Developing the Athletic Training Clinical Scholar

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Key Phrases
Practice-based research, practice-led research, quality improvement

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EDITORIAL

The 2020 Standards for Accreditation of Professional Athletic Training Programs[1] requires that athletic training programs prepare their graduates to integrate the core competencies into their clinical practice. The core competencies derived from the former Institute of Medicine,[2] and now National Academy of Medicine healthcare competencies, include patient-centered care, interprofessional and collaborative practice, evidence-based practice, quality improvement, health care informatics, and professionalism. Throughout these core competencies graduates are expected to use evidence to inform practice (Standard 62), use systems of quality improvement (Standard 63), and use data to drive informed decisions (Standard 64).[1] In the development of a patient care plan, graduates will need to be able to assess the patient's status on an ongoing basis by collecting and analyzing patient-reported and clinician-rated outcomes (Standard 69).[1] All of these tactics contribute to scholarly clinical practice by informing decisions locally, but could also inform the practice of others, thus having a global affect through dissemination as practice-based research.

As programs strategize how to teach these tactics to students, administrators are also likely deliberating how to support core faculty and planning for ongoing training of preceptors to demonstrate contemporary expertise. Programs should consider this an opportunity to meet all of the Standard expectations using the aforementioned scholarly clinical practice tactics and practice-based research. However, to effectively engage students, preceptors, and core faculty, program administrators must cultivate buy-in and expose everyone to different types of practice-based research. Specifically, a shift from faculty-led student scholarship to preceptor-facilitated clinical scholarship will need to occur. But this shift can't perpetuate conflicts between "the classroom" and "the athletic training facility" where these often assumptions between stakeholders in both environments that scholarly practices is not occurring. As these expectations shift, programs need to provide resources and help preceptors recognize that implementing these tactics will not only improve their clinical practice, but will also have the added benefits of enhancing clinical teaching and creating opportunities for collaboration with faculty to disseminate practice-based research.

Practice-based research involves clinicians answering relevant healthcare questions that matter to them and their patients, and translating research findings into practice. This can be achieved through a variety of scholarly activities. Examples of scholarship that require critical appraisal of the literature include evidence to practice reviews and validation case reports. In an evidence to practice review, a clinical scholar develops a question, hopefully about a problem they are trying to solve in their own practice, reviews the available literature, identifies a systematic review or meta-analysis, and helps to interpret and summarize this Level 1 evidence for others. To apply this evidence to practice, the clinical scholar can take the systematic review or meta-analysis and apply the research recommendations with one patient, or a series of

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patients, to determine if the best-evidence recommendations actually work in clinical practice. These are validation case reports and help us understand whether controlled studies with homogenous participant populations can translate in the real world. Athletic training students and preceptors can partner in development of evidence to practice reviews and validation case studies, especially as a scholarly activity early in an academic program where critical appraisal of the literature is the primary learning outcome.
Quality improvement is a systematic approach to analyzing clinical practice and improving performance. One of the first mechanisms of quality improvement is self-reflection, such as accurately viewing our own practice, and is achievable through tasks such as chart reviews. Reflection should be a regular habit in clinical practice, and can move from self-reflection to seeking feedback from others such as colleagues or a directing physician. The act of chart reviewing can also serve as a mechanism to explore shared characteristics of patient histories, how we use selective tissue testing in developing a differential diagnosis, rates of diagnoses, or time to recovery after using specific interventions. Document and chart reviews serve as an appraisal of one's own practice and help clinical scholars appreciate the landscape of the healthcare clinic or facility. They help us define what is currently happening and are the first step in the plan-do-study-act cycle of quality improvement. These are also a form of point-of-care research, particularly those that synthesize several patient cases to determine trends in practice. From a preceptor perspective, this might serve as a preliminary mechanism to teach athletic training students about the expectations of medical documentation while also helping to inform clinical practice decisions in the future.

Once a clinical scholar has a good understanding of the current practice landscape, they can begin to explore what changes need to be made to enhance efficiency by comparing current processes with those detailed as best-practices in the evidence. Then the clinical scholar can apply and study the change; analyze the data, and determine if the change resulted in the expected outcome. Finally, based on the data, clinical scholars will adapt, adopt, or abandon the change. This process, the plan-do-study-act cycle, is a form of quality improvement and can be documented and disseminated. The key to any quality improvement project is to understand that it is a continuous process, not just a one-time activity. So engaging students in this process regularly and continuously will socialize them to the tactics and make them habitual in clinical practice.

To effectively assess a patient's progress, athletic trainers need to be collecting and analyzing patient-reported and clinician-rated outcomes. Clinical outcomes research is a mechanism for communicating how measurement tools have been used in practice. Because these papers can be written from a variety of perspectives, clinical scholars could evaluate a specific outcome measure, or compare multiple measures in several patients from the same population or experiencing the same injury or illness. The application of outcome measures with one single patient is a great first step toward clinical integration. This data gathering technique can help with individual patient progress and ensure patient safety. As clinical scholars evolve, they should consider applying outcome measures to larger populations to determine clinician effectiveness, specifically regarding the interventions we apply. Clinical practice effectiveness of physical medicine and rehabilitation procedures is largely unknown, especially regarding interventions applied to patients that are not college-aged, white, or male. Unfortunately, most best-practice recommendations have been developed from high quality evidence, but in very homogeneous and often uninjured populations, which limits some of the recommendations. Clinical outcomes research can help develop evidence to support our decision-making, and because it is a tactic that we should be doing with each and every patient in their personalized care plans, it should be part of daily duties. As athletic training students move from interdependence to independent clinical

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care, one mechanism for practice performance evaluation in clinical education is a clinical outcomes research report, where the student demonstrates clinical competence through patient outcomes to preceptors and program personnel.

Clinicians hoping to integrate evidence into their practice are looking for clinically relevant research, which is evidence that comes from within practice and informs decisions at a global level. The traditional thesis is no longer relevant to meet these needs, especially for developing a clinical scholar. Professional masters programs should strongly consider these practice-based research initiatives as they meet multiple Standards1 and outcomes of the program. These activities should transcend the program through sequentially planned experiences over the course of the curriculum. A constructivist approach that has students making meaning from experience to experience, reinforces the previous learning and minimizes the stigma of research in clinical practice. This is how we change the culture of athletic training and embrace evidence in clinical practice!

REFERENCES

1. Commission on Accreditation of Athletic Training Education. 2020 Standards for Accreditation of Professional Athletic Training Programs. Available at: https://caate.net/wp-content/uploads/2018/09/2020-Standards-for-Professional-Programs-copyedited-clean.pdf. Accessed on January 26, 2019.
2. Institute of Medicine. Crossing the quality chasm: A new health care system for the 21st century, Washington, DC; 2001.

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Best Practices in Patellar Tendinopathy Management: An Evidence to Practice Review

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ABSTRACT

Patellar tendinopathy (PT) is a degenerative condition that is common in sporting populations due to the loads placed on the tendon during dynamic activity. PT often occurs in overtraining situations; however, it may also occur in conjunction with and/or worsen through poor biomechanics, persistent inflammation, and altered movement patterns. Although sports medicine practitioners have evidence to support the prevalence of this injury, we do not have a strong base of evidence surrounding the contributing factors and pathophysiology that lead the pain and disability reported in patients with PT. The purpose of this evidence to practice review was to summarize a systematic review on interventions to treat PT. The authors aimed to include any randomized controlled trial that treated patients with PT and used the Victorian Institute of Sport Assessment Patellar Tendon Questionnaire (VISA-P) as an outcome measure. Seven different PT interventions were described and summarized by the authors in this review. On the conservative end of the treatment spectrum, eccentric loading programs and extracorporeal shockwave therapy were found to be effective at reducing pain. More invasive approaches often utilized after failed conservative treatment, such as platelet-rich plasma injections and arthroscopic tenotomy, were also deemed effective. Therapeutic ultrasound and sclerotherapy were found to be ineffective treatments, and corticosteroid injections are contraindicated in patients with PT. The review highlights that both conservative and invasive treatment approaches can reduce pain in patients with PT. However, there is still no consensus on the optimal treatment protocols for patients with PT due to the variability in in protocols. Thus, we recommend utilizing an individualized approach and appropriate clinical judgement to guide treatments derived from a thorough patient history and physical/biomechanical examination to identify interventions with the highest likelihood of resolving symptoms.

Key Phrases
Therapeutic devices, therapeutic exercise, rehabilitation

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Click Here for **Supplemental Videos**

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ORIGINAL REFERENCE AND SUMMARY

Everhart JS, Cole D, Sojka JH, Higgins JD, Magnussen RA, Schmitt LC, Flanigan DC. Treatment options for patellar tendinopathy: A systematic review. Arthroscopy. 2017;33(4):861-872.

SUMMARY

CLINICAL PROBLEM AND QUESTION

Patellar tendinopathy (PT) is a common, degenerative condition that affects up to 45% of collegiate and elite jumping athletes.[1] Many athletes with PT suffer from long-term knee pain and movement impairments which frequently causes athletes to limit or discontinue sport participation.[2,3] Several risk factors have been identified including an increased training load, decreased hamstring flexibility, an inferiorly-placed patella, and reduced quadriceps strength.[4,5] The majority of these risk factors are modifiable, suggesting there is a strong likelihood that patients can respond positively to therapeutic intervention.[4,5]

Despite the frequency of PT, the pathological sequence and contributing factors to the reports of pain and disability are not universally agreed

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upon. Histopathological findings of patients suggest symptoms are not due to the inflammatory response and are rather due to degeneration of the tissue.[6] Collagen fiber pattern disruption is often noticeable during sonographic examination in those with PT.[7] Although not an inflammatory response, the involved patellar tendon may show thickening and have a greater cross-sectional area upon inspection.[8,9] This poor understanding of the pathological sequence leads to a decreased ability to develop and identify treatments that can effectively treat PT. Due to the lack of consensus of the causes and perpetuation of PT, intervention protocols vary widely. Therefore, the purpose of the reviewed study was to assess the effectiveness of interventions used to manage PT.

SUMMARY OF LITERATURE

The guiding systematic review's authors conducted a systematic search of PubMed, Google Scholar, CINAHL, UptoDate, Cochrane Reviews, and SPORTDiscus to identify published clinical trials for the treatment of PT. Studies that were included in the systematic review had to meet the following inclusion criteria: (1) patients must have been diagnosed with chronic or acute PT, (2) used the Victorian Institute of Sports Assessment Patellar Tendinopathy Questionnaire (VISA-P) as an outcome, (3) have a clinical trial/therapeutic outcome design, (4) be reported in English, and (5) be an original research study published in a peer-reviewed journal.

The search identified 691 potential articles that were screened for inclusion criteria, resulting in a total of 15 studies included in the systematic review and meta-analysis. Five studies investigated eccentric exercise training, 4 studies evaluated surgical intervention, 4 studies evaluated extracorporeal shockwave therapy, 2 investigated platelet-rich plasma (PRP) injections, 2 evaluated steroid injection therapy, 1 evaluated therapeutic ultrasound, and 1 study investigated sclerotherapy.

SUMMARY OF INTERVENTIONS

Seven different treatment strategies were reported ranging from a more conservative approach of using eccentric therapeutic exercises to surgical intervention. Eccentric exercise protocols ranged from twice weekly to 7 days a week and from 5-weeks long to 12-weeks long. Exercises included eccentric strength training of the quadriceps and hamstrings, and single-limb squats on a 25° decline board. These were performed at a slow speed, approximate 30 seconds count, at 15 repetitions for three sets. Surgery involved both open and arthroscopic patellar tenotomy, with a range of post-operative rehabilitation protocols incorporating eccentric exercises. Extracorporeal shockwave therapy ranged from a single treatment session to 3 sessions in 3-day to 1-week intervals, with up to 1500 impulses of 0.18mJ/mm2. PRP injections were given in the most painful location, up to 2 treatments over a 2-week period. Up to two corticosteroid injections were investigated, and one protocol began eccentric rehabilitation exercises 3-4 days after receiving the steroid injection. Low-intensity pulsed ultrasound was applied for 20-minutes a day, 7-days a week for 12 weeks (2-ms burst of 1 MHz @ 100Hz). Sclerotherapy is a treatment that destroys microvessels that form during the pathophysiological sequela of PT; the investigation included in this SR used a single dose of a sclerosing agent guided by ultrasonography.

SUMMARY OF OUTCOMES

The authors of the guiding systematic review utilized the VISA-P to determine the efficacy of each PT intervention. The VISA-P is a patient-reported outcome that assesses the symptoms, ability to complete functional tasks, and ability to

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complete sports.10 It can be scored within each domain, but composite scores range from 0 to 100, with 0 representing maximal levels of perceived disability, and 100 representing no symptoms (i.e. healthy).10 A minimal clinically important difference of 13 from pre- to post-testing has been established for the VISA-P.[11] With the ease of administration and grading, the VISA-P is a useful tool in determining treatment responses in patients with PT.

FINDINGS AND CLINICAL IMPLICATIONS

This systematic review assessed the evidence and elucidated intervention strategies that appear to be the most effective in patients with PT (**Table 1**). In addition, athletes and recreationally active individuals often push through activities despite their condition, playing, and practicing through low to moderate pain and symptoms. These behaviors make it difficult for clinicians as they may have to choose between symptom management rather than promote tissue healing.[12] Evidence also suggests that promoting tissue healing and managing symptoms are not mutually exclusive, as complete removal from sport may be contraindicated as loading is necessary to maintain healthy tendons.[13] The key for clinicians is to manage and reduce training loads, which can be done by utilizing a pain-monitoring model with visual analogue scales.[14] In addition, poor patient compliance with eccentric protocols are often implicated in the lack of overall success due to their painful nature.[15] Heavy slow resistance training has become popular as an alternative method to traditional eccentric exercises to improve patient outcomes, as the treatment techniques is considered less painful while demonstrating improvements of histological factors associated with tendon healing.[16]

Based on the findings of the systematic review, our own review of the evidence, and clinical expertise, we propose a framework for treating patients with PT (**Figure 1**). A thorough patient history and physical examination should be used to identify painful movements and any postural alignment issues/biomechanical insufficiencies which may need to be addressed during therapeutic rehabilitation. In both acute and chronic PT, the primary management strategy should consist of a two-pronged approach incorporating a loading program and therapeutic modalities. The loading program can aid in long-term pain relief, and should consist of eccentric and heavy slow resistance exercises (See supplemental videos).[17] Heavy slow

Table 1. Summary of Treatment Efficacy for Patients with Patellar Tendinopathy

Intervention	# of studies	Effect size of Improvement in VISA-P Scores (95% CI)
Eccentric Exercises	5	61% (53% to 69%)
PRP Injections	2	55% (5% to 105%)
Extracorporeal Shockwave Therapy	4	54% (22% to 87%)
Steroid Injections	2	20% (-20% to 60%)
Surgery	4	57% (52% to 62%)
Low-dose Therapeutic Ultrasound	2	50% (42% to 58%)
Moderate-dose Therapeutic Ultrasound	1	86% (82% to 90%)
High-dose Therapeutic Ultrasound	1	27% (21% to 34%)

Effect sizes reported reflect the magnitude of improvement on the VISA-P from pre-intervention scores. Thus, a pre-intervention score of 50 and a post-intervention score of 75 would represent a 50% improvement in the VISA-P. Based on this data, patellar tendinopathy patients treated with either eccentric exercises or surgery consistently display a positive response to their treatment.

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resistance exercises consist of a concentric action over a longer period of time (about 30 seconds),[17] thus emphasizes both concentric and eccentric strength of agonist and antagonist muscle groups. The current systematic review also supports the use of extracorporeal shockwave therapy and PRP injections for pain reduction in patients with PT. Extracorporeal shockwave therapy has also shown efficacy in patients with medial tibial stress syndrome.[18,19] However, it is an expensive treatment and not practical for all athletic trainers. Therefore, we recommend one considers both the time and financial investments implicated with using extracorporeal shockwave therapy when treating patients with PT. If pain and function fail to improve in your patient over a 6-month period, we suggest athletic trainers refer their athlete to a surgeon to discuss a patellar tenotomy. Surgery has been shown to be effective in the long-term at reducing pain in patients with PT. However, this is not the ideal approach for all athletes or patients with PT, thus we also suggest several adjunct therapies. Consistent evidence supports the use of isometric exercises for reducing pain in patients with PT.[17] PRP injections may also be used, either prior to beginning a loading program, or afterwards to accelerate recovery. Strapping may also be considered when managing patients with PT, as infrapatellar strapping has been shown to reduce pain and alter lower limb biomechanics.[20,21] Ineffective approaches include both low- and high-dose therapeutic ultrasound, as well as sclerotherapy. Corticosterioid injections may sound like a logical treatment, however they are contraindicated for patients with PT and should not be used. While this systematic review reports varied levels of efficacy of different treatments for reducing pain in patients with PT, they all used the VISA-P as an outcome. We strongly recommend clinicians continue to utilize such validated patient-reported outcomes as a mean to track treatment success and aid in the clinical decision-making process. We also recommend incorporating quality improvement practices that utilizes patient-reported outcomes to address patients on an individual basis, in an effort to optimize your clinical management of patients with PT.

CLINICAL BOTTOM LINE

Several treatment protocols are available with varying success to manage patients with PT. Exercise protocols including isometric, eccentric, and heavy slow resistance exercises often report the best patient outcomes. Extracorporeal shockwave therapy and PRP injections are also effective adjuvant interventions, and can be incorporated when a patient is not responding to an initial conservative treatment approach. Failed conservative treatments often lead to surgical interventions such as debridement to remove degenerative tissues to promote healing. Due to the wide variety of options, there is no consensus on the optimal treatments to improve outcomes in patients with PT. However, the literature shows that nearly all patients with PT can be treated effectively. Considerable evidence supports the use of conservative eccentric loading exercises, however, in lieu of a positive response to such conservative approaches, surgical intervention is effective at improving patient outcomes.

REFERENCES

1. Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am J Sports Med. 2005;33(4):561-567. https://doi.org/10.1177/0363546504270454.
2. Khan KM, Maffulli N, Coleman BD, Cook JL, Taunton JE. Patellar tendinopathy: some aspects of basic science and clinical management. Br J Sports Med. 1998:346-355. https://doi.org/10.1136/bjsm.32.4.346

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3. Cook JL, Khan KM, Harcourt PR, Grant M, Young DA, Bonar SF. A cross sectional study of 100 athletes with jumper's knee managed conservatively and surgically. The Victorian Institute of Sport Tendon Study Group. Br J Sports Med. 1997;31(4):332-336. http://dx.doi.org/10.1136/bjsm.31.4.332.
4. Morgan S, Van Vuuren ECJ, Coetzee FF. Causative factors and rehabilitation of patellar tendinopathy: A systematic review. S Afr J Physiother. 2016;72(1). https://dx.doi.org/10.4102%2Fsajp.v72i1.338.
5. Morton S, Williams S, Valle X, Diaz-Cueli D, Malliaras P, Morrissey D. Patellar tendinopathy and potential risk factors: an international database of cases and controls. Clin J Sport Med. 2017;27(5):468-474. https://doi.org/10.1097/JSM.0000000000000397.
6. Khan KM, Cook JL, Kannus P, Maffulli N, Bonar SF. Time to abandon the "tendinitis" myth. BMJ (Clin res ed). 2002;324(7338):626-627. https://doi.org/10.1136/bmj.324.7338.626.
7. Peace KAL, Lee JC, Healy J. Imaging the infrapatellar tendon in the elite athlete. Clin Radiol. 2006;61(7):570-578. https://doi.org/10.1016/j.crad.2006.02.005.
8. Helland C, Bojsen-Moller J, Raastad T, et al. Mechanical properties of the patellar tendon in elite volleyball players with and without patellar tendinopathy. Br J Sports Med. 2013;47(13):862-868. https://doi.org/10.1136/bjsports-2013-092275.
9. Pfirrmann CW, Jost B, Pirkl C, Aitzetmuller G, Lajtai G. Quadriceps tendinosis and patellar tendinosis in professional beach volleyball players: sonographic findings in correlation with clinical symptoms. Eur Radiol. 2008;18(8):1703-1709. https://doi.org/10.1007/s00330-008-0926-9.
10. Visentini PJ, Khan KM, Cook JL, Kiss ZS, Harcourt PR, Wark JD. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group. J Sci Med Sport. 1998;1(1):22-28. https://doi.org/10.1016/S1440-2440(98)80005-4.
11. Hernandez-Sanchez S, Hidalgo MD, Gomez A. Responsiveness of the VISA-P scale for patellar tendinopathy in athletes. Br J Sports Med. 2014;48(6):453-457. https://doi.org/10.1136/bjsports-2012-091163.
12. Rudavsky A, Cook J. Physiotherapy management of patellar tendinopathy (jumper's knee). J Physiother. 2014;60(3):122-129. https://doi.org/10.1016/j.jphys.2014.06.022.
13. Saithna A, Gogna R, Baraza N, Modi C, Spencer S. Suppl 3: Eccentric Exercise Protocols for Patella Tendinopathy: Should we Really be Withdrawing Athletes from Sport? A Systematic Review. Open Orthop J. 2012;6:553. https://dx.doi.org/10.2174%2F1874325001206010553.
14. Silbernagel KG, Thomeé R, Eriksson BI, Karlsson J. Continued sports activity, using a pain-monitoring model, during rehabilitation in patients with Achilles tendinopathy: a randomized controlled study. Am J Sports Med. 2007;35(6):897-906. https://doi.org/10.1177/0363546506298279.
15. Lorenzen J, Krämer R, Vogt P, Knobloch K. Systematic review about eccentric training in chronic patella tendinopathy. Sportverletz Sportschaden. 2010;24(4):198-203. https://doi.org/10.1055/s-0029-1245818.
16. Malliaras P, Barton CJ, Reeves ND, Langberg H. Achilles and patellar

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tendinopathy loading programmes. Sports Med. 2013;43(4):267-286. https://doi.org/10.1007/s40279-013-0019-z.
17. Lim HY, Wong SH. Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review. Physiother Res Int. 2018;23(4):e1721. https://doi.org/10.1002/pri.1721.
18. Moen M, Rayer S, Schipper M, et al. Shockwave treatment for medial tibial stress syndrome in athletes; a prospective controlled study. Br J Sports Med. 2012;46(4):253-257. https://doi.org/10.1136/bjsm.2010.081992.
19. Newman P, Waddington G, Adams R. Shockwave treatment for medial tibial stress syndrome: a randomized double blind sham-controlled pilot trial. J Sci Med Sport. 2017;20(3):220-224. https://doi.org/10.1016/j.jsams.2016.07.006.
20. De Vries A, Zwerver J, Diercks R, et al. Effect of patellar strap and sports tape on pain in patellar tendinopathy: A randomized controlled trial. Scand J Med Sci. 2016;26(10):1217-1224. https://doi.org/10.1111/sms.12556.
21. Rosen AB, Ko J, Brown CN. Single-limb landing biomechanics are altered and patellar tendinopathy related pain is reduced with acute infrapatellar strap application. Knee. 2017;24(4):761-767. https://doi.org/10.1016/j.knee.2017.03.003.

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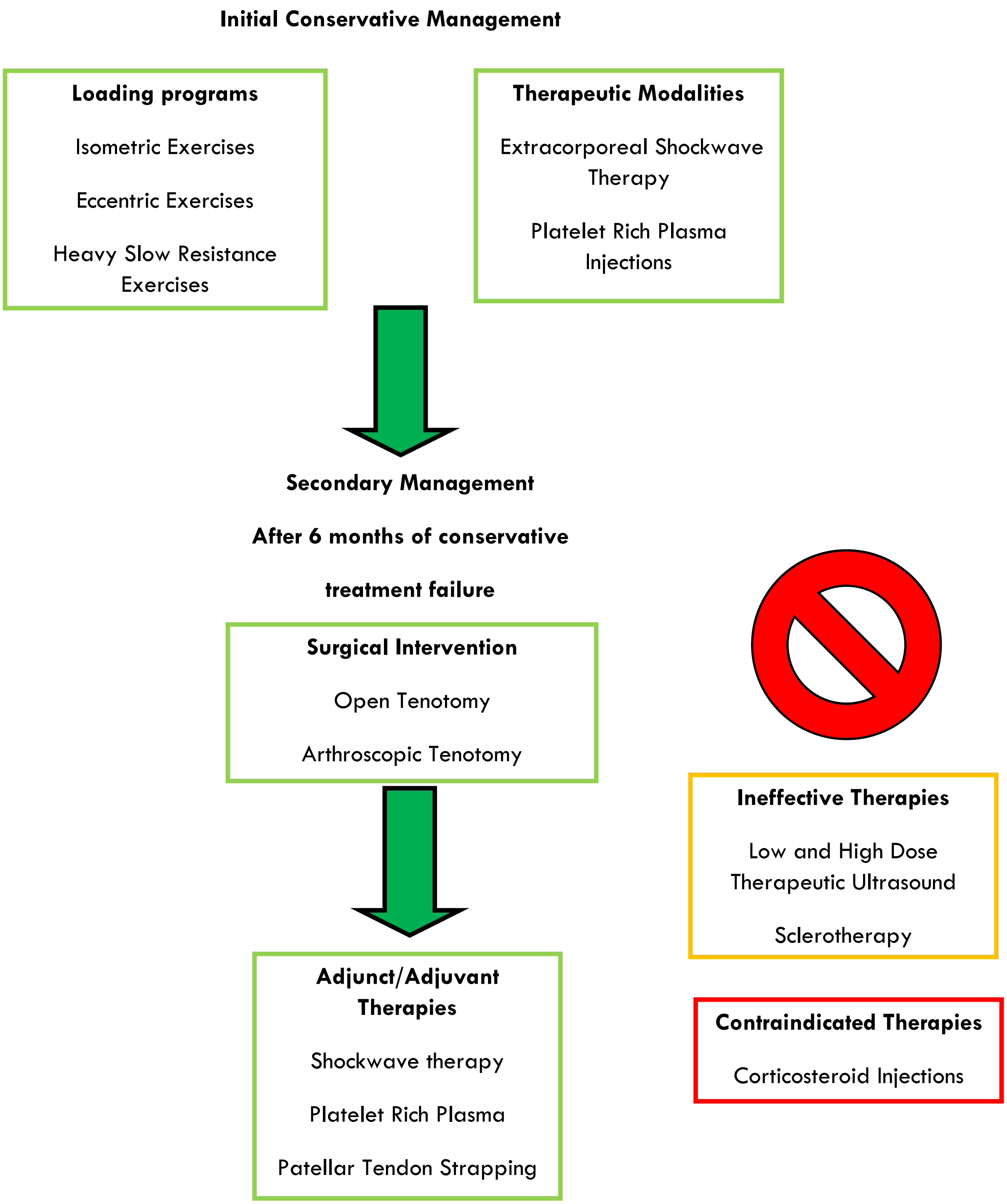
Figure 1. Overview of effective therapies and recommended course of treatment.



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Range of Motion Changes in Female Elite Swimmers Throughout a Competitive Season

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ABSTRACT

Upper extremity injuries are the most common injury in swimming athletes specifically in the collegiate setting. Females in particular, are more likely to suffer these injuries when comparing to male collegiate swimmers. "Swimmer Shoulder", a generic term for overuse shoulder injuries in the swimming population occurs with high rate and intensity of training. Significant factors that have been found to contribute to this pathology are deficits in internal rotation, lack of stability, and increased demands on the shoulder. The aim for this clinical outcomes project was to evaluate changes in range of motion (ROM) total arc of the shoulder, and patient-perceived function in female elite swimmers throughout a competitive season. Shoulder total arc ROM was measured passively with the student-athlete supine. A digital inclinometer was used to make it simpler for the clinician to assess ROM on their own. The Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC) was used to measure self-perceived upper extremity function in sport. It consisted of a set of demographic and participation questions followed by 10 visual analogue scale questions about upper extremity function during sport. Upper extremity stability was also measured using the closed-kinetic chain upper extremity stability test (CKCUE). Results showed shoulder ROM (total arc) restrictions occurred during times of increased training intensity and volume. When patients had smaller total arc measurements, the student-athletes reported lower KJOC scores for sport related function. There was an increase in ROM at a time where intensity, and distance of training were decreased. Overall upper extremity stability gradually improved over the course of a competitive season.

Key Phrases
Clinician-rated outcome, college and university patient population, patient-reported outcomes

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INTRODUCTION

Upper extremity injuries, specifically to the shoulder, neck, and back, are the most common injury in swimming athletes specifically in the collegiate setting.[1,2] Sallis et al.[3] established that females sustained shoulder injuries three times more often and are five times more likely to sustain neck and back injuries than men. When these injuries occur, drop off in performance and participation can occur due to their debilitating nature. Factors such as technique, yardage, training, and intensity are contributing factors to such injuries. Physical factors like posture, technique, strength, and range of motion (ROM) may also contribute to higher risk of injury.[2] Intrinsically, factors like integrity of the ligaments of the shoulder girdle, core and scapular muscle control, muscle imbalances in the shoulder and scapulothoracic region and extrinsically, factors like high-level, high-intensity training in and out of the pool, sports specialties, history of injury, and age all contribute to an increased risk of injury in swimming.[2]

The shoulder joint is complex, allowing for substantial mobility, while sacrificing stability. Both the dynamic and static stability are reliant on the coordination of the rotator cuff muscle and complimentary ligaments.[4] Any movement, especially repetitive movement, requires coordination of these static and dynamic stabilizers to maintain proper joint position to avoid injuries derived from overuse. ROM abnormalities have been associated with pain, decreases in performance, and the development of shoulder pathologies.[5] "Swimmer Shoulder" is a pathology that occurs with high rate and

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intensity of training,[6] and is a generic term for shoulder overuse injuries in the swimming population.[2,3,7]

Swimming athletes have unique mechanics and movement patterns and a better understanding of dysfunction and pain within this population is needed in order to develop prevention strategies to avoid overuse injuries. We aimed to understand ROM changes and characteristics of disease through measures of ROM, upper extremity stability, and changing perceptions of function over the course of a season. Although there are many factors that could contribute, deficits in internal rotation, lack of stability, and increased demands on the shoulder have all been theorized to increase risk of injuries.[8] Also, previous research in collegiate overhead throwing athletes showed changes in rotational ROM, over the course of a season.[9] However, these changes and potential pathology that often come from excessive ROM have not been explored in swimmers. The purpose of clinical outcomes research is to describe patient- and clinician-reported outcomes measured in clinical practice. The measurements were part of clinical practice as a means of assessing various changes in student-athletes over the course of a season, to help the clinicians working with these student-athletes identify when they were at an increased risk for injury.

PATIENTS

Twenty female swimmers (age = 19 ± 1 years, height = 85.78 ± 34.26 in., weight = 123.65 ± 41.40 lbs.) from a Midwestern National Collegiate Athletic Association Division I institution were followed over the competition season. Each student-athlete was cleared to participate in sport, per department guidelines that each student-athlete is required to be seen by various medical personnel as part of a mass pre-participation screening. All student-athletes continued to be active in their sport and training regimens throughout the season, including weight lifting, conditioning, whole body musculoskeletal injury prevention, and core-focused workouts. None of the student-athletes were excluded from measurement sessions due to injuries suffered before or during the competitive season. The main objective of the outcomes assessment was to observe changes over the duration of the season; one student-athlete was excluded from statistical analysis for absence from more than two measurement sessions. Student-athletes who experienced injuries sought treatments and inventions on an individual basis with the athletic training staff. Because outcomes research is a collection of outcomes in clinical practice, interventions were not controlled.

OUTCOMES MEASURES

Measurement sessions occurred seven times over the course of the season by the same clinician. Measures were collected monthly with the sessions lasting around one hour for the whole team. We collected measurements from the start to the end of the NCAA collegiate swimming season (lasting 7 months). The first collection (September) occurred before the first official meet and the last collection (March) was after post-season competition was complete. Each collection was completed on a similar day and time each month in order to replicate the state of tissue. Many factors could not be controlled such as activity outside of sport and voluntary additional practice. The day and time chosen each week month fell on a day that the team had only a single practice session. Collection was done before the student-athletes participated in any team activities. On each measurement session day, one clinician completed glenohumeral total arc measurements and the closed-kinetic chain upper extremity stability test (CKCUES) as well as asked the student-athlete to complete the Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC) on a paper form.

Glenohumeral ROM

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Glenohumeral ROM can be measured in a variety of ways. The use of goniometry is the gold standard for measuring joint ROM.[10] Due to the shoulder's vast mobility and wide ranges of motion, finding the correct position to measure glenohumeral motion alone can cause some difficulties. Collecting passive ROM for the shoulder in external and internal rotation can sometimes cause difficulties for a single clinician. Attempts to avoid inconsistency in student-athlete positioning can be tasking for clinicians while trying to move the shoulder through the ROM with

Figure 1. Digital Goniometer Measure of External ROM

the goniometer. A standard goniometer has two working arms that need to be positioned precisely with the body and the limb being measured in order to gather an accurate measurement. This becomes a process that can be challenging to recreate consistently. Other options for measuring ROM include digital inclinometer,[11] bubble inclinometer, and video analysis.[7] We used a digital inclinometer (Saunders Baseline Digital Inclinometer, The Saunders Group Inc, Chaska, MN) and a nylon fabric strap glued on to protective guards to attach the device to the forearm (**Figure 1**). This aided the clinician to ensure proper positioning throughout the ROM measurement. During measurement sessions, the clinician measured bilaterally for glenohumeral ROM. We calculated total arc of motion by combining measures of external ROM and internal ROM while the patient was lying in the supine position. The student-athlete was positioned in 90° of glenohumeral abduction position as shown in **Figure 1**. The practitioner passively moved the patient through the ROM and end-range ROM was decided based on the firm end-feel of the glenohumeral joint and the rise of the scapula off the table.[10]

Closed-Kinetic Chain Upper Extremity Stability Test (CKCUES)

We measured upper extremity stability with the CKCUES. The CKCUES test is an easy-to-use clinical test that has been validated on a variety of populations. It requires very little equipment and a brief commitment to complete. The student-athlete was placed in a pushup position (**Figure 2**) with their hands 36 inches apart (designated with tape on the floor), where they were asked to touch the supporting or weight-bearing hand with the unattached hand and alternate as many times as possible within 15 seconds. They completed this functional outcome measure three times for 15 seconds each.[12,13] Every touch was recorded as one toward the score for that trial. The patients completed a 45-second rest between trials. The average of the three trials are recorded as the final measure.[13] Although swimming is an open kinetic chain activity, this functional movement outcome measure mimics a number of other training activities such as dry land activities and strength programs. For healthy individuals, there is great intersession reliability.[14]

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Figure 2. Starting Position for CKCUES

Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC)

The KJOC is a patient-rated outcome measure created for highly functioning individuals participating in sport. In comparison to other similar measures, the KJOC has less of a ceiling effect allowing for it to measure changes for higher functioning individuals.[15] Although it was originally created for throwing athletes, the wording of the questions do not address throwing directly, and is therefore applicable to all overhead athletes. The first part of the tool addresses history of injury and sport participation. The second part is a series of 10 visual analogue scale questions about current pain or dysfunction. The left side of the line represents high levels of pain or dysfunction while the right side indicates no pain or dysfunction. The tool is scored based on an average of the 10 visual analogue scale measure from 0 to 10 cm.[15] Research studies done on the KJOC in other high-level athletes demonstrate that this tool is more sensitive to athletes compared to other upper extremity patient-rated outcome tools.[16] This same study found that there was a high predictability of lower scores if the patient missed practice or game(s) in the last year.[16] The researchers also found that time of administration had no effect on the outcome.[16] No minimal clinically important difference (MCID) has been established for this tool. This was also collected at each measurement session.

RESULTS

Student-athlete demographic data was analyzed using means, standard deviations, frequencies, and percentages. Means and standard deviations were calculated for the bilateral total arc ROM, CKCUES (average of three trials), and KJOC (total score) for each month (**Table 1**). We analyzed the outcome measures using three separate repeated measures ANOVAs and significance was set a priori at <0.05.

We identified a significant main effect for time and total arc ROM in the right arm ($p<0.001$), and specifically we identified that months one, two, and five deviated more than 5° below 180° associating restriction. Months six and seven mean measures deviated 7° more than 180° suggesting possibly hypermobility. We also identified a significant main effect for time and total arc ROM in the left arm ($p<0.001$). Month one deviated 10° below 180° and month seven deviated 7° above 180° in the left arm. There was a gradual increase in CKCUES touches through the duration of the outcomes assessment ranging from an average of 13.7 touches in the first month to 20 touches in the last month ($p<0.001$). The KJOC scores indicated high levels of function among the student-athletes over the course of the competitive season (mean = 88.16 ± 3.29 points [total score possible 100 points]). Month two was significantly different compared to the other months with a mean score of 81.14 points ($p<0.001$).

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Table 1. Monthly Outcome Measures

Month	KJOC	Total Arc (R)	Total Arch (L)	CKCUES
1	88.4±16.1	172.7±14.6	169.7±11.4	13.8±2.5
2	81.1±19.9	169.1±13.0	177.1±9.4	15.6±2.9*
3	88.2±12.3	180.4±14.9	178.3±12.5	17.8±1.5*
4	88.9±13.7	180.2±18.4	178.6±11.8	19.2±3.2
5	88.8±14.8	175.3±16.5	170.3±15.4	19.4±2.7
6	90.9±13.2	188.7±12.0	187.0±16.9*	19.5±2.8
7	90.7±13.5	187.6±21.9	179.4±12.6	20.5±3.5

Values are expressed in the mean ± standard deviation.
*Significantly different from previous month ($P<.05$).

DISCUSSION

The primary purpose of this outcomes assessment was to evaluate changes in passive glenohumeral total arc, closed-kinetic chain upper extremity stability, and self-perceived function over the course of a competitive season in collegiate female swimmers. Clinical outcomes research is meant to help clinician's measure patient- and clinician-rated outcome measures and to use those measures to improve their own clinical practice. Sample size and techniques to control data collection are not necessary in clinical outcomes research and were therefore not utilized here. However, based on our data, we were able to monitor patients over the course of a season and future prevention programs may be developed.

Since the reliability of goniometry measurement is varied and often hard to complete with one clinician, we chose an alternative method using a digital inclinometer. Methods of collection helped to free the hands of the clinician in order to assure proper passive ROM and to make it more clinically applicable. The intra-rater reliability of the digital inclinometer is excellent (ICC (3,k) =0.94-0.98).[18] Other ways to measure ROM of the shoulder include bubble inclinometers and emerging used of cellphone application. Advances in technology and future research on electronic goniometer could help in incorporate these measures into clinicians' practice more frequently. Changing methods are helping to ensure that measurements, especially in the shoulder, could be collected efficiently and independently.

Largely, we saw more variation on the right arm ROM than the left. Month one, two, and five had significant restrictions. Restrictions in internal rotation ROM has been connected to increased rate of internal impingement and posterior shoulder limitations.[19] Decrease of total arc greater than 25° increases the likelihood of a patient to experience an upper extremity injury by four times.[5] Another consideration when measuring total arc is humeral torsion. Posterior fibers of the rotator cuff and posterior capsule have been hypothesized to change orientation with significant humeral torsion. This can affect ROM measurements[19] because the fiber changes effect placement of the humeral head on the glenoid over time, possibly causing injury. Age also plays a factor in identifying these changes and addressing postural corrections can help aid in prevention.

The CKCUES is an easy and low-cost clinician-rated outcome measure used to assess upper extremity stability in a close-kinetic chain position. Although closed-kinetic chain is not a characteristic of the swimming motion itself, dry land training and other conditioning activities are completed in the closed-kinetic chain postures.[20] Anecdotally, patients complained of more discomfort and

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strength deficits when completing closed-chain activities compared to swimming activities. In the previous study, active females, positioned in a kneeling stance, produced mean scores ranging from 27 to 31 touches. The men in the study, whose procedures matched ours, ranged from 24 to 27 touches on average.[14] The mean touch counts for the student-athletes in this outcomes assessment was well below where other active females and males have scored despite positioning.[14] A connection can be made that due to the physical adaptions in open-chain training, participating in closed-chain exercise is more difficult and therefore could possibly be a cause for injury risk or a reduction in performance. Patients showing instability or dysfunction while completing this stability test should be considered for changes in dry-land training and an assessment of these deficits before returning to previous activity status. It is evident that there could be a learned effect when completing the test so frequently. The test-retest means found by Tucci et al[14], saw increases in all populations possibly justifying a similar improvement among the student-athletes in this study. In total, the CKCUES may not be a great indicator of injury in open-chain activities but should be used to help guide closed-chain training.

The KJOC was a tool developed for specific high functioning individuals participating in sport. It has sensitivity and reliability and is thought to demonstrate more subtle changes in high functioning individuals. The student-athletes we monitored scored 88 points for all seven months with a significant decrease in month two. Measurements returned to the 88-point range after month two. Kraeutler et al.[21] reported normalized values in asymptomatic professional baseball players well above 90 points. Out of 44 players, only seven reported scores below 90.[17] Our population was significantly below the 94.8 points reported previously.[21] The differences could be attributed to the higher impact that swimming can have on upper extremity function, specifically where baseball involves the use of unilateral shoulder movement, the nature of swimming is bilateral. The sport level may also play a role in the KJOC scores.

CLINICAL APPLICATION

Overall, we observed significant increases in total arc ROM bilaterally, improved upper extremity stability, and consistent perceived function in collegiate female swimmers. Future implementations of these measurements sessions should look to correlate mileage and training intensity to determine the relationships between these changes and workload. It is very likely that the student-athletes developed a learned effect to the upper extremity stability testing and those findings may not inform clinical practice; however, student-athletes did report pain doing this test, indicating that further exploration of swimmers and this test may be necessary. Identifying risks of injury and making decisions on prevention strategies should incorporate many different factors such as ROM, stability, and self-perceived function. Similar clinician-rated outcomes research has examined rotational ROM outcomes in the baseball and softball patients[9] and patient-rated outcomes research with the KJOC scores in elite level baseball players.[9] We found similar changes in rotation ROM described, but found the student-athletes in this population scored substantially lower than elite overhead throwing athletes. Although both populations are considered overhead athletes, swimming includes bilateral use of the upper extremity while throwing utilizes unilateral workloads and the difference in mechanics may require specific considerations when developing prevention strategies.

Prevention strategies for the shoulder and upper extremity in the literature are inconsistent. Practice patterns for prevention among team-based care secondary or tertiary in nature. By conducting similar clinical outcome measures can provide information specific to the population and help to

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guide changes in injury prevention on a primary level. Although these are preliminary measures to understand changes over the course of a competitive swimming season, it has described the benefits and limitations of various patient and clinician-rated outcome measures. Once more appropriate measures are identified for this population, future clinical outcomes research could be used to test prevention strategies.

REFERENCES

1. Wanivenhaus F, Fox AJ, Chaudhury S, Rodeo SA. Epidemiology of injuries and prevention strategies in competitive swimmers. *Sports Health*. May 2012;4(3):246-251. https://dx.doi.org/10.1177%2F1941738112442132.
2. Wolf BR, Ebinger AE, Lawler MP, Britton CL. Injury patterns in Division I collegiate swimming. *Am J Sports Med*. Oct 2009;37(10):2037-2042. https://doi.org/10.1177/0363546509339364.
3. Sallis RE, Jones K, Sunshine S, Smith G, Simon L. Comparing sports injuries in men and women. *Int J Sports Med*. Aug 2001;22(6):420-423. https://doi.org/10.1055/s-2001-16246.
4. Weldon EJ, 3rd, Richardson AB. Upper extremity overuse injuries in swimming. A discussion of swimmer's shoulder. *Clin Sports Med*. Jul 2001;20(3):423-438. https://doi.org/10.1016/S0278-5919(05)70260-X.
5. Shanley E, Rauh MJ, Michener LA, Ellenbecker TS, Garrison JC, Thigpen CA. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *Am J Sports Med*. Sep 2011;39(9):1997-2006. https://doi.org/10.1177/0363546511408876.
6. Rupp S, Berninger K, Hopf T. Shoulder problems in high level swimmers--impingement, anterior instability, muscular imbalance? *Int J Sports Med*. Nov 1995;16(8):557-562. https://doi.org/10.1055/s-2007-973054.
7. Kevern MA, Beecher M, Rao S. Reliability of measurement of glenohumeral internal rotation, external rotation, and total arc of motion in 3 test positions. *J Athl Train*. Sep-Oct 2014;49(5):640-646. https://doi.org/10.4085/1062-6050-49.3.31.
8. Beach ML, Whitney SL, Dickoff-Hoffman S. Relationship of shoulder flexibility, strength, and endurance to shoulder pain in competitive swimmers. *J Orthop Sports Phys Ther*. 1992;16(6):262-268. https://doi.org/10.2519/jospt.1992.16.6.262.
9. Dwelly PM, Tripp BL, Tripp PA, Eberman LE, Gorin S. Glenohumeral rotational range of motion in collegiate overhead-throwing athletes during an athletic season. *J Athl Train*. Nov-Dec 2009;44(6):611-616. https://doi.org/10.4085/1062-6050-44.6.611.
10. Awan R, Smith J, Boon AJ. Measuring shoulder internal rotation range of motion: a comparison of 3 techniques. *Arch Phys Med Rehabil*. Sep 2002;83(9):1229-1234. https://doi.org/10.1053/apmr.2002.34815.
11. Mullaney MJ, McHugh MP, Johnson CP, Tyler TF. Reliability of shoulder range of motion comparing a goniometer to a digital level. *Physiother Theory Pract*. Jul 2010;26(5):327-333. https://doi.org/10.3109/09593980903094230.
12. Roush JR, Kitamura J, Waits MC. Reference Values for the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) for Collegiate Baseball Players. *N Am J Sports Phys Ther*. Aug 2007;2(3):159-163.
13. Goldbeck TG, Davies GJ. Test-retest reliability of the closed kinetic chain upper

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extremity stability test: a clinical field test. *J Sport Rehabil*. 2000;9(1):35-45.
14. Tucci HT, Martins J, Sposito Gde C, Camarini PM, de Oliveira AS. Closed Kinetic Chain Upper Extremity Stability test (CKCUES test): a reliability study in persons with and without shoulder impingement syndrome. *BMC Musculoskelet Disord*. Jan 03 2014;15:1. https://doi.org/10.1186/1471-2474-15-1.
15. Alberta FG, ElAttrache NS, Bissell S, et al. The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *Am J Sports Med*. May 2010;38(5):903-911. https://doi.org/10.1177/0363546509355642.
16. Franz JO, McCulloch PC, Kneip CJ, Noble PC, Lintner DM. The utility of the KJOC score in professional baseball in the United States. *Am J Sports Med*. Sep 2013;41(9):2167-2173. https://doi.org/10.1177/0363546513495177.
17. Lim JY, Kim TH, Lee JS. Reliability of measuring the passive range of shoulder horizontal adduction using a smartphone in the supine versus the side-lying position. *J Phys Ther Sci*. Oct 2015;27(10):3119-3122. https://dx.doi.org/10.1589%2Fjpts.27.3119.
18. Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. *Int J Sports Phys Ther*. Jun 2012;7(3):306-313.
19. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Med*. Mar 2006;34(3):385-391. https://doi.org/10.1177/0363546505281804.
20. Butler R, Arms J, Reiman M, et al. Sex differences in dynamic closed kinetic chain upper quarter function in collegiate swimmers. *J Athl Train*. Jul-Aug 2014;49(4):442-446. https://doi.org/10.4085/1062-6050-49.3.17.
21. Kraeutler MJ, Ciccotti MG, Dodson CC, Frederick RW, Cammarota B, Cohen SB. Kerlan-Jobe Orthopaedic Clinic overhead athlete scores in asymptomatic professional baseball pitchers. *J Shoulder Elbow Surg*. Mar 2013;22(3):329-332. https://doi.org/10.1016/j.jse.2012.02.010.

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A Novel Approach to Treating Acute Hamstring Functional Neuromuscular Disorder-Effects of Primal Reflex Release Technique

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ABSTRACT

Hamstring injuries have an occurrence rate of 3.05 per 1000 athlete exposures in intercollegiate athletics. Current clinical practice recommendations for rehabilitation of hamstring injuries are based on pathoanatomical muscle tissue healing timeframes. The purpose of this study was to examine the effects of modulating the nervous system with Primal Reflex Release Technique (PRRT) in patients clinically diagnosed with functional neuromuscular hamstring muscle-related disorder (FNHD). In this a priori case series, PRRT was utilized in four patients participating in intercollegiate, National Collegiate Athletic Association Division II, athletics to evaluate Numeric Pain Rating Scale (NRS) for current pain, Disablement of the Physically Active (DPA) scale, modified Patient Specific Functional Scale (PSFS), and Active Knee Extension Test (AKET). The initial pre-treatment to post-treatment average difference for NRS (3.25±2.5 points) and AKET (11±2.16°) improved by an amount that satisfied MCID and MCD respectively. The pre-treatment to one-week follow-up average difference for NRS (5.5±2.3 points), PSFS (4.75±2.5 points), and AKET (20.5±14°) improved by an amount that satisfied MCID or MCD. The average timeline for discharge to full unrestricted activity was 2.75 days. In the four patients classified with a functional neuromuscular muscle disorder (FNMD), PRRT was utilized as the only manual therapy intervention. Through modulation of the nervous system, the outcomes reported by the patients were both meaningful and clinically significant. Based on the results and the current standard of care for similar patients, the need for further research into this paradigm is warranted. Hamstring injuries continue to be a significant clinical injury in the athletic patient population. A thorough evaluation and appropriate classification of muscle injury can help clinicians decided an effective treatment for the patient. Clinicians seeking to improve patient outcomes may benefit from considering a paradigm that modifies the neural allostatic loads.

Key Phrases
Autonomic nervous system, patient-reported outcomes, clinician-rated outcomes

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INTRODUCTION

Hamstring injuries are a common pathology within physically active patient populations.[1-6] Injury to the hamstring muscle complex can present as tissue damage leading to pain and functional limitations.[1-4,5-8] Structural damage, ranging from micro-trauma to macro-trauma, can occur when the force placed on the hamstring muscle is greater than the mechanical limits of the tissue.[9,10] Functional limitations, not structural damage, are frequently used to classify a patient with a hamstring injury, and determine treatment parameters based on recommendations of tissue healing timeframes.[6-8,11] It is possible that a portion of these injuries have minimal or no structural damage and are FNMDs, thus they do not need to adhere to the recommended tissue healing timeframes.

Hamstring injuries are prevalent in the intercollegiate athletic population, with a rate of 3.05 per 1000 athlete exposure.[12] The goals of hamstring rehabilitation include decreasing pain, restoring function, and returning to the prior level of sports performance with minimal risk of reinjury.[1,2,7,11] Previous research on hamstring treatment and return to play programs has been completed for patients classified with hamstring injury. However, the re-injury rates for this clinical significant injury have been consistent over the past 20 years.[1,2,4,8,11-13] With an increased risk of re-injury rate in intercollegiate athletics, further research is required to determine more effective interventions and treatment theories to decrease pain, restore range of motion (ROM), and improve function following classification of a hamstring injury.

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The pathoanatomical evaluation is recommended as the means for assessing a patient with a possible hamstring injury.[1,2,7,8,10,14] The widely used, O'Donoghue Muscle Injury Classification system correlates tissue damage to loss of function.[15] Based on this classification system, patients who present with pain and decreased function would be classified with a grade I or II hamstring strain. A recent consensus statement on muscle injuries in sport provides a new comprehensive classification system.[16] The Munich Muscle Injury Classification system (**Figure 1**) was used by the treating clinician (TC) to sub-classify these patients. Based on this new classification system, patients treated in this case series would be classified as having a FNMD. The neural component of a musculoskeletal injury can easily be overlooked as it is not commonly associated or treated under the tissue model.[17] As rehabilitation theories evolve to meet the progressive neurophysiologic research, clinicians may desire interventions purposed to create ideal function of the neurological system, rather than protocols encompassing the myopic muscle tissue healing model.

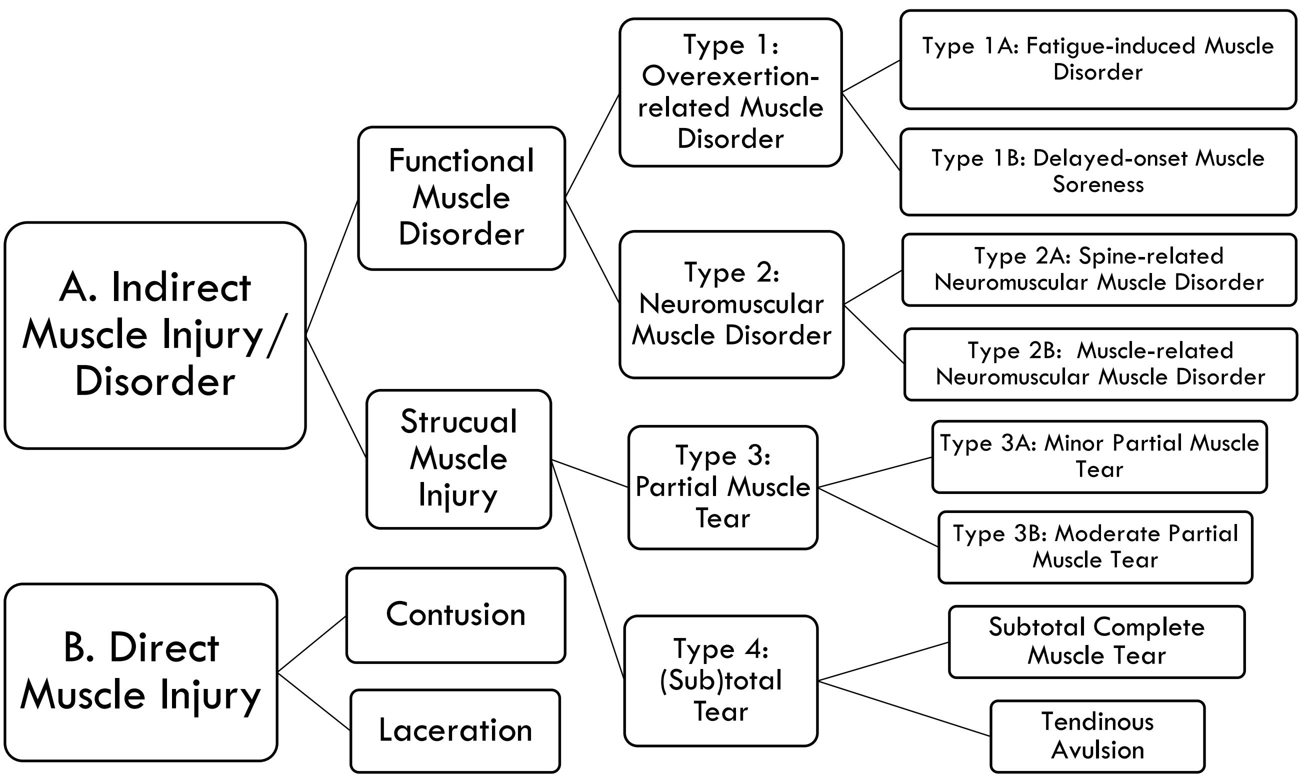

Figure 1. Munich Muscle Classification[16]
Patients with hamstring injuries in this study were classified with a Type 2A Muscle-related Neuromuscular Muscle Disorder and treated with PRRT, an innovative neurophysiological approach to treatment *Patients with hamstring injuries in this study were classified with a Type 2B Muscle-related Neuromuscular Muscle Disorder and treated with PRRT, an innovative neurophysiological approach to treatment.*

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The central nervous system (CNS) and peripheral nervous system (PNS) are directly related, and function in unison to provide appropriate sensory information to the brain to maintain a state of allostasis throughout the body.[18-20] Allostatic modulations in loading of the muscle tissue are often due to facilitated neurons and/or inhibited neurons creating abnormal function.[20] Neurophysiologist, Sir Charles Sherrington, introduced the law of reciprocal innervation which is used in therapeutic techniques, such as proprioceptive neuromuscular facilitation, to relax the agonist muscle via reflexive stimulation of the antagonist muscle.[21] The use of reciprocal innervation may be an effective treatment when the nervous system is in need of a modulating external stimulus.[22] Expanding on this theory, withdrawal and startle reflexes that lead to muscle spasm and possibly pain can be due to mal-adaptation or abnormal stimulation of the nervous system.[19] As a result of trauma (e.g., high speed running or agility movements), the nervous system may remain "up-regulated" and unable to restore a state of more ideal allostasis. In this up-regulated state, the use of an external stimulus to reset the CNS can resolve pain and restore function instantly.[19,23] The creator of PRRT, John Iams, recognized that reflex responses to startling and/or painful events may persist in the form of facilitated or inhibited muscles, which leads to compensatory patterns, pain, dysfunction.[23] Through modulating the CNS through the PNS, PRRT, an innovative treatment paradigm, can help reset the nervous system to a more ideal allostatic load following a traumatic incident such as a mechanism of injury leading to a hamstring injury. The use of PRRT in clinical practice has been demonstrated in the literature.[24-26] The purpose of this study was to examine the effects of modulating the nervous system with PRRT in patients classified with functional neuromuscular hamstring muscle-related disorder (FNHD).

PATIENTS

Four patients (3 males and 1 female) averaging (19.75±1.5 years of age) actively participating in intercollegiate athletics (**Table 1**) reported to the athletic training clinic with posterior thigh pain. All four patients were evaluated by a certified athletic trainer and met criteria to be included in this study. Each patient was classified with FNMD and treated by the same athletic trainer with four years of clinical practice experience who had completed, The Primal Reflex Release Technique™ Home Study Course, and The Primal Reflex Release Technique™ Live-Training Seminar. Based on the a priori design, the patients were not treated with any other therapeutic interventions. Patient-oriented evidence (POE) and clinician-oriented evidence (COE) outcome measures were collected for each patient over the course of treatment. The Numeric Pain Rating Scale (NRS) for current pain, Disablement of the Physically Active (DPA) scale, and modified Patient Specific Functional Scale (PSFS) were all included as POE. The COE classified measure was the, Active Knee Extension Test (AKET), and hamstring manual muscle test (MMT). The Institutional Review Board (IRB) of the two universities involved in this study approved the collection and dissemination of outcomes. All participants provided written

Table 1. Demographics and Evaluation Information

Patient	Age	Gender	Sport	Location of Pain in Posterior Thigh	Involved Side
1	18	Female	Cross Country	Lateral Distal Third	Right
2	19	Male	Soccer	Middle Third	Left
3	21	Male	Basketball	Lateral Middle Third	Left
4	21	Male	Basketball	Medial Proximal Third	Left

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consent to have their non-identifiable information included in this study.

At the time of initial evaluation, each patient reported pain with a decrease in active ROM and function in the affected extremity compared bilaterally. Due to the short time period from onset of injury to evaluation of the patient (within 1-2 days), lack of structural damage diagnosis, and Munich muscle injury classification each patient was determined to have sustained a neuromuscular muscle disorder. One patient self-reported a previous "hamstring strain" on his contralateral side, while the other patients reported no previous hamstring pathology. Following the evaluation, POE and COE measures were completed. Patients were included if they had the following outcome scores; NRS of ≥2/10, AKET measurement of ≤70° on involved side, and a PSFS score of ≤8/10 (**Table 2**).

INTERVENTION

The initial PRRT treatment session was completed immediately following the initial evaluation and collection of baseline patient outcome measures. The patient was positioned supine on a treatment table for all treatments. Then the TC provided a tactile stimulus the patient's muscle bellies and tendons, or a quick movement the patient's limb to create a reflexive response. The stimulus activates proprioceptors in the local tissue through reciprocal innervation that can lead to a more ideal allostatic load in the nervous system.[21-23] Starting with the involved side, each technique was completed for approximately 12 seconds, followed by the intervention on the contralateral limb. Four PRRT treatment techniques in the same sequence were utilized on each patient.

The intervention consisted of the following sequence: Hamstring Down-Regulate (dR) (**Figure 2**), Gastrocnemius Reset (**Figure 3**), Medial Knee/ Sacroiliac (SI) Joint Reset (**Figure 4**), and SI Bilateral Release (**Figure 5**), and was completed bilaterally, for a total of 2-3 minutes per session. After completion of the treatment, the patient stood up and then walked the length of the clinic two times, a total of approximately 60 feet. Then AKET and PSFS were reassessed, along with the NRS, at the conclusion of the initial treatment session.

OUTCOME MEASURES

The NRS, PSFS, MMT, and AKET were assessed at the following time-points: pre- and post-initial treatment session, discharge, one-week, and six-week follow-up assessment. The DPAS was collected at the pre-initial treatment session, one-week, and six-week follow-up assessment. Following the evaluation and collection of initial outcome measures, each patient received the PRRT sequence described below. Total number of treatments and days to discharge were tracked for each patient.

Numeric Rating Scale & Disablement of the Physically Active

The NRS and DPAS patient-reported outcomes assessments measured each patient's perception of pain and disablement. The NRS is an 11-point pain scale where 0 is "no pain" and 10 is "the worst pain imaginable." Scores reported for the NRS represent patient reported current pain in a weight bearing position (i.e. standing) at the time of assessment. A change of 2 points or greater is considered a Minimal Clinically Important Difference (MCID) for the NRS.[27] The DPAS was designed and validated for assessing disablement in physically active individuals. A 64-point scale with 16 possible identifiers of disablement individually scored on a 5-point Likert scale where zero is "no issues" and 4 is a "severe" issue. For acute conditions, a MCID is reached with a 9-point difference in scores.[28]

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Table 2. Inclusion and Exclusion Criteria

Inclusion	Exclusion
Acute, sudden posterior thigh pain NRS of ≥2/10	Gross deformity
MOI: acceleration or deceleration during running	Visible ecchymosis
Tender area to palpate on hamstring	Previous hamstring strain
Weakness compared bilaterally with knee flexion <5/5 MMT	within 6 months
Asymmetrical range of motion >5°	No specific MOI
Involved side AKET measurement of <70°	
Modified PSFS ≤8/10	

Figure 2. Hamstring down-regulate (dR).[22-23] Patient rests foot on the TC's shoulder while stimulation is applied to the patella tendon and each hamstring (semitendinosus, semimembranosus, and biceps femoris) muscle bellies.

Figure 3. Gastrocnemius Reset.[23] Patient maintains hip and knee flexion and ankle dorsiflexion while the TC applies stimulation to the patella tendon and ankle dorsiflexors (tibialis anterior, and extensor digitorum longus).

Figure 4. Medial knee/Sacroiliac (SI) joint Reset.[23] Stimulation is provided to the adductor magnus muscle superior to the knee and pes anserine inferior to the knee.

Figure 5. SI Bilateral Release.[22] The TC provided an external rotation stimulus into external hip rotation which the patient reacted against activating his/her internal hip rotators.

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Range of Motion (ROM)

To objectively assess ROM, the AKET was completed. The AKET is completed with the patient lying supine. First, the Clinometer phone application (plaincodeTM, Stephanskirchen, Germany) was utilized to position the angle of hip flexion at 90° by placing the device on the posterior aspect of the thigh. Once in 90° of hip flexion the patient was advised to straighten at his/her same knee while the patient maintained a fixed 90° hip flexion position.[29,30] The Clinometer was then moved to the anterior tibial shaft to assess the amount of knee extension which was recorded as the AKET measurement, a straight knee was considered 90° of movement. The standard error of measurement (SEM) has been reported at 3.8°.[29,30] The Minimal Detectable Change (MDC) has been recorded between 9.7° and 10.5°.[29,30]

Strength Testing

Manual Muscle Tests were included to grade muscular strength during evaluations.[31] Each patient was positioned prone and queued to flex his/her knee through the full ROM. If the patient could not move through the full ROM against gravity a grade of 2 was documented. No patients had a trace amount of movement, grade 1. When full ROM accomplished against gravity with no pain and the same ROM compared bilaterally a grade of 3 was documented. Next, the TC placed force on the posterior aspect of the calcaneus while the patient's knee was flexed to 90° and then asked the patient to resist. If the patient was able to resist the same force bilaterally a grade of 5 was recorded, grade of 4 was provided when full ROM was obtained but one side was unable to resist the same force as the contralateral side.[31]

Patient Specific Functional Scale

For assessment of perceived function, a modified PSFS was implemented for uniformity between patients and the a priori design. The PSFS classified each activity on an 11-point scale with 10 defined as, able to perform the same as before injury. An MCID is established for the PSFS when a score for a single activity changes by 3 points.[32] For the single activity, the patient was asked to stand with his/her feet about an inch apart and then cued to "bend forward and touch your toes". Following completion of the task the patient was asked to score the task on the 11-point scale.

RESULTS

Four patients were evaluated and treated by the TC and were discharged to full unrestricted activity in an average of 2.75 days from the start of treatment (**Table 3**). During the treatment sessions, POE and COE outcomes were collected to assess the patient's pain and function. Immediately following the initial treatment all the patients reported a decrease in pain that met MCID standards and three out of the four patients had an increase AKET measurement that was greater than the MDC (**Table 4**). Prior to returning to full unrestricted activity (i.e. competitive event) the patients had decrease in NRS, as well as increases in PSFS, MMT and AKET (**Table 5 & Table 6**). At the one-week assessment all the patients reported a MCID for NRS and DPAS while all but one had a MCID recorded for PSFS (**Table 6**). The AKET measures for each patient were all greater than the MDC at the six-week follow-up assessment (**Table 5**). At the six-week follow-up after discharge each patient reported no re-injury and maintained outcome scores.

DISCUSSION

The initial treatment of PRRT resulted in immediate improvements on the NRS and AKET for all four patients classified with a FNHD (**Table 4**). Applying the PRRT hamstring treatment sequence to these patients paired with appropriate activity progression (restricted to

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Table 3. Course of Treatment Timeframe

Patient #	Time from Injury to Tx (Days)	Number of Tx Sessions	Limited Participation in Sport (Days)	Discharged from Tx (Days)	Unrestricted Activity (Days)
1	1	3	2	4	3
2	<1	2	1	3	3
3	<1	3	2	3	3
4	<1	2	1	2	2

Tx = Treatment

Table 4. Initial Pre-Intervention to Post-Intervention Outcome Scores

Patient #	Pre-Tx NRS	Post-Tx NRS	Pre-Tx PSFS	Post-Tx PSFS	Pre-Tx AKET	Post-Tx AKET	Pre-Tx MMT	Pre-Tx MMT
1	4	2 [a]	5	8[a]	55	67[b]	2/5	3/5
2	8	6 [a]	2	4	23	31	2/5	2/5
3	5	3[a]	7	8	52	65[b]	3/5	3/5
4	7	0[a]	5	5	62	73[b]	3/5	3/5

Tx = Treatment; [a]= MCID, [b]= MDC

Table 5. Outcome Measurements Discharge to 6-Week Follow Up

Patient #	Discharge MMT	1 Week MMT	6 Week MMT
Clinician Oriented Outcome Measures			
Manual Muscle Testing			
1	4/5	4+/5	5/5
2	4+/5	5/5	5/5
3	5/5	5/5	5/5
4	4/5	5/5	5/5
Active Knee Extension Test			
1	67[a]/65	66/66	72/75
2	64[a]/68	68/70	63/64
3	70[a]/74	78/77	85/85
4	73[a]/77	78/78	71/73
Patient Oriented Outcome Measures			
Numeric Rating Scale			
1	0[b]	0	0
2	2[b]	1	0
3	0[b]	0	0
4	0[b]	0	0
Disablement of the Physically Active			
1	-	18[b]	0
2	-	0[b]	0
3	-	6[b]	4
4	-	19[b]	0
Patient Specific Functional Scale			
1	10[b]	8	10
2	10[b]	10	10
3	9	9	8
4	9[b]	8	10

AKET = affected limb/unaffected limb; [a]= MDC from discharge to unrestricted activity; [b]= MCID from discharge to unrestricted activity

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unrestricted activity) assisted the patients in returning to pre-injury participation levels. The focus of the four PRRT treatment techniques was on modifying the nervous system rather than a muscle tissue healing model which is commonly followed after the classification of an acute hamstring injury. Treating hamstring injuries with neurophysiological based interventions can have positive effects on pain, ROM, and function of the patient. The results of this case series support the use of intervention theories to modulate the CNS to assist patients classified with FNHD return to normalized allostatic loads demonstrated by outcomes improving before expected muscle tissue healing timeframes.

The classification of FNHD was based on the Munich muscle injury classification system. This system takes into account past classification systems based on structural damage and systems that explored functional deficits. By adding increased specifications for muscle injury, the Munich muscle injury classification system supports the use of a more patient-centered intervention approach. In patients that do not have structural muscle damage a FNMD guides clinicians to consider the neurological mechanisms of injury, which are often overlooked.

The goals for a patient following a hamstring injury is to decrease pain followed by restoring normal ROM, strength, and function, while minimizing injury recurrence rates.[1,2,7,11] Pain management is the initial goal of any rehabilitation program. Pain could be the prolonged symptom that needs to be addressed before function can be fully restored.[6,11,33,34] Decreasing pain is commonly achieved through heat, ice, ultrasound, electrical stimulation, mechanical therapies, and rest.[1,2,13,33-35] Following a decrease in pain, ROM must be restored before strength and functional activities can improve.[35-38] Clinicians assess musculoskeletal injuries in this manner based on a hypothesized correlation with severity of signs and symptoms. Rehabilitation is progressed based on decreased signs and symptoms assumed to be associated with tissue healing.[7,14,36,37] New classification systems are warranted as Ekstrand et al., found that patients classified with structural injuries through clinician evaluation only had evidence of MRI diagnosed muscle tear in 29% of patients.[39] No diagnostic imaging was completed during this case series. Through an innovative treatment used with these patients to modify neural allostatic loads, immediate changes in pain and function occurred leading to discharge criteria being achieved faster than the traditional timeframes associated the muscle tissue healing. Each patient in this study reported immediate decreases in pain at an amount that satisfied a MCID and increased ROM greater than a MDC at the one-week follow-up for each patient (**Table 5 & Table 6**). Immediate changes in pain and ROM are useful to clinicians and further research should be completed on treatments that have similar effects.

Hamstring injury and re-injury rates have been consistent for the past 20 years and have been associated with prolonged symptoms in physically active populations.[3-5, 12] Most traditional treatments for acute hamstring injuries have been studied in physically active populations and include stretching techniques paired with strengthening (e.g., eccentric) exercises, and trunk stabilization and agility drill progressions.[13,34, 38] Most of these stretching techniques are time consuming and rely on tissue change that may not restore neuromuscular connections that are also responsible for functional deficits. Range of motion increases have been linked to sensory perception instead of the commonly cited mechanical theories to increase muscle extensibility.[17,40] Currently, the best recommendations do not recommend clinicians to consider modifying the neural allostatic loads following an acute hamstring injury.[1,2,13,35-38] To improve on the hamstring injury and re-injury rates new innovative treatments should be explored. Treatments that

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attempt to adjust dysregulated neural allostatic loads created during a mechanism of injury/trauma need to be considered in future research, as well as implemented into clinical practice. Sherry et al., reported that re-injury occurs in one-third of patients within two weeks of returning to unrestricted activity from a stretching and strengthening hamstring injury treatment program.[13] None of the patients in the current case series suffered re-injury upon returning to full team activities at six-week follow-up which supports the effectiveness of PRRT in a short-term period.

The nervous system is sophisticated from the reflex circuits that occur at the spinal level to the descending motor pathways that control voluntary movement. Following injury or even perceived tissue damage the nervous system reacts with reflexes (e.g., flexor reflex, autogenic inhibition reflex, myotatic reflex).[19,20] Each of these movements are facilitated by an external stimulus and provide sensory information to the neurons within the spinal cord which result in motor neurons being activated to diffuse the external stimulus. When the reflex circuit is functioning appropriately the nervous system is effective at recognizing and responding to potentially dangerous external stimuli. However, in some cases external stimuli cannot be managed solely by the reflex circuit.[40,41] The sensory information travels through the spinal cord to the brainstem and forebrain, which then sends a signal through the descending motor pathway to respond to the stimulus.[19,20,40] If addition sensory information continues to ascend to the CNS, the allostatic load will remain increased thus leading to hypersensitivity of the nervous system. Through modulation of the CNS, reflexes can be stimulated to modify the allostatic load which would potentially result in immediate changes at the local site of musculoskeletal injury.[22]

There are several programs that are available to guide the treatment of acute hamstring injury. Sherry et al., provided an outline of differential diagnosis, prognosis, and return to play protocol for acute hamstring injury.[11] This protocol recommends 3 phases over eight weeks to progress a patient to return-to-activity. The return-to-activity was based on pain-free palpation over the injury site, full muscle strength, full muscle endurance, and no kinesiophobia. Patients classified with acute hamstring strain return-to-play in a range of 6-22 days.[4,7,13] Gibbs et al., assessed 31 patients classified with grade I hamstring strain. Fourteen of the patients had normal MRI and returned to full team activities at an average of 6 days while 17 patients averaged 20 days to return to full team activities.[7] Comparatively, the patients in this current study were discharged to return to full unrestricted activity and able to complete full team activities at 2.5 days.

With no peer-reviewed articles specific to the treatment of patients classified with acute hamstring injury, PRRT has been found to have a positive effect on pain and function when implemented in other areas of the body. Hansberger et al. reported a decrease pain in patients with chronic and acute plantar fasciitis in an intercollegiate athletic training clinic.[24] The current study employed treatment procedures that were similar in design and time for intervention to the case series by Hansberger. Hansen-Honeycutt et al., reported an immediate decrease in musculoskeletal pain in three patients using PRRT and breathing reflex triggering exercises in a intercollegiate athletic training clinic.[25] After utilizing these techniques, each patient reported a decrease in tenderness to palpation over his/her tender areas or with primary musculoskeletal complaint.[25] The samples for both studies were patients in intercollegiate athletic training clinics.[24,25] A third study was a case report on a patient with shoulder impingement syndrome treated with PRRT which resulted with immediate reduction of POE for pain, disablement, and perceived function.[26]

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These examples of PRRT decreasing or resolving pain in 1 to 3 treatments warrants further investigation of this technique in other musculoskeletal disorders such as acute hamstring injury.

Based on outcomes recorded in the current study, treatments focused on modulating the CNS warrant further investigation in both clinical and laboratory settings that utilize randomized controlled methods. As expressed by the results, the intervention, PRRT, used in the current case series may have been effective at creating ideal function of the nervous system instead of a healing the tissue based on a myopic muscle tissue healing model. Future studies should incorporate a larger sample size of patients with acute hamstring injury treated and assess the effectiveness of PRRT in patients with and without MRI evaluated hamstring injuries. To expand on the effectiveness of PRRT, cohort studies comparing PRRT versus other treatment interventions for acute hamstring injury would help support if the effects of this study were due to the use of PRRT.

The case series presented was the first to report the outcomes of PRRT for treating acute hamstring injury. Some of the limitations include a small sample size, and no clinician reliability. The TC was a novice practitioner with one year of clinical application of PRRT and therefore had not become an expert at the technique through years of practice. The TC providing the treatment also obtained measurements (e.g. MMT, ROM) and was not blind to results. The patients were young, physically active intercollegiate athletes therefore the effects may be expected in the same population.

CLINICAL APPLICATION

Through the case series performed by a certified athletic trainer in an athletic training clinic, the results of PRRT to treat patients with FNMD were reported. In this isolated case series patients, had an immediate change in pain and ROM following treatment sessions. Treating patients classified with FNMD with PRRT led to immediate and short-term changes in the POE and COE outcomes along with successful return-to-activity. The use of PRRT possibly modified the neural allostatic load of the patient, which could explain the improved patient outcomes in the current study. The standard of care for hamstring muscle injuries is guided by the goal of creating a tissue change to decrease pain, restore function, improve strength, and limit reinjury.[1,2,7,11] In the current study, COE and POE outcomes were positively affected in a shorter amount of time compared to pathoanatomic healing timeframe for similar patients classified with grade 1 hamstring strain. The available research on PRRT supports, through clinic practice outcomes, a neurophysiological approach to treatment of acute hamstring injury. Based on the outcomes of the study, clinicians looking to improve patient outcomes may benefit from considering a paradigm that modifies the neural allostatic loads during treatment prior to or in conjunction with other techniques rather than relying solely on the pathoanatomical theory of tissue healing.

REFERENCES

1. Clanton TO, Coupe KJ. Hamstring strains in athletes: diagnosis and treatment. J Am Acad Orthop Surg. 1998;6: 237-248.
2. Opar DA, Williams MD, Shield AJ. Hamstring strain injuries. Sports Med. 2012; 42: 209-26. https://doi.org/10.2165/11594800-000000000-00000.
3. Malliaropoulos N, Papacostas E, Kiritsi O, Rad PM, Papalada A, Gougoulias N, Maffulli N. Posterior thigh muscle injuries in elite track and field athletes. Am J Sports Med. 2010;38: 1813-9. https://doi.org/10.1177/0363546510366423.
4. Elliott MC, Zarins B, Powell JW, Kenyon CD. Hamstring muscle strains in professional

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All rights reserved. ISSN Online 2577-8188

football players a 10-year review. Am J Sports Med. 2011;39: 843-50. https://doi.org/10.1177/0363546510394647.

5. Ekstrand J, Gillquist J, Möller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. Am J Sports Med. 1983;11: 63-7. https://doi.org/10.1177/036354658301100203.
6. Askling C, Saartok T, Thorstensson A. Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level. Br J Sports Med. 2006;40: 40-4. https://doi.org/10.1136/bjsm.2005.018879.
7. Gibbs NJ, Cross TM, Cameron M, Houang MT. The accuracy of MRI in predicting recovery and recurrence of acute grade one hamstring muscle strains within the same season in Australian Rules football players. J Sci Med Sport.2004;7(2):248-58. https://doi.org/10.1016/S1440-2440(04)80016-1.
8. Chan O, Del Buono A, Best TM, Maffulli N. Acute muscle strain injuries: a proposed new classification system. Knee Surg Sports Traumatol Arthrosc. 2012;20(11):2356-62. https://doi.org/10.1007/s00167-012-2118-z.
9. Morgan DL. New insights into the behavior of muscle during active lengthening. Biophys J. 1990;57: 209-21. https://doi.org/10.1016/S0006-3495(90)82524-8.
10. Schuermans J, Van Tiggelen D, Danneels L, Witvrouw E. Biceps femoris and semitendinosus—teammates or competitors? New insights into hamstring injury mechanisms in male football players: a muscle functional MRI study. Br J Sports Med. 2014;48: 1599-606. https://doi.org/10.1136/bjsports-2014-094017.
11. Sherry MA, Johnston TS, Heiderscheit BC. Rehabilitation of acute hamstring strain injuries. Clin Sports Med. 2015;34(2):263-84. https://doi.org/10.1016/j.csm.2014.12.009.
12. Dalton SL, Kerr ZY, Dompier TP. Epidemiology of hamstring strains in 25 NCAA sports in the 2009-2010 to 2013-2014 academic years. Am J Sports Med. 2015;43: 2671-9. https://doi.org/10.1177/0363546515599631.
13. Sherry MA, Best TM. A comparison of 2 rehabilitation programs in the treatment of acute hamstring strains. J Orhto Sports Phys Ther. 2004;34(3):116-25. https://doi.org/10.2519/jospt.2004.34.3.116.
14. Schneider-Kolsky ME, Hoving JL, Warren P, Connell DA. A comparison between clinical assessment and magnetic resonance imaging of acute hamstring injuries. Am J Sports Med. 2006; 34:1008-1015. https://doi.org/10.1177/0363546505283835.
15. O'donoghue DH. Treatment of injuries to athletes. Philadelphia, PA: WB Saunders Company; 1984.
16. Mueller-Wohlfahrt HW, Haensel L, Mithoefer K, Ekstrand J, English B, McNally S, Orchard J, van Dijk CN, Kerkhoffs GM, Schamasch P, Blottner D. Terminology and classification of muscle injuries in sport: a consensus statement. Br J Sports Med. 2012;47(6): 342-50. https://doi.org/10.1136/bjsports-2012-091448.
17. Weppler CH, Magnusson SP. Increasing muscle extensibility: a matter of increasing length or modifying sensation? Phys Ther. 2010;90: 438. https://doi.org/10.2522/ptj.20090012.
18. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. Clin Spine Surg. 1992;5: 383-9.

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19. Yeomans JS, Li L, Scott BW, Frankland PW. Tactile, acoustic and vestibular systems sum to elicit the startle reflex. Neurosci & Biobehav Rev. 2002;26: 1-1. https://doi.org/10.1016/S0149-7634(01)00057-4.
20. Noakes TD, Peltonen JE, Rusko HK. Evidence that a central governor regulates exercise performance during acute hypoxia and hyperoxia. J Exp Biol. 2001;204: 3225-34.
21. Sherrington CS. On reciprocal innervation of antagonistic muscles. Third note. J R Soc Med. 1896;60: 414-7. https://doi.org/10.1098/rspb.1907.0026.
22. Sharman MJ, Cresswell AG, Riek S. Proprioceptive neuromuscular facilitation stretching. Sports Med. 2006;36: 929-39. https://doi.org/10.2165/00007256-200636110-00002.
23. Iams J. What is the primal reflex release technique for pain relief? 2012. Available at http://www.theprrt.com/what-is-the-primal-reflex-release-technique-for-pain-relief.php. Accessed December 6 2016.
24. Hansberger BL, Baker RT, May J, Nasypany A. A novel approach to treating plantar fasciitis–effects of primal reflex release technique: a case series. Int J Sports Phys Ther. 2015;10(5): 690-9.
25. Hansen-Honeycutt J, Chapman EB, Nasypany A, Baker RT, May J. A clinical guide to the assessment and treatment of breathing pattern disorders in the physically active: Part 2, a case series. Int J Sports Phys Ther. 2016;11(6): 971-79.
26. Carnahan K. Inclusion of primal reflex release technique (PRRT) plan of care for shoulder pain: A case study. ND. Retrieved from http://theprrt.com/files/prrtpatient-case-study.pdf.
27. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole M. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain. 2001;94: 149-158.
28. Vela LI, Denegar C. The disablement in the physically active scale, part II: The psychometric properties of an outcomes scale for musculoskeletal injuries. J Athl Train. 2010;45: 630-641. https://dx.doi.org/10.4085%2F1062-6050-45.6.630.
29. Hamid MS, Ali MR, Yusof A. Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. J Phys Ther Sci. 2013;25: 957-61. https://dx.doi.org/10.1589%2Fjpts.25.957.
30. Reurink G, Goudswaard GJ, Oomen HG, Moen MH, Tol JL, Verhaar JA, Weir A. Reliability of the active and passive knee extension test in acute hamstring injuries. Am J Sports Med. 2013;41: 1757-61. https://doi.org/10.1177/0363546513490650.
31. Kendall FP, McCreary EK, Kendall HO. Muscles, Testing and Function: Testing and Function. Philadelphia, PA: Lippincott Williams and Wilkins; 1983.32.
32. Horn KK Jennings S Richardson G Vliet DV Hefford C Abbott JH. The patient-specific functional scale: Psychometrics, clinimetrics, and application as a clinical outcome measure. J Orhto Sports Phys Ther. 2012;42: 30-42. https://doi.org/10.2519/jospt.2012.3727.
33. Mason DL, Dickens V, Vail A. Rehabilitation for hamstring injuries. Cochrane Database Syst Rev. 2012;12:CD004575. https://doi.org/10.1002/14651858.CD004575.pub3.
34. Mendiguchia J, Brughelli M. A return-to-sport algorithm for acute hamstring injuries. Phys Ther Sport. 2011;12: 2-14. https://doi.org/10.1016/j.ptsp.2010.07.003.
35. Copland ST, Tipton JS, Fields KB. Evidence-based treatment of hamstring tears. Curr Sports Med Reports. 2009;8: 308-14. https://doi.org/10.1249/JSR.0b013e3181c1d6e1.

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36. Järvinen TA, Järvinen TL, Kääriäinen M, Äärimaa V, Vaittinen S, Kalimo H, Järvinen M. Muscle injuries: optimising recovery. Best Pract Res Clin Rheumatol. 2007;21: 317-31. https://doi.org/10.1016/j.berh.2006.12.004.
37. De Vos RJ, Reurink G, Goudswaard GJ, Moen MH, Weir A, Tol JL. Clinical findings just after return to play predict hamstring re-injury, but baseline MRI findings do not. Br J Sports Med. 2014;48: 1377-84. https://doi.org/10.1136/bjsports-2014-093737.
38. Wangensteen A, Tol JL, Witvrouw E, Van Linschoten R, Almusa E, Hamilton B, Bahr R. Hamstring reinjuries occur at the same location and early after return to sport: a descriptive study of MRI-confirmed reinjuries. Am J Sports Med. 2016;44: 2112-21. https://doi.org/10.1177/0363546516646086.
39. Kilcoyne KG, Dickens JF, Keblish D, Rue JP, Chronister R. Outcome of Grade I and II Hamstring Injuries in Intercollegiate Athletes A Novel Rehabilitation Protocol. Sports Health. 2011;3: 528-33. https://doi.org/10.1177/1941738111422044.
40. Ekstrand J, Askling C, Magnusson H, Mithoefer K. Return to play after thigh muscle injury in elite football players: implementation and validation of the Munich muscle injury classification. Br J Sports Med. 2013. https://doi.org/10.1136/bjsports-2012-092092.
41. Kingsley RE. Concise Text of Neuroscience. 2nd ed. Baltimore, MD: Lippincott Williams & Watkins; 2000. Motor systems III: The basal ganglia; 285–310.
42. Siegelbaum SA, Hudspeth AJ. Principles of neural science. Kandel ER, Schwartz JH, Jessell TM, editors. New York City, NY: McGraw-hill; 2000.
43. Turl SE, George KP. Adverse neural tension: a factor in repetitive hamstring strain? J Orhto Sports Phys Ther. 1998;27: 16-2. https://doi.org/10.2519/jospt.1998.27.1.16.

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