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Rehabilitation of a PCL reconstruction : a case study

Ashley Vogds
San Jose State University

REHABILITATION OF A PCL RECONSTRUCTION: A CASE STUDY

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Ashley Vogds

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REHABILITATION OF A PCL RECONSTRUCTION: A CASE STUDY

by

Ashley Vogds

APPROVED FOR THE DEPARTMENT OF KINESIOLOGY

3/16/08

Leamor Kahanov, Ed.D, ATC, Department of Kinesiology   Date

3/16/09

Emily H. Wughalter, Ed.D. Department of Kinesiology   Date

3/16/09

Holly Brown, M.A., ATC, Department of Kinesiology   Date

APPROVED FOR THE UNIVERSITY

7/1/09

Associate Dean   Office of Graduate Studies and Research   Date

ABSTRACT

REHABILITATION OF A PCL RECONSTRUCTION: A CASE STUDY

by Ashley Vogds

Due to the lack of literature regarding the posterior cruciate ligament (PCL) and surgical/rehabilitation outcomes a consistent prescription is unknown. Therefore practitioner application of rehabilitation, as well as post-surgical treatment, is not standardized. Because of the unknown outcomes with PCL injuries and surgeries, and a lack of investigation on a broad based scale, a case study may aid in understanding some of the intricacies in PCL surgery and rehabilitation. Thus, the purpose of this study was to detail a PCL surgical and rehabilitation case study of a 24- year old male senior collegiate football player who presented with unique complications post surgery and during rehabilitation. The presentation of the athlete's complications include tibial screw transfixation pain, prolonged healing of incisions, and residual laxity of the knee joint. This case study may aid in further providing information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation.

ACKNOWLEDGEMENTS

The achievement of this document would not have been possible without the guidance of my committee members, Dr. Leamor Kahanov, Dr. Emily Wughalter, and Holly Brown. In addition to San Jose State University staff I would like to thank my co-workers at Menlo College for reviewing my multiple drafts and their humor throughout my case study research experience. Additionally I would like to thank Dr. Donahue for viewing the manuscript and helping me understand surgical concepts. I would also like to specially thank my aunt and uncle who have generously helped me reach my goal of completing my master degree. Also I would like to extend a thank you to my mom and my grandfather for their encouragement in completion of my school studies.

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Chapter 1

INTRODUCTION

Knee injuries account for 15-50% of all sports injuries, with 40% of knee injuries involving the ligaments. Knee injury research has focused primarily on the Anterior Cruciate Ligament (ACL), emphasizing a lack of understanding of other ligamentous injuries (Margeritini, Rihn, Musahl, Mariani & Jarner, 2002). Posterior Cruciate Ligament (PCL) rupture research is approximately 10 years behind research of the ACL (Johnson, 2003), yet PCL integrity is important as a primary knee stabilizer preventing posterior translation of the tibia on the femur. Knee injury research and popularity has primarily focused on the ACL; this may be because athletes can still function at a high level with an isolated PCL rupture (Margheritini, et al., 2002). The PCL, compared to the ACL, has a secondary role in limiting the amount of external varus and valgus restraint of the knee joint (Lopes et al., 2008, Margheritini, et al., 2002). In addition to these functions, the PCL has twice the strength of the ACL, yet an understanding of the biomechanical role, surgical repair, treatment and rehabilitation is lacking (Margheritini, et al., 2002). The purpose of this study will be to provide information about a specific PCL injury regarding surgical choice, rehabilitation, and complications.

PCL injuries commonly occur in car accidents when the passenger is sitting in the front seat with bent knees (at or around 90 degrees); the driver may abruptly apply the brakes forcing the passenger forward into the dash board. The force of the impact causes the tibia to be translated posteriorly on the femur, possibly causing the PCL to tear (Petrigliano & McAllister, 2006). In sport, the same type of trauma occurs to cause injury whereby the PCL is torn by landing on a bent knee with an anterior force on the proximal portion of the tibia, the foot is also planter flexed (Petrigliano & McAllister). This biomechanical situation places the PCL in an elongated taut position which is more likely to rupture.

PCL injury most commonly occurs in football; however, it is important to consider occurrence in all sports (Petrigliano & McAllister, 2006). The National Hockey League (NHL) has an occurrence rate of one rupture every three years for every team in the league (Margheritini, et al., 2002). Soccer and basketball programs have a PCL rupture incidence rate of 2-4% for all knee injuries (Margheritini, et al.). The National Football League (NFL) pre draft examination discovers 4 to 6 players per year with a PCL tear, which is approximately less than 2% of the draft population. The fact that the players made the draft and were competing for a position on the roster indicates that function is possible without an intact PCL, yet secondary injury and morbidity is unknown (Margheritini, et al.). Therefore, further examination to understand the mechanics of PCL deficient individuals, athlete's ability to continue activity with minimal deficit, secondary injury, and the efficacy of surgical reconstruction is warranted.

Due to inconclusive literature regarding PCLs and surgical/rehabilitation outcomes, a consistent prescription is unknown. Therefore, practitioner application of rehabilitation, as well as post-surgical treatment is not standardized. Currently unknown outcomes regarding PCL injuries and surgeries exist primarily due to a lack of investigation on a broad based scale. A case study may therefore aid in understanding some of the intricacies in PCL surgery and rehabilitation. The purpose of this study is to detail a PCL surgical and rehabilitation case study to further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation.

The information gathered for this research was written with the intent to submit an article for publication to the *Journal of Athletic Training* (Appendix B). The article is presented in Chapter 2 of this thesis and contains an abstract, texts, references, and legends and figures per the *Journal of Athletic Training's* requirements. Within the abstract the following should be present: objective, background, differential diagnosis, treatment, uniqueness, conclusions and keywords. This particular case study examines the common PCL mechanism of injury where the athlete landed on a bent knee while diving for a football pass. The orthopedic surgeon recommended surgical repair of the PCL using the tibial tunnel technique. Approximately one month post surgery, the athlete developed an abnormal posterior tibial translation on his affected leg when compared bilaterally. In addition, the athlete had a complication with prolonged incision healing, and tibial screw pain. Due to knee pain development and effusion present, the athlete began to wear a valgus unloader brace that seemed to control pain symptoms. The athlete incurred a prolonged rehabilitation as well as unusual complications. After 11 months, the athlete was able to play in the 2008 football season symptom free; he is currently pursuing a career in football.

The final chapter contains the extended support material that was originally the thesis proposal document. The extended support material includes all three sections of the proposal document, including an introduction chapter, a literature review chapter, and a methods chapter. Following Chapter 3 are the appendices that include human subjects-institutional review board approval (Appendix A) and the *Journal of Athletic Training* author's guide (Appendix B).

Due to inconclusive research, determination of how to best treat a ruptured PCL is absent. Residual laxity outcomes should be examined to identify reasons as to the occurrence, possible contributions to laxity based on the surgical technique, post surgical rehabilitation, or other unidentified variables. Therefore, a case study that outlines potential complications may lend insight to research regarding surgical technique and clinical outcomes of surgical versus non surgical patients, and a clearer understanding of optimal rehabilitation and treatment techniques.

Chapter 2

JOURNAL ARTICLE

Rehabilitation of a PCL Reconstruction: A Case Study

Ashley R. Vogds, Leamor Kahanov, Emily H. Wughalter, Holly Brown

San Jose State University, San Jose, CA

Address correspondence to Ashley R. Vogds 2588 Dumbarton Ave San Jose CA, 95124
Address email to vogds3546@hotmail.com

Objective: To present a case study of a 24- year old male football player who ruptured his posterior cruciate ligament (PCL) while receiving a pass. The research will further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation.

Background: In athletics, PCL rupture occurs most commonly in football but also transpires in hockey, soccer, and basketball. Athletes may be asymptomatic after a PCL rupture and able to continue to participate, while others experience more severe symptoms resulting in surgical repair. The lack of studies detailing the results of surgery versus nonsurgical treatment precludes practitioners from providing an optimal or standardized treatment routine.

Differential Diagnosis: Posterior lateral corner, lateral meniscus tear.

Treatment: The PCL of this athlete was repaired using the tibial tunnel surgical technique. An Achilles allograft was used for the replacement ligament. Rehabilitation was performed under the direction of a certified athletic trainer and a physical therapist. The rehabilitation consisted of range of motion gains, followed by strength, proprioception, stability, cardiovascular exercises and, lastly, agility exercises. **Uniqueness:** Surgical repair of a PCL is not usually the first option of treatment; however, this athlete opted to have the ligament surgically repaired. A month later the athlete developed posterior residual joint laxity. The athlete also had consistent tibial screw pain and was directed to wear a valgus unloader brace for symptoms of pain and medial knee effusion.

Conclusions: After referring to other outcome studies residual laxity was a common finding in surgically repaired ligaments. However, valgus unloader brace use was not a common treatment course for people with knee pain. Future studies should focus on PCL surgical options and rehabilitation on a larger population so optimal treatment protocols can be developed.

Key Words: Surgery, joint laxity, rehabilitation

INTRODUCTION

PCL injuries have been reported to account from 3.4% of the knee ligament injuries, to as high as 16-20%.[1] Due to a lack of outcomes research on treatment and surgical options for the PCL deficient knee, a standard and/or optimal treatment protocol involving surgical and rehabilitative decisions are unknown.[2] Therefore, practitioner application of rehabilitation, as well as post-surgical treatment are not consistent. The unknown outcomes regarding PCL injuries and surgeries, and a lack of investigation on a broad based scale, a case study may aid in understanding some of the intricacies in PCL surgery and rehabilitation.

The knee accounts for 15-50% of all sports injuries with 40% of these injuries involving the ligaments of the knee.[3] Knee injury research and popularity has typically focused on the anterior cruciate ligament (ACL), possibly because a rupture of the ACL may cause more disabling symptoms than an isolated PCL rupture. The purpose of this study was to detail a PCL surgical and rehabilitation case study of a 24-year old male senior collegiate football player who presented with complications post surgery and during rehabilitation. This case study may aid in further providing information regarding treatment options, surgical procedures and potential complications encountered in rehabilitation.

CASE REPORT

Upon human subject review and approval, the patient was asked permission to participate in the study two months post surgery and agreed. The patient also provided consent to the researcher for access to medical records including: orthopedic notes, surgical reports, diagnostic reports, x-ray and Magnetic Resonance Imagining (MRI) films.

The 24- year old male senior football player injured his PCL in the beginning of October 2007. The patient jumped off the ground to catch the football and landed on the proximal tibia while the knee was flexed.

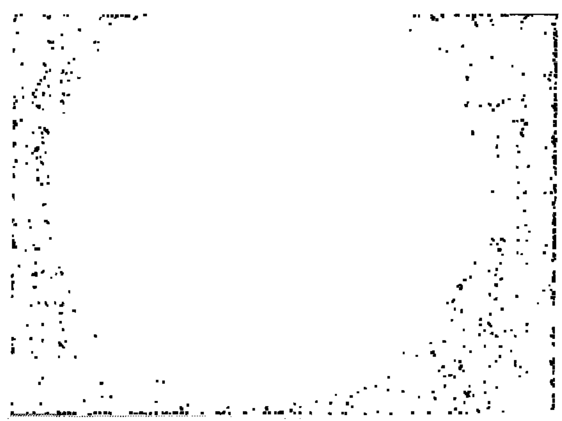

Figure 1. Arthroscopy of a PCL rupture

The athlete was evaluated by a certified athletic trainer (ATC) immediately after injury on the field and was also evaluated by an orthopedic surgeon 2 days post injury at a scheduled appointment. Special tests including Lachman's, posterior drawer, lateral shift, and McMurray's were preformed indicating only the PCL was damaged with no additional structural damage such as the ACL or lateral corner and meniscus involvement. An MRI was conducted 2 days post injury which was the same day as the orthopedic visit due to positive findings with the clinical examination. The MRI displayed a PCL rupture (Figure 1). The orthopedist suggested that a surgical repair may be best due to the patient's discomfort and desire to continue athletic activities.

Surgical arthroscopic exploration indicated no other structures were damaged. The athlete received allograft tibial tunnel surgical treatment 8 days post injury. Tissue healing for the first 4 weeks and light rehabilitation were normal. Prolonged incision healing was the first complication noted by the ATC. The incisions were red and swollen, and a clear thick exudate was visible at the incision sites. Keflex was prescribed to treat infection 4 weeks post surgery; due to this setback the pool was not utilized to facilitate gait and range of motion exercises. In addition to the infection, unexpected complications occurred during his rehabilitation 7 weeks after the surgical treatment. Complications included tibial screw transfixation pain, prolonged incision healing, and residual laxity.

Before the laxity was discovered the first 7 weeks progressed normally through range of motion, and strength protocols as directed by the orthopedist, the athlete was compliant. Range of motion exercises were not instituted until 2 weeks post surgery. Knee flexion exercises were instituted at the beginning of 3 weeks and his brace was locked at 0 degrees during activities of daily living.

One month after the surgery date the postoperative brace was unlocked and the athlete had unlimited range of motion; however, no open chain exercises, running, or jumping was permitted. Closed kinetic chain exercises began 6 weeks post surgery. Forty-nine days after surgery, a posterior laxity was discovered. The athlete reported to rehabilitation stating he could translate his own tibia posteriorly, and upon examination he had a positive posterior drawer. The athlete's orthopedist was contacted and an immediate appointment was made. The surgeon ordered the athlete to wear his post surgical brace locked at 0° for one week. Flexion was to be avoided for that week. The orthopedist aspirated 30cc of fluid from the knee and then injected a steroid.

Early December 2008, 3 months after the initial injury, the athlete began to have locking symptoms; he had to bend and straighten his own knee multiple times to achieve normal range of motion and activity when this symptom occurred. An observational philosophy was taken by the orthopedist pertaining to the symptoms, so no further limitations were made and progression was ordered. After removal from the straight leg brace, the athlete began exercising again. In mid January the athlete was cleared by the orthopedist to begin light jumping, shuffling, and closed kinetic strength exercises. Due to the athlete's condition and fear of setback, the athlete was taken to the pool to begin high knees, jumping and fast paced walking, and deep water running. Two weeks after the pool rehabilitation began, the athlete participated in 2 days per week of running on a track and light jumping on land. Strength exercises occurred 3 times per week, with the objective to increase stability and proprioceptive awareness to decrease unstable sensations. By early February 2008, 5 months after the initial injury, the athlete began developing tibial screw pain with deceleration and jumping activities. Another surgery was recommended to address the continued laxity, which was thought to be the cause of patellar pain, joint effusion, and joint locking. Upon a second MRI ordered by the orthopedist, 6 months post surgery, the athlete was found to have posterior horn medial meniscus tear, chrondral erosions and fraying of the chondra; however, the PCL remained intact. The orthopedic stated another surgery to repair the damaged structures may be in order; however, the patient declined the surgery and sought a second opinion.

A second orthopedic surgeon recommended the athlete wear a 5 degree valgus unloader brace at all times.

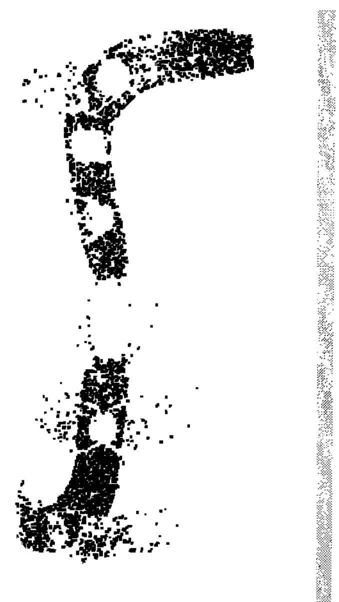

Figure 2. Valgus unloader brace

The beginning of June 2008, 8 months post surgery, a third MRI indicated a mildly stretched PCL with fibers still in congruence, no further medial chondral loss, chronic posterior horn meniscal tear, and a decrease in joint effusion. The tibial screw was removed in the beginning of August 2008 due to chronic pain and irritation at the site.

The 2008 football season began in early August; however, the athlete did not participate until mid September 2008. The athlete's only restriction back to participation in mid September was for him to wear his functional knee brace; he had no residual problems associated with his knee. Currently, the athlete is training for a post college football career and has minimal discomfort with his high intensity workouts. The participant was chosen for this study because PCL reconstruction is rare and the use of the valgus unloader brace is an uncommon treatment route, although it decreased the athlete's symptoms allowing for continued rehabilitation. Residual laxity is noted multiple times throughout literature; however, it may not be well known that residual laxity is a common outcome post surgery. [1, 2, 4, 5, 6, 7]

DISCUSSION

PCL injury most commonly occurs in football; however, it is important to consider occurrence in all sports.[8] The National Hockey League (NHL) has an occurrence rate of one rupture every three years for every team in the league.[3] Soccer and basketball programs have a PCL rupture incidence rate of 2-4% for all knee injuries.[3] The National Football League (NFL) pre draft examination discovers 4 to 6 players per year having a PCL tear. A definite decision for treatment including surgery or conservative care, type of surgery, post surgical rehabilitation, or a combination of treatments are not delineated in the literature. Therefore, an understanding of typical complications and optimal regimes are elusive.

Surgical Options

Multiple surgical techniques are currently used to treat a PCL rupture, the techniques include tibial inlay vs. tibial tunnel, double vs. single femoral tunnels, posterior inlay with either a single or double bundle, and allograft vs. autograft[9]. Each technique has its own complication such as killer turn development by way of the tibial tunnel technique, added surgical time with the tibial inlay technique, disease risk, or graft rejection occurring with allograft use. Currently, literature stating which surgical option should be used as the gold standard for treatment is lacking.

Two important concepts in PCL surgical repair are tibial inlay and tibial tunnel involving the killer turn (Figure 3). Depending on the surgical technique chosen, either tibial inlay or tibial tunnel can be used to repair the ruptured PCL. The tibial inlay technique avoids the possibility of killer turn development, which could lead to graft elongation and added stress onto the graft during crucial healing time of the new graft.[10]

Important distinctions exist between the two techniques; the tibial tunnel technique allows the patient to stay supine throughout the procedure; however, it creates the killer turn and increases graft elongation and thinning.[11] The tibial inlay begins with the patient supine and then ends with the patient prone; while prone, the gastrocnemious and semitendinosus are distracted to the side to expose the posterior structures.[11] The tibial inlay technique does take an additional 15 minutes but does not require tourniquet use, which allows for homeostatis.[11] Inserting the graft from the dorsal side of the body allows for a more accurate anatomic insertion of the PCL onto the tibia, thus avoiding complications with the killer turn.[11] More outcome studies need to be completed so an optimal surgical treatment can be provided.

The athlete in this case study incurred a tibial tunnel single bundle surgical technique. Upon visiting the orthopedist follow-up MRIs showed the PCL was still intact with no signs of rupture, only distal fraying, which might suggest that the killer turn was not the cause of graft laxity nor was placing the graft to superior. The cause of the fraying or additional complications is complex and generally unknown given the multiple variables from surgical technique to post-operative rehabilitation.

Another surgical consideration is whether bundle replacement of the PCL

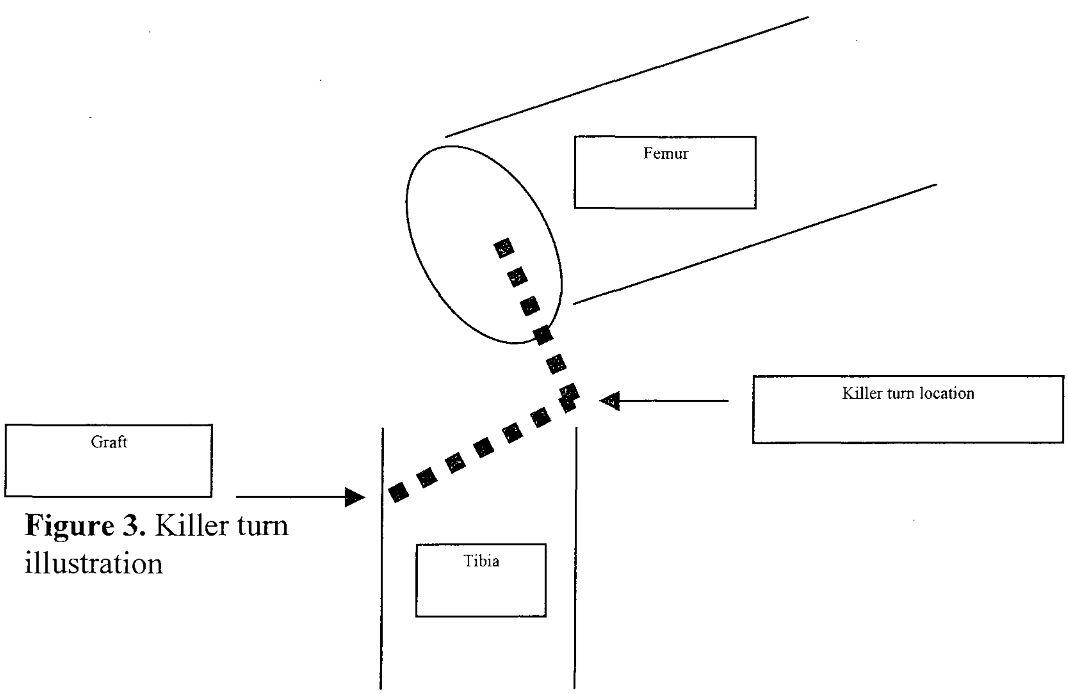

Figure 3. Killer turn illustration

should be single or double. If a single bundle repair is conducted, then the anterior portion of the PCL bundle will be reconstructed due to its superior size and stiffness compared to the posterior bundle.[11] After the repair, the patient will have only one bundle present.[12] However, Nyland[13] indicated that the anterior bundle alone failed to restore normal knee joint mobility, while Cooper[10] reported satisfactory results with a single bundle reconstruction. The double bundle technique has been theorized to restore knee kinematics, although current literature is inconclusive. [6, 14] Due to the multiple surgical options and lack of an operative gold standard, surgical complications are unpredictable. As a medical professional it may have been beneficial for the ATC to be more knowledgeable about the functional outcome to help the athlete make a treatment decision. Conservative treatment was not part of the plan in the presented case study but may need to be assessed for patients on an individual basis. Outcomes research has suggested positive gains from a non-surgical route. [15, 3] However, this particular case study does not provide any insight into rehabilitation as a sole treatment plan for PCL rupture.

There are a few reasons why surgery may not restore PCL function completely, including incorrect tunnel placement,[1] high graft forces during the maturation phase of graft remodeling,[2] complexity of fiber pattern, femoral footprint attachment awareness, and killer turn development.[10] Healing times and rehabilitation alteration may occur if injury to other structures such as the posterior lateral corner need to be repaired versus an isolated PCL injury. In addition, the PCL has a complex fiber pattern that is exceedingly difficult to replicate.[11] The femoral footprint is large, causing a wide variation of tension throughout the knee range of motion.[10] If a graft has excess tension during the remodeling phase of tissue maturation, it may be in an everlastingly stretched position, thus possibly creating posterior residual laxity.[2] Surgical placement of the tibial tunnel is difficult and, as stated earlier, is an important factor when considering the outcome of success, and, lastly, there may be development of increased graft stress and elongation.[10] The athlete's reason for residual laxity is unknown. Some reasons for the laxity may include early range of motion during crucial graft healing time, poor positioning of the femoral tunnel, killer turn complication, or surgical technique. Considering the multiple variables that can inhibit unremarkable healing, rehabilitation protocol(s) has/have not been defined. A better understanding of PCL reconstruction and rehabilitation may aid in advising health care providers on optimal rehabilitation plans to minimize graft elongation and proper placement of the graft and tunnel.

Conservative rehabilitation is also another treatment option if the athlete does not qualify for surgery or elects not to have the procedure. To treat the injury non-operatively, the knee should be placed in an extension brace and non weight bearing to partial weight bearing for two weeks.[8] With the knee in full extension, the tibia is reduced, preventing posterior sag, and keeps the hamstring from contracting, thus pulling the tibia posterior.[3] Furthermore, in full extension the least amount of tension is applied to the anterolateral portion of the PCL bundle allowing it to heal effectively.[3] Range of motion can then be introduced slowly along with quadriceps strengthening.[8] Return to activity can vary from 4 to 6 weeks. For grade III tears with no other complications, rehabilitation may take 3 to 4 months.[8]

Due to multiple treatment options and no standardized surgical care of the ruptured PCL, treatment may be dependent on the orthopedist's experiences. More research needs to be conducted on the athletic population and the functionality of the newly repaired PCL once they have returned to sport. Included in this research should be information regarding rehabilitation and documentation on posterior residual laxity. Researching this information may allow for orthopedics to determine treatment specifically for the injured athlete and may help decide if surgical treatment should occur immediately post injury or if conservative treatment can be used to allow the athlete to play through the remainder of the season.

Outcome Studies

Consideration regarding research articles pertaining to surgical and non surgical treatment variations should be reviewed based on several criteria, including return to participation, length of rehabilitation, surgical outcome data, and patient satisfaction.[15] Conservative treatment should be the initial choice since the level of functional disability rather than the objective instability is the primary factor in assessment.[15] Another consideration is the long term effects of the injury if it is not treated appropriately, including increased clinical instability and arthritic changes. These considerations, however, are debatable due to the lack of patient pre injury chondral wear patterns.[12]

The current surgery options have inconsistent results and do not appear to completely resolve abnormal posterior laxity. [2] MacGilivray[12] suggests no difference between tibial inlay or tunnel technique when comparing the outcomes in posterior drawer, functional testing, Lysholm, Tenger, and American Academy of Orthopedic Surgery (AAOS) knee scores. Inconclusive research was determined when considering double or single bundle techniques. In studies done by Cooper[10], Garofalo[14], and Nyland[13], success in PCL reconstruction was found in both single and double bundle techniques. Conservative treatment is suggested to be effective when no other knee structures are involved and no PCL avulsion is present.[15, 16] With conservative treatment a decrease in activity is warranted. Sixty five percent of the patients with injured PCLs are limited in activities, 90% have knee pain during activity, 43% have knee pain when walking, and 45% have swelling present.[15]

Since only the PCL was damaged to the athlete in this case study, with no other structures harmed, conservative treatment may also have worked for the athlete presented in this case study.

CONCLUSIONS

Outcome studies which clearly define treatment and surgical protocol are needed to thoroughly benefit athletic patients who incur a PCL injury. Current research suggests that people who suffer a grade III rupture combined with other damage to the knee will benefit from surgical repair.[3, 5, 7, 13, 14] However, outcomes in the literature as well as this particular case indicate residual laxity is a possibility with potential for setbacks, such as a decrease in stability and surface degeneration. A better understanding of the outcome will also provide a platform for rehabilitation specialists to devise plans to match the surgical technique and patient needs.

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Chapter 3

EXTENDED SUPPORT MATERIALS

Introduction

Knee injuries account for 15-50% of all sports injuries, with 40% of these injuries involving the ligaments of the knee (Margeritini, Rihn, Musahl, Mariani & Jarner, 2002). Knee injury research and popularity has typically focused on the anterior cruciate ligament (ACL), possibly because a rupture of the ACL may cause more disabling symptoms then an isolating Posterior Cruciate Ligament (PCL) rupture. Because ACL injury has been a focal point of research, studies regarding the (PCL) are limited. PCL rupture research is approximately 10 years behind research of the ACL (Johnson, 2003), yet PCL integrity is important as a primary knee stabilizer preventing posterior translation of the tibia on the femur. The PCL furthermore, has a secondary role in limiting the amount of external varus and valgus forces (Lopes et al., 2008, Margheritini, et al., 2002). In addition to these functions, the PCL has two times the strength of the ACL (Margheritini, et al., 2002).

PCL injuries commonly occur in car accidents when the passenger is sitting in the front seat with bent knees (at or around 90 degrees), and the driver may abruptly apply the brakes forcing the passenger forward into the dash board. The force of the impact causes the tibia to be forced posteriorly on the femur, possibly causing the PCL to tear (Petrigliano & McAllister, 2006). In sport, the same type of trauma occurs to cause injury whereby the PCL is torn by landing on a bent knee with an anterior force on the proximal portion of the tibia, the foot is also planter flexed (Petrigliano & McAllister). This biomechanical situation places the PCL in an elongated taut position which increases the PCL chance of rupture.

The injury is most commonly occurs in football; however, it is important to consider occurance in all sports (Petrigliano & McAllister, 2006). The National Hockey League (NHL) has an occurrence rate of one rupture every three years for every team in the league (Margheritini et al., 2002). Soccer and basketball programs have a PCL rupture incidence rate of 2-4% for all knee injuries (Margheritini et al.). The National Football League (NFL) pre draft examination discovers 4 to 6 players, which is approximately less than 2 percent of the draft population per year having a PCL tear. The fact that the players made the draft and were competing for a position on the roster indicates that function is possible without an intact PCL, yet secondary injury and morbidity is unknown (Margheritini et al.). Therefore, further examination to understand the mechanics of PCL deficient individuals, their ability to continue activity with minimal deficit, secondary injury, and the efficacy of surgical reconstruction is warranted.

Surgical construction of the PCL is currently experimental, lacking a gold standard of care because at certain degrees of knee flexion the graft is as lax as the PCL pre surgery status (Gill, DeFrate, Wang, Carey, Zayontz, & Zarins, 2003). The surgical techniques currently instituted, but not standardized are: tibial inlay, tibial tunnel, and single and double bundle techniques. Surgical repair is determined based on the grade of tear and other affected structures that are damaged. Currently, no standardized technique exists, unlike anterior cruciate ligament (ACL) reconstruction, due to lack of outcome research on PCL surgery and rehabilitation. Unlike the ACL, the PCL has received considerably less research attention in determining how to rehabilitate and treat the injury (Davis, Goltz, Fithian, & D'Lima, 2006).

Due to inconclusive literature regarding PCLs and surgical/rehabilitation outcomes a consistent prescription is unknown. Therefore, practitioner application of rehabilitation, as well as post-surgical treatment, is not standardized. Due to the unknown outcomes with PCL injuries and surgeries, and a lack of investigation on a broad based scale, a case study may aid in understanding some of the intricacies in PCL surgery and rehabilitation. Thus the purpose of this study is to detail a PCL surgical and rehabilitation case study to further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation.

Problem Statement

The purpose of this study will be to present a case study of a 24-year old male football player who ruptured his PCL while receiving a pass; the research will further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation.

Assumptions

The assumption of this case study is that other surgically repaired PCLs may have similar post surgical complications, such as tibial screw transfixation pain, prolonged healing of incisions, residual laxity of the knee joint, and may be applicable to future treatment and rehabilitation.

Delimitations

This case study is delimited to a single male collegiate football player who sustained a PCL rupture. He reports the following post surgical reconstructive complications: tibial screw transfixation pain, prolonged healing of incisions, and residual laxity of the knee joint..

Limitations

The limitations of this case study include a lack of control over external factors that may have affected this case, the athlete's post surgical healing response, and the athletic trainer's time away from the athlete. In addition, this study is not meant to be indicative of translating to the general population or other athletes.

Definitions

Medical Terminology

Allograft. A type of transplant tissue that is obtained from another member of like species (Venus, 1997).

Autograft. Tissue removed from one part of a person's body and relocated to another location within the same body (Venus, 1997).

Full Range of Motion (FROM). Complete movement of a joint, such as in the knee, without any restriction to movement (Davis, 1997).

Killer turn. An acute bend around the proximal posterior tibia that is developed when the tibial tunnel technique is used to repair the PCL (Weimann et al. 2007).

Posterior Cruciate ligament (PCL). One of the two cruciate ligaments of the knee; it is the stronger of the two cruciates, and arises from the posterior part of the intercondylar area of the tibia (Moore & Agur, 1995).

Posterior Drawer . A special test used to determine the amount of laxity present due to a PCL rupture, the knee is flexed to 90 degrees, the foot is in a neutral position, and force is exerted in a posterior direction at the proximal tibial plateau (Prentice, 2003). Reconstruction. The surgical repair or restoration of a damaged body tissue, (Davis, 1997).

Tibial Inlay. A surgical technique where a posterior arthrotomy is preformed and a small osseous recess is created in the posterior portion of the tibia at the posterior insertion of the PCL (Oakes, Markolf, McWilliams, Young & McAllister, 2002).

Tibial Tunnel. A surgical technique where the graft must make an acute turn around the posterior component of the tibia (Oakes et al., 2002).

General Terminology

Athlete. A person who competes in competitive sports (The American Heritage Dictionary, 1994).

Certified Athletic Trainer (ATC). Unique health care provider who specializes in the prevention, assessment, treatment, and rehabilitation of injuries and illnesses (National Athletic Trainers Association, 2009).

Orthopedist. A person who restores normalcy to the deformities of the musculoskeletal system due to injury (Prentice, 2003).

Rehabilitation. The process of treatment and education that help disabled individuals to attain maximum function, a sense of well being and a personally satisfying level of independence (Davis, 1997).

Surgeon. A medical practitioner who specializes in surgery (Davis, 1997).

Surgery. A branch of medicine dealing with manual and operative procedures for the correction of deformities and defects within the body, in addition it is the repair of injuries and a form of treatment for certain diseases (Davis, 1997).

Summary

PCL rupture treatment outcome data is currently inconclusive, thus assessment of the most effective way to treat the injury is unknown. Literature regarding PCL surgical and rehabilitative outcomes is needed to aid health care professionals' awareness of the many treatment options so the most effective treatment route can be chosen. Thus the purpose of this study is to detail a PCL surgical and rehabilitation case study to further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation. This case study may aid in better knowledge to properly help choose an effective treatment option and make medical professionals aware of surgical outcome possibilities. This case study will be submitted to the *Journal of Athletic Training* for publication.

Literature Review

Introduction

The knee accounts for 15-50% of all sports injuries, and 40% of these injuries involve the ligaments in the knee (Margeritini, Rihn, Musahl, Mariani & Jarner, 2002). Knee injury research of the anterior cruciate ligament (ACL) receives more attention than the posterior cruciate ligament (PCL) (Johnson, 2003). In fact, it is stated by Don Johnson (2003) that PCL research is at least 10 years behind research of the ACL, possibly because more people injure the ACL.

The PCL can be injured commonly in motor vehicle accidents and sports such as football, the most common sport to have the injury, and skiing (Petrigliano & McAllister, 2006). Surgical reconstruction of the PCL is debated because at certain degrees of knee flexion the graft is more lax than pre injury status (Gill, DeFrate, Wang, Carey, Zayontz & Zarins 2003). Residual laxity is documented in the literature as a common outcome of surgery (Lipscomb et al., 1993, Nyland, Hester, Caborn, 2002, Oakes, Markolf, McWilliams, Young, McAllister, 2002). Surgical repair is determined depending on the grade of tear, and if other structures in addition to the PCL are damaged. Multiple surgical techniques are possible when repairing the PCL: tibial inlay, tibial tunnel, and double and single bundle techniques. A thorough anatomy of the knee allows for better surgical treatment and the understanding of the biomechanics of the PCL. Outcome research of surgical and conservative treatment for PCL injury is lacking and, therefore, inconclusive. Thus, further research and literature are necessary to determine when a certain situation warrants surgery and what technique should be used, in addition to appropriate rehabilitation.

Anatomy of the Knee

The knee joint is considered a hinge joint, although not a true hinge joint due to rotational movements (Prentice, 2003). Multiple components, such as the bones, muscles, cruciate ligaments, collateral ligaments, and joint surfaces must work in synchronicity for the leg to function properly. In order to comprehend the biomechanical requirement of knee movement the anatomical structures must be defined. Four bones constitute the knee joint: the femur, tibia, fibula and the patella, which is the largest sesamoid bone in the body. The femur is conformed convex at the distal end so it can articulate with the patella and the plateau of the tibia. Attached to the tibia are two fibrocartilages called menisci that deepen the plateaus of the tibia allowing for increased cushion and stabilization. The knee musculature involved with flexion is biceps femoris, semitendinosus, semimembranosus, gracilis, sartorius, gastronemius, popliteus, and plantaris muscles. Knee extension is produced by the vastus medialis, mastus lateralis, vastus intermedius, and the rectus femoris. Both the knee flexor and extensor muscles serve as dynamic stabilizers of the knee. External rotation of the tibia is produced by biceps femoris, while internal rotation is produced by the popliteal, semitendinosus, semimembranosus, sartorius, and gracilis muscles. The joint capsule itself is the largest capsule within the body, with four regions of the capsule reinforced by different anatomical structures. The posterolateral corner is reinforced by the iliotibial band (IT), the popliteus, biceps femoris, lateral collateral ligament (LCL), and the arcuate ligament;

postermedial corner is reinforced by the medial collateral ligament (MCL), pes anserinus tendons, semimembranosus and posterior oblique ligament; anteriorlateral corner is reinforced by the IT band, patellar tendon, and lateral patellar retinaculum; and, lastly, the anteromedial corner is supported by the superficial MCL and the medial patella retinaculum. These structures are static stabilizers of the knee (Prentice, 2003).

The structures that compose the knee are either static or dynamic stabilizers of the joint. The lateral collateral ligament (LCL), the arcuate ligament complex, the fabellofibular ligament, and the posterior horn of the lateral meniscus compose the lateral part of the posterior capsule (Margeritini et al., 2002). Of these structures the dynamic stabilizers are the popliteus complex, the biceps tendon and the ileotibial tract (Margeritini et al.). When examining these structures, the LCL and the popliteus complex are considered the focal stabilizers providing varus and external rotatory stability to the knee (Margeritini et al.). Static and dynamic components make up the popliteus complex. The static stabilizers consist of the popliteofibular ligament, the popliteotibial fascicles, and the popliteomensical fascicles, all of these originate from the popliteus tendon and insert onto fibula, the tibia, and the meniscus (Margeritini et al.). The importance of static and dynamic stablizers should be considered because without both types of stabilizers fine movements preformed with accuracy may not be able to be completed. Also, without these stabilizers muscular endurance and precise movement within the joint may not be as possible due to quicker fatigue by the larger muscle groups.

The medial collateral ligament (MCL) and the lateral collateral ligament (LCL), provide stability to the knee as well as keep the knee in alignment for biomechanical movement. The MCL has two components, the superficial and the posterior portions. The posterior part connects onto the capsular ligament and the semimembranous, portions of the semimembranous muscle connects to the medial meniscus and pulls the meniscus backward during flexion, therefore damage to the MCL may put increased pressure onto the meniscus causing damage. The LCL attaches to the lateral meniscus, the lateral meniscus also attaches to the ligament of Wrisberg and the popliteal tendon; if these structures are damaged, mechanical compensation would occur elsewhere in the knee, decreasing stability and adding to potential secondary injuries (Prentice, 2003).

The anatomy of the knee and specifically the PCL is a detailed complex. Due to the lack of PCL research, specifics regarding the anatomical orientation are not well known. The PCL orientation begins at the posterior tibia 1cm below the joint line and continues anteromedially to the lateral portion of the medial femoral condyle (Margeritini et al., 2002). On average the PCL is between 32mm and 38mm long and has a cross sectional area of 31.2mm, which is 1.5 times that of the ACL cross-sectional area (Margeritini et al.). Two components compose the PCL, the anterior and posterior bundles (Margeritini et al.). While the insertion sites of the two bundles are equal in size, the anterior bundle is larger, stronger, and stiffer (Margeritini et al.). The two different bundles each are taut at different ranges of motion; for example, when the knee is in full flexion the anterior bundle is taut, whereas in full extension the posterior bundle is taut (Margeritini et al.). Although the bundles have been separately measured for tensile strength in situ situations, neither bundle was stronger than the other, which demonstrates that both bundles may be needed to restore normal kinematic function (Harner et al., 2000). Without proper restoration the possibility of instability and/or arthritic changes is possible (Harner et al.).

The origin and insertion footprints of the PCL must also be discussed since they will be important components of the femoral tunnel portion of the surgical procedure. In a 20 cadaveric knee study conducted by Lopes et al., (2008) the femoral footprint was a semicircle in 15 of the 20 knees, and oval shaped in five. Lopes et al., also determined the attachment to be concave in 19 of the knees and flat in one. The average size of the PCL attachment site was 33.82 mm^2, the posterior bundle was 16.13 mm^2 while the anterior bundle was 23.95 mm^2. Using digital imaging, an osseous prominence, named the medial intercondylar ridge was located and travels through the entire femoral footprint. In 8 of the 20 knees another osseous ridge, was identified as traveling between the anterior and posterior bundles of the PCL. More research needs to be conducted on the femoral footprint so orthopedics can accurately place the femoral tunnel, for the PCL reconstruction. In relation to the tibial tunnel multiple sources determined the femoral tunnel location to be more important than the tibial tunnel due to graft forces (Lopes et al., 2008). No research was identified that discusses the tibial insertion footprint of the PCL.

In addition to the bundles, two meniscalfemoral ligaments, Wrisberg (posterior) and Humphry (anterior) travel alongside the PCL and provide stability to the lateral meniscus; however, presence of these ligaments is variable, and the importance of the ligaments is also inconsistent throughout the literature (Margeritini et al., 2002). Both ligaments originate from the posterior horn of the lateral meniscus and continue along side of the PCL and insert anterior and posterior to the PCL on the medial femoral condyle (Margeritini et al.). If either of these meniscalfemoral ligaments is damaged, more stress can be placed onto the menisci, causing further damage to other structures due to compensation. Another structure in the complex is the popliteus ligament, the structure is responsible for aiding in knee flexing and unlocking the joint from extension; this ligament is also attached to the lateral collateral ligament, so damage to this ligament may have compensating consequences on the menisci (Moore & Agur, 1995). Studies have indicated that when the knee is at 90 degrees of flexion the maximum potential for translation can occur at the joint (Margeritini et al., 2002). With this known, posterior lateral structures of the knee can also be damaged, and those structures need to be considered during surgical or rehabilitative intervention. Knowing the anatomy of the knee and the structures that have potential for being damaged allows for a comprehensive awareness of what could be damaged after the mechanism has occurred.

Mechanism of Injury

PCL injury most commonly occurs in car accidents when the passenger is sitting in the front of the seat with his or her knee bent (at or around 90 degrees), the driver may abruptly apply the brakes forcing the passenger into the dashboard; the force of the impact causes the tibia to be forced posteriorly on the femur, possibly causing the PCL to tear (Petrigliano & McAllister, 2006). In athletics the same mechanism of trauma causes PCL injury. The PCL is torn by landing on a bent knee with an anterior force on the proximal portion of the tibia, the foot is also planter flexed (Petrigliano & McAllister).

Football is the most common sport to sustain PCL injury (Petrigliano & McAllister), followed by baseball and skiing (Margheritini et al., 2002). Football, baseball, and skiing all have high contact forces and less pivoting and cutting, which may be why these sports have higher incidence rates than a sport like basketball (Margheritini et al.).

In addition to this mechanism of injury, hyperextension or hyperflexion of the knee with a force to the proximal tibia can also cause a tear (Petrigliano & McAllister, 2006). Although landing on a bent knee with the force on the proximal tibia accounts for most of the occurrences, 51.6% of athletes are unable to remember a specific instance of injury, and the knee does not start to be problematic until after the fall occurs later on in life (Petrigliano & McAllister). For the lateral corner to be involved there has to be a form of rotation that occurs simultaneously (Petrigliano & McAllister). In addition to an athlete's lack of recall to a specific instance, low incidence of PCL rupture may occur because the direction of the force and the amount of force does not commonly occur in athletics. Secondly, as previously stated, the PCL has a higher tensile load than other ligaments within the knee, and, lastly, there is often no symptoms of instability when comparing the injury to an ACL rupture (Margheritini et al., 2002).

Diagnosis of Injury

Three different severity grades exist to define PCL damage. In a normal knee the tibia is one centimeter anterior to the femoral condyles (Davis et al., 2006). Grade I has the least amount of damage and laxity present; the tibia is still anterior to the femoral condyles but a regression of 0-5 mm is felt with a posterior drawer test (Davis et al.). If the tibia is 5-10 mm, or equal to the femoral condyles, a grade II tear is present (Davis et al.). Lastly, if the tibia can be pushed beyond the condyles, a grade III injury is present (10+ mm) (Davis et al.). A grade III tear has an increased possibility that other structures are involved.

Diagnosing the grade of PCL injury should include assessment of other structures in the knee for possible injury. The posterior medial corner (PMC) and posterior lateral corner (PLC) of the knee need to be checked for injury. As much as 60% of PCL tears involve the lateral structures (Margeritini et al., 2002).

To determine the extent of these injuries, the dial and pivot shift tests may be used (Starkey & Ryan 2002). The dial test, also known as the external rotation test, for posterolateral knee instability is used to determine isolated arcuate ligament damage, trauma to the PCL, and posterolateral knee structure damage. The patient is lying prone and the knees are flexed to 30°; using the medial boarder of the foot as a reference mark, the examiner will grasp the heels and rotate the feet externally; a comparison is made between feet and the test is repeated with the knees at 90°. A positive test is a 10° difference between feet. A 10° disparity at 30° but not 90° indicates injury to the arcuate complex and the posterolateral structures. A 10° difference at 30° and 90° indicates trauma to the PCL posterolateral structures and the arcuate complex. Lastly if there is a 10° difference at 90° and not 30° indicates a isolated PCL tear. The pivot shift test, or the lateral pivot shift test, evaluates the posterlateral capsule, arcuate ligament, and the IT band. No degree difference at 30° or 90° was identified upon orthopedic special tests suggesting there was no lateral damage to the knee of the patient.

For the pivot shift test, the patient will be lying supine, the examiner will be standing at the side of the leg being tested. The hand furthest from the patient's head will grasp the heel and the other hand will be place around the lateral joint line. The foot will be internally rotated to 20°, and the leg will be in full extension. While maintaining this position, a valgus force will be applied at the knee while the knee is brought into flexion. A positive test will be the femur reducing on the tibia in the degree range of 30-40. When the leg is brought back into extension, a subluxation will be felt at the lateral knee. This test may be indicative of a posterolateral capsule, arcuate ligament complex, or the IT band.

The patient lays supine and the examiner stands on the injured side of the body for the pivot shift test. One hand of the examiner grasps the heel and internally rotates the tibia 20°; the knee will be in extension and sagging; the opposite hand of the examiner grasps the posterior lateral knee at the tibiofibular joint and applies increasing internal rotation. While the knee is flexed, a valgus force will be applied. A positive test will be the tibia reducing on the femur while the leg is flexed in the range of 30° to 40°, during extension a subluxation will be felt (Starkey & Ryan, 2002).

The meniscus should also be evaluated for a possible tear; McMurray's, Apley's compression, and duck walking tests may be used to rule out this injury (Starkey & Ryan, 2002). McMurray's positive test will present with popping, clicking, or locking of the knee or a similar pain produced with activity. The patient should lie on his or her back while the examiner stands next to the knee being tested. One hand of the examiner will cup the heel of the patient while the other hand is placed on the joint line of the knee tested. Three motions of the knee will then be made: 1) with the knee bent as much as possible, the tibia is not rotated internally or externally, but in a neutral position, and a valgus stress is applied while the knee is extended through a full range of motion (FROM); 2) the tibia is then internally rotated by the hand positioned at the heel, a valgus stress is applied while the knee is extended and flexed through a FROM, 3) the tibia is externally rotated by the hand positioned at the heel, and a valgus stress is applied while the knee is extended and flexed through a FROM. Apley's compression also tests for meniscal tears, and a positive test occurs when pain is present with the compression component and is absent with the distraction component. The patient lies on his or her stomach and the knee is flexed to 90°. The examiner stands at the side of the patient being tested. The heel will be grasped as a downward rotating pressure is applied while flexing and extending the knee. The distraction test consists of the examiner grasping onto the heel of the patient and placing the other hand on the distal hamstring group. The hand holding the heel will apply an upward pressure while the hand on the hamstrings will keep the leg from rising off the table. Internal and external rotation will also occur with flexion and extension of the knee (Starkey & Ryan).

The duck walking test is performed with the patient squatting in a catcher's position and taking steps forward; a positive test will be pain while performing this activity. The importance of testing these ligaments will allow the surgeon to decide whether a conservative route should be taken, or if surgery should be done to repair the damage to the posterolateral stability of the knee. Therefore, degree of damage to any of the structures should be identified and often the meniscalfemoral ligaments may not be considered in the clinical setting. Practitioners who are unable to assess meniscalfemoral ligaments with special tests may need to employ a referral for MRI, which may be more sensitive for diagnosis tissue damage. The integrity of meniscalfemoral ligaments, Humphry and Wrisberg, need to be evaluated and may be done so by magnetic resonance imaging (MRI) or Posterior drawer. If these ligaments are injured, stability to the lateral meniscus can be compromised, (Margeritini et al., 2002), thus creating a positive special test for meniscal pathology.

Clinical evaluation is only one way and typically the preliminary evaluation used to determine the extent of the injury: weight bearing radiographs, stress graphs, (MRI) and bone scans are all possible imaging evaluative tools. The gold standard for a diagnostic tool is the MRI, which can determine the location of the PCL rupture, and indicate possible damage to other ligaments, menisci, and cartilage in the knee (Wind, Bergfeld & Parker, 2004). The MRI has been reported to have between 96% and 100% sensitivity and specificity in detecting PCL rupture; however, in chronic grade I and II injuries the PCL may look normal, so physical examination is more important (Margheritini et al., 2002, Wind et al., 2004). Radiographs are also useful to rule out any avulsion fractures or posterior sagging (Wind et al., 2004). Stress radiographs allow for the amount of posterior translation to be accurately known without being invasive (Wind et al.).

MRI or diagnostic imaging ordered by a physician will allow for a more triangulated diagnosis by providing information as to where the rupture occurred in the PCL, if it is a PCL isolation injury, if other structures are damaged, and to what extent.

Once the imaging has been done and the impressions have been made, the surgeon may have a better idea if surgery should be warranted or if a conservative approach should be taken for healing to occur. Knowing what structures are damaged will also allow the physician to determine a rehabilitation protocol.

Treatment

With a complete rupture of the PCL, other anatomical structures may be involved in the injury. Two treatment routes can be advanced for an isolated PCL tear: non-operative and operative.

Operative treatment is recommended for individuals who have a grade III instability with other ligamentous damage. Surgery should be performed between 2 to 3 weeks post injury date to reduce the amount of scarring that could develop (Petrigliano & McAllister, 2006). With operative treatment, an allograft of the Achilles tendon is the preferred tissue to replace the PCL (Petrigliano & McAllister). The Achilles is similar to the PCL because it has large quantity of collagen, and it splits easily into the anterior and posterior bundles of the PCL (Petrigliano & McAllister). The calcaneous portion of the graft allows for a quality fixation to the tibia (Petrigliano & McAllister).

Grades I and II are usually treated non-operatively; however, if there is other structural instability to the knee, surgery should be considered (Petrigliano & Mcallister, 2006). To treat the injury non-operatively, the knee should be placed in an extension brace and non weight bearing to partial weight bearing for 2 weeks (Petrigliano & McAllister). With the knee in full extension, the tibia is reduced, preventing posterior sag and keeps the hamstring from contracting, thus pulling the tibia posterior

(Margheritini et al., 2002). Furthermore, in full extension the least amount of tension is applied to the anterolateral portion of the PCL bundle, allowing it to heal effectively (Margheritini et al.). Range of motion can then be introduced slowly along with quadriceps strengthening (Petrigliano & McAllister). Return to activity can vary from 4 to 6 weeks. For grade III tears with no other complications, rehabilitation may take 3 to 4 months (Petrigliano & McAllister).

Surgical Techniques

Multiple surgical techniques are currently under research, including: tibial inlay vs. tibial tunnel, double vs. single femoral tunnels, posterior inlay with either a single or double bundle, and allograft vs. autograft (Johnson, 2003). Each technique has its own complication, such as killer tunnel development, added surgical time, or disease risk. Currently, literature stating which surgical option should be used as the gold standard for treatment is lacking.

Two important differences in tibial inlay and tibial tunnel surgical concepts of PCL repair involve killer turn development. Depending on the surgical technique chosen, either tibial inlay or tibial tunnel can be used to repair the ruptured PCL. The tibial inlay technique avoids the possibility of killer turn development, which could lead to graft elongation and added stress onto the graft during crucial healing time of the new graft (Cooper & Stewart, 2004).

Important distinctions exist between the two techniques; one is the position of the patient during surgery. The tibial tunnel technique allows the athlete to stay supine throughout the surgery, and the tibial inlay begins with the patient supine and then ends with the patient prone; while prone, the gastrocnemious and semitendinosus are distracted to the side to expose the posterior structures. The tibial inlay technique does take an additional 15 minutes but does not require tourniquet use, which allows for homeostatis (Wind et al., 2004). Inserting the graft from the dorsal side of the body allows for a more accurate anatomic insertion of the PCL onto the tibia, and this technique also avoids complications with the killer turn. One technique has not been identified as superior over the other, but, more outcome studies need to be completed so a gold standard of treatment can be known.

The tibial tunnel technique creates a sharp turn at the exit of the tibial tunnel, thereby creating the complication of the killer turn (Wind et al., 2004). The killer turn is a phrase used to describe the angle the graft has to make while inside the posterior portion of the knee (Johnson, 2003). The tibial inlay technique avoids this sharp turn and the possibility producing abrasion, thinning, and possible elongation of the graft, creating tibial laxity (Weimann et al., 2007). A tibial tunnel that is placed too far superior is likely to fail due to increased stretching and fraying of the tendon repair (Johnson, 2003). Another consideration is whether the replacement PCL will be a single or double bundle repair. If a single bundle repair is conducted then the anterior portion of the PCL bundle will be reconstructed due to its superior size and stiffness compared to the posterior bundle, so after the repair the patient will have only one bundle present. (MacGillivray et al., 2006). However, other studies have indicated that anterior bundle alone failed to restore normal knee joint mobility. The double bundle technique has been thought to restore knee kinematics although current research is inconclusive (Garofalo, Jolles &

Moretti, 2006). Due to the multiple surgical options and no existing operative gold standard, surgical complications are more likely.

A few reasons exist why the inability of surgery restores PCL function completely. One reason complications can occur is that other ligaments can commonly be involved with PCL rupture and also need repair, another is that the PCL has a complex pattern that is exceedingly difficult to replicate, and thirdly, the femoral footprint is large causing a wide variation of tension throughout the knee range of motion (Cooper & Stewart, 2004). A graft that has excess tension during the remodeling phases of tissue maturation may be in an everlastingly stretched position, thus possibly creating residual laxity (Oakes et al., 2002). In addition, surgical placement of the tibial tunnel is difficult and, as stated earlier, is an important factor when considering the outcome of success, and, lastly, there may be development of increased graft stress and elongation (Cooper & Stewart, 2004). The athlete's reason for residual laxity is unknown. In conclusion, some reasons for the laxity may include early range of motion during crucial graft healing time, poor positioning of the femoral tunnel, killer turn complication, or surgical technique. Considering these many reasons, proper rehabilitation protocol has not been defined, thus indicating further research in terms of PCL reconstruction and rehabilitation. Possible research direction could be graft elongation and range of motion time line to avoid laxity.

Outcome Research

Consideration regarding research articles pertaining to surgical and non surgical treatment variations should be reviewed based on several criteria, including return to participation, length of rehabilitation, surgical outcome data, and patient satisfaction.

According to Shino et al. (1995), conservative treatment should be the initial choice since the level of functional disability rather than the objective instability should be the primary factor in assessment. Another consideration is the long term effects the injury can have on the body if it is not treated; these are increased clinical instability and arthritic changes, although these considerations are debatable due to the lack of researchers' pre injury knowledge of chondral wear patterns (MacGillivray et al., 2006). The proposed case study athlete was not allowed any chance for conservative treatment, but had surgery soon after the injury occurred.

The current surgery options have inconsistent results and do not appear to completely resolve the knee of abnormal posterior laxity (Oakes et al., 2002). A study researched by MacGilivray et al., (2006) suggests no difference between tibial inlay amd tunnel technique when comparing the outcomes in posterior drawer, functional testing, Lysholm, Tenger, and American Academy of Orthopedic Surgery (AAOS) knee scores. Research was determined inconclusive when considering double or single bundle techniques. In studies done by Cooper and Stewart (2004), Garofalo et al. (2006), and Nyland, Hester and Caborn (2002), success in PCL reconstruction was found in both single and double bundle techniques. Conservative treatment is suggested to be effective when no other knee structures are involved and no PCL avulsion is present (Shino et al., 1995, Dandy & Pusey, 1982). With conservative treatment a decrease in activity is warranted: 65% of the injured people are limited in activities, 90% have knee pain during activity, 43% have knee pain when walking, and 45% have swelling present (Shino et al., 1995).

Since only the PCL was damaged with no other structures harmed, conservative treatment may have benefited the athlete. Research that could compare conservative and surgical treatments is difficult to demonstrate due to independent and dependent variables. No information has linked a specific surgery technique to rehabilitation.

Injury to the PCL and possibly other structures is possible when the knee is at 90°, the foot is planter flexed, and a force is at the proximal tibia (Petrigliano & McAllister, 2006). Football is the most common sport for PCL injury, and rupture can also occur if the knee makes contact with the dashboard (Petrigliano & McAllister). A detailed anatomy of the knee is important so all damaged structures can be identified and a holistic view for treatment can be decided. Treatment options include surgical or conservative protocols; the conservative route will involve the patient wearing a straight leg brace for two weeks; increasing ROM and quadriceps strength should also be improved with return to play in 4-6 weeks. Surgical options include tibial inlay and tibial tunnel, double bundle or single bundle, and autograft or allograft. A standard treatment for surgical repair has not yet been identified; therefore, no rehabilitation protocols have been developed.

Methods

The purpose of this study will be to present a case study of a 24-year old male football player who ruptured his PCL while receiving a pass; the research will further provide information regarding treatment options, surgical procedures, and potential complications encountered in rehabilitation. The following five sections will include discussion about the participant, procedures, and research design.

Participant

The patient who injured his PCL is a 24-year old male senior football player. The patient jumped off the ground to catch the football and landed on his flexed knee. The athlete was evaluated by a certified athletic trainer on the field and was also evaluated by an orthopedic surgeon. He received surgery 8 days after injury with complications during his rehabilitation that were unexpected; these complications included tibial screw transfixation pain, prolonged incision healing, and posterior residual laxity. The complications may be attributed to lack of knowledge about the possible surgical outcomes. The participant was chosen for this study because PCL reconstruction is rare, and there were unforeseen complications over a seven month period. These complications have not been noted in the literature with the exception of residual laxity and may have implications for continued participation. The patient was asked permission to participate in the study two months post operation and agreed; the patient also gave permission to the researcher for access to medical records. Prior to acquisition of medical records, the human subjects approval was sought (Appendix A). Consent was given to the researcher to access all medical records for this patient including: orthopedic and surgical reports, diagnostic reports, x-ray, and MRI film.

Research Design

This particular case study is a descriptive case study design, and was chosen for a few reasons; one reason was the daily contact the researcher had with the patient, as a health care provider this allowed detailed medical notes and observations. Two, there were multiple specific complications consisting of tibail screw transfixation pain, prolonged healing of incisions, and residual laxity of the knee joint. Three, the descriptive nature of the study was chosen to better understand this injury phenomenon due to its rarity and complexities.

Procedure

This case examined the participant's medical records, Subjective, Objective, Assessment, Plan (SOAP) notes, and literature regarding PCL ruptures. SOAP notes are medical records that include but are not limited to girth measurements, modalities used to treat symptoms, patient attitude, and progress made. At the request of the athletic trainer the athlete was asked to retrieve his medical documentation and provided the athletic trainer with the information, these documents included orthopedic diagnoses, pre and post surgical notes as well as operative notes. The researcher was responsible for the information contained in the medical records for review, categorization, and analysis. The medical documentations were requested for a better understanding of the injury and to understand fully the techniques used to repair the rupture. The medical reports were used to create a timeline of events of the injury beginning with the initial injury; the timeline was a daily and summative outline of the medical treatment. Daily occurrences were phrased in outline format on a timeline sheet; they were then used to create time blocks of like information. The like blocks of information were used to create a text of summative information that was compared and contrasted with current literature. In addition to the timeline and time blocks, the summative information was used to write an article for the *Journal of Athletic Training (JAT)*, and the summative categories were based on requirements for the *JAT* for publication.

Ebsco host was used to access research related to PCL ruptures and the possible complications for comparison and contrast of the current PCL case with past literature. The criteria for the articles were anatomical characteristics, diagnosis, treatment, surgical technique, and outcomes from surgical procedure. The journals included, but not limited to *The American Journal of Sports Medicine, Sports Medicine and Arthroscopy Review, The Journal of Arthroscopic and Related Surgery,* and *The Journal of Bone and Joint Surgery.*

Case Study Design

This particular case study is a descriptive case study design, and was chosen for a few reasons; one reason was the daily contact the researcher had with the subject, which allowed for detailed medical notes and observations. Two, the single patient has had multiple specific complications such as tibial screw transfixation pain, prolonged incision healing, and residual knee laxity. Three, the descriptive nature of the study was chosen to better understand this injury phenomenon due to its rarity and complexities. The case study design allows for exploration of a specific event about a person (Merriam, 1988).

Multiple methods of data collection were used for this case study, which is another characteristic of the case study design method. A definition of a case study that describes this particular case study well is "the examination of an instance in action" (Merriam). Examination of the situation has occurred by ATCs, orthopedics, and the participant himself starting at the time of injury until the athlete returned to play. Because multiple levels of knowledge have been used throughout the investigation, an important method of data collecting has evolved and is termed triangulation; using this technique allows for multiple conformations establishing a stronger validity (Merriam).

Case Study Analysis

Milestones of the case will be placed into a timeline and evaluated by the researcher, an orthopedic surgeon with 10 years experience, an ATC with 10 years of experience, and the patient himself. The evaluators independently reviewed the case and then met to assess both the daily and summative medical information for consistencies and inconsistencies of the timeline treatment regime and articulation with current literature to begin triangulation of the data. Triangulation is an important case study characteristic because it uses multiple sources to confirm the findings of the research (Merriam, 1988). Based on the reviewer consensus, an article for publication to the *Journal of Athletic Training* according to their authors' guild will be compiled (Appendix B). The case study article requirement categories are: objective, background, differential diagnosis, treatment, uniqueness, conclusions, and key words, this information will precede a 300 word abstract. Upon completion of the manuscript, the athlete will be requested to read the article as a method of member checking. Any inconsistencies will be rectified and the article will be amended as needed.

Summary

This case study is presented in a case study format and allows for knowledge development relating to PCL reconstruction. The athletic trainer was directly involved in the data collection; the collection was made possible through medical files and literature research.

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APPENDIX A. Consent Form

Agreement to Participate in Research

Responsible Investigator: Ashley Vogds, San Jose State University Graduate Student

Title of Protocol: Rehabilitation of a PCL Reconstruction: A Case Study

I, ________________________________ volunteer to participate in the research project entitled Surgical Complications in a PCL Reconstruction to be conducted at San Jose State University under the direction of Leamor Kahanov, Ed.D. The procedures have been explained to me and I understand them. They are as follows: the purpose of the study is to exam the surgical outcome and possible complications of PCL reconstruction. The task involves viewing orthopedic and surgical notes, documenting milestones and changes taking place throughout the rehabilitation and return to play events. I understand that this consent and data may be withdrawn at any time without penalty. I have been given the right to ask questions, and my questions, if any, have been answered to my satisfaction. I understand that no risks are anticipated with this case study. I understand there will be no direct benefits to myself or to those conducting the case study research. I understand no compensation for my participation in the study will be made. Although the results of this study may be published, data that could identify me will be kept confidential. At no time will service of any kind be jeopardized if I choose not to participate.

Questions about this case study can be directed to Ashley Vogds (414) 530-9338. Complaints about the research may be directed to the department chair Shirley Reekie (408) 924-3010.

APPENDIX B

Authors Guide

(Revised January 2009)

The mission of the *Journal of Athletic Training* is to advance the science and clinical practice of athletic training.

SUBMISSION POLICIES

1. Submit online at http://jat.msubmit.net
2. The following forms (available at the *JAT* Web site: www.journalofathletictraining.org) should be either scanned and uploaded with the manuscript or faxed to the Editorial Office (706-494-3348):

a. Copyright form. A letter signed by each author must contain the following statements: ''This manuscript 1) contains original unpublished material that has been submitted solely to the *Journal of Athletic Training,* 2) is not under simultaneous review by any other publication, and 3) will not be submitted elsewhere until a decision has been made concerning its suitability for publication by the *Journal of Athletic Training.* In consideration of the NATA's taking action in reviewing and editing my submission, I the undersigned author hereby transfer, assign, or otherwise convey all copyright ownership to the NATA, in the event that such work is published by the NATA. Further, I verify that I have contributed substantially to this manuscript as outlined in item #2 of the current Authors' Guide.'' By signing the letter, the authors agree to comply with all statements. Manuscripts that are not accompanied by such a letter will not be reviewed. Accepted manuscripts become the property of the NATA. Authors agree to accept any minor corrections of the manuscript made by the editors. Text changes to proofs in excess of 5 to correct items other than factual, typographic, or copy editor errors will be billed to the author at $5 per correction. Replacing or editing figures at the proof stage will be billed at $25 for a black-and-white figure and $30 for a photograph.
b. Authorship form. The *Journal of Athletic Training* conforms to the International Committee of Medical Journal Editors' Uniform Requirements for Manuscripts Submitted to Biomedical Journals. Each author must be specifically identified in the published manuscript, in accordance with the Uniform Requirements for Manuscripts Submitted to Biomedical Journals: ''Authorship credit should be based only on 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published. Conditions 1, 2, and 3 must all be met. Acquisition of funding, the collection of data, or general supervision of the research group, by themselves, do not constitute authorship.'' (Categories borrowed with the permission of the *Annals of Internal Medicine.*) Contributors to the manuscript who do not qualify for authorship should be thanked in the Acknowledgments section.
c. Signed releases are required to verify permission for the *Journal of Athletic Training* to 1) reproduce materials taken from other sources, including text, figures, or tables; 2) reproduce photographs of individuals; and 3) publish a Case Report. A Case Report cannot be reviewed without a release signed by the individual being discussed in the Case Report.
3. Financial support or provision of supplies used in the study must be acknowledged. Grant or contract numbers should be included whenever possible. The complete name of the funding institution or agency should be given, along with the city and state in which it is located. If individual authors were the recipients of funds, their names should be listed parenthetically.
4. Authors must specify whether they have any commercial or proprietary interest in any device, equipment, instrument, or drug that is the subject of the article in question. Authors must also reveal if they have any financial interest (as a consultant, reviewer, or evaluator) in a drug or device described in the article.
5. For experimental investigations of human or animal subjects, state in the Methods section of the manuscript that an appropriate institutional review board approved the project. For those investigators who do not have formal ethics review committees (institutional or regional), the principles outlined in the Declaration of Helsinki should be followed (41st World Medical Assembly. Declaration of Helsinki: recommendations guiding physicians in biomedical research involving human subjects. *Bull Pan Am Health Organ.* 1990;24:606–609). For investigations of human subjects, state in the Methods section the manner in which informed consent was obtained from the subjects. (Reprinted with permission of *JAMA* 1997;278:68, copyright 1997, American Medical Association.) If informed consent was not required because the study was exempt, provide the reason for the exemption.
6. The *Journal of Athletic Training* uses a double-blind review process. Authors and institutions should not be identified in any way except on the title page.
7. Manuscripts are edited to improve the effectiveness of communication between author and readers and to aid the author in presenting a work that is compatible with the style policies found in the *AMA Manual of Style,* 9th ed. (Williams & Wilkins), 1998. Page proofs are sent to the author as PDFs for proofreading, and any changes must be returned within 48 hours. Important changes are permitted, but authors will be charged for excessive alterations.

STYLE POLICIES

8. Each page must be formatted for 8½-by-11-inch paper, double spaced, with 1-inch margins in a font no smaller than 10 points. Include line counts on each page to facilitate the review process. Do not right justify pages.
9. Manuscripts should contain the following, organized in the listed order, with each section beginning on a separate page:
a. Abstract and Key Words (first numbered page)
b. Text (body of manuscript)
c. References
d. Legends to figures The title page and acknowledgmeuts should be submitted online as supplemental materials. Tables should be submitted in a separate file, as should figures; neither should be included in the manuscript.
10. Begin numbering the pages of your manuscript with the abstract page as #1; then, consecutively number all successive pages.
11. Units of measurement shall be recorded as SI units, as specified in the *AMA Manual of Style,* except for angular displacement, which should be measured in degrees rather than radians. Examples include mass in kilograms (kg), height in centimeters (cm), velocity in meters per second ($m \cdot s^{-1}$ or m/s), angular velocity in degrees per second ($° \cdot s^{-1}$), force in Newtons (N), and complex rates (mL/kg per minute).
12. Titles should be brief within descriptive limits (a 16-word maximum is recommended). If a technique is the principal reason for the report, it should be named in the title. If a disability is relevant, it should be named in the title.
13. The title page should also include the name, title, affiliation, and e-mail address of each author, and the name, address, phone number, fax number, and e-mail address of the author to whom correspondence is to be directed. No more than 4 credentials should be listed for each author. The ''ATC'' credential is under the copyright protection of the NATA Board of Certification. Therefore, the proper listing of an additional state credential is ''LAT, ATC'' or ''ATR, LAT.''
14. A structured abstract of no more than 300 words must accompany all manuscripts. Type the complete title (but not the authors' names) at the top, skip 2 lines, and begin the abstract. Items that are needed differ by type of article. **Quantitative Original Research** articles: Context, Objective, Design, Setting, Patients or Otber Participants, Intervention(s), Main Outcome Measure(s), Results, Conclusions, and Key Words. **Qualitative Original Research** articles: Context, Objective, Design, Setting, Patients or Other Participants, Data Collection and Analysis, Results, Conclusions, and Key Words. **Meta-Analysis and Systematic Review** articles: Objective, Data Sources, Study Selection, Data Extraction, Data Synthesis, and Key Words. **Case Reports**: Objective, Background, Differential Diagnosis, Treatment, Uniqueness, Con-clusions, and Key Words. **Clinical Techniques**: Objective, Background, Description, Clinical Advantages, and Key Words. **Evidence-Based Practice:** Reference/Cita-tion, Clinical Question, Data Sources, Study Selection, Data Extraction, Main Results, Conclusions, Key Words, and Commentary. **Literature Reviews**: An author who wishes to submit a literature review is advised to contact the Editorial Office for instructions.
15. Begin the text of the manuscript with an introductory paragraph or two in which the purpose or hypothesis of the article is clearly stated and developed. Tell why the study needed to be done or the article written, and end with a statement of the problem (or controversy). Highlights of the most prominent works of others as

related to your subject are often appropriate for the introduction, but a detailed review of the literature should be reserved for the Discussion section. In a 1-to 2-paragraph review of the literature, identify and develop the magnitude and significance of the controversy, pointing out differences among others' results, conclusions, and/or opinions. The Introduction is not the place for great detail; state the facts in *brief*, specific statements and reference them. The detail belongs in the Discussion. Also, an overview of the manuscript is part of the abstract, not the introduction. Writing should be in the active voice (for example, instead of ''Participants were selected,'' use ''We selected participants'') and in the first person (for example, instead of ''The results of this study showed,'' use ''Our results showed'').

16. The body or main part of the manuscript varies according to the type of article (examples follow); however, the body should include a Dis-cussion section in which the importance of the material presented is discussed and related to other pertinent literature. When appropriate, a subheading on the clinical relevance of the findings is recommended. Liberal use of headings and subheadings, charts, graphs, and figures is recommeuded.

a. The body of an **Original Research** or a **Meta-Analysis** or **Systematic Review** article consists of a Methods section, a presentation of the Results, and a Discussion of the results. The Methods section should contain sufficient detail concerning the methods, procedures, and apparatus employed so that others can reproduce the results. The Results should be summarized using descriptive and inferential statistics and a few well-planned and carefully constructed illustratious. For more information on preparing research manuscripts, authors are advised to consult the MOOSE and QUORUM statements, which are available through the *JAT* Web site.

b. The body of a **Case Report** should include the following components: personal data (age and sex and, when relevant, race, marital status, and occupation but not name or initials), chief complaint, history of present complaint (including symptoms); results of physical examination (example: ''Physical findings relevant to the rehabilitation program were . . . ''); medical history (surgery, laboratory results, examination, etc); diagnosis, treatment and clinical course (rehabilitation until and after return to competitiou); criteria for return to competition; and deviation from expectations (what makes this case unique).

c. The body of a **Clinical Techniques** article should include both the *how* and *why* of the technique: a step-by-step explanation of how to perform the technique, supplemeuted by photographs or illustrations, and an explanation of why the technique should be used. The Discussion concerning the *why* of the technique should review similar techniques, point out how the new technique differs, and explain the advantages and disadvantages of the technique in comparison with other techniques.

d. The body of an **Evidence-Based Practice** article provides a short review of current scientific literature and applies the findings to clinical athletic training practice. All articles submitted for this section should be concise reviews of published systematic reviews or meta-analyses on topics relevant to the 7 domains of athletic training (Prevention, Assessment/Evaluation, First Aid/ Treatment, Rehabilitation, Organization/ Administration, Counseling, and Education). Reviews of individual, large, controlled clinical trials will also be considered. The review must begin with the complete article title and reference and a statement of the clinical question the review addresses. The rest of the review consists of a summary of the article and must include the following sections: data sources and search terms used; study selection (inclusion and exclu-sion) criteria; the methods used to extract and review data, including a list of the primary outcome measures; results of the search strategy; and primary outcome measures and conclusions. A separate commentary section should address the application of the information to the clinical athletic training setting. Authors may use supplementary scientific literature (up to a maximum of 5 references) to support the commentary.

17. Percentages should be accompanied by the numbers used to calculate them. When reporting nonsignificant results, a power analysis, in-cluding confidence or effect size, should be provided.

18. **Communications** articles, including official Position Statements and Policy Statements from the NATA Pronouncements Committee; Technical Notes on such topics as research design and statistics; and articles on other professional issues of interest to the readership are solicited by the *Journal*. An author who has a suggestion for such a paper is advised to contact the Editorial Office for instructions.

19. The manuscript should not have a separate summary section—the abstract serves as a summary. It is appropriate, however, to tie the article together with a list of conclusions at the end of the Discussion section or in a summary paragraph.

20. References should be numbered consecutively, using superscripted arabic numerals, in the order in which they are cited in the text. No more than 30 references should be cited in Original Research manuscripts. References should be used liberally. It is unethical to present others' ideas as your own. Also, use references so that readers who desire further information on the topic can benefit from your scholarship.

21. References to articles or books, published or accepted for publication, or to papers presented at professional meetings are listed in nu-merical order at the end of the manuscript. Journal title abbreviations conform to *Index Medicus* style. Examples of references are illustrated below. See the *AMA Manual of Style* for other examples.

Journals:

1. Pitney WA, Ehlers GG. A grounded theory study of the mentoring process involved with undergraduate athletic training students. *J Athl Train*. 2004;39(4):344–351.

2. White LM, Miniaci A. Cruciate and posterolateral corner injuries in the athlete: clinical and magnetic resonance imaging features. *Semin Musculoskelet Radiol*. 2004;8(1):111–131.

Books:

1. Magee DJ. *Orthopedic Physical Assessment*. Philadelphia, PA: WB Saunders Co; 2002:45–56.

2. Robertson G, Caldwell G, Hamill J, Kamen G, Whittlesey S. *Research Methods in Biomechanics*. Champaign, IL: Human Kinetics; 2004:128–136.

Presentations:

1. Layton JA, Thigpen CA, Padua DA, Karas SG. Reliability of scapula protraction strength measures. Presented at: 55th Annual Meeting and Clinical Symposia of the National Athletic Trainers' Association; June 17, 2004; Baltimore, MD.

Videos:

1.*Spine Injury Management* [videotape]. Champaign,IL:Human Kinetics; 2001.

Software:

1. *SPSS Base for Windows* [computer program]. Version 13.0. Chicago, IL: SPSS Inc; 2005.

Internet Sources:

1. National Athletic Trainers' Association position statement: management of sport-re-lated concussion. Available at: http:// www.nata.org/publicinformation/files/ concussion.pdf. Accessed January 3, 2005.

2. ACSM guidelines for healthy aerobic activity. Available at: http://www.acsm.org/pdf/ Guidelines.pdf. Accessed January 3, 2005.

22. Personal communications are cited in the text as follows: ''. . . (J.A. Smith, written communication, January 2005).'' The written or oral nature of the communication is stated, and the communication does not appear in the reference list. Authors must provide written permission from each personal-communication source. A form is available on the *JAT* Web site and from the Editorial Office.

23. Table Style: 1) Title is bold; body and column headings are roman type; 2) units are set above rules in parentheses; 3) numbers are aligned in columns by decimal; 4) footnotes are indicated by superscripted lower-case letters (a, b, c); 5) capitalize the first letter of each major word in titles; for each column or row entry, capitalize the first word only. See a current issue of *JAT* for examples.

24. Figures should conform to the requirements as described on the *JAT* Web site. Line art should be of good quality and should be clearly pre-sented on white paper with black ink, sans serif typeface, and no box. Figures that require reduction for publication must remain readable at their final size (either 1 column or 2 columns wide). The resolution for line art and photographs must be at least 200 dpi for adequate reproduction. Authors wishing color reproduction should request same in a cover letter with the submitted manuscript. Authors will be notified of the additional cost of color reproduction and must confirm acceptance of the charges in writing.

25. Legends to figures are numbered with arabic numerals in order of appearance in the text. Legends should be printed on separate pages at the end of the mauuscript.

26. The *Journal of Athletic Training* follows the redundant publication guidelines of the Council of Science Editors, Inc (*CBE Views*. 1996; 19:76–77; also available on the *JAT* Web site). Authors in violation of redundant publication will have sanctions invoked by the Journal Committee of the National Athletic Trainers' Association, Inc.

PUBLICATION POLICIES

27. Original Research manuscripts will be categorized under the following table of contents subheadings: clinical studies, basic science, educational studies, epidemiologic studies, and observational/informational studies.

28. Only Case Reports and Clinical Techniques that define and establish the optimal standard of care or the practice of athletic training will be considered for publication in *JAT*. Case Reports and Clinical Techniques that do not profoundly affect the standard of care but that contain potentially useful information for athletic trainers will be considered for publication in the *NATA News*.

29. Media Reviews will appear in the *NATA New*