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Ulnar Collateral Ligament Reconstruction with Traditional Docking Compared to Novel Surgical Techniques

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Abstract

Background: Ulnar Collateral Ligament Reconstruction (UCLR) is a surgical procedure on one of the main ligaments that provides normal stability for the elbow joint against excessive valgus stress. Damage to this ligament is common in athletes performing overhead throwing activities, primarily baseball players, due to excessive valgus stress during the throwing motion. The most common form of treatment for this type of injury is reconstructive surgery of the ligament, especially if athletes wish to return to sport participation. This type of surgery is extremely invasive and requires extensive post-operative rehabilitation in order to facilitate return to play. To date, many surgical techniques have been proposed and evaluated, but there are no conclusive comparison studies on patient outcomes following UCLR. **Purpose:** The purpose of this paper is to analyze previous studies on UCLR techniques and determine if there is a single superior surgical method leading to improved biomechanical outcomes and decreased failure measures. Our focused clinical question was identifying if the traditional docking technique compared to novel docking techniques during UCLR superior in relation to biomechanical outcomes and failure measures in cadaveric tissue. **Methodology:** The study design in this paper is a critically appraised topic. Various scholarly databases such as PubMed, MEDLINE and SportDiscus were utilized to search for studies related to UCLR surgical techniques. After an initial search, a list of fifteen relevant studies were identified. Each study was then scrutinized and evaluated to meet predetermined inclusion criteria and a minimum score of 6/9 on the PEDro scale. All studies not meeting these requirements were excluded. This left a total of five articles which were then used to answer the clinical question for this paper. The inclusion criteria involved meeting a cadaveric age of 16-60 y, objective measures of valgus testing, angular displacement, stiffness and modes of failure as post-operative outcomes. Further, we included studies that had a minimum of seven cadaver pairs tested, and studies were required to compare traditional docking to at least one novel technique. **Results:** All five studies involved compared at least one novel surgical technique to the docking technique. Four studies found no significant overall difference between the native and reconstructed states of any surgical technique. One study found no overall significant difference, but did identify slight differences in biomechanical properties. **Discussion:** All conclusions from individual studies demonstrate comparable findings between all UCLR techniques. Biomechanics, kinematics and failure modes in the acute stages following surgery in cadavers are similar between UCLR techniques. Despite all that has been done, additional research is still necessary to determine a superior surgical technique.

Clinical Scenario

Interest in ulnar collateral ligament (UCL) injuries and their treatment has spiked due to the recent increasing epidemic of injury among youth and adults involved in throwing sports[1] One epidemiological study, in particular, reported that between 2007 and 2011 there was an increase in UCLR of 4.2%.[3] Patients aged 15-19 years old accounted for the most surgeries, with a 9.12% increase per year.[26] The 20-24 year old age group was the second most common age group requiring reconstructive surgery, with it performed more often in southern states.[3] UCL injuries are progressive injuries with initial signs and symptoms of pain and soreness in localized areas. If stress to the elbow joint continues, eventually, partial tears, or complete tears, may occur.[1] Towards the latter end of this injury progression after repetitive stress to the joint, reconstructive surgery is often the method of repairing a torn ligament. When the UCL becomes partially or fully torn from the bones surrounding it, there is an extreme decrease in stability of the elbow joint. In athletes, this often manifests itself as a decrease in throwing velocity or performance, numbness, and tingling in the affected area.[1] Athletes often describe it as feeling as if the ball you are throwing is not going where you intended it. These are all common issues in patients with UCL damage or instability. Individuals presenting with these issues should not continue activity in their sport for fear of further damage to the ligament or surrounding tissues. Due to these complications, surgery is often necessary for athletes to return to their sport. UCLR is a great option for this population. This surgery entails partial reconstruction of the elbow joint that utilizes a completely new ligament in place of the injured ligament. All reconstructive options restore the elbow anatomy to how it was before the injury and result in significant increases in sport performance.

UCLR surgical techniques have continued to evolve since the origin of the gold standard, the Jobe technique, which was introduced in 1974.[8,9] While there continues to be question and debate over which surgical method is most effective in repairing the UCL and restoring native biomechanical properties, the studies outlined in this paper aim to compare common surgical techniques to begin identifying a possible superior method. All studies examined in this paper utilize cadaveric tissue to test surgical techniques and subsequent biomechanical testing. While working with cadavers does have limitations, it is an essential first step when looking at a novel surgical approach. Cadavers ensure physicians fully understand what they are doing before performing reconstruction in a live population, along with both positive and negative outcomes of various procedures. It is near impossible to test novel surgical methods and perform tests of biomechanical properties such as load to failure testing, modes of failure and torsional torque and stiffness in living individuals. The use of cadavers combats this by allowing surgeons to perform and perfect techniques, allowing only the best to be implemented in the human population.

Focused Clinical Question:

Is the traditional docking technique compared to novel docking techniques during UCLR superior in relation to biomechanical outcomes and failure measures in cadaveric tissue?

Summary of Best Evidence, and Key Findings:

- The literature search was conducted to limit studies with level 2b evidence or higher that used biomechanics and kinematics to compare various surgical methods in correcting UCL damage/injury.
- The Oxford Centre for Evidence-based Medicine categorizes different studies based on both what the studies are looking at (i.e. therapy, prognosis, diagnosis, etc.) and their level of evidence. Level of evidence ranges from a 1a, being superior, to a 5, being poorest. All of the studies in this paper were found to be a level 2b indicating that they were individual cohort studies with low quality randomized controlled trials and less than 80% follow-up.
- All studies were controlled laboratory studies that utilized cadavers with an age range of 16-60 and no known history of previous damage/injury to the ligament or metabolic diseases/disorders.
- One study compared the TightRope technique to traditional ulnar bone tunnels used during docking.[6] Another study compared the Jobe technique to the ZipLoop plus humeral docking technique.[9] A third study compared the traditional docking technique to that of the newer docking plus.[8] A fourth study compared the docking technique to the novel GraftLink method.[7] The final study compared an ulnar suspension fixation to currently available techniques, such as those explained above.[5] An explanation of each surgical method can be seen in Table 1.
- Several studies found that each of the newer reconstruction techniques restored biomechanics and kinematics similar to that of both the original docking technique and the native elbow. [5,6,7,9] One study found that the docking plus technique produced greater ligament stiffness and demonstrates a higher failure moment immediately after reconstruction than the docking technique alone.[8]
- An explanation of surgical techniques can be found in Table 1.

Clinical Bottom Line

All conclusions from individual studies demonstrate comparable outcomes following all UCLR techniques. Biomechanics, kinematics and failure in the acute hours following surgery in cadavers are similar between UCLR techniques.

Strength of Recommendation: Using the strength of recommendation taxonomy, there is Level 1 Evidence suggesting comparable acute outcomes following UCLR in patients 16-60 years of age.[2]

Search Strategy

Terms Used to Guide Search Strategy:

- **P**atient/Client Group: *General population*
- **I**ntervention: *ulnar collateral ligament reconstruction, original Jobe technique, traditional docking*
- **C**omparison: *Novel reconstruction techniques, other surgical methods*
- **O**utcomes: *Biomechanical evaluation, kinetic and kinematic markers, reconstruction failure*

Table 1. Explanation of Surgical Techniques

	Traditional Docking	TightRope	ZipLoop Ulnar Fixation	Docking Plus	GraftLink	Suspension Button Fixation
Explanation of Method	One continuous double strand graft is looped through converging ulnar bone tunnels and docked to different humeral tunnels. The two graft ends are then tied with a suture across a bone bridge that attaches from the distal end of the humerus to the proximal end of the radius or ulna.[12]	This technique offers ulnar fixation completely within the native UCL footprint and on the ulna[3]A guide pin is used to create an ulnar socket. One end of the single strand graft is whipstitched, threaded through an Arthrex device and the TightRope (TR) is advanced through the socket. The whipstitched end is passed through the humeral socket and the TightRope side is tensioned to fully seat the graft in the socket before final sutures are tied.[3]	A guide pin is used to create a tunnel to the distal cortex of the ulna. An osseous tunnel is created in the humerus. Two drill holes are created in the humerus and directed towards the osseous tunnel. A bone bridge is maintained between the tunnels. Both graft ends are then whipstitched and docked to the humerus by suture. Sutures are then pulled tight and tied over the bone bridge.[4]	Two holes are created at the insertion of the anterior bundle. A closed suture is passed through an ulnar tunnel. A socket is created in the humerus with 4 additional holes from the medial epicondyle converging into the socket. The graft is passed through the ulnar tunnel and sutured to the longer end. Suture ends are threaded through the humeral tunnel and held tight. The non-tensioned side is passed through various tunnels, then tied together with the tensioned side and reinforced.[9]	Guide pin is used to create an ulnar socket and hole in the lateral ulnar cortex. An additional guide pin is placed on the humeral attachment. Sutures are passed around each end of the graft to prepare it, and set aside. The graft is then passed through various sockets and tunnels of the elbow before being tensioned to fully position the graft in the socket. Sutures are then tied over both the graft, and additional sutures on each limb for reinforcement.[12]	Conventional Tommy John tunnels are created in the ulna. The bone bridge is then intentionally broken. A hole is created in the lateral ulnar cortex along with an ulnar socket. A humeral tunnel is then drilled. Smaller drill holes are created in the medial epicondyle and converged into the humeral tunnel. One end of the graft is looped and sutured for use in the ulnar tunnel. The graft is pulled into the ulnar socket and held under tension. A knot pusher is inserted into the ulnar tunnel to tie down the loop within the socket. Lastly, a suture is used to pass the remaining graft through the humeral tunnel and the sutured ends are tied with the graft tensioned.[16]

Sources of Evidence Searched

- PubMed
- MEDLINE
- SportDiscus (Ebsco)

Inclusion and Exclusion Criteria

Inclusion

- 16-60 year old age group
- Post-surgical testing methods that utilized biomechanical properties for evaluation, failure testing (both load to failure and mode of failure), torsional stiffness and angular displacement
- Studies were at least eight years old or newer
- A minimum of 7 cadaver pairs tested (14 single cadavers total, with 7 cadaver arms randomized into each surgical treatment group)
- Comparing the traditional docking technique to any novel surgical technique for UCLR
- Minimum level of 2b evidence, which included the studies being considered a randomized-controlled trial
- PEDro score of at least 6/9

Exclusion

- Patient population older than 60 years of age
- Papers published before 2010
- Level of evidence below 2b
- Less than 14 cadavers utilized in the study
- Trials that did not randomly allocate cadavers to a surgical method group
- Trials that did utilize the docking method as a primary comparison surgical technique.
- PEDro score that was under 6/9

Results of Search

In an initial search, a total of fifteen studies were identified as potentially useful. After narrowing down inclusion and exclusion criteria, however, a total of five studies were found and are included in this paper.[5,6,7,8,9] All of the studies were scrutinized using the PEDro scale. In this review, only 9 out of the 10 PEDro criteria were used to appraise articles. One criteria of the scale determines if there was blinding of subjects involved. This one was removed because all of the studies utilized cadavers, and you cannot blind cadavers. This made the best possible score for the research papers a 9/9, with all articles used in this review scoring at least a 6/9. All included studies are further explained in Table 2.

Table 2. Characteristics of Included Studies

Article:	Lynch et al (2013)	Morgan et al (2010)	McGraw et al (2012)	Lynch et al (2013)	Lee et al (2010)
Participants:	Seven pairs of cadaver arms with a mean age of 44.71 +/- 15.8 with no history of musculoskeletal disorder.	Eight matched cadaver elbows with a mean age of 38 years and no previous elbow injury.	Ten pairs of cadaver elbows with a mean age of 52 +/- six years.	Seven matched pairs of cadaver arms with a mean age of 56.4 +/- 5.8 years. The specimens had no history of musculoskeletal or metabolic disorders, fractures, dislocations or ligament injuries.	Nine matched pairs of cadaver elbows with a mean age of 45 years.
Intervention:	First, native biomechanics were tested on all cadavers to assess a baseline. Each extremity was then randomized into the docking (DO) or TightRope (TR) reconstruction groups.	One specimen from each pair was randomized into either the ZipLoop group of the Jobe technique group. The other specimen of the pair was placed in the opposite group.	One elbow from each pair was randomized to either the docking (DO) or docking plus (DP) technique. Repair type was alternated between left and right elbow.	Specimens within a matched pair were randomized to either the docking group (DO) or the GraftLink group (GL). All reconstruction were performed by the same fellowship-trained orthopedic surgeon.	One elbow from each matched pair was randomly selected for reconstruction and kinematic testing, while the contralateral elbow was used as a control for the same testing protocol.
Outcomes:	Primary outcomes included kinematic testing and failure testing. During kinematic testing, all specimens, both native and reconstructed, were tested at multiple flexion angles. During failure testing, all reconstructed specimens were preloaded at the same level and rotated in the valgus direction until failure.	Outcomes included valgus displacement, change in valgus angle between intact and reconstructed groups, load-to-failure testing and mode of failure for each group.	All native specimens were testing for failure before reconstruction and after reconstruction occurred. Load-to-failure rate was recorded again along with mode of failure.	Specimens within a matched pair were randomized to either the docking group (DO) or the GraftLink (GL). All reconstructions were performed by the same fellowship-trained orthopaedic surgeons.	Kinematic testing was performed on the native elbow. Following UCL reconstruction, the same testing was performed for comparison. Load-to-failure testing was then determined.

Table 2. Characteristics of Included Studies Continued

Article:	Lynch et al (2013)	Morgan et al (2010)	McGraw et al (2012)	Lynch et al (2013)	Lee et al (2010)
Main Findings:	There was no significant difference between the DO and TR groups for either angular displacement, peak torques, torsional torque and stiffness.	For both reconstructions, the greatest valgus angle increase occurred at 8 degrees of flexion. Under non-loaded kinematic testing all differences were due to a surgical overcorrection under loading conditions, results at all angles except 20 degrees, were similar between both groups and the intact ligament. Finally, humeral tunnel pullout was the mode of failure for all but one specimen for which it was ulnar fracture.	Modes of failure for the native group included; midsubstance ruptures (9/10) ulnar avulsions (9/10), and humeral avulsions (2/10). DO modes of failure were; suture pullout (4/10), suture rupture (1/10), graft rupture (4/10) and humeral fracture (1/10). DP modes of failure were; suture rupture (5/10), suture pullout (3/10), midsubstance graft rupture (1/10) and ulnar fracture (1/10). Both average moment of failure and stiffness was greatest for the native ligament, and greater for the DP group than the DO group.	Results from the testing methods show equivalence between both reconstruction types during suture pull-out testing. Additionally, there was no difference in stiffness, ultimate failure load, or displacement at failure when reconstruction groups were compared directly. The main difference between the two reconstruction groups were mode of failure. For the DO group, tendon-suture interface on the humeral side was most common, while the GL group had a wide variability in failure mode.	Load-to-failure testing showed significantly less reconstructed elbow. There was no difference in angular displacement or valgus angle for certain degrees of flexion. When failure modes were identified, failures due to humeral fixation was most common, with various other failure modes still occurring.
Level of Evidence:	2b	2b	2b	2b	2b
Validity Score:	6/9 on PEDRo	6/9 on PEDRo	6/9 on PEDRo	6/9 on PEDRo	6/9 on PEDRo
Conclusion:	Both DO and TR groups restore joint kinematics under low loading conditions. The TR technique does not lower strength or stiffness compared to the DO group and might be less invasive. Both reconstructions restore joint stability, with the DO group restoring greatest.	Close restoration of joint kinematics were recorded for both reconstruction groups. Both techniques are biomechanically equivalent and restore valgus stability similar to that of the native UCL.	The DP technique was significantly greater than the DO technique. It could be that the DP group could be advantageous for healing and increasing stiffness due to the use of the entire tendon graft, unlike the DO technique.	The results suggest that both techniques restore kinematics to a similar state of the native UCL. The DO group was found to fail at higher torques and exhibit greater laxity and UTJ gapping, therefore, the GL technique should be considered a reasonable option for UCL reconstruction.	The study proves that various elbow kinematics were restored upon reconstruction. This novel technique using a suspension button fixation may be considered useful and equivalent in a primary reconstruction or revision setting.

Best Evidence

The final five studies included in this paper were the best overall matches for our particular inclusion and exclusion criteria, based on surgical methods and post-surgical assessments (Table 2).

Implications for Practice, Education and Future Research

UCL injuries lead to pain, discomfort, and decreased strength, performance and endurance.[6] Currently, there are many different techniques available for UCLR. With the prevalence of UCL damage and injury continuing to rise, finding the most appropriate and effective surgical technique is imperative. The superior technique should aid in reducing the chances of revision surgery and restore appropriate post-surgical biomechanics. This should lead to the reestablishment of the individual's pre-operative function in both daily life and sports. While all of the surgical methods compared in this paper appear comparable based on conclusions from individual papers, there are limitations to every method, and elements that need continued study before definitive conclusions can be identified.

One of the main causes of concern when looking at UCLR cadaveric studies is the large variance in age. All studies utilized did have specimens ranging from 16-60 years of age; however, this is not an accurate representation of the patient population typically undergoing UCLR.[5,7,8] Additional factors such as bone mineral density, medical/surgical history and postmortem storage time are possible components of discrepancy within the studies because of the use of cadavers.[3] Controls such as matched pairs, and repeated-measures statistics enable accurate comparison of techniques, and many studies used these or additional measures to ensure adequate comparison.[7]

Another implication of this research is the use of tendons within surgical methods. All UCLR techniques primarily utilize either the Palmaris Longus tendon of the forearm, or the biceps femoris tendon of the hamstring, from the posterior aspect of the individual's thigh. Two studies utilized fresh bovine extensor tendons in order to standardize biomechanical properties of the tendon graft.[6,7] A second study utilized gracilis allografts,[9] and yet another study used the flexor digitorum superficialis in half of their cadavers when the Palmaris Longus tendon was not available.[8] While it is important to standardize surgical techniques as much as possible for comparison, not using primary tendons utilized during live human reconstructions could result in variations of the reported data, or discrepancies in live humans.[8]

Moreover, the UCL experiences many different loading types during both simple activities of daily living, and high-performance sport and exercise. This implies that multiple loading directions and environments should be tested in the cadaveric state for accurate comparisons, but one study, in particular, did not do this.[6] This study utilized only a single loading rate.[6] Related to the single loading environment limitation is that of the loading force. In one particular study, there was only a 3-N·m (just over 2 pounds) load place on the elbow.[9] This is roughly equivalent to loads seen during the early stages of the rehabilitation period. After initial range of motion goals are met and the patient begins light weighted ball exercises, shoulder and forearm strengthening. Although important, these loads are significantly less than loads applied during overhead throwing activities.[9] Similar to this, another study reported conducting two load-to-failure tests on the same specimen initially and after receiving surgery.[8] The authors noted it is not clear how much damage was done to surround tissue and the joint structure itself during stress maneuvers in this study.[8]

Yet another limitation to these cadaveric studies is the absence of post-surgical healing time.[5] These studies examined only the acute postoperative state. If graft-bone healing occurred before post-operative testing, as it does in live populations, it may have resulted in higher maximum load failures and less tunnel egress for many of the reconstruction techniques.[9]

A final limitation is the lack of use of a consistent testing apparatus. This particular system enabled the adjustment of elbow flexion and accounted for elbow carrying angle, but notes that true kinematics might be better assessed with a dynamic elbow simulator or with a 3D motion analysis system.[7]

Future clinical and laboratory studies are necessary to continue comparison of different UCLR surgical techniques to decide if there is a superior method.

Clinical Application

Based on the research conducted or this paper, no known studies were published regarding limitations to any of these surgical techniques. Because of this, it is left to other factors such as individual characteristics and the post-operative rehabilitation program to understand the healing process and outcomes of UCLR and the particular surgical techniques discussed in this paper. Although the type of surgical technique itself is extremely important when performing UCLR, the post-operative rehabilitation protocol is equally as important. There is still much discussion on what constitutes the best rehabilitation program for a patient following UCLR. Factors such as the extent of damage at the elbow and length of time from the injury until the surgery are just a few things that need to be considered when creating an individual's rehabilitation program.[10] Most post-operative rehabilitation time frames are twelve to fourteen months. The patient performs simple range of motion (ROM) stretches and strengthening exercises for the first few months, and eventually progresses to a throwing program. Again, individual differences need to be considered when determining the length of time a patient needs to stay in phase one of the rehabilitation program before moving to phase two, the throwing portion. There is much debate from clinicians on this factor as well when it comes to determining when the patient is ready to progress to the next stage of the rehabilitation program. Having a post-op patient throw too early could significantly increase the likelihood of revision surgery, or a player's inability to return to the sport. Conversely, throwing a player too late could lead to significant setbacks in their daily life or future athletic career.

Return to Play/Return to Sport

With such an invasive surgery, the patient must have confidence that they will be able to return to their sport again. This evokes the question of which, if any, surgical technique predicts/sees a greater return to play/return to sport (RTP/RTS) percentage, and what actually constitutes a patients readiness to return to their sport.

As far as RTS is concerned, there is no one governing body giving surgeons and clinicians an exact answer to when their patient is able to return to their sport. It is a multi-step progression consisting of performance, practice and play sequence. Once phase one of the rehab program is completed, this is the performance phase, the patient moves on to phase two, the throwing program. This phase incorporates both practice and play sequence. Once the physical therapist or athletic trainer administering the post-operative rehab feels the patient is able to return to competitive play, they, along with the primary physician, clear the patient for play. It is imperative to note that this is not a one size fits all protocol. As mentioned previously, every individual progresses at different rates, and those individual differences must be taken into strong consideration when determining when the patient is ready to return to play again.

Other measurements such as the use of KJOC scores (Kerlan-Jobe Orthopedic Clinic) can be used to aid in determining a player's readiness to return to play. This is a questionnaire often utilized at various levels of sport, primarily in baseball, to determine symptoms of discomfort in player's elbows. A score of above 90 is typical for a healthy athlete.[4]

In addition to these clinician centered outcomes, functional outcomes – or patient centered outcomes – are equally, if not more, important. Post-operative individuals may meet the physical therapist or athletic trainer's goals for range of motion, strength and performance, but the patient needs to feel confident if their outcomes and progression in rehabilitation in order to be successful upon returning to their sport.

Works Cited

Bruce, Jeremy R., and James R. Andrews. "Ulnar Collateral Ligament Injuries in the Throwing Athlete." *Journal of the American Academy of Orthopedic Surgeons*, vol. 22, no. 5, May 2014, pp. 315–325., dx.doi.org/10.5435/JAAOS-22-05-315.

Ebell, Mark H., et al. "Strength of Recommendation Taxonomy (SORT): A Patient-Centered Approach to Grading Evidence in the Medical Literature." *American Family Physician*, 1 Feb. 2004, www.aaft.org/afp.

Erickson, Brandon J., et al. "Trends in Medial Ulnar Collateral Ligament Reconstruction in the United States." *The American Journal of Sports Medicine*, vol. 43, no. 7, 2015, doi:10.1177/0363546515580304.

Kraeutler, MJ, et al. "Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Scores in Asymptomatic Professional Baseball Pitchers." *Journal of Shoulder and Elbow Surgery*, vol. 22, no. 3, Mar. 2013, pp. 329–332., doi:10.1016/j.jse.2012.02.010.

Lee, Gregory H., et al. "Revision Ulnar Collateral Ligament Reconstruction Using a Suspension Button Fixation Technique." *The American Journal of Sports Medicine*, vol. 38, no. 3, 2010, doi:10.1177/0363546509350109.

Lynch, Jamie L., et al. "Biomechanical Evaluation of the TightRope Versus Traditional Docking Ulnar Collateral Ligament Reconstruction Technique." *The American Journal of Sports Medicine*, vol. 41, no. 5, 2013, doi:10.1177/0363546513482567.

Lynch, Jamie L., et al. "The GraftLink Ulnar Collateral Ligament Reconstruction." *The American Journal of Sports Medicine*, vol. 41, no. 10, 2013, doi:10.1177/0363546513498999.

McGraw, Molly A., et al. "Biomechanical Evaluation of the Docking Plus Ulnar Collateral Ligament Reconstruction Technique Compared With the Docking Technique." *The American Journal of Sports Medicine*, vol. 41, no. 2, 2012, doi:10.1177/0363546512466375.

Morgan, Robert J., et al. “A Biomechanical Evaluation of Ulnar Collateral Ligament Reconstruction Using a Novel Technique for Ulnar-Sided Fixation.” *The American Journal of Sports Medicine*, vol. 38, no. 7, 2010, 10.1177/0363546510363463.

Seto, Judy L., et al. “Rehabilitation Following Ulnar Collateral Ligament Reconstruction of Athletes.” *The Journal of Orthopaedic and Sports Physical Therapy*, vol. 14, no. 3, Sept. 1991, pp. 100–105.