<tr>
<td>External Rotation</td>
</tr>
<tr>
<td>Internal Rotation</td>
</tr>
</tbody>
</table>

CLINICAL IMPRESSION 2

The primary impairments identified during the examination were left shoulder pain and loss of ROM that prevented participation in volunteer activities, work, and self-care activities. At this point in the examination, the pathoanatomic differential diagnosis consisted of adhesive capsulitis, impingement, and/or a rotator cuff tear. Differential diagnosis for MDT classification included articular dysfunction, contractile dysfunction, and derangement.

The subject presented with generalized tenderness to palpation of the anterior left glenohumeral joint as well as impaired posture (forward head, rounded shoulders). A positive Empty Can test indicated possible supraspinatus pathology, Hawkins-Kennedy test possible shoulder impingement, and Speed’s test indicated possible biceps LH pathology. A gross strength assessment revealed full strength for all shoulder motions with pain upon resistance in all shoulder motions, indicating possible muscular pathology. However, impingement findings and painful resisted tests are not uncommon with a diagnosis of adhesive capsulitis.34 PROM was decreased and painful with firm-end feel demonstrating probable capsular pathology. Following performance of scapular retractions and shoulder extension during repeated motion testing (two sets of 20 repetitions for each motion) her ROM and pain levels for all shoulder motions demonstrated immediate improvement. The mechanical diagnosis of a derangement was assigned to the subject based on the rapid change in her symptoms during repeated movements, despite her medical diagnosis of adhesive capsulitis.

Given the subject’s few co-morbidities, intermittent symptoms, and excellent response to repetitive motion testing, she was an excellent candidate for physical therapy. Additionally, individuals with a diagnosis of derangement syndrome have been reported to generally demonstrate a very quick response to therapy.1,3,25 She was very motivated,
which indicated that she would be very compliant with her HEP. As a result, it was expected that she would make a full recovery in a short period of time.

Based on the mechanical diagnosis, the subject was sent home with scapular retractions and shoulder extension exercises (two sets of 20 repetitions of each exercise, four to five times per day) to continue treatment. It was agreed that the subject would attend therapy once per week, with overall therapy goals to increase ROM to be equal bilaterally, and to decrease pain.

**INTERVENTIONS**

The subject was provided with a thorough explanation of her condition (adhesive capsulitis), and mechanical classification (derangement), and then goals were established for physical therapy. Given her positive initial reaction to therapy, it was decided that she did not require outside referral for further medical intervention, and was appropriate for physical therapy management.

As described above, shoulder extension and scapular retractions decreased the concordant signs, increased A/PROM, and decreased pain levels to 1/10 during the initial evaluation. Therefore, interventions were designed to favor these movements. The upper body ergometer (Cybex, Bayshore, NY) was performed as a warm up to increase synovial fluid and blood flow, and the subject then completed standing scapular retractions followed by shoulder extension with a dowel (Appendix 1). Standing rowing with red tubing (Theraband, Akron, OH) was added for inter-scapular strengthening and postural re-education (Appendix 1). It was expected that improved activation and strength of the inter-scapular musculature and postural re-education would improve scapula-humeral rhythm, shoulder biomechanics, and posture. Finally, the subject was given pictures and demonstrations to convey therapy and HEP exercises, as this was her preference. This included the subject performing the given stretches four to five times throughout the day (two sets, 20 repetitions). She was also advised to avoid other potentially provocative shoulder motions.

Due to continued improvements in ROM, pain, and function over the following sessions, it was determined that the correct directional preference had been identified. Treatment was then progressed according to MDT methodology for treatment of derangements. Once the subject could perform challenging activities without aggravating symptoms, exercises were progressed to include all planes of motion while continuing her previous exercise program (shoulder extensions, scapular retractions). It should be noted that exercises incorporating external rotation (ER) were added in the treatment program at visit 4, causing the subject’s symptoms to become aggravated. The subject’s symptoms quickly returned to baseline after external rotation was removed as an intervention on visit 5, with a subsequent improvement of ER range of motion to normal by visit 6. The subject was instructed to continue the initial exercises after discharge to prevent the derangement from re-occurring.

**OUTCOMES**

At discharge the subject had met or exceeded all PT goals, with the exception of the UEFI score. However, she did show a clinically significant improvement of 11 points the UEFI [MCID 9-10 points]. PROM on the involved side was equal to the unaffected side with firm end feel and no pain. VAS scores revealed that the subject experienced only mild pain (2/10) during overhead activities. All special tests (including the Hawkins-Kennedy, Empty Can and Speed’s) were negative, demonstrating resolution of her symptoms throughout the treatment process. Since pain was infrequent, and continued to diminish, the subject was advised to continue with her home exercise program. Initial and final examination findings are detailed in Table 4, and Figures 1-3 detail changes in ROM and pain that occurred at each visit.

**DISCUSSION**

Given the questionable sensitivity and specificity of pathoanatomic models for diagnosis and treatment of shoulder pathology, a model based upon patient response may allow for more accurate treatment of individual patients. Considering the moderate levels of sensitivity and specificity reported for the diagnostic tests used with this subject: Empty Can Test (SN 0.69-0.78, SP 0.52-0.62), Speed's Test (SN 0.48, SP 0.55) and Hawkins-Kennedy Test (SN 0.79, SP 0.59) as well as research demonstrating that structures other than rotator cuff tendons are impinged.
Table 4. *Initial vs. Final Outcome Results.*

<table>
<thead>
<tr>
<th>Outcome Measurements</th>
<th>Initial Visit</th>
<th>Final Visit</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UEFI (function)</strong></td>
<td>55/80</td>
<td>66/80</td>
<td>75/80 (improved but not met) X</td>
</tr>
<tr>
<td><strong>VAS (pain)</strong></td>
<td>Current: 4/10</td>
<td>Current: 0/10</td>
<td>0/10 (goal met) ✓</td>
</tr>
<tr>
<td></td>
<td>24 hour max: 7/10</td>
<td>24 hour max: 2/10</td>
<td>No goal made specifically about this</td>
</tr>
<tr>
<td><strong>Empty Can Test</strong></td>
<td>Positive</td>
<td>Negative</td>
<td>Goal met ✓</td>
</tr>
<tr>
<td><strong>Hawkins-Kennedy Test</strong></td>
<td>Positive</td>
<td>Negative</td>
<td>Goal met ✓</td>
</tr>
<tr>
<td><strong>Speed’s Test</strong></td>
<td>Positive</td>
<td>Negative</td>
<td>Goal met ✓</td>
</tr>
<tr>
<td><strong>Gross Strength Assessment</strong></td>
<td>5/5 all shoulder motions (abduction, IR, ER painful)</td>
<td>5/5 all shoulder motions (mild pain only with ER)</td>
<td>No pain with resisted motions (goal met) ✓</td>
</tr>
<tr>
<td></td>
<td>5/5 all elbow motions (flexion, extension, pronation, supination painful)</td>
<td>5/5 all elbow motions</td>
<td>0/10 pain with resisted motions (goal met) ✓</td>
</tr>
<tr>
<td><strong>AROM</strong></td>
<td>Gross limitations all shoulder motions with pain</td>
<td>AROM equal bilaterally with no pain</td>
<td>AROM on left equal to right with 0/10 pain (goal met) ✓</td>
</tr>
<tr>
<td><strong>PROM</strong></td>
<td>Right: 178 abduction 180 flexion 101 ER 56 IR (firm end feel)</td>
<td>Right: 178 abduction 180 flexion 101 ER 56 IR (firm end feel)</td>
<td>No goal addressed this</td>
</tr>
<tr>
<td></td>
<td>Left: 152 abduction 155 flexion 70 ER 62 IR (pain, firm end feel)</td>
<td>Left: 177 abduction 178 flexion 99 ER 62 IR (firm end feel, pain-free)</td>
<td>Full PROM (when compared to right) with 0/10 pain (goal met) ✓</td>
</tr>
</tbody>
</table>

UEFI=Upper Extremity Functional Index, VAS=visual analog scale for pain, AROM=active range of motion, PROM=passive range of motion, ER=external rotation, IR=internal rotation

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**Figure 1.** Range of motion at initial evaluation and discharge, compared to uninvolved side.

**Figure 2.** Range of motion at initial evaluation and discharge, compared to uninvolved side.
during impingement testing, and the diagnostic uncertainty of adhesive capsulitis, an individualized approach based upon symptom behavior appears to be a viable alternative to pathoanatomic diagnosis. The literature supports the reliability of this system among trained clinicians, with 85.5% diagnosis categories remaining consistent throughout treatment. Evaluation to determine specific mechanical behaviors allows the therapist to select treatments that demonstrate symptom alleviation, limiting the need for determination of a specific pathoanatomic diagnosis. This may be particularly beneficial when treating adhesive capsulitis, as this condition and its comorbidities are frequently misdiagnosed. Although it is possible that this subject was misdiagnosed as having adhesive capsulitis, this remains questionable as adhesive capsulitis is primarily a clinical diagnosis, and the subjects symptoms were consistent with the ICD 10 criteria as described earlier. Authors have concluded that the diagnosis of idiopathic versus secondary adhesive capsulitis may be elusive. Regardless of the actual pathoanatomic diagnosis, in this case the subject's physical therapy treatment was effective as it was tailored to specific responses to movement rather than a medical diagnosis.

With the application of MDT methodology, it was determined that the subject's condition was not a shoulder dysfunction (the mechanical classification for adhesive capsulitis) but rather a derangement based upon the subject's rapid symptomatic improvement following repeated motions. Derangement has previously been identified as the most common cause of shoulder pain identified by MDT practitioners. Specifically, this subject recovered following repeated shoulder extension. This is in agreement with the case series of Aytona and Dudley, who found that there was a trend towards recovering following repeated extension in subjects with shoulder derangement. A recent study also identified extension as the most common directional preference in the shoulder. This finding requires further study to confirm its relevance.

There is conjecture about the pathoanatomic basis of obstructed movement in peripheral joints. In a cadaveric study, it was revealed that intra-articular intrusions (deformable space fillers composed of fat pads and fibroadipose meniscoids) could proliferate within joints. It is thought that cartilage fragments, joint capsule, a portion of the labrum, or any other component of the joint can become interposed between the joint surfaces causing blocked movement and abnormal stress on peri-articular structures. Pain is derived from deformation of the joint capsule and supporting ligaments when the normal resting position is disturbed. These have been suggested as a potential cause for derangement in the extremities, but this still requires much investigation. Therefore, it is proposed that due to the nature of derangements, performing exercises that go against the identified directional preference can prevent the tissue from re-aligning itself, or can cause the tissue to become displaced even further. This was seen during the treatment of this subject when stretches incorporating ER were added prematurely on visit four with aggravating affects, which may have also interfered with subject outcomes at discharge, although the subject's symptoms returned to baseline rapidly after discontinuing ER on visit five.

There are several limitations of this case report that merit discussion. This report does not attempt to demonstrate a cause-and-effect relationship between the use of MDT methodology and successful outcomes for individuals' that are being treated with injuries to the shoulder complex. During the examination of the subject, the therapist did not test accessory motions of the shoulder complex, which is a common practice when dealing with adhesive
capsulitis. Therefore, it is not known if joint mobilization would have had specific benefit for this subject; however, the capsular end feels identified during examination would suggest that this may have been an appropriate alternative. Furthermore, integrating motions that favored external rotation into the exercise program, which is also common practice in treatment of adhesive capsulitis, had a short term detrimental effect with this subject. While in this case it appears that avoiding external rotation exercises was beneficial, this may not be the case for other patients diagnosed with adhesive capsulitis. Although the subject demonstrated rapid improvements in symptoms throughout the duration of treatment, these limitations need to be considered prior to the application of this methodology.

CONCLUSIONS
The outcomes of this report suggest that the use of MDT techniques can be effective in the treatment of shoulder pathology. The ability to establish a cause-and-effect relationship is limited as this is a report of a single case, particularly as there is no long-term follow-up available. However, the rapid improvements that were observed suggest that the use of MDT methodology may be a useful approach to the examination, and potentially management, of patients with shoulder pain. More research is required comparing the outcomes of individuals treated with MDT methodology compared to traditional therapy methods, and to determine if this is a valid approach for treatment of the extremities. Overall, this method offers a patient specific approach to treating the shoulder, particularly when the pathoanatomic structure affected is unclear.

REFERENCES


27. Petersen T, Christensen R, Juhl C. Predicting a clinically important outcome in patients with low back pain following McKenzie therapy or spinal manipulation: a stratified analysis in a randomized controlled trial. BMC Musculoskeletal Disorders. 2015;16(74).


ABSTRACT

Background: Competitive cyclists are susceptible to injury from the highly repetitive nature of pedaling during training and racing. Deviation from an optimal movement pattern is often cited as a factor contributing to tissue stress with specific concern for excessive frontal plane knee motion. Wedges and orthoses are increasingly used at the foot-shoe-pedal-interface (FSPI) in cycling shoes to alter the kinematics of the lower limb while cycling. Determination of the effect of FSPI alteration on cycling kinematics may offer a simple, inexpensive tool to reduce anterior knee pain in recreational and competitive cyclists. There have been a limited number of experimental studies examining the effect of this intervention in cyclists, and there is little agreement upon which FSPI interventions can prevent or treat knee injury. The purpose of this review is to provide a broader review of the literature than has been performed to date, and to critically examine the literature examining the evidence for FSPI intervention in competitive cyclists.

Methods: Current literature examining the kinematic response to intervention at the FSPI while cycling was reviewed. A multi-database search was performed in PubMed, EBSCO, Scopus, CINAHL and SPORTdiscus. Eleven articles were reviewed, and a risk of bias assessment performed according to guidelines developed by the Cochrane Bias Methods Group. Papers with a low risk of bias were selected for review, but two papers with higher risk of bias were included as there were few high quality studies available on this topic.

Results: Seven of the eleven papers had low bias in sequence generation i.e. random allocation to the test condition, only one paper had blinding to group allocation, all papers had detailed but non-standardized methodology, and incomplete data reporting, but were generally free of other bias sources.

Conclusions: Wedges and orthoses at the FSPI alter kinematics of the lower limb while cycling, although conclusions about their efficacy and response to long-term use are limited. Further high quality experimental studies are needed examining cyclists using standardized methodology and products currently used to alter SPFI function.

Level of Evidence: 3

Key words: Bicycling injury, orthoses, wedges
INTRODUCTION
Repetitive micro-trauma to the knee complex is one of the most significant musculoskeletal factors in recreational and competitive cycling. Incidence of knee pain is 50% in competitive cyclists, resulting in reduced training and racing in 57% of professional cyclists. Cycling involves extending and flexing the knee over five million times per year in a competitive cyclist riding in the order of 25-35,000km every year, so that even small inefficiencies in pedaling are likely to contribute to knee pain.

In seated cycling, there are three main areas of contact between the cyclist and bicycle; the hands, pelvis and feet. Since the foot is the direct point of contact with the drivetrain (pedal-crank-chain-gear system), optimization of this link is of interest to cyclists, clinicians and coaches. This link between foot and pedal influences the kinematics of cycling and is comprised of two elements; the foot-shoe interface (FSI), and the shoe-pedal interface (SPI). (Figures 1a and Figure 1b)

Intervention in footwear alters kinematics of over ground gait, and it stands to reason that intervention at the foot-shoe-pedal interface (FSPI) might alter axial and frontal plane knee function while cycling. Deviation from optimal frontal plane kinematics has been implicated as a predictive factor for injury in sports such as running, basketball and soccer. Excessive, or sub-optimal non-driving moments (knee varus/valgus forces, axial tibial internal or external rotation) are largely considered to be responsible for knee pain in cyclists. Multi-planar kinematics can be altered using orthotics in footwear for walking and running, and increasingly, wedges and orthotics are used to correct aberrant knee motion in cycling.

Despite a large body of literature on the effect of orthotic intervention in walking and running, there has been limited investigation into the kinematic effects of wedge and orthotic intervention in cyclists. A recent systematic review of the effect of various types of orthoses in cycling concluded that orthoses produce significant changes in pressure and contact area in the foot while not compromising cycling performance. The review by Yeo et al examined six articles, only one of which examined cycling kinematics, the majority of the articles examined physiological parameters while cycling with orthoses. The authors determined that orthoses produced a non-systematic, subject-specific effect on some lower extremity variables. The study in question did not control for shoe type, cleat type and pedal system, and the methodological design limits firm conclusions on the kinematic effect of orthoses in cycling. The authors concluded that further study in this field is warranted. In response, this updated review of the FSPI includes four additional papers, which examined different pedal systems on cycling kinematics and included EMG responses to changes at the foot-pedal interface in cyclists. The articles reviewed herein, address the kinematic effects of each element of the foot-shoe-pedal-inter-
face: i.e. the effect of a sneaker compared with a cycling shoe, the effect of multi-planar mobility in the pedal-cleat system, and the effect of wedges and orthoses on cycling kinematics. FSPI modifications may be a simple, inexpensive and unobtrusive solution to managing anterior knee pain in cyclists without compromising cycling performance. Cyclists, their coaches and health care professionals, would benefit from research-based guidelines to assist in management of anterior knee pain. To date, there is little agreement upon which FSPI interventions can prevent or treat knee injury, but this review aims to assist the clinician by providing a broader review of the literature than has been performed to date.

While acknowledging that training load is a major contributing factor to overuse injuries of the lower limb in cycling, this review will focus on understanding the kinematics of cycling, including the role of FSPI interventions. The purpose of this review is to provide a broader review of the literature than has been performed to date, and to critically examine the literature examining the evidence for FSPI intervention in competitive cyclists. This information will assist the clinician to use evidence-informed interventions in managing knee pain in cyclists.

KINETICS OF CYCLING

In seated cycling, the knee maximally flexes to 110° and extends to 20-35°. Knee extension produces almost 40% of the total lower limb muscle moments, with the remainder from hip extension (27%), ankle plantar flexion (20%), hip flexion (4%) and knee flexion (10%). Moments in the sagittal plane are propulsive or driving forces, moments in the transverse and frontal planes are considered non-driving forces. While the majority of lower limb motion during cycling is in a sagittal plane, there are also associated accessory joint movements in transverse and frontal planes. Small amounts of tibial and foot rotation (approximately 10°) occur in the transverse plane. These rotational moments in the transverse plane have an effect on the patellofemoral contact pressures proximally and ankle/foot pressures distally. Frontal plane motion (hip adduction/abduction, tibial abduction/adduction) occurs through the recovery and power phase of cycling, and patterns vary between cyclists, with 2-8 cm movement of the knee center in the frontal plane, creating valgus and varus angles at the knee. As the knee extends through the power phase from the top dead center (TDC or 0°) where the pedal is at its most vertical in the cycle, the knee maintains a varus moment (7N), moving to a valgus moment (1-2N) at bottom dead center (BDC or 180°) later in the power phase when pushing down on the pedal, returning to a valgus moment in the recovery phase to the top of the cycle. Some studies examining cyclists with a history of knee pain or injury indicate a valgus or medial positioning of the knee. Alteration of the knee alignment through the pedaling cycle is achieved by changing inter-pedal stance width using washers between the pedal and crank arm or with longer pedal spindles (altering the “Q factor”) as well as by canting the foot medially or laterally relative to the pedal. Charging the inter-pedal stance width is limited by fixed bicycle frame dimensions and limited pedal spindle lengths and bottom bracket widths, so intervention at the FSPI may be a more feasible method of altering cycling kinematics. Laterally or medially inclined wedges are increasingly recommended in the cycling industry to alter the frontal plane knee angle and position relative to bicycle centerline. While 10° wedges have been demonstrated to alter kinematics of the pedaling limb, there have been few studies using commercially available products which are in 1 degree increments to a maximum of 4-5 degrees. Inclined wedges are used by coaches and bike-fitters to modify medio-lateral deviation of the knee, as a pedaling pattern with a more vertical shank is considered optimal. The hypotheses that a vertical shank is optimal for cycling, and that an inclined wedge at the SPI can alter cycling kinematics, need to be explored in controlled experimental studies, where wedges of consistent size and inclination are examined for effectiveness in altering cycling kinematics.

BICYCLE ADJUSTMENTS

Altering the cycling position and using clipless pedal systems (i.e. no toe clips/straps), rigid soled cycling shoes or shoe inserts can modify forces on the lower limb. Studies have examined the influence of many variables on cycling performance, (saddle height, handlebar height, cadence, workload, foot position on pedal fixed vs. ‘float’ (motion available in both the transverse plane (0°-15°) and frontal plane (0-10mm) between the shoe and pedal) vs.
Intervention at the FSPI with wedges and in-shoe orthoses in cycling, is purported to contribute to improved kinematics, increased power output, altered plantar pressures at the foot, and a reduction of knee joint forces, but there is limited available literature to allow sports performance and health professionals to definitively support their use.

### Table 1. Bicycle adjustments, associated physiological responses, and clinical implications

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjustment</th>
<th>Response</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-pedal width</td>
<td>Variable with spacers 1-20 mm. Limited adjustability secondary to frame width.</td>
<td>Alters Q angle in frontal plane. Narrower stance improves efficiency</td>
<td>Too narrow or too wide a stance width can adversely affect frontal plane knee angle, increasing lateral or medial knee strain, creating foot stress in shoes, pressure points in shoes.</td>
</tr>
<tr>
<td>Cleat position fore-aft</td>
<td>Adjusts 0-10mm in most cleats.</td>
<td>Alters the point of pedal contact with the shoe sole. Changes location of pedal pressure on the foot in a fore-aft direction.</td>
<td>Too far forward a position could increase stress on metatarsals and increase pressure points in plantar aspects of feet.</td>
</tr>
<tr>
<td>Cleat lateral-medial</td>
<td>Adjusts 0-5mm in most cleats, adjusted in combination with pedal stance width.</td>
<td>Alters the point of pedal contact with the shoe sole. Changes location of pedal pressure on the foot in a medio-lateral direction.</td>
<td>Can be used to alter pedal stance width. Could increase lateral/medial knee frontal plane strain.</td>
</tr>
<tr>
<td>Cleat internal-external rotation</td>
<td>Adjusts 0-15° in most cleats.</td>
<td>Alters the transverse plane angle at which the shoe connects to the pedal. Some cleats allow “float” which allows movement in this plane.</td>
<td>Inadequate foot rotation transfers axial load proximally potentially straining meniscal and articular knee tissues. Cleat “float” reduces axial loading at the pedal and knee.</td>
</tr>
<tr>
<td>Cleat varus/valgus tilt</td>
<td>Adjustable with use of medially or laterally inclined wedges 1° to 5°.</td>
<td>Varus/valgus alters Q angle and foot pressure points.</td>
<td>Potentially increases lateral or medial knee frontal plane stress.</td>
</tr>
</tbody>
</table>

Toe straps but adjustments commonly made at the SPI are largely based on interpretation of cadaveric or biomechanical modeling studies, and historical practice. An outline of most common SPI adjustments, associated kinematic responses, and clinical implications is presented in Table 1.

### The Foot-Shoe-Pedal Interface

Competitive cyclists constantly seek to improve performance, and equipment is always evolving in the quest for greater power production and cycling efficiency. The modern clipless pedal system was developed in response to technological developments in the ski industry in the 1970s, and a cleat on the undersurface of the cycling shoe now connects directly into the pedal. This allows the shoe to remain in greater contact with the pedal, assisting propulsion during the recovery phase of the pedaling cycle (i.e. from 180° to 360/0°).

Intervention at the FSPI with wedges and in-shoe orthoses in cycling, is purported to contribute to improved kinematics, increased power output, altered plantar pressures at the foot, and a reduction of knee joint forces, but there is limited available literature to allow sports performance and health professionals to definitively support their use.
## Table 2. Specific FSPI adjustments

<table>
<thead>
<tr>
<th>Author</th>
<th>Participants (n, sex, type)</th>
<th>FSPI intervention</th>
<th>Methods</th>
<th>Outcome</th>
<th>Clinical implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson et al 41</td>
<td>6 male, 4 females, untrained cyclists.</td>
<td>Posted 4° rearfoot, 4° forefoot molded orthoses. Mixed rigid shoe and sneakers.</td>
<td>Cycle ergometer, preferred geometry, workload moderate and maximal. Different shoe types and workloads.</td>
<td>No significant differences in O2 consumption and HR different between conditions</td>
<td>Small N might contribute to non-significance. Tendency for higher HR with sneakers/lower HR with rigid shoes at higher load, supporting use of rigid cycling shoes to increase cycling efficiency.</td>
</tr>
<tr>
<td>Bousie et al 39</td>
<td>8 male, 4 female cyclists.</td>
<td>Prefabricated orthoses vs. flat inserts.</td>
<td>Cycle ergometer, preferred geometry, 12/20 RPE (Borg) Cyclists own rigid cycling shoe and clipless pedals.</td>
<td>Inc. plantar pressure, inc. contact area, in medial &gt; lateral sole. Orthoses inc. pressure at heel, and inc. perceived support but not comfort</td>
<td>Prefabricated orthoses increase plantar contact and improve perceived support in rigid cycling shoes.</td>
</tr>
<tr>
<td>Boyd et al 23</td>
<td>10 male cyclists.</td>
<td>Instrumented pedal, rigid cycling shoe. 2 degrees of freedom in pedal.</td>
<td>Cycle ergometer, preferred geometry, 90rpm, and 250W.</td>
<td>Allowing 2 degrees of freedom at pedal reduces moments at FSPI but not at the knee</td>
<td>Transverse and frontal plane pedal float does not significantly change force driving the pedal. Pedal float alters moments at the FSPI but not significantly at the knee.</td>
</tr>
<tr>
<td>Cruz et al 42</td>
<td>4 male triathletes</td>
<td>Clipless pedal and cycling shoe vs. toe-clip and sneakers.</td>
<td>Cyclists own bicycle, 100rpm. Stationary rollers.</td>
<td>EMG lower in HS, GS for clipless pedals. No statistical analysis.</td>
<td>Muscle activity may change with different FSPI systems.</td>
</tr>
<tr>
<td>Dinsdale et al 58</td>
<td>6 male untrained cyclists.</td>
<td>Rigid cycling shoe, clipless pedal, 1-4° medial wedge under shoe, forefoot varus matched with appropriate medial wedge.</td>
<td>Cycle ergometer, 30s anaerobic test (Wingate).</td>
<td>Correlation between power increase and FF varus correction Peak power and mean power not improved with wedges</td>
<td>Custom orthoses for Forefoot Varus may improve anaerobic power.</td>
</tr>
<tr>
<td>Gregersen 8</td>
<td>15 male cyclists.</td>
<td>Instrumented pedal with rigid cycling shoe. 5-10° medial and lateral pedal inclination.</td>
<td>Cycle ergometer, preferred geometry, 90rpm, and 225W.</td>
<td>Varus wedge (10°) caused increased EMG VM/VL ratio with reduced TFL activity and reduced varus moment at knee 38-72% CV for varus-valgus moments. 59% CV for axial moments.</td>
<td>Varus wedge alters Quad ratio, reduces knee moments and may have implications for PFPS patients. Wedge is significantly larger than those used commercially.</td>
</tr>
</tbody>
</table>
The quality of the available literature limits conclusions about the effectiveness of FSPI intervention, as the majority of studies have small sample sizes, and examine mostly competitive, young adult male participants. This restricted sampling limits study power, generalizability of results to females and older cyclists, and impedes the application of findings to cyclists of varying skill and experience. With increasing demand for performance improvement and injury mitigation, there is a need for experimental studies to guide clinicians. Only one known systematic review has been performed on the effect of foot orthoses and wedges on cycling, concluding that further study in this area is warranted.16 Table 2 presents

<table>
<thead>
<tr>
<th>Reference</th>
<th>Gender</th>
<th>Participants</th>
<th>Insole Type</th>
<th>Protocol</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hennig et al 40</td>
<td>26 male, 3 female</td>
<td>Rigid cycling shoe, toe-clip pedal system vs. sneakers.</td>
<td>Cycle ergometer, preferred geometry, 80rpm 100W, 200W, 300W, 400W.</td>
<td>An increase in workload causes increased medial forefoot and first toe pressure, in cycling shoe vs. sneaker. Greater index of effectiveness with cycling shoe†</td>
<td>Cycling shoes improve applied force to the pedal, and increase pressure in the medial foot.</td>
</tr>
<tr>
<td>Jorge et al 59</td>
<td>6 male cyclists</td>
<td>Rigid cycling shoe, toe-clip system vs. sneakers</td>
<td>Bicycle on rollers, 80rpm, seat height 100% of trochanter height</td>
<td>Sneakers produced higher EMG in Quads, and Hamstrings, lower in Rectus Femoris and Gastrocnemius</td>
<td></td>
</tr>
<tr>
<td>Koch, et al 56</td>
<td>18 male cyclists.</td>
<td>Pre-fabricated carbon insoles</td>
<td>Rigid cycling shoe, clipless pedal system. Anaerobic test (Wingate) Cyclists’ own bike, shoe, and pedal system.</td>
<td>No significant difference in mean power, peak power, cadence</td>
<td>Short effort may not reflect longer endurance efforts.</td>
</tr>
<tr>
<td>O’Neill 13</td>
<td>9 males, 3 females, cyclists.</td>
<td>Custom orthoses, varied types posted and molded, varied materials.</td>
<td>Rigid cycling shoe, clipless pedal system. Cycle ergometer, 5′ @85% max HR.</td>
<td>Orthoses produced a trend towards increased knee distance from bicycle centerline and reduced tibial IR, but was not statistically significant. Small group numbers may have underpowered the study.</td>
<td>Custom orthoses may alter knee position in frontal plane.</td>
</tr>
<tr>
<td>Sanderson et al 31</td>
<td>28 mixed gender cyclists.</td>
<td>10° medial or lateral wedge (not commercially available)</td>
<td>Toe-clip pedal system. Own bicycle, 90rpm, standard gearing.</td>
<td>Lateral wedge significantly altered distance of knee from centerline † but wedges did not significantly alter the frontal plane knee angle</td>
<td>Wedges altered knee position in frontal plane. Wedge is significantly larger than those used commercially. There was wide inter-individual variance in response to wedges.</td>
</tr>
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</table>

† = Statistically Significant

Table 2. Specific FSPI adjustments (continued)
the most recent experimental studies published in peer-reviewed journals examining FSPI intervention.

**METHODS**

A literature search was performed in October 2015 using the following databases: PubMed, EBSCO, Scopus, CINAHL and SPORTdiscus using the following search terms: (cycling OR bicycling) AND ((orthotic OR orthoses OR orthoses) OR (wedges OR wedge) AND kinematics), 29 articles were returned and when Full-text, English language filters were applied, and 27 articles were examined. Inclusion criteria were as follows: Experienced cyclists, standard bicycle frame or cycle ergometer, experimental design, orthotic device or wedge. Eleven articles were selected for review, seven met criteria for inclusion in the literature review, and four additional papers meeting these criteria were obtained from other reference lists within journal articles.

A risk of bias analysis was performed according to guidelines developed by the Cochrane Bias Methods Group. Articles were reviewed with an effort to determine bias in selection (randomized allocation), performance (blinding of participants and personnel), detection (blinding of outcomes), attrition (management of incomplete data) and reporting (selectivity of outcome reporting) of data. Table 3 displays the relative risk of bias for each paper under consideration.

Seven of the eleven papers had low bias in sequence generation i.e. random allocation to the test condition, only one paper had blinding to group allocation, and no papers described blinding of outcome assessors or other personnel. All papers had detailed methodology sections, but had incomplete data reporting, with lack of detail about missing data, missing outcomes, and how such data were handled during analysis. Per Cochrane guidelines, all of the papers were generally free of other bias sources such as sample homogeneity, unequal variance or other threats to validity.

**RESULTS**

**Shoe-type**

Competitive cyclists did not universally and simultaneously adopt the now ubiquitous rigid shoe and clipless pedal systems, so both types of footwear were often included in earlier studies. Two studies examined the kinematic effects of FSPI intervention using both rigid cycling shoes and sneakers, but only one study directly compared the effect of two different shoe types on cycling kinematics. Cruz examined the EMG response in four cyclists when pedaling with sneakers with toe clip pedals or rigid soled cycling shoes with clipless pedals, plotted data for each subject, and visualized that there was reduced EMG activity in the biceps femoris and gastrocnemius muscles when cycling using a rigid cycling shoe. The authors concluded that use of the rigid shoe with clipless pedals was more efficient. While they did not directly study cardiovascular efficiency, they inferred from EMG trace data that it was more efficient, as it has a reduced amplitude compared with prior recordings from participants cycling with sneakers and flat pedals. While the raw EMG signal was normalized to the signal average, no statistical analyses were reported, limiting support for their conclusions. The observations from their study were supported by Andersen et al, who demonstrated a lower heart rate while cycling in rigid cycling shoes when compared with sneakers. Henning et al compared sneakers and rigid shoes with resultant higher medial foot pressure and greater cycling effectiveness when pedaling using rigid shoes. Their observations of greater pressures in the medial foot when using a rigid cycling shoe were supported in a later study by Bousie et al. While earlier studies on FSPI intervention examined both sneakers and cycling shoes, use of a rigid cycling shoe has now become standard in experimental studies, increasing internal validity by reducing confounding variables.

**Pedal system**

Authors have compared different cleat-pedal systems (Figure 2) and resultant cycling kinematics. Reduced axial (internal rotation) knee moments have been demonstrated effectively with clipless float pedal design without changing pedal loads or moments. Combined axial (internal rotation) and frontal plane (valgus) moments applied at the pedal have been demonstrated to increase patellofemoral contact loading area by 29%, and loading force by 28%, with greatest load on the patellofemoral joint obtained.
at 90° flexion.23 This is the point in the downstroke where maximal propulsion, muscular forces and joint moments occur,3 so alleviation of potential excessive patellofemoral pressure via use of pedals that allow transverse plane mobility may be desirable. However, not all cyclists respond to pedal-float with predictable kinematic responses.22,23,29 Wheeler et al made direct comparisons of knee joint moments using clipless,

<table>
<thead>
<tr>
<th>Paper</th>
<th>Sequence generation</th>
<th>Allocation concealment</th>
<th>Blinding</th>
<th>Incomplete data</th>
<th>Selective outcome reporting</th>
<th>Other validity threats</th>
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<tr>
<td>Anderson et al34</td>
<td>L</td>
<td>Randomly assigned to</td>
<td>U No indication of</td>
<td>U The study did</td>
<td>L Protocol is available</td>
<td>H Males and females</td>
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<td>orthosis test condition</td>
<td>allocation concealment process</td>
<td>not address this outcome</td>
<td>and reports include expected outcomes</td>
<td>did not complete the same protocol, flaw in study design</td>
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<td>Bousie et al35</td>
<td>L</td>
<td>Randomly assigned to</td>
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<td>U The study did</td>
<td>L Protocol is available</td>
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<td>pedal test condition</td>
<td>allocation concealment process</td>
<td>not address this outcome</td>
<td>and reports include expected outcomes</td>
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<td>Boyd et al23</td>
<td>L</td>
<td>Randomly assigned to</td>
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<td>Cruz et al32</td>
<td>H</td>
<td>No random allocation to pedal test condition</td>
<td>U No indication of allocation concealment process</td>
<td>U The study did not address this outcome</td>
<td>L Protocol is available and reports include expected outcomes</td>
<td>L The study appears to be free of other sources of bias</td>
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<td>Dinsdale et al38</td>
<td>L</td>
<td>Randomly assigned to</td>
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<td>Gregersen et al39</td>
<td>L</td>
<td>Randomly assigned to</td>
<td>U No indication of</td>
<td>U The study did</td>
<td>L Protocol is available</td>
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<tr>
<td>Hennig et al40</td>
<td>H</td>
<td>No random allocation to shoe test condition</td>
<td>U No indication of allocation concealment process</td>
<td>U The study did not address this outcome</td>
<td>L Protocol is available and reports include expected outcomes</td>
<td>L The study appears to be free of other sources of bias</td>
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<td>Jorge et al39</td>
<td>H</td>
<td>No random allocation to shoe test condition</td>
<td>U No indication of allocation concealment process</td>
<td>U The study did not address this outcome</td>
<td>L Protocol is available and reports include expected outcomes</td>
<td>L The study appears to be free of other sources of bias</td>
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<tr>
<td>Koch et al56</td>
<td>L</td>
<td>Randomly assigned to</td>
<td>L Participants were blinded to the allocation</td>
<td>U The study did not address this outcome</td>
<td>L Protocol is available and reports include expected outcomes</td>
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<td>orthoses test condition</td>
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<td>O’Neill et al13</td>
<td>H</td>
<td>No random allocation to orthoses test condition</td>
<td>U No indication of allocation concealment process</td>
<td>U The study did not address this outcome</td>
<td>L Protocol is available and reports include expected outcomes</td>
<td>L The study appears to be free of other sources of bias</td>
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<tr>
<td>Sanderson et al31</td>
<td>L</td>
<td>Randomly assigned to</td>
<td>U No indication of</td>
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L = Low bias risk, U = Unclear bias risk, H = High bias risk
toe clip and flat pedals while cycling at several different work rates (150W to 350W). Increasing power output from 150W to 350W resulted in an almost linear increase in knee moments with a fixed pedal system. Clipless fixed pedals produced the greatest knee axial and varus moments, which were attenuated by use of a clipless system allowing transverse rotation, with 50% reduction in internal rotation moment at 250W power output. Ruby and Hull had previously demonstrated most significant reductions in pedal and knee moments when using a multi-axial instrumented pedal which allowed rotational mobility in the transverse plane. Boyd et al used a custom multi-axial pedal platform to introduce two degrees of freedom to the SPI resulting in a significant reduction of axial and transverse plane moments at both the pedal and the knee, and pedal systems offering this mobility have been widely adopted by competitive and recreational cyclists. Alteration of cleat angle in order to modify an individual’s lower limb alignment (tibial torsion, tibial varum etc.) might be a consideration in preventing or managing injury to the knee in cyclists. Supported by these findings, there are many recommendations to use cleat rotation to reduce potentially adverse moments on the knee while cycling, and the majority of competitive cyclists currently use clipless pedal systems.

In addition to reducing stress at the knee joint, it is thought that clipless pedals produce more efficient cycling patterns than toe-clip pedals. Most studies examining the effect of SPI intervention in cycling have examined joint kinetics; few have examined resultant changes in muscle activity with different degrees of pedal constraint. Cruz et al compared visual plots of EMG RMS data from lower limb when cycling (n = 4) with combinations of clipless pedal/cycling shoe and toe-clip/sneaker and flat pedal. Cyclists using clipless pedals demonstrated lower activation levels of hamstring muscles. The authors concluded that a reduction in EMG represented a more efficient pedaling action, but did not address the influence of shoe type on the measured EMG. Since only four cyclists were examined, normalized EMG data were not processed for statistical analysis. Without a larger group of subjects, removal of confounding factors (different shoe types) and appropriate statistical analysis, it is not possible to determine the influence of pedal type on EMG pattern. Patterns of muscle activity in cyclists using clipless pedal systems have been documented with noted difference between competitive and novice cyclists, but further studies of EMG responses to FSPI intervention are needed.

**Wedges/Insoles**
A coupled linkage between the talo-crural joint of the ankle, and the joints of the foot has been examined extensively in over-ground walking and provides...
the basis for much of the orthoses-based interventions used during human gait. Rigid modern cycling shoes can have medially or laterally inclined wedges bolted to the undersurface of the sole influencing cycling kinematics. Changes in cycling kinematics have been observed in biomechanical modeling studies using instrumented multi-axial pedals and in experimental studies using wedges at the SPI. Sanderson used a 10° wedge and measured frontal plane knee angle in 28 cyclists, with wedges altering the knee distance from centerline. There was no significant difference between the neutral condition and a 10° medial wedge or the neutral condition and a 10° lateral wedge. Participants exhibited a significant response to the SPI intervention only between extreme wedge angles, i.e. between 10° valgus and 10° varus wedges, with a small magnitude of frontal plane knee motion of approximately 10mm. The study used two dimensional (2D) video analysis, which has much less accuracy and reliability than current gold-standard three dimensional (3D) motion analysis systems and the recently available handheld mobile devices.

Anderson et al examined metabolic responses to use of custom orthoses while cycling. Rearfoot and forefoot posting of 4° did not significantly alter cycling efficiency, but shoe type was related to changes in heart rate (HR). Using a rigid cycling shoe was associated with a lower HR when compared with a soft running sneaker, both with and without orthoses (mean change 22 bpm for males and 33 bpm for females). A mean change in HR of 26bpm was not statistically significant, but would be clinically significant in most physiologic studies, indicating that the study (n = 10) was likely underpowered.

Bousie et al compared contoured pre-fabricated orthoses with flat inserts in cycling shoes of 12 experienced cyclists. Plantar pressure, contact area and perceived support were significantly increased with contoured orthoses (p < 0.001) but the intervention was limited to 20 minutes of seated, steady state cycling. Replication of this study using long-duration or fatigue protocols would produce information about cycling performance closer to typical racing conditions, as well as more realistic information about the relationship between pressure and comfort at the FSPI over timeframes approximating training and competition.

Boyd et al used an instrumented pedal platform with freedom from SPI constraint in two planes (x and y, approximating sagittal and transverse planes). Transverse motion ranged from 6.3° to 17.3°, and caused reduction of moments at both pedal and knee, although the changes in knee moments were not statistically significant. This study was unique as it relied on custom-built dynamometer pedals. This capability is likely to become increasingly available as technological advances have led to commercially available pedals and sensors that can measure power output, shear forces and pedal forces orthogonal to the pedal. The ability to use the cyclist’s own bike with these instrumented pedals will provide for improved implementation of research findings into clinical practice.

More closely approximating normal practice in the cycling athlete, O’Neill examined the kinematic responses to orthoses of different types. The distance of the knee to the bicycle centerline and the frontal plane knee angle was reduced when using orthoses (37.2° to 34.8° p < 0.001) with significant responses demonstrable within-subjects. While the orthoses produced reduced tibial axial internal rotation in many participants (mean change from 16.8° to 15.2°), there were no significant systematic effects (p = 0.072). The study was possibly underpowered, with only 12 cyclists, but, there was a tendency towards kinematic changes similar to those in gait studies, with tibial rotation reduced in the order of 2-3° when using orthoses while cycling. As knee loads in seated cycling are <50% lower than walking and stair climbing, it remains to be seen whether this small reduction in tibial rotation is important in cycling.

Gregersen et al monitored the response of thigh muscle activation ratios when laterally inclined wedges were placed at the SPI while cycling. There was a significant reduction in tensor fascia lata (TFL) EMG activity, improved vastus lateralis / vastus medialis (VL/VM) ratios (i.e. increased VM activation correlated with reduction in knee varus (r² = 0.65-81, p < 0.0001), and reduced knee varus moments (53-55%, p < 0.001) with a lateral wedge. Varus loading (4-10N) at the knee occurs in the power phase...
of cycling at 80-100° and is considered to be a potential source of pain and injury when excessive. An imbalance between the ratios of quadriceps and hamstring muscle activity has been implicated in contributing to excessive patella-femoral loading and can contribute to excessive repetitive loading in regions of the patella-femoral articular surfaces, but variance in the Gregersen et al study is large (tibial varus-valgus coefficient of variation (CV) = 38-72%, tibial rotation CV = 59%) warranting caution in extrapolation and inferences from this data. The 5-10° wedge used in this study is larger than the 1-4° wedges most commonly used in competitive cycling, so it remains to be determined if the smaller wedges in current use have similar effects on muscle activation.

Wedges and insoles have been examined for their effect on power output while cycling. Koch et al examined the effect of prefabricated carbon insoles on power output during an anaerobic test, with non-significant results (p = 0.76 Mean Power and p = 0.53 Peak Power) similar to a prior study. There was no standardization of bicycle, pedal or shoe system, possibly introducing excessive variance in measurements. In an effort to match participants' forefoot anatomy with appropriate wedge intervention, Dinsdale used 1° to 4° varus wedges inside the cycling shoe to correct for forefoot varus, and examined subsequent power output in a 30s anaerobic test. While the results were not statistically significant for changes in mean power or peak power, there was strong correlation between the degree of varus correction and improved power (r = 0.957) indicating that cyclists with the greatest forefoot varus benefitted the most from varus corrective wedges. The sample was very small (n = 6) and the authors express caution about the study being underpowered. Untrained athletes were used in the study, yielding less important information than if competitive athletes had been used, since there are known EMG and kinematic differences between untrained and trained cyclists. While this is a small study, it is the one of the few published studies using commercially available wedges, which are in current use by cyclists, bike-fitters and coaches, and thus, merits attention.

DISCUSSION
Since the foot is attached to the pedal while cycling, two components of this attachment that influence lower limb kinematics are the foot-shoe interface (FSI) and shoe-pedal interface (SPI). A recent systematic review by Yeo et al highlighted a dearth of high quality experimental studies of the effect of interventions at the FSI on kinematics of cycling. The results of the Cochrane risk of bias assessment completed for the current paper concur with Yeo’s findings; the studies examined for this review are relatively low in bias, but the majority of the reviewed studies do not report adequately on assessor and participant blinding or data management. Few studies use standardized methodology for fitting the cyclist on the bicycle, despite the existence of many standardized bike-fitting protocols in the literature. No studies used the same testing protocol or products, limiting conclusions drawn about their comparative efficacy.

Despite these shortcomings, the studies reviewed herein have provided some insight into possible effects in lower limb biomechanics during cycling. Orthoses have been shown to improve perceived support, improve peak power in sprints, and alter knee position. A rigid cycling shoe reduces EMG activity in the biceps femoris and gastrocnemius muscles, and is more efficient than a soft-soled sneaker or soft cycling shoe. Studies examining the specific influence of inclined wedges used at the SPI on the kinematics of cycling have shown that they induce changes in knee position,9,30 moments at the knee,9 and alter EMG ratios in thigh and hip muscles. At the SPI, the choice of pedal system (clipless float vs. no float, clipless vs. platform pedal) also influences moments at the pedal and knee. Wedges at the SPI and orthoses at the FSI are thought to influence the knee position via the talo-crural coupling mechanism. To date, there have been no published studies examining the effect of such commercially used wedges on the kinematics of cycling. Determining the relative influences of interventions at the FSI and SPI on cycling kinematics will likely improve guidelines for management of cyclists with knee pain, but there are insufficient experimental data to determine whether such a difference exists. Future study should compare the kinematic effect of wedges and orthoses in cyclists.
Many kinetic and kinematic studies investigating intervention at the SPI\textsuperscript{9,22,30,38,39,42} and FSI in cyclists\textsuperscript{14,15,41,56} have been conducted. Two SPI studies demonstrate significant changes in lower limb moments and EMG activity.\textsuperscript{9,22} One SPI study demonstrated significant response to changes in the frontal plane knee angle.\textsuperscript{30} One FSI study also demonstrated changes in the frontal plane,\textsuperscript{14} but there are no peer-reviewed studies examining the effect of FSI intervention on lower limb EMG or knee moments. Studies examining FSI intervention on cycling kinematics have been fewer in number. Short-term power output may be improved with FSI correction of forefoot varus.\textsuperscript{14} Perceived comfort is improved with FSI intervention\textsuperscript{38} which may be important in studies which examine performance over long periods of cycling. While the current literature indicates some specific kinematic responses to FSI intervention, the applications for clinicians and coaches remain unclear. In order to determine the kinematic responses to FSI and to create specific guidelines for clinicians and coaches, studies with improved methodologies are needed. Standardizing the position of the cyclist on the bicycle for seat height, knee angle at the bottom of the pedaling cycle and foot position on pedal is critical to determine if the intervention is effective, or the variability in cyclist positioning limits correct interpretation of the data. Standardizing cycling equipment such as footwear, pedal system, and the wedges or orthoses being tested, will reduce systematic bias and errors in the data. Controlling for sex and experience, and testing larger numbers of participants will reduce variance, increase homogeneity, and improve statistical power. In the interim, with limited supporting evidence for intervention at the FSI to manage cyclists with anterior knee pain, it is the authors belief that such intervention should be individualized, methodically monitored, and modified based on the cyclist’s feedback and performance. In summary, and in agreement with Yeo et al,\textsuperscript{18} while there is theoretical plausibility that orthoses and wedges could influence cycling kinematics, there is a need for further high quality studies in this field.

**CONCLUSIONS**

Excessive frontal plane loading is a significant contributor to knee dysfunction but can be effectively changed with cueing and movement retraining. Because injured cyclists demonstrate kinematic patterns than uninjured cyclists, strategies to correct such aberrant kinematics might be useful to coaches, clinicians and cyclists. Wedges and orthoses at the FSI appear to alter kinematics of the lower limb while cycling, although conclusions about their efficacy are limited. Further studies are needed examining cyclists using standardized experimental conditions and equipment used to alter FSI function. Determination of the effect of FSI alteration on cycling kinematics may offer a simple, inexpensive tool to reduce anterior knee pain.

**REFERENCES**


ABSTRACT

Background: Dry needling is an evidence-based treatment technique that is accepted and used by physical therapists in the United States. This treatment approach focuses on releasing or inactivating muscular trigger points to decrease pain, reduce muscle tension, and assist patients with an accelerated return to active rehabilitation.

Issue: While commonly used, the technique has some patient risk and value of the treatment should be based on benefit compared to the potential risk. Adverse effects (AEs) with dry needling can be mild or severe, with overall incidence rates varying from zero to rates of approximately 10 percent. While mild AEs are the rule, any procedure that involves a needle insertion has the potential for an AE, with select regions and the underlying anatomy increasing the risk. Known significant AEs from small diameter needle insertion include pneumothorax, cardiac tamponade, hematoma, infection, central nervous system injury, and other complications.

Purpose/Objective: Underlying anatomy across individuals has variability, requiring an in-depth knowledge of anatomy prior to any needle placement. This commentary is an overview of pertinent anatomy in the region of the thorax, with a ‘part two’ that addresses the abdomen, pelvis, back, vasovagal response, informed consent and other pertinent issues. The purpose of the commentary is to minimize the risk of a dry needling AE.

Conclusions/Implications: Dry needling is an effective adjunct treatment procedure that is within the recognized scope of physical therapy practice. Physical therapy education and training provides practitioners with the anatomy, basic sciences, and clinical foundation to use this intervention safely and effectively. A safe and evidenced-based implementation of the procedure is based on a thorough understanding of the underlying anatomy and the potential risks, with risks coordinated with patients via informed consent.

Levels of Evidence: Level 5

Key Words: Adverse effect, anatomy, dry needling, informed consent, pneumothorax

CORRESPONDING AUTHOR
John S. Halle, PT, PhD, ECS
Professor, School of Physical Therapy
Belmont University
1900 Belmont Blvd
Nashville, TN 37212
E-mail: John.halle@belmont.edu
INTRODUCTION

Dry needling is an adjunctive treatment procedure that is recognized as being within the physical therapy scope of practice by the 2014 version of the ‘Guide to Physical Therapy Practice’,1 and is now recognized by state licensing boards in at least 33 states, including the District of Columbia.2 While the first dry needling Medline citation by Karel Lewit occurred over 25 years ago,3 this is a technique that, based on the number of articles in print, has gained significant popularity over the past five years. A review of the term ‘dry needling’ in the national PubMed database, by year, yielded one reference in 2000,4 seven new references in 2009, and 51 new references in 2014. This technique has advanced from being taught in one physical therapy curriculum at Georgia State University in 2006,5 to a technique that is introduced to entry level physical therapy students in many of the Physical Therapy programs in the United States. Dry needling may also be called ‘Intramuscular Manual Therapy’ (according to the Federation of State Boards of Physical Therapy),6 and the two terms can be used synonymously. The typical needle for dry needling (DN) is a solid filament needle and since it does not inject anything, the technique is referred to as ‘dry needling’.7 The popularity is due to both patient acceptance and the demonstration that this technique has ‘evidence based procedure’ data for conditions like upper-quarter myofascial pain, where both immediate reduction of pain (grade A), and reduction of pain at four weeks (grade A), have been demonstrated.8

As an evolving treatment modality, high-quality evidence remains to be clearly established for short or long-term pain and disability reduction for musculoskeletal pain syndrome for all regions of the body,9 but there are studies that demonstrate a clinically significant reduction of pain for conditions that span osteoarthritis of the knee and hip,10,11 shoulder pain,4,12 neck pain,13,14 and low-back pain.15,16 Other factors, such as the optimal frequency (number of treatments), duration (length of time that a needle should remain inserted), intensity (the number of needles that should be used), and the use of electrical stimulation remains to be determined.9,17 While the science behind the procedure continues to evolve, there is now widespread acceptance and use of this therapeutic intervention by physical therapists. The popularity of dry needling is due to the versatility of the technique for a variety of musculoskeletal conditions, combined with the many examples of clinical success.

Dry needling involves placing a solid filament needle into tissue for the management of pain and neuromusculoskeletal dysfunctions.7 The diameter of the needle used is very small, just thick enough to allow the tissue to be pierced while maintaining needle integrity (for perspective, the typical needle is about five times the diameter of a single muscle fiber, with the needle gauge ranging from 32 to 36 equivalent to .25 mm to .20 mm).18 Normally, the needle is usually placed in muscle trigger points (MTrPs) in the proximity of nerves, or placed in connective tissue.9,19 Some position statements by State Boards of Physical Therapy have specifically defined dry needling as an ‘intramuscular procedure involving the isolated treatment of myofascial (muscle) trigger points’.19 A more expansive view of dry needling includes the target areas of muscles, ligaments, tendons, subcutaneous fascia, scar tissue, peripheral nerves, bones, and neurovascular bundles.9 Dry needling can also be performed in tissues that vary in terms of the depth of needle penetration, with some dry needling performed at either a superficial or deep tissue level that may or may not include MTrPs. The many theories that are associated with dry needling suggest that the observed pain relief may be due to a variety of factors, to include: (1) peripheral and central pain modulation, such as that discussed with the ‘gate control theory of pain modulation’ by Melzak and Wall;20 (2) central pain modulation that utilizes the endogenous opioid system;21 (3) ‘central sensitisation’, where conditions with enhanced nociception (hyperalgesia) and allodynia, are disrupted by the implementation of dry needling; (4) disruption of MTrPs, where there may be local ischemia and hypoxia due to excessive release of acetylcholine at the motor endplate;22 (5) ‘distal to proximal’ remote effects, where stimulation of a distal MTrP could result in reduced irritability of a proximally located MTrP;23,24 and (6) placebo effects.22 Dunning et al9 in a review article, points out that research has demonstrated increases in blood flow and oxygen saturation levels following dry needling, increased fibroblastic activity and endocrinological and neurological effects that decrease the activation of the lim-
bic system. Whatever the physiological mechanism or multiple neurophysiological mechanisms are that function to provide relief with dry needling turn out to be, the preponderance of the evidence suggests that the technique does offer relief for a variety of neuromusculoskeletal conditions.9,12,13,25

As referenced above, dry needling is now being introduced in many entry-level physical therapy programs as a therapeutic treatment option. In these entry level programs as well as phase 1 certification courses for DN, the gluteal region is a site that is commonly taught since the muscle is large and placement of a needle within this structure is relatively safe. During an introduction to dry needling, one of the authors had a chance observation that led to this topic of minimizing AEs. The issue that was evident during the orientation was that a site where dry needles are placed, can be the same site many health professionals are taught to avoid when injecting compounds or vaccines, due to the potential for damaging the sciatic nerve.26 Specifically, several recommended sites where the gluteus maximus could be dry needled for MTRPs were demonstrated that placed the needle approximately midway between the ischial tuberosity and greater trochanter, over the sciatic and other smaller nerves. At least one of the dry needling sites was in a location where a different type of needle, one with a lumen that injects a drug, should be avoided.27 The literature outlines cases of intramuscular needles damaging nerves in the gluteal region resulting in motor and/or sensory deficits. Villarejo et al annotated 370 injection injuries to nerves and Pandian et al described 36 additional cases, predominantly in young children with limited body mass.27,28 In addition to the negative motor and/or sensory implications of a sciatic or posterior cutaneous nerve of the thigh injury, a key finding was that only 28 percent of the injuries ultimately had a good recovery.27 While recognizing that there are differences between a hypodermic needle and a dry needle, the underlying anatomy suggested that there is some potential risk when placing a dry needle in the gluteal region along the approximate course of the sciatic nerve. The apparent disconnect between sites to avoid with differing needles used for different purposes led to consideration of potential of AEs associated with small gauge needle utilization. The small gauge (diameter) needle used is approximately similar when comparing acupuncture needles, dry needles, and the needles employed for diagnostic electromyography (EMG). Since they all will have the same impact on underlying anatomy, the literature associated with AEs from all of these procedures are referenced.

ADVERSE EFFECTS

One of the largest needling studies ever performed looked at the question of adverse effects (AEs) with acupuncture, and the study was designed to collect data to develop a medical information and consent form.29 In this study by Witt et al, 229,230 patients self-reported any AEs following treatment for chronic osteoarthritis pain of the knee, hip, low back, neck, or for headache, allergic rhinitis, asthma, or dysmenorrhea.29 The average patient received 10.2 ± 3.0 acupuncture treatments, for a total treatment session count of approximately 2.2 million sessions. Of these, 8.6% (19,726 patients) reported experiencing at least one adverse effect, and 2.2% (4,963 patients) reported an adverse effect that required further treatment.29 The most common AEs were bleeding or pain, but two patient's experienced a pneumothorax, and one patient had a nerve lesion with side effects that lasted 180 days. While the collective findings cited above demonstrate that AEs do occur, the numbers reported in the Witt et al study, are probably lower than the actual incidence, since this study was based on patient's self-reporting rather than on actual incidence.29

Adverse effects have also been documented with dry needling.30-32 While most of the AEs are mild, any time that a needle is placed in a patient there is the potential for an AE. Regardless of the skill level of the practitioner, recognizing and documenting AEs may be enhanced if the health care provider is looking for them. This typically takes training and reflection. For example, past research with areas like 'plicae' causing knee pain or 'acetabular impingement syndrome' (AIS) as the etiology for hip pain, have demonstrated that conditions are not referenced until clinicians are aware and trained to look for those conditions. This is evident in a search using AIS as the search key within the National Library of Medicine’s PubMed, with virtually no research articles on AIS in the year 2000, and by 2013 over 300 articles identified. Based on this realization, the
purpose of this two-part clinical commentary is to examine three key topics related to DN and AEs. First, this Part 1 will deal with the thorax, examining the underlying anatomy that is at risk with specific dry needling sites, outlining cases reported in the literature and what might be done to minimize patient risk. A similar anatomical and clinical review will be performed for the abdomen, pelvis, and back in Part 2. The subsequent manuscript will also provide a description of a vasovagal response that can occur due to a variety of causes ranging from a needle stick to any strong emotional response. Lastly, the clinical commentary will outline one system that might be used to provide medical information and informed consent to a patient that is appropriate for dry needling intervention, along with several concluding observations.

**Thorax and the risk of a pneumothorax**

There are a number of DN sites in and around the thorax that treat conditions like adhesive capsulitis of the shoulder, upper quarter myofascial pain, neck pain, and headaches. Dry needling is often advocated for these areas based on generally favorable clinical outcomes, although effectiveness does vary between studies. To maximize the potential for safe needle placement in and around the thorax, clinicians often use a 'bracketing technique' where a bony backdrop is positioned to stop the needles progression, or the needle is placed in a way to be stopped by bone, such as the supraspinal fossa. When correctly done, this can be an effective way to minimize the chance of penetrating an unwanted region, such as the pleural cavity. Accidents can happen, however, when the needle slips along the side of a rib and penetrates further than anticipated, with the result being compromise of the pleural lining and a pneumothorax. Several studies have demonstrated that needling of the serratus anterior, rhomboids, supraspinatus, iliocostalis, and the lower cervical paraspinals can result in pneumothorax.

While the incidence of pneumothorax with small gauge needles has been reported in one study examining AEs to be less than one in 100,000 patient's treated, when it occurs it can be a serious injury. In addition to the potential for a pneumothorax, it should be emphasized that when this type of adverse event (AE) occurs, it is not consistently spontaneous at the time of the needle penetration and not consistently a complete pneumothorax. Three case reports demonstrate this fact. Cummings et al, describe a physician that was participating in a deep dry needling hands-on workshop. One of the participants described the following after a 0.3 x 50 mm Seirin needle was used to needle the iliocostalis muscle using a rib as a blocking site. In the case described the needle was advanced deeper than what was expected and the subject reported feeling pain. The subject described diffuse aching pain centered on the scapula, which began immediately and continued into the next day. The subject also had pain during inspiration, a dry cough, and a feeling of breathlessness, which worsened during physical
activity to include walking. To provide a narrative picture of what he experienced, the subject provided the following description:

“The needling was mid-morning and by mid-day I had a deep ache and stiffness in my left chest posteriorly. It was fairly diffuse, but was centered on the scapula. This continued the rest of the day and into the next day. By the morning I was also aware of a feeling of constriction on breathing and pain on taking or trying to take a deep breath, which I felt I couldn’t actually perform fully. I also developed a dry cough, the breathlessness felt like an exacerbation of asthma symptoms (albeit more lateralized to the left) and was more noticeable on walking. I was also aware of a dull ache in the shoulder tip in the region of the acromioclavicular joint”.30,p.517

A radiograph on the second day after the needling demonstrated a 20% left sided pneumothorax, with some breathlessness on exertion that was still present at two weeks, but was completely resolved by eight weeks. A second pneumothorax incident reported in the literature occurred during an acupuncture treatment for neck and right upper thoracic pain, with the patient experiencing shortness of breath and pain.48 Four to five hours after treatment the pain became more intense, and after tolerating the pain and dyspnea for two days, the patient presented to the emergency room where the pneumothorax was verified.48 In a case reported in the EMG literature with an attempted needle stick to the rhomboid major muscle, symptoms occurred within 40 minutes of the needle stick.43 These three cases all demonstrate that the onset of pain and presentation of pneumothorax symptoms are not uniform, with one immediate presentation of symptoms and the others delayed minutes to hours. There are also reports where the symptoms have been delayed as long as three days.43 When the pneumothorax is partial, it is often treated conservatively. When a large pneumothorax occurs, it may require a tube thoracostomy and the patient should be referred for emergency care.

The cases outlined previously demonstrate that the very small gauge needle used with DN can cause a pneumothorax, and that the presentation can be quite variable in terms of time of onset and the extent of lung involvement.30,43 Clinicians performing DN should be well versed in the underlying anatomy and the potential for AEs and should notify the patient of foreseeable possible risks prior to performing the procedure with signed informed consent. In addition, an open line of communication should be developed with the patient when they are being treated. In the event that during a dry needling treatment the patient should need to cough, sneeze, or perform any other sudden movement, they should have been informed that it is imperative to notify the provider immediately so the needle can be withdrawn.

**Anatomical Considerations**

When performing dry needling in the region of the thorax, knowledge of the size and location of the pleural cavity is critical. The pleural cavity contains the right and left lungs, and these structures are intimately covered by parietal pleural (external) and visceral pleura (intimately associated with the lung tissue), which are housed within the thoracic cavity that is lined by endothoracic fascia.26 The space between the visceral and parietal pleura is a potential space with a very small amount of lubricant that allows the two surfaces to move on one another with minimal resistance/friction. The layers that must be penetrated to create a situation where air could be introduced between these two layers are, from outside of the body to the pleural cavity: (1) skin, (2) superficial fascia (fat), (3) muscle with its surrounding deep investing fascia [in the case of the intercostals, this would be the external intercostals, the internal intercostals, the innermost intercostals, and the deep investing fascia of each of those muscles], (4) endothoracic fascia, and then the (5) parietal and visceral pleura.26 While it is intuitively apparent that the lungs are present in the thorax, the relatively thin thoracic wall and the vertical dimension of the lungs are not so clear. In a thin individual, a very short needle is able to penetrate all of the layers above and inadvertently enter the pleural cavity. Thus, while using a ‘bracketing technique’ with a thin muscle that lines the ribcage, like the serratus anterior muscle, a small misstep could result in an AE.44 With a slightly longer needle, and not as intuitively obvious, the apex of the lung can be penetrated with a needle stick in the lower cervical paraspinals or the upper trapezius muscle. This was the case that Honet et al46 described with a patient that developed a pneumothorax following a low paracervical EMG needle insertion. This
unexpected event was followed-up by this professional with a cadaveric review of the region, with 23 cadavers examined for the location of the apex of the lung compared to the clavicle. The results of this investigation demonstrated that five of the 23 cadavers examined had lung tissue that extended above the clavicle, with a minimum distance from the skin to lung tissue of only 3.1 centimeters. This anatomical feature of the apex of the lung extending up into the lower cervical region was also described by McCutcheon and Yelland, who noted that the apex of the lung extends 2 – 3 cm above the clavicular line. Thus, any needle penetration in the region of the upper trapezius, lower cervical paraspinals, rhomboids, supraspinatus, or other similarly placed muscle (e.g., levator scapulae, etc), is at a level where lung tissue needs to be considered.

Spanning inferiorly, the lower limits of lung tissue and the associated pleura are also not intuitively clear. Conceptually, the lungs proceed inferiorly to the level of the diaphragm that is the structural boundary that divides the thorax from the abdomen. The two lungs are separated by the thoracic contents standing in the middle (the mediastinum), that contain principally the heart, great vessels, and are surrounded by the pericardial sac that is tethered to the top of the diaphragm. Since the diaphragm is a domed structure, it proceeds further inferiorly where it is affixed to the spine and lower ribs, extending down to the 12th rib posteriorly. Anteriorly, the mediastinal pleura covers the structures of the mediastinum, including the pericardial sac. This pushes the pleura laterally from the mid-line, (there is a portion of the right and left sternal lines of reflection that can be immediately contiguous, but they occur under the body of the sternum), so that the sternal line of pleural reflection on the right side turns laterally at the level of the 6th costal cartilage. On the left side, the equivalent sternal line of pleural reflection laterally occurs at the 4th intercostal space, but this line of reflection starts at the mid-clavicular line sagittally, due to the presence of the pericardial sac. From these positions, the sternal lines of pleural reflection continue laterally and are now termed costal lines of pleural reflection that then become continuous with the diaphragmatic pleura inferiorly. The costal lines continue laterally and inferiorly passing across the mid-clavicular line at the 8th rib, and the mid-axillary region at the level of the 10th rib, and descend posteriorly and inferiorly to the level of the 12th ribs. It should be noted that while the inferior aspect of the lung has the ability to expand and fill the space down to the level of the 12th rib, it is not consistently at this inferior level, due to inspiration and expiration. During expiration, the lungs do not fully occupy the pulmonary cavities and potential spaces named the costodiaphragmatic recesses are created. The key point from a practitioner’s perspective when placing a needle in the lower thorax, is to be aware that the pleural cavity does proceed inferiorly to the level of the necks of the 12th ribs. Thus, when placing a needle in a muscle such as the iliocostalis, as was demonstrated in the Cummings article, there is the potential to create a pathway for air and an AE such as a pneumothorax.
bundle of vein, artery and nerve. This design allows expiration and inspiration, a passageway for nerves and blood vessels, and strength without a great deal of associated muscular weight. The combined intercostal muscles are too thin to reasonably attempt a dry needle insertion.

The brief overview of the anatomy of the lungs within the thorax provides a foundation from which specific needle placements can be considered. The pleural cavities in many individuals span above the clavicle, and they can be inadvertently accessed by a needle if that relationship is not appreciated. It should also be recognized that the anatomy discussed in textbooks and atlases is simply the most common variant and not necessarily what will be present within any given subject or patient. Honet et al. noted this variability when stating that “patients with long necks (more vertebrae above the clavicle) appear most susceptible. A Valsalva maneuver may also cause the lung apex to rise. Lung tissue is more vulnerable with the neck in flexion than in extension." Extending this overview to the thoracic wall, the relatively thin wall created by the ribs and the combined intercostal muscles suggests that significant caution should be used when placing a needle in any structure that is near or adjacent to the thoracic wall. Similarly, with the recognition that the pleural lining extends inferiorly as far as T12, any needle placement in muscles such as the iliocostalis needling site needs to take into account the location on the thoracic wall and the potential depth of needle penetration. The descriptions that follow are designed to minimize the likelihood of an AE like a pneumothorax when needling in the region of the thorax, based on the underlying anatomy. While dry needling education varies, instructors do discuss anatomy when teaching dry needling techniques.

**Lower cervical spine**

The safest way to place a needle in this region is to place it close to the midline, staying medial to the lateral dimension of the transverse process. Honet points out that if lateral to the transverse process, needle penetration of lung tissue is possible when placing a needle in the lower cervical paraspinal muscles. The author further suggests that in individuals with long and thin necks, that if a needle placement in this region is desired, it would be prudent to auscultate the neck with a stethoscope to determine if lung tissue is in the region of the needle placement. The length of the needle should be considered, since it has been demonstrated that a needle as short as 3.1 cm can reach lung tissue, and in the cadaver study performed, the average distance from the skin to the lung field was 3.3 cm. If the needle being placed is an EMG needle, he further suggests that the audio be turned on so that muscle electrical activity can be monitored during the procedure.

**Trapezius**

The trapezius is a thin muscle that spans the neck and thorax, with the lateral aspects inserting on the lateral half of the clavicle and on the spine of the scapula. It is the most superficial muscle of the neck and upper thorax, being covered only by the skin and superficial fascia (fat). It is very thin, and it is technically challenging to place a needle in this muscle layer unless the clinician has feedback when inserting the needle, as is the case with a clinician performing an electrophysiological examination. In a small number of individuals, the superficial location of the trapezius can be complicated by the presence of a soft tissue lipoma since these are often found in the upper back and neck, with an estimated prevalence of 2.1 per 100 persons. Medially along the midline, there are a number of muscles that would also have to be penetrated, before the thoracic cage would be compromised. These include as an abridged list, the rhomboid major and minor (at the level of the scapula), thin structures such as the serratus posterior superior, various portions of the erector spinae muscle mass, and the intercostal muscles. In the region of the upper trapezius and lower cervical spine, however, lateral to the spinous processes, there are fewer muscle layers between the trapezius muscle and the lungs. As noted in the paragraph above, needles in the range of 3 cm can reach lung tissue. From a safety perspective, placing a dry needle medially presents less risk than more lateral needle placements, especially if attempting to needle the middle or lower portions of the trapezius.

**Supraspinatus**

This is typically a very safe muscle to place a needle into, since superior to the spine of the scapulae the supraspinatus fossa provides a bony ‘shelf’ that
normally functions to protect the thoracic cage and it provides a bony backstop. Reinstein et al\textsuperscript{45} have provided a case report where the expected protection provided by the supraspinatus fossa did not occur. In this case, a 37 mm, 27-gauge needle was inserted into the supraspinatus muscle just above the midline of the spine of scapulae, and the needle advanced until the scapula was encountered. Due to the placement of the needle, the scapula did not serve as a backstop and the patient experienced sudden, severe pain and difficulty breathing. Subsequent chest x-rays revealed a 10\% pneumothorax. In response to this incident, the authors reviewed the anatomy and recommended that if a needle is placed in the supraspinatus muscle, then it should be placed three-quarters of the distance from the acromion to the vertebral border of the scapula, closer to the vertebral border. The reason for this is that the supraspinous fossa is narrowest at the midpoint, and in this region there is also the supra- scapular notch that houses the suprascapular nerve. In this narrow, mid-point region along the spine of the scapula, there is the potential to miss the bony backstop and penetrate the thorax.

**Infraspinatus**

As is the case with supraspinatus, placing a needle into the infraspinatus is considered safe as long as the needle stays within the confines of the scapula. Structurally, the infraspinatus fossa provides a bony backstop and protects the underlying ribcage and lungs. McCutcheon and Yelland note that congenital foramina have been reported in the infraspinatus fossa with an incidence of 0.8 to 5.4\%.\textsuperscript{31} These foramina have presented with diameters up to 2 to 5 mm in size, clearly large enough that they could be penetrated by a small gauge needle. While rare, this finding again demonstrates that the anatomy atlases provide the most common variant when describing a region, and not necessarily the underlying anatomy of any individual patient.\textsuperscript{54,56} A clinician needs to be aware of the depth of penetration and not rely solely on bone to stop the progression of the needle.

**Rhomboid muscles**

The rhomboids lie under the trapezius, so to reach them, a needle has to penetrate the skin, any underlying superficial fascia (fat), the trapezius, and then the rhomboids. Since these muscles are traditionally thin, the needle placement has to be precise to stay superficial to the lung field. An inadvertently deep needle stick can easily penetrate the pleural cavity, particularly if the needle is placed perpendicular to the plane of the skin. If performing a manual muscle test of the rhomboids with the patient prone, the arm on the involved side internally rotated and extended, it may be possible to detect the rhomboids where they insert on the medial border of the scapulae. This position can lift the muscle fibers off of the thoracic cage and permit an obliquely oriented needle to be positioned so that the elevated undersurface of the scapula (that is lifted off of the thoracic cage) can serve as a backstop should the needle penetrate too far. While possible, the key question for this muscle remains, ‘is the benefit greater than the inherent risk’? A 1990 case report by Miller outlines the case of a patient who was being evaluated for a potential C5 radiculopathy and the left rhomboid major muscle was examined with an EMG needle since this is a C4-C5 innervated muscle.\textsuperscript{43} Approximately 40 minutes after the procedure, the patient “became acutely anxious, restless, and short of breath. Chest x-ray revealed a large pneumothorax with rightward shift of the mediastinum”.\textsuperscript{43} This case report illustrates the reality that placing any type of a needle into the rhomboid muscles has some inherent risk. While the highlighted case study was associated with a small gauge needle used during an electrophysiologic examination, the implications are relevant for any needle placement in this area. Miller concludes his description by stating, “EMG of thorax is not a benign procedure and the risk of a pneumothorax must be weighed against its diagnostic benefits when selecting patients”.\textsuperscript{43, p.653}

**Pectoralis Major**

Trigger point dry needling of the pectoral muscles has been shown to be an effective treatment for chest wall pain and specific conditions like costochondritis.\textsuperscript{37} The pectoralis major overlies the anterior aspect of the thorax, with a clavicular and sternal segment, and in many individuals, a slip from the abdomen.\textsuperscript{28} The specific attachments to the thorax include the anterior half and medial aspect of the clavicle, anterior surface of the sternum, and fibers that arise from the aponeurosis of the external abdominal oblique muscle. Distally, the muscle inserts into the lateral lip
of the intertubercular sulcus of the humerus. It is the most superficial muscle of the anterior thorax, lying directly under the skin and superficial fascia (fat) that in this region also includes specialized breast tissue in women. Under the pectoralis major, is the thin pectoralis minor that extends from ribs three to five to the coracoid process. The only other muscle layer deep to the pectoralis minor are the thin muscles represented by the intercostal muscles and/or their aponeurotic extensions. Internal to the ribs is endothoracic fascia and immediately internal to that layer is the parietal pleura of the lungs. The challenge with placing a dry needle in this area, apart from the most lateral portions of the muscle as it becomes aponeurotic prior to inserting into the humerus, is that in many individuals this muscle is relatively thin, and is covered by a significant amount of superficial fascia associated with the breast tissue of both genders. When inserting a needle into the pectoralis major, there is the potential of overshooting the muscle tissue itself and extending the needle into the thoracic cage. A technique to minimize this risk would be placing the clinician’s fingers along either side of an identified rib, and place the needle between the fingers, counting on a rib to serve as a ‘backstop’ for the needle. While this will often prove to be effective, it is relatively easy for the needle to pass along an edge of the rib and this not be realized until the pleural cavity has been breached, as was demonstrated in a previously referenced case report.\(^\text{30}\) Due to the presence of breast tissue that overlies this muscle, there is gender sensitivity associated with a significant hands-on component, particularly with a female patient. Additionally, due to the general thickness of the superficial fascia layer (fat) overlying the muscle, specific knowledge regarding the depth of penetration is problematic. Should needling of the pectoralis major muscle be indicated clinically, it will be safest to do this in the lateral aspect of the muscle close to the humeral attachment. Safety would also be increased by orienting the needle obliquely so that should the needle extend through the thickness of the muscle, it would pass lateral to the ribs and avoid the lung fields.

**Sternum**

An alternate site to needle the pectoralis major is medially, since the axial skeleton attachment includes the anterior surface of the sternum and superior six costal cartilages.\(^\text{26}\) This is also a site that some practitioners that provide acupuncture use.\(^\text{58}\) Since the sternum is a flat bone that is easily palpated, placement of a needle in this region is typically very safe. As was the case with the infraspinatus fossa, however, the literature describes an incomplete ossification and fusion of the sternal plates, that most commonly occurs at the level of the fourth intercostal plate.\(^\text{31}\),\(^\text{59}\) This type of incomplete fusion can occur with an incidence as high as 5 to 8%. Peuker and Cummings note that “a congenital sternal foramen is usually not able to be palpated due to overlying muscle tendon fibers and connective tissue”\(^\text{59}\). The recommendation from this anatomical reality is that since an inadvertent needle placed through the sternum could penetrate the pericardial sac, dry needling in this region should be done superficially and in an oblique manner over the sternum. In the available literature, there are at least seven reported cases of cardiac tamponade associated with acupuncture.\(^\text{58}\),\(^\text{60}\)

**Serratus Anterior**

The serratus anterior covers the lateral surface of the upper eight ribs, and then inserts into the medial border of scapula. Since it is a thin muscle in most individuals overlying the lateral ribs, if an individual performing dry needling or electrophysiologic testing chooses to place a needle in this muscle overlying the lateral thorax, a ‘bracketing technique’ where a rib is positioned between two fingers is advocated.\(^\text{31}\) Theoretically, if the needle stays within the fingers on either side of the rib, the rib will serve as a bony wall protecting the underlying thorax and pleural cavity. Caution is indicated, however, since it is easy for a needle to slide over the end of a rib, and with many patient’s today with increased superficial fascia (fat) overlying the ribs and serratus, clear palpation of this muscle can be technically challenging.

**Iliocostalis**

As has been highlighted in the preceding case study of a physician that was involved in a dry needling workshop of the erector spinae muscles of the back, it is possible to penetrate the thoracic cavity and have a resulting pneumothorax.\(^\text{30}\) While blocking the depth of needle penetration by bracketing a rib, the relatively thick muscles that are part of the erector spinae (spinalis, longissimus and iliocostalis), with
overlying skin and fat, create a challenge for the clinician. In the case described, a 0.3 x 50 mm Seirin acupuncture needle was used, but when the needle was redirected following the first attempt when pain was experienced, a rib was touched at a depth of approximately 10 to 15 mm. Since there is not a clear oblique needle orientation that can be utilized in this case, in addition to the rib ‘bracketing’ that is typically utilized, it may be advantageous to seriously consider the length of the needle utilized. If a rib would be encountered at 10 to 15 mm depth, a short needle might be considered, and the clinician should be aware of the combined needle length extending from the skin as well as the approximate depth of the potential tissue layers penetrated.

**Extremely rare but possible anatomical consideration in the thorax**

While the above descriptions have focused on the remote possibility of a pneumothorax or penetration of the pericardial sac (in the case of needling in the vicinity of the sternum), other underlying anatomy can also be at risk. While extremely rare, there is a case of an acute cervical epidural hematoma as a complication of dry needling. In this case, a 58 year old woman was treated with dry needling over the patient's neck and arm. Approximately one hour after treatment, she developed sudden weakness and numbness of her right arm and leg. This progressed to manual muscle test weakness that was 1/5 on the left and 4/5 on the right. Imaging showed an acute cervical epidural hematoma that at surgery was shown to be 9 x 1.2 x 0.5 cm in size, overlying the lower portion of the dura from C2 to T1. Etiology was attributed to dry needling performed six hours prior to the patient presenting to the emergency room, with depth of needle insertion not known. The patient did well following surgery to correct the hematoma. This is a rare case that demonstrates that bleeding is an additional potential concern when introducing a needle into tissue. The DN solid filament needle does not have a cutting edge, but has more of a rounded tip to push tissue aside rather than cut through it. Additionally, the high gauge of the needle (very small diameter needle), minimizes the likelihood of any significant bleeding. So, an AE associated with bleeding is small and the potential for a case like that described above is extremely rare. Having noted that, the literature does cite other cases with acupuncture needles where the spinal cord has been impacted, subarachnoid hemorrhage has occurred, and peripheral nerve tissue damaged. These very rare cases all demonstrate, however, that the skilled clinician always needs to be cognizant of the structures at the tip of the needle and consider the way that a patient might react in response to the treatment provided.

While Part 1 of this clinical commentary provided an overview of the most significant AEs associated with the thorax, dry needling is performed at many other anatomical sites. Depending on the needs of a given patient, there may be a need to place a needle in the abdomen, pelvis, back, or other area such as the extremities. Part 2 of the clinical commentary will address some of these areas, as well as cover the potential for a vasovagal response, informed consent, the obese patient, the fearful patient, and DN as an adjunctive procedure.

**CONCLUSION**

Dry needling is an evidence based treatment modality that has broad application in the treatment of numerous neuromusculoskeletal complaints, when applied by a skilled and knowledgeable professional. The approach focuses on releasing or inactivating muscular trigger points to decrease pain, reduce muscle tension, and assist patients with accelerated return to active rehabilitation. To be performed effectively and safely, minimizing the chance that an adverse effect might occur, the clinician must have a clear understanding of the underlying anatomy of the region being dry needled. In the spirit of *primum non nocere* (first do no harm), the professional application of DN must be done with knowledge of and respect for the underlying anatomy. Part 1 of this clinical commentary outlined some areas of potential concern associated with the neck and thorax. In Part 2, the abdomen, pelvis, back, and other conditions such as a vasovagal response, informed consent, the obese patient, the fearful patient, and DN as an adjunctive procedure will be covered. Recognizing the need for a thorough understanding of anatomy and a systematic approach with the application of dry needling should work to minimize the incidence of adverse effects and increase the positive results obtained with this therapeutic approach.
REFERENCES


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Available in bulk roll and pre-cuts. Follows the authentic TheraBand® Trusted Progression

Available on the App Store
Available on Google Play

Representative typical values at 100% elongation.

Yellow 3.0 Lbs
Red 3.7 Lbs
Green 4.6 Lbs
Blue 5.8 Lbs
Black 7.3 Lbs
Silver 10.2 Lbs
Gold 14.2 Lbs

Kevin E. Wilk, PT, DPT
Champion Sports Medicine
A Physiotherapy Associates Facility
Birmingham, AL

* not made with natural rubber latex

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