1990

Postsurgical evaluation of two methods of treatment for acutely ruptured Achilles tendons

Gregory Jon Steele
San Jose State University

Order Number 1342738

Postsurgical evaluation of two methods of treatment for acutely ruptured Achilles tendons

Steele, Gregory Jon, M.A.

San Jose State University, 1990

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

POSTSURGICAL EVALUATION OF TWO METHODS OF TREATMENT FOR ACUTELY RUPTURED ACHILLES TENDONS

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Gregory Jon Steele

December, 1990

APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE:

Rod A. Harter, Ph.D.

Richard G. Deivert, Ph.D.

Martin Trieb, M.D.

APPROVED FOR THE UNIVERSITY:

ABSTRACT

POSTSURGICAL EVALUATION OF TWO METHODS OF TREATMENT FOR ACUTELY RUPTURED ACHILLES TENDONS

by Gregory Jon Steele

The purpose of this retrospective study was to evaluate the outcomes of two methods of surgical treatment for acute closed ruptures of the Achilles tendon, specifically, the primary open repair and the percutaneous repair techniques, utilizing (a) ankle range of motion values; (b) isokinetic plantarflexion (PF) strength at 60 and 120°/s; (c) midcalf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postrsugical complications were compared between techniques. Twenty male patients (mean, 43.8 ± 9.4 yrs) who sustained sport-related Achilles ruptures participated in this study.

The two Achilles tendon surgical repair techniques produced similar funcional outcomes in the patient population studied, subjects possessed significant postsurgical limb asymmetries irrespective of surgical technique. The results suggest that the percutaneous technique, by design less invasive and less prone to postoperative complications, is a viable alternative procedure to the more traditional open surgical repair of the ruptured Achilles tendon.

ACKNOWLEDGEMENTS

I would like to extend my greatest appreciation to the man that made this thesis possible. It was only through Dr. Rod A. Harter's continued pursuit of excellence that this paper made it to completion. He is a wonderful professor, advisor and friend.

My sincere thanks to Dr. Rich Dievert and Dr. Marty Trieb for serving as committee members for this project.

My sincere thanks to Dr. A.J. Ting and the rest of the physicians at Sports Orthopedic and Rehabilitation Medical Associates (SOAR) Clinic in Portola Valley, California for assisting in this project and providing the subject pool for me to study.

I would also like to extend my sincere thanks to John Ceglia of Santa Clara Sports Therapy, for providing the facilities in which I conducted all of my testing for this thesis.

Last but certainly not least, I'd like to thank my mother and father for always being there for me, and my wife Mary for putting up with me while I completed my degree.

Table of Contents

Appendix

Appendix

Appendix

Page

Tables

CHAPTER I

INTRODUCTION

The significance of the Achilles tendon dates back to the mythological Greek warrior Achilles, who was dipped in the waters of the Styx River by his mother, Thetis, making his body invulnerable accept for the heel. According to legend, Achilles later died in the Trojan war after being wounded in the heel by Paris (Tripp, 1970).

Achilles tendon ruptures were first documented in medical literature in 1575, but the treatment of this injury remains controversial (Beskin, Sanders, Hunter, & Hughston, 1987). Quenu and Stoinovitch (1929) concluded that ruptures of the Achilles tendon should be operated on without delay.

Injuries to the Achilles tendon are one of the most common acute injuries in the lower leg (Schepsis & Leach, 1987). The Achilles tendon, the distal attachment of the triceps surae, is involved in pushoff during normal gait and can be ruptured by a forceful and sometimes unexpected plantarflexion of the ankle (Beskin et al., 1987).

Research emphasis is now being placed on minimizing the complications associated with surgical techniques, rather than the clinical outcomes (Beskin et al., 1987). Currently there are a number of surgical procedures for treating the ruptured Achilles tendon: (a) the direct repair with Bunnel or modified Kessler suturing of the tendon ends, (b) augmentation with the peroneus

brevis tendon, (c) augmentation with the plantaris tendon, and (d) the three bundle technique (Beskin et al., 1987). While each of these surgical procedures is currently used, the reported functional outcomes have been less then favorable (Inglis & Sculco, 1981; Ma & Griffith, 1977). Postoperative complications such as skin sloughs, infections, tendon adhesions to the overlying skin, tendon ruptures, fistulae, skin necroses, sensory losses, deep vein thrombi, high rates of reruptures, and deaths secondary to pulmonary embolism have been reported in 16 to 30% of surgical repairs of the Achilles, and have led some physicians to employ nonoperative treatment for the rupture of the Achilles tendon (Edna, 1980; Gilles & Chalmers, 1970; Lea & Smith, 1968; Lildholdt & Munch-Jorgensen, 1976; Ma & Griffith, 1977; Nistor, 1981).

Nonoperative treatment, as described by Lea and Smith (1972), consisted of casting the foot in a "gravity equinus position" for eight weeks followed by the use of a 2.5 cm heel lift for four weeks. This nonoperative technique was found to produce less than optimal results (Beskin et al., 1987). Reported incidences of Achilles tendon reruptures with nonoperative treatment range from 10 to 35% (Edna, 1980; Nistor, 1981). Some patients have also experienced decreased strength and endurance following treatment with the nonoperative methods (Beskin et al., 1987). Based upon the high percentage (30%) of his patients who experienced reruptures of the Achilles following nonsurgical treatment, Edna (1980) advocated surgical repair for the treatment of acutely ruptured Achilles tendons.

In reaction to the many complications associated with open surgical repair of ruptured Achilles tendons, a percutaneous technique for suturing the tendon was developed by Ma and Griffith (1977). The percutaneous suturing of the torn Achilles tendon attempts to approximate the ruptured tendon ends, thus increasing the likelihood of tissue regeneration.

Statement of Problem

Only one research study to date has evaluated the efficiency of percutaneous repair of the ruptured Achilles tendon (Ma & Griffith, 1977). These authors reported favorable results with the technique, but additional research must by conducted to further evaluate the effectiveness of the percutaneous suturing technique in direct comparison with the open surgical repair technique.

Purpose of the Study

The purpose of this retrospective study was to evaluate the results of two methods of surgical treatment of acute closed ruptured Achilles tendons, specifically, the percutaneous repair and the primary open repair procedures, utilizing the following objective measures: (a) ankle joint range of motion; (b) plantarflexion isokinetic strength at 60 and 120°/s; (c) mid-calf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postsurgical complications associated with the two methods of treatment was compared.

Hypotheses

The following research hypotheses were formulated:

1. At follow-up examination, patients who underwent percutaneous repair of the Achilles tendon will demonstrate no significant differences in ankle joint range of motion, isokinetic strength or endurance, midcalf or tendon girth, or ankle joint proprioception when compared to patients who received open surgical repair for their ruptured Achilles tendons.

2. Subjects who underwent percutaneous repair of the Achilles tendon ruptures will experience postsurgical complications at a rate equivalent to those patients who had the open surgical treatment method.

3. No significant differences among the evaluative parameters between the postsurgical and the contralateral normal lower leg of subjects will be found.

Delimitations

The following delimitations in the interpretation of the data were acknowledged:

1. Each subject participating in this study received surgical treatment for an acute rupture of the Achilles tendon from the medical staff at the Sports, Orthopedic and Rehabilitation Medicine Associates (SOAR) clinic in Portola Valley, California.

2. Isokinetic testing was performed at two speeds; specifically, 60 and 120°/s to evaluate plantarflexion strength.

3. Patients who previously sustained bilateral Achilles tendon injuries were permitted to participate in the study.

Limitations

The following limitations were acknowledged:

1. The duration and specific type of physical therapy received following surgery varied among subjects, as they were treated at various physical therapy clinics throughout the greater Northern California area.

2. The subjects' individual goals and motivation levels may have affected their compliance with rehabilitation programs, and therefore, the postsurgical results may be influenced by a lack of sufficient rehabilitation.

Definitions

1. Achilles tendon: The common tendon of the soleus and gastrocnemius muscles at the posterior aspect of the heel (Tortora & Anagnostakos, 1984).

2. Percutaneous: Effected through the skin (Thomas, 1985).

Assumptions

1. It was assumed that all subjects possessed bilateral symmetry in ankle range of motion, plantarflexion isokinetic strength and endurance, mid-calf and tendon girth, and ankle joint proprioception prior to the initial Achilles tendon injury.

2. It was assumed that the subjects involved in this study possessed the desire and motivation to regain preinjury range of motion, strength, mid-calf and tendon girth, and joint proprioception

levels in their postsurgical limbs as rapidly as possible without violating safety precautions or interfering with the healing process.

3. It was assumed that the subjects' rehabilitation protocols were competed as prescribed by the surgeons.

Summary

The treatment of Achilles tendon ruptures remains controversial. As with any injury, the end goal in treatment is to return the individual to full activity, whether it be in the work force or in athletics, as soon as possible. Ma and Griffith (1977) developed a percutaneous surgical procedure for acute Achilles tendon ruptures and reported that the technique enabled patients to return to their elected activity quickly with little or no postoperative complications. Since Ma and Griffith (1977) have published the only postoperative evaluation of the percutaneous technique to date, additional investigations and comparisons among Achilles tendon surgical techniques are warranted.

CHAPTER II

REVIEW OF LITERATURE

Introduction

The purpose of this retrospective study was to evaluate the results of two methods of surgical treatment of acute closed ruptured Achilles tendons, specifically, the percutaneous repair and the primary open repair procedures, utilizing the following objective measures: (a) ankle joint range of motion; (b) plantarflexion isokinetic strength at 60 and 120°/s; (c) mid-calf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postsurgical complications associated with the two methods of treatment was compared.

In this chapter, the following topics will be reviewed: anatomy of the Achilles tendon; pathogenesis of Achilles tendon ruptures; mechanism of Achilles tendon injuries; diagnosis of Achilles tendon injuries; open surgical repair of ruptured Achilles tendon, and percutaneous repair of the ruptured Achilles tendon.

The Achilles Tendon

Anatomical and Functional Characteristics

The Achilles tendon is composed of the triceps surae (gastrocnemius and soleus muscles), which inserts onto the posterior surface of the calcaneus. The gastrocnemius is formed by two heads on the posterior surface of the femur (Thompson & Doherty, 1962). The muscle bellies are flattened in shape and

descend to form one-half to one-third of the Achilles tendon (Thompson & Doherty, 1962). The Achilles tendon is the strongest and thickest tendon in the human body, and can be palpated from the lower one-third of the calf to the calcaneus (Hoppenfeld, 1980). The Achilles tendon is surrounded by the paratenon, rather than a synovial sheath. The paratenon is a fatty tissue that surrounds the tendon (Thomas, 1985). Williams stated that the mesotendon was responsible for the blood supply reaching the Achilles tendon (Williams, 1986). The mesotendon is a tissue that lines a fibrous sheath that attaches the sheath to the tendon (Thomas, 1985).

The soleus is the primary plantarflexor of the ankle (Winter, 1979; Williams, 1986). Winter (1979) concluded that the soleus has a cross-sectional area of 67 sq cm, where as the gastrocnemius medial and lateral head combined has a cross-sectional area of 35 sq cm. The gastrocnemius assists in plantarflexion, and also is a potential flexor of the knee joint (Gardner, Gray, O'Rahilly, 1975; Williams, 1986).

Blood Supply

The Achilles tendon does not have an independent blood supply (Pickrell, Thompson, Nichol, & Kasdan 1970). The Achilles tendon receives the majority of its blood supply from the mesotendon (Williams, 1986). Williams (1986) also noted that the paratenon supplies the tendon. A region between 2 and 6 cm proximal to the distal insertion of the tendon is relatively avascular (Lagergren & Lindholm, 1958). In athletes, Williams (1986) noted that the blood

supply to the Achilles tendon comes through the calcaneal attachment of the soleus fibers on the deep surface of the tendon. The gastrocnemius and the soleus also have their own blood supplies. The gastrocnemius is unique, in that it is one of the few muscles that only has one source of blood supply. Both the medial and lateral heads of the gastrocnemius are supplied by branches of the popliteal artery (Gardner et al., 1975). The posterior tibial artery is responsible for the blood supply to the soleus (Gardner et al., 1975).

Pathogenesis of Injury

The pathogenesis of Achilles tendon ruptures is still unclear, but several theories have been postulated. The first of these theories involves a chronic tendon degeneration and a failure of the inhibitory mechanism in the musculotendinous unit (Beskin et al., 1987). Inglis and Sculco (1981), in support of this theory, suggested that the primary cause of Achilles tendon rupture was a malfunction of the normal inhibitory mechanism of the musculotendinous unit that prevents Achilles tendon failure from excessive or uncoordinated muscle contraction. Fatigue or poorly coordinated muscle contractions may also contribute to Achilles tendon ruptures (Inglis & Sculco, 1981). Achilles tendon ruptures occur more in the left ankle than in the right (Stein & Luekens, 1976). This is thought to be due to the fact that most people are right handed, and jump off of the left foot, as in a basketball layin (Stein & Luekens, 1976). Inglis and Sculco (1981) concluded that limb dominance does not play a significant role in Achilles tendon disorders, noting that 74

of their patients sustained ruptures of the left tendon, 89 patients sustained ruptures of the right tendon, and four patients experienced bilateral ruptures. The average age was 36.6 years for the entire group.

In addition to the [illegible]al pathologies for Achilles tendon ruptures, steroid injection[illegible]endon have been associated with ruptures. Kellam, H[illegible] McElwain (1985) reported that 63% of the athletes with [illegible]endon ruptures in their study had previously received a local corticosteroid injection. In a study by Beskin et al. (1987) 14.3% of the patients with ruptured Achilles tendons were diagnosed as having gout, as well as high serum cortisol levels.

Etiology of Injury

An intact Achilles tendon is needed for adequate pushoff during normal gait activities (Beskin et al., 1987). These authors also reported that the greatest amount of force was applied to the Achilles tendon during the pushoff phase in running or jumping. Thompson and Doherty (1962) studied 46 patients and found that 64% of the ruptures came from a sudden push off, 21% from a sudden dorsiflexion, 13% from a fall, and the final 2% of Achilles tendon ruptures from a traumatic blow from behind directly on the Achilles.

The mechanisms of injury to the Achilles tendon are in most cases, defined by the well-recognized patterns of jumping, pushing off, or a significant fall that forces the ankle into dorsiflexion (Carden, Noble, Chalmers, & Ellis, 1987). The Achilles tendon

commonly ruptures in men with sedentary occupations who engage in occasional strenuous physical activity (Hooker, 1963). Hooker (1963) also identified sudden springing, jumping, or twisting while the tendon is taut as the most common predisposing factors in Achilles tendon ruptures. A sudden blow to a taut Achilles tendon can also cause rupture (Carden et al., 1987).

Differential Diagnosis of Injuries

While injuries to the Achilles tendon are common, ruptures of the Achilles tendon are not a common lesion, so physicians' individual experiences with it are low (Inglis, Scott, Sculco, & Patterson, 1976). The diagnosis of rupture was often missed because there may be little or no pain, no gap to be felt, and no obvious impairment of plantarflexion (Hooker, 1963). Inglis et al. (1976) stated that 25% of all Achilles tendon ruptures are missed by the primary physician.

Differential diagnosis of complete Achilles tendon ruptures can be made by analyzing the patient's history, and through careful observation. Upon tearing the Achilles tendon, the subject will most often feel the heel cord snap, followed by a limp and difficulty in plantarflexing on the affected foot (Williams, 1986). A loud snap will usually be heard by the individual or by bystanders at the time of the rupture (Hooker, 1963). According to Hooker (1963), when the examiner can palpate a gap in the tendon, the diagnosis of a complete rupture of the Achilles tendon can be made. The tendon

most commonly ruptures 2 to 3 cm proximal to its insertion, in an are of decreased vascularity (Inglis et al., 1976).

The Thompson test or squeeze test has been shown to be nearly 100% positive in diagnosing ruptured Achilles tendons (Thompson & Doherty, 1962). To perform the Thompson test, the patient lies prone with their feet over the edge of the examination table. While the patient is relaxed, the examiner squeezes the calf muscle. A positive test is indicated by the absence of plantarflexion when the calf is squeezed, and is indicative of a ruptured Achilles tendon (Thompson & Doherty, 1962). Reinig, Dorwart, and Roden (1985) observed that the Thompson test may be negative in a partial tear of the Achilles tendon, and that other procedures for diagnosis such as computed tomography, sonographic diagnosis, and magnetic resonance imaging (MRI) should be performed. Keene, Edward, Lash, Fisher, and DeSmet (1989), however, concluded that the Thompson test is effective, and a MRI is not required to document that an Achilles tendon injury has occurred.

An example of an additional diagnostic procedure is computed (axial) tomography. Computed tomography (CT) images provide good definition of the tendon, but are limited by the lack of contrast between the tendon and hemorrhage (Reinig et al., 1985). Edema may also be present at the site of the injury (Reinig et al., 1985).

Magnetic resonance imaging (MRI) provides clear definition of the injured Achilles tendon (Reinig et al., 1985). Stein and Luekens (1976) observed that roentgenograms in the lateral plane may show

changes in soft tissue patterns, indicating interruption of the Achilles tendon. Lildholdt and Munch-Jorgensen (1976) also believed that "soft-part radiography" should be used to ensure a greater diagnostic certainty. Some authors suggest that sonograghic images are particularly useful in diagnosing a partially-torn Achilles tendon (Leekam, Salsberg, Bogoch, & Shankar, 1986).

Open Surgical Repair of the Achilles Tendon

There are several different operative methods that have been advocated for treatment of the ruptured Achilles tendon (Nistor, 1981). Beskin et al. (1987) identified four surgical procedures: (a) "Bunnell" or modified "Kessler" suturing of the tendon ends; (b) augmentation with the plantaris tendon; (c) augmentation with the peroneus brevis tendon; and (d) the three-tissue bundle technique. According to Beskin et al. (1987), the first three techniques mentioned are commonly used be orthopaedic surgeons today.

The fourth technique is a relatively new procedure, and thus warrants further discussion. The three-tissue bundle technique gathers the disorganized tendon fibers into three bundles. The three bundles are then sutured together in a functional position (Beskin et al., 1987). In most procedures, a equinus plaster cast is used to immobilize the ankle, and the use of a equinus cast that includes the knee made no difference in the results of the surgery (Hooker, 1963). Completely ruptured tendons that were surgically repaired exhibited greater muscle power than those treated nonsurgically in a study by Inglis and Sculco (1981).

In the three-bundle repairs, an average of 3 to 5° of plantarflexion was lost when compared to the unaffected side (Beskin et al., 1987). When using the unaffected leg as a control, the average difference in calf circumference was 0.7 cm in the early repairs (performed within 1 to 30 days of initial injury; mean, 5.8 days) and 1.2 cm in late repairs (performed within 2.5 to 48 months following initial injury; mean 11 months) (Beskin et al., 1987).

In the Beskin et al. (1987) study, five patients receiving three-bundle repairs required an average of 9.1 months to return to maximal function from the time of repair. In 88% of the early repairs and 80% of the late repairs, patients returned to their preinjury activity levels. In early repairs 88% of the patients had return of muscular power (range, 59 to 100%), while those undergoing late repair averaged 76.8% return of power (range, 49 to 100%). Endurance measured by plantarflexion at 180°/s revealed that the early repair group had a 74% return of muscular endurance (range, 33 to 125%) and the late repair group had a 85% return (range, 66 to 100%) (Beskin et al., 1987).

Inglis et al. (1976) conducted a study in which isokinetic testing was performed on 30 patients one your postoperatively, and found that strength measures had returned to 100% of that on the contralateral normal limb, 88% of the power had returned, and 91% of the endurance had returned. Thirty-six of the 39 patients surveyed 1 year postoperatively were satisfied with the results of their surgery, and had returned to their previous level of activity

(Inglis et al., 1976). In this follow-up study, no reruptures of the Achilles tendon occurred, and the two wound infections which occurred postsurgically healed without further complications.

In a similar study, Kellam et al. (1985) evaluated 68 patients who were treated surgically for ruptured Achilles tendons and found that 92% achieved "satisfactory" results, in that they were able to return to their preinjury activity level. Only 3% of these patients experienced reruptures of the Achilles.

Ting believed that the use of a tourniquet, and the duration of the hospitalization period were two weaknesses which affected the success of open surgical procedures for Achilles tendon ruptures (A.J. Ting, M.D., personal communication, March 13, 1989). Inglis and Sculco (1981) found that the average length of stay in the hospital for surgical treatment of the Achilles tendon was nine days (range, 3 to 26 days). The patients that were treated with the open repair missed an average of 13 weeks (range, 0 to 30 weeks) of work (Nistor, 1976).

According to Lea and Smith (1972), complications associated with open surgical repair of the torn Achilles are numerous, as 18 of 105 patients (17%) studied had a major complication and 22% of the patients experienced minor complications. Carden and associates (1987) reviewed 103 cases of torn Achilles tendons and reported that 12.6% of the patients (n=13) had major complications following open surgical repair while 19.4% (n=20) experienced minor complications.

Postsurgical Complications

In their review of the literature, Beskin et al. (1987) found several reports of complications following Achilles tendon surgery, including sensory loss due to damage of the sural nerve, skin necrosis, and up to 42% rate of rerupture of Achilles tendons. Edna (1980) cited a risk of venous thrombosis in surgically repaired Achilles tendons. In addition, keloid formation, and more importantly, sloughing (the separation of dead tissue from living tissue) of the overlying skin and tendon were reported as common postsurgical complications (Gillies & Chalmers, 1970).

Sinus (scar tissue) formation associated with the use of nonabsorbable suture material was the most frequent complaint with the open surgical repair method (Kellam et al., 1985). Hooker (1963) stated that the suture material had no effect on the outcome of the surgical procedure, but the use of nonabsorbable material may cause discharge of suture material and sinus formation. According to Kellam et al. (1985), when treating a ruptured Achilles tendon surgically, the sural nerve needs to be avoided, absorbable suture material should be used, reinforcement with the plantaris or some fascial material should be used, and immobilization should be done with a below the knee cast with the foot in as much dorsiflexion as the repair will allow.

Percutaneous Repair of the Achilles Tendon

Percutaneous suturing for the repair of the acute closed Achilles tendon rupture is a technique designed to produce less

postsurgical complications than the open surgical repair technique (Ma & Griffith, 1977). The repair is done with a local, regional or general anesthesia, and without a tourniquet (Ma & Griffith, 1977). These authors utilized a number 0 or number 1 nonabsorbable suture, 30.5 to 35.5 cm in length. Each suture end was threaded with a 7.6 cm straight needle (Ma & Griffith, 1977). The percutaneous repair consists of nine separate steps (Figure 1). In the first step, small stab wounds 2.54 cm proximal to the tendon defect are made on the medial and lateral sides of the tendon. Beginning on the lateral side, the needle and suture are passed transversely through the two stab wounds, and the suture is adjusted so that the medial and lateral suture ends are equal. During the second step, th 7.6 cm straight needles are passed through the ipsilateral stab wounds at 45° angles, passing through the tendon and out the skin on the contralateral side. Traction is applied to the two suture ends once they are pulled completely through the skin. Next, a curved needle in the lateral suture is passed distally between the tendon sheath and the subcutaneous tissue and out through the skin about 1.25 cm distal to the rupture. The distal exit hole is than enlarged, and the suture is pulled through the skin at the distal puncture hole. The suture is then passed through the lateral hole transversely through the distal Achilles tendon, and out through the skin on the medial side (Figure 1).

Next, the suture on the medial side is pulled taut, and then the distal medial suture is passed back through between the

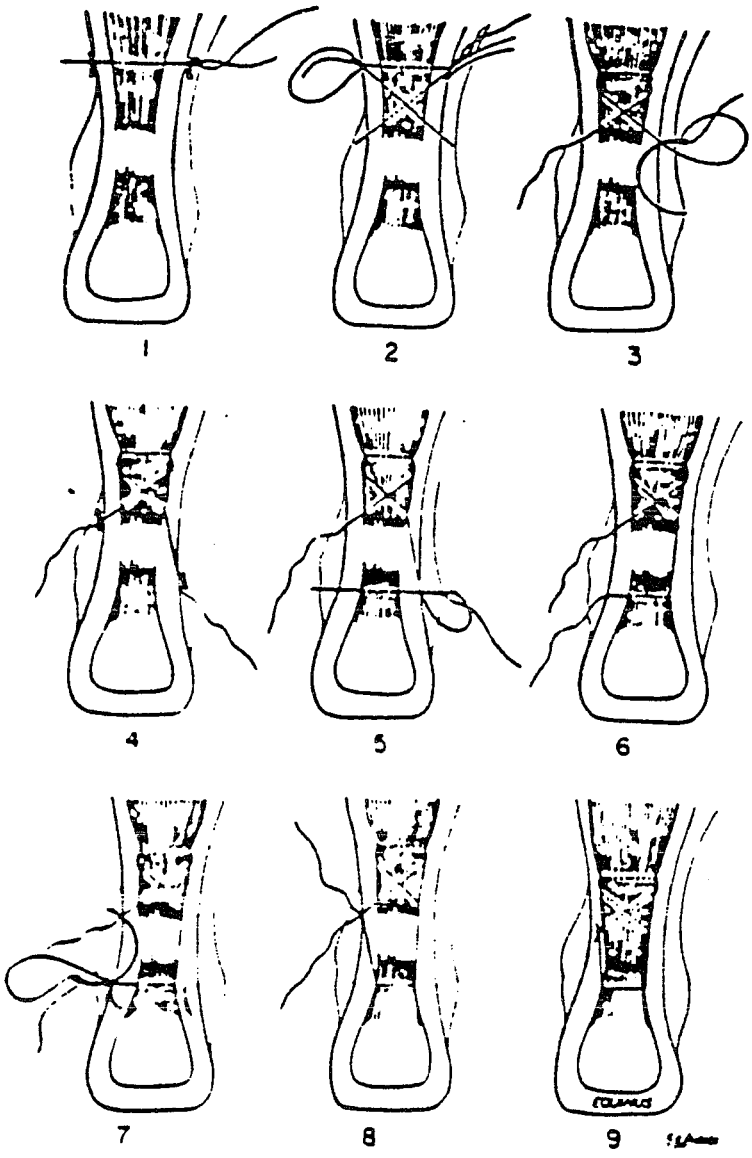


FIGURE 1. NINE STEPS INVOLVED IN THE PERCUTANEOUS SURGICAL REPAIR OF THE ACHILLES TENDON (Ma and Griffith, 1977, p. 250).

subcutaneous tissue and tendon sheath, and out through the puncture hole at the level of the rupture site. Traction is then applied to both of the suture ends protruding through the medial meddle hole while the ankle joint is held in maximum plantarflexion, and the tendon ends are approximated. The suture is then tied and the ends are cut and the knot is pushed subcutaneously. No skin sutures are required. The final step is to apply a short leg nonweight-bearing cast for four weeks following surgery with the foot in an equinus position.

Typically, patients are treated four additional weeks with a low-heel weight-bearing equinus cast, followed by four weeks of range of motion and strengthening exercises (Ma & Griffith, 1977).

Dr. A.J. Ting advocated a postoperative regimen of four weeks in a nonweight-bearing equinus cast, followed by four weeks in a weight-bearing cast, and finally two months in a walking brace (personal communication, March 13, 1989).

Percutaneous repair is an outpatient procedure that lasts approximately 20 minutes (A.J. Ting, M.D., personal communication, March 13, 1989). According to Ma and Griffith (1977), percutaneous suturing of the Achilles tendon restores tendon continuity, minimizes trauma to the tenuous blood supply, reduces the surface area available for adhesion formation, and reduces the possibility of contamination. In 18 cases of percutaneous Achilles repair evaluated at an average of 40 months postsurgery, Ma and Griffith reported that 75% of the patients had a normal gait following treatment, 50% had no more than 5 mm of calf atrophy,

and no patient lost more than 5° of range of motion. In 12 patients studied one year after treatment there was a 86% return of muscular power; in eight additional patients, there was a 89% return of muscular power 2 years postoperatively (Ma & Griffith, 1977). Their patient population consisted of 14 males (78%) and 4 females (22%), with an age range of 25 to 66 years. To date, only these authors have evaluated this procedure involving only acute, closed Achilles tendon ruptures. Therefore, from a statistical standpoint, the results from this study cannot be compared with reports on late surgical techniques greater than 3 days postinjury for treating ruptured Achilles tendons (Ma & Griffith, 1977).

The only complications cited for the percutaneous procedure were skin retraction dimples at the operative site, and tender nodules at the site of the surgical knot (Ma & Griffith, 1977). These authors reported no incidence of Achilles reruptures nor wound infections.

Dr. A.J. Ting expressed concern about compression on the sural nerve, but believed that use of absorbable suture material would eliminate these complications without compromising the treatment results (personal communication, March 13, 1989).

Summary

Rupture of the Achilles tendon is an injury that is often misdiagnosed. A number of studies have been published which describe the open surgical procedure for treating a ruptured Achilles tendon. The open surgical treatment has been shown to have

numerous postsurgical complications. It is for these reasons that the percutaneous repair of the Achilles tendon was developed.

CHAPTER III
PROCEDURES

The purpose of this retrospective study was to evaluate the results of two methods of surgical treatment of acute closed ruptured Achilles tendons, specifically, the percutaneous repair and the primary open repair procedures, utilizing the following objective measures: (a) ankle joint range of motion; (b) plantarflexion isokinetic strength at 60 and 120°/s; (c) mid-calf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postsurgical complications associated with the two methods of treatment was compared.

This chapter contains information on methodology and testing procedures, and descriptions of the subject pool, screening procedures, testing apparatus, and testing protocols.

Subjects

The subject pool for this study consisted of patients treated at Sports Orthopedic and Rehabilitation Medicine Associates (SOAR) clinic in Portola Valley, California from January 1986 to September 1989. Subjects were identified through examination of patient and surgical records at the orthopedic clinic. To qualify for participation in the study, patients were required to meet the following criteria: (a) must have a normal contralateral Achilles tendon for comparative purposes; (b) must have Achilles tendon

repair no later than September 1989; and (c) must have only one surgical repair of their torn Achilles tendon.

Patients who met these criteria were initially contacted by telephone utilizing a prepared script (Appendix A), and later were sent a follow-up letter inviting their participation in the study (Appendix B). Subjects who agreed to participate in the study were required to return to the Santa Clara Sports Therapy clinic in Santa Clara, California for examination, interviews, and objective testing. All examinations, interviews, and tests were conducted by the primary investigator during each subject's one-time visit to the clinic.

Instrumentation

The popularity of isokinetic equipment in measuring muscle force has grown in recent years, partially because of its increased safety over the other methods of muscular testing (Osternig, 1986). A Cybex II+ isokinetic dynamometer (Cybex Division of Lumex Corporation, Ronkonkoma, New York) was used to measure plantarflexion range of motion, strength, and ankle proprioception. Additionally, a Cybex upper-body exercise and testing table (UBXT) and a Cybex data reduction computer (CDRC) (Cybex Division of Lumex Corporation, Ronkonkoma, New York) were employed in the testing procedures. The UBXT was designed to improve patient positioning and provide additional stabilization for testing and exercise (Cybex Handbook, 1983).

The CDRC provides a fast and accurate isokinetic testing procedure by providing digital output of performance measurements and eliminating the need to interpret analog graphs. The software utilized by the CDRC eliminates errors that occur in manual goniometer settings, and calculates power, torque acceleration energy, total work, and endurance ratios (Cybex Handbook, 1983). In addition, one other vital function of the CDRC software is the ability to provide for gravity correction for the effects of limb mass, which, if uncorrected, would erroneously inflate plantarflexion torque, and conversely reduce dorsiflexion torque values.

Mid-calf girth measurements were taken with a Lufkin fiberglass tape fitted with a Gulik handle in order to provide identical tension throughout the testing of all subjects.

In addition to the objective testing parameters (Appendix C), subjects also completed a subjective questionnaire intended to assess subjects' attitudes toward the functional outcomes of their surgical procedures (Appendix D).

Testing Protocols

All subjects were required to read and sign an informed consent form consistent with San Jose State University's Institutional Review Board of Human Subjects prior to the testing or gathering of any data (Appendix E). Following the signing of the informed consent form, the various test were administered in the following order: (a) subjective questionnaire; (b) girth measurements; (c) isokinetic strength evaluation; (d) ankle joint

proprioception; (e) range of motion testing. All subjects participated in a 6 minute warm-up period on an exercise bike prior to physiologic testing.

All information gathered in this study was kept confidential. The data and questionnaire results are being kept under lock and key, in the sole possession of the examiner.

Questionnaire

Prior to the physiologic testing, subjects were asked to complete a subjective questionnaire designed to assess their attitudes toward the functional outcomes of their surgical procedures. Subjects expressed their opinions of their surgical procedures on a Likert-type scale (Appendix D).

Girth Measurements

Prior to isokinetic evaluation, girth measurements were taken. The circumference measures were taken with a Lufkin fiberglass tape fitted with a Gulik handle. With the ankle in the anatomical neutral position (90°), measurements were taken at two different positions; (a) mid-calf, and (b) 4 cm proximal to the medial malleoli. The mid-calf measurements were used to determine the amount of hypertrophy or atrophy, and the measurements proximal to the medial malleoli were used to determine the amount of tendon thickening postoperatively.

Isokinetic Evaluation

Each subject performed maximum voluntary plantarflexion isokinetic strength tests at 60 and 120°/s, in accordance with

previously established protocols for isokinetic strength testing (Cybex Handbook, 1983). Damping was set at "1," since significant peak torque overshoot does not occur when testing ankle plantarflexion strength (CDRC Manual, 1983). Maximum torque values at 20° and 35° of plantarflexion were measured to evaluate surgical/nonsurgical limb symmetry. In the protocol selected, plantarflexion testing was performed with the knee at 0° and 90° of flexion in order to isolate the gastrocnemius and the soleus, respectively. The dynamometer was interfaced with the CDRC which provided digital output of the plantarflexion strength values. Analog torque and position values were plotted on a 2-channel chart recorder.

To perform isokinetic testing of the gastrocnemius, the subjects were placed in a prone position, and the foot of the limb to be tested was secured to the plantarflexion/dorsiflexion footplate with two Velcro straps with the knee extended (Figure 2). To isolate the soleus for isokinetic testing, the subjects were placed in a supine position. The knee was flexed to 90° and stabilized utilizing the upper body extremity table (UBXT) (Figure 3). All subjects were given the same verbal instructions prior to and during the testing period (Appendix F). Subjects performed 4 repetitions at 60°/s, and 20 repetitions at 120°/s. The setting of 120°/s was selected for two reasons. First, it was found that 120°/s is the highest speed that the ankle can move and still produce a measurable

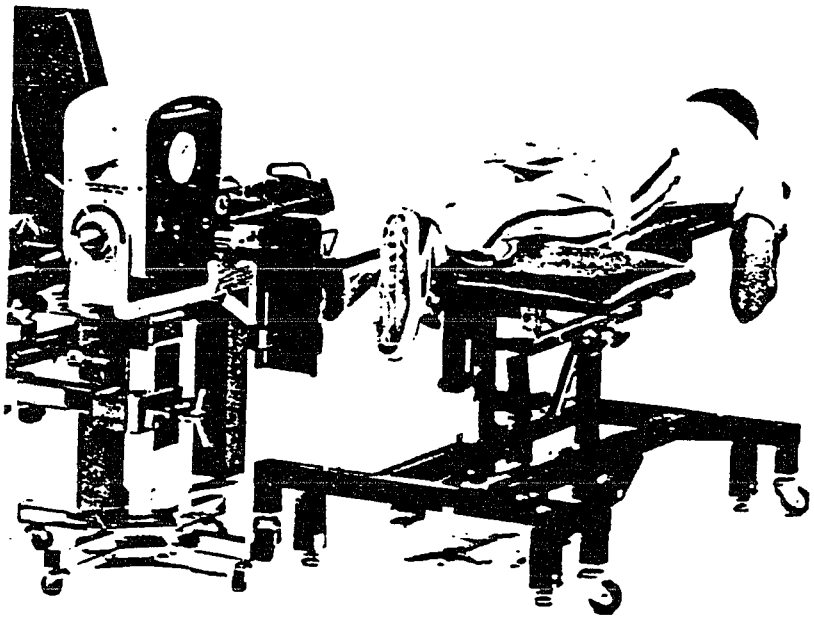


FIGURE 2. PATIENT PLACEMENT TO ISOLATE THE GASTROCNEMIUS FOR ISOKINETIC TESTING.

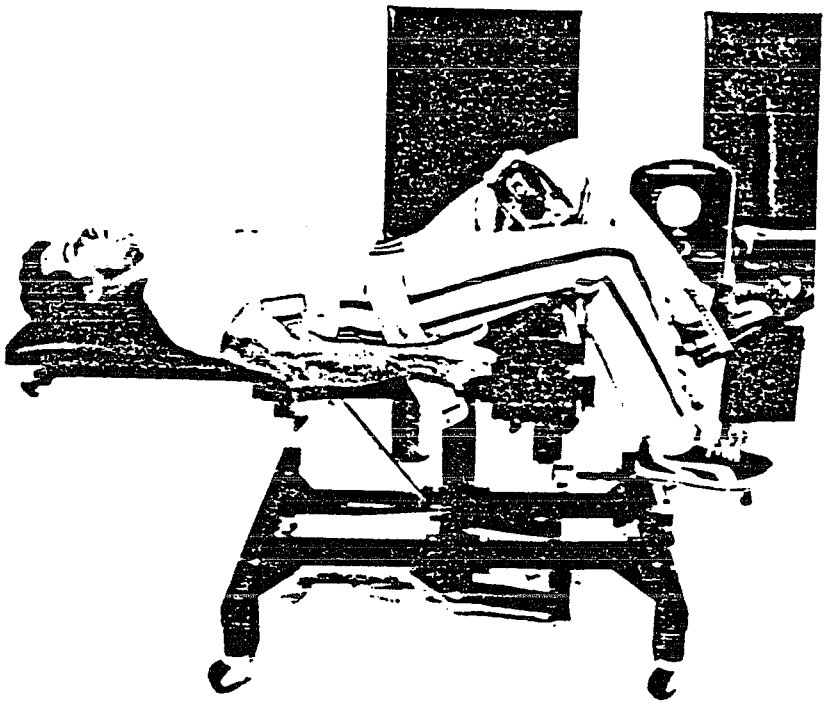


FIGURE 3. PATIENT PLACEMENT TO ISOLATE THE SOLEUS FOR ISOKINETIC TESTING.

isokinetic torque curve (Shields, Kerlan, Kobe, Carter, & Lombardo, 1978). Second, the 120°/s protocol is often used in the physical therapy setting for rehabilitation of the Achilles tendon, so the subjects will already be accustomed to this setting (Kevin T. Gibbons, P.T., A.T.,C., personal communication, March 7, 1990).

The order of isokinetic testing was counterbalanced with a Latin squares design to control for learning effects and fatigue (Appendix G). The subjects were allowed a 30 second rest between experimental conditions. Standardized vocal encouragement was given to the subjects during the testing to encourage maximal output in the isokinetic testing (Appendix F).

Ankle Joint Proprioception

To evaluate ankle joint proprioception, the subjects were positioned as if to undergo isokinetic testing, but were blindfolded to remove visual input. Starting in the anatomical neutral position (knee at 0° flexion; ankle at 90°), the examiner passively positioned the ankle in 1 or 2 plantarflexion positions (20 or 35°) by pulling on the dynamometer lever arm. The ankle was held in this position for approximately 3 seconds, and passively returned to the anatomical position. The subject was then asked to actively reproduce the previously placed position (target angle). The subjects were asked to give a verbal cue when they perceived they had reached the target angle. The test was repeated three times for each target angle for both the postsurgical and contralateral normal limbs.

The real-time digital output from the dynamometer's internal goniometer was used to quantify target angle error in degrees. Utilizing the analog signal from the 2-channel chart recorder, the absolute value of the amount of undershoot or overshoot of the target angle on each trial was later calculated and analyzed.

Range of Motion

Subjects' active range of motion (AROM) values were determined utilizing the goniometer within the isokinetic dynamometer. To quantify AROM, subjects were instructed to maximally plantarflex and dorsiflex their ankles. Utilizing the goniometer mode available with the CDRC software, the extremes of both plantarflexion and dorsiflexion were output in a digital format, and measured to the nearest degree. Only the plantarflexion AROM values were used for analysis.

Statistical Treatment

In a study such as this which examined multiple dependent variables, the obvious experimental design of choice is a multivariate analysis of variance (MANOVA). Unfortunately, this retrospective study lacked randomization, as the researcher had no control over which patient received a particular surgical technique. Further, the small patient population (N=30) and problem of multicollinearity of the multiple dependent variables made analysis with MANOVA techniques impossible.

To evaluate differences between the postsurgical and contralateral normal Achilles tendons, irrespective of surgical

techniques, multiple paired T-tests were employed using a modified Bonferroni adjustment of alpha from .05 to .01 to reduce experimentwise error with multiple tests.

To evaluate differences between the two surgical techniques for Achilles tendon repair, a series of univariate one-way (surgical technique) analysis of variance (ANOVA's) were employed. Likewise, the alpha level was adjusted *a priori* from .05 to .01 to reduce experimentwise error present with multiple ANOVA's.

Finally, the subjective questionnaire data were evaluated for significant differences utilizing the nonparametric chi square statistic. Alpha level was set at .05.

Summary

Subjects for this study were solicited from a pool of patients treated at the Sports Orthopaedic and Rehabilitation Medicine Associates Clinic in Portola Valley, California from January 1986 to September 1989. The results of percutaneous repair versus open repair of acute ruptured Achilles tendons were compared utilizing: (a) isokinetic strength; (b) girth measurements; (c) ankle joint proprioception; and (d) ankle range of motion. An evaluation of postoperative function was also done utilizing a subjective questionnaire.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this retrospective study was to evaluate the results of two methods of surgical treatment of acute closed ruptured Achilles tendons, specifically, the percutaneous repair and the primary open repair procedures, utilizing the following objective measures: (a) ankle joint range of motion; (b) plantarflexion isokinetic strength at 60 and 120°/s; (c) mid-calf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postsurgical complications associated with the two methods of treatment was compared.

Results

Demographics

Thirty surgical patients who had been treated at the Sports Orthopedic and Rehabilitation Medical Associates (SOAR) clinic in Portola Valley, California for acutely ruptured Achilles tendons between January 1986 and September 1989 were identified through a review of pertinent medical records. All 30 patients were telephoned and sent a letter requesting their participation in the study. Twenty of the 30 patients from the subject pool volunteered to participate in the study. Of the 10 patients who did not participate, two (20%) had subsequent reruptures of the repaired Achilles tendon, and two others (20%) incurred bilateral Achilles ruptures, and therefore did not meet the criteria for participation in

the study. Six patients were lost to follow-up study because of geographical constraints and/or an unwillingness to participate.

Eighteen of the 20 patients (90%) who participated in the study injured their Achilles tendons during sports participation. A summary of the sport activities in which the injuries occurred is presented in Table 1.

Table 1.

Etiology of Achilles Tendon Ruptures (N=20)

Racquetball	5(25%)
Basketball	4(20%)
Volleyball	3(15%)
Running	2(10%)
Tennis	2(10%)
Unknown	2(10%)
Diving	1(5%)
Softball	1(5%)

Patients who agreed to participate in the study were tested at the Santa Clara Sports Therapy (SCST) clinic in Santa Clara, California during the period from May 15, 1990 to June 15, 1990. All postoperative testing was completed during a one-time visit to SCST; the total time required to evaluate each subject was approximately 45 minutes. All subjects read and signed the informed consent form prior to testing, in accordance with San Jose State University's Institutional Review Board for Human Subjects policy. Subjects participated voluntarily, and no financial

compensation was given. The sample population demographics are summarized in Table 2.

Table 2.

Summary of Subject Demographic Data (N=20)

Parameter	Mean ± SD	Range
Age (yrs)	43.7 ± 9.5	32 to 67
Weight (kg)	83.1 ± 9.2	72 to 99.5
Height (cm)	187.0 ± 6.3	170 to 193
Length of Postoperative Period (months)	22.9 ± 8.3	13 to 44
Length of Postoperative Physical Therapy (months)	13.6 ±3.3	9 to 24

Peak Plantarflexion

Peak plantarflexion torque occurred at 8.2° ± 1.4° at 60°/s and 13.6° ± 2.7° at 120°/s with the knee in the anatomical position (0° flexion). With the knee at 90° of flexion, the average position that peak torque occurred was 16.6° ± 4.7° at 60°/s, and 21.0 ± 5.2 at 120°/s.

Paired t-Test Analyses

The results of paired T-tests performed on selected parameters revealed significant differences ($P<.002$) between the subjects' surgical and normal contralateral limbs for 7 of 14 parameters. Surgical limb deficits ranged from 2% (mid-calf girth)

to 87% (ankle proprioception at 20° position with the knee in 0° flexion). The paired T-test results are summarized in Tables 3 and 4.

Analyses of Variance

A one-way analysis of variance (ANOVA) was performed on each of eight dependent variables selected for analysis. The results of the ANOVAs revealed no significant differences ($P>.01$) between the percutaneous repair and open surgical repair groups for any of the parameters (Table 5). Summary tables for each of the ANOVAs are presented in Appendix J through Appendix Q.

Chi-Square Analysis

All subjects completed a two-page written questionnaire which assessed their attitudes toward the functional outcomes of their surgical procedures. Chi square analysis revealed no significant differences ($P>.05$) for any of the responses between the two surgical groups. A summary of the individual subject's responses to the questionnaire is presented in Appendix R.

Discussion

The demographic composition of the patients who participated in this study was similar to the patient populations evaluated in previous Achilles tendon surgery studies (Barnes, 1986; Beskin et al., 1987; Inglis & Sculco, 1981; Schepsis & Leach, 1987; Shields et al., 1978). All 20 subjects in the present study were male, with an average age of 44.0 ± 9.5 years. Achilles tendon ruptures are a common occurrence in "middle aged men"; thus, the subjects studied

Table 3

Results of Paired t-Test for Isokinetic Parameters (Surgical versus Nonsurgical Limbs)

Parameter		Surgical Limb (Mean ± SD)	Nonsurgical (Mean ± SD)	Relative Difference	T-value	P
1.	Max Torque at 20° PF at 60°/s (0° Knee Flexion)	54.2 ± 16.5 Nm	68.3 ± 14.8 Nm	20.6%	5.07	.001*
2.	Max Torque at 35° PF at 60°/s (0° Knee Flexion)	20.7 ± 13.2 Nm	33.2 ± 13.8 Nm	38%	3.99	.001*
3.	Max Torque at 20° PF at 120°/s (0° Knee Flexion)	42.0 ± 14.9 Nm	50.9 ± 14.5 Nm	18%	3.55	.002*
4.	Max Torque at 20° PF at 120°/s (0° Knee Flexion)	19.5 ± 12.9 Nm	29.5 ± 12.6 Nm	34%	3.63	.002*
5.	Max Torque at 20° PF at 60°/s (90° Knee Flexion)	54.9 ± 20.5 Nm	64.7 ± 14.9 Nm	15%	2.45	.024
6.	Max Torque at 35° PF at 60°/s (90° Knee Flexion)	35.6 ± 13.4 Nm	39.3 ± 14.6 Nm	9%	1.25	.227

* = P<.01

Table 3 continued:

Parameter	Surgical Limb (Mean ± SD)	Nonsurgical (Mean ± SD)	Relative Difference	T-value	P
7. Max Torque at 20° PF at 120°/s (90° Knee Flexion)	36.7 ± 12.6 Nm	42.8 ± 10.9 Nm	14%	3.57	.002*
8. Max Torque at 35° PF at 120°/s (90° Knee Flexion)	27.9 ± 10.6 Nm	31.5 ± 10.6 Nm	12%	1.89	.074

*P<.01

Table 4

Paired t-Tests Results for Surgical versus Nonsurgical Limbs

	Parameter	Surgical Limb (Mean ± SD)	Nonsurgical (Mean ± SD)	Relative Difference	T-value	P
1.	Ankle Proprioception (90° Knee Flexion)	3.65 ± 1.93°	3.00 ± 1.83°	-21.7%	1.64	.119
2.	Ankle Proprioception (0° Knee Flexion)	2.65 ± 2.09°	2.60 ± 2.31°	-1.9%	0.08	.939
3.	Mid Calf Girth	36.05 ± 3.06 cm	36.93 ± 3.12 cm	-2.4%	3.85	.001*
4.	Tendon Girth	22.56 ± 1.56 cm	22.93 ± 3.19 cm	-1.6%	0.66	.520
5.	Max Active ROM (Plantarflexion) 0° Knee Flexion	46.55 ± 4.79°	48.75 ± 3.19°	-4.5%	2.22	.039
6.	Max Active ROM (Plantarflexion) 90° Knee Flexion	51.15 ± 4.26°	50.95 ± 3.61°	.04%	0.21	.833

* P<.01

Table 5

Summary of ANOVA Results for Differences in Postsurgical/Contralateral Normal Limb Ratios Between Achilles Tendon Surgical Techniques (mean ± SD, F ratio, significance level). (a)

	Parameter (D.V.)	Open Repair Technique	Percutaneous Repair	F ratio	P
1.	Maximum PF Strength at 20° at 60°/s (0° Knee Flexion)	78.3 ± 20.3	80.8 ± 17.3	0.09	.76
2.	Maximum PF Strength at 35° at 60°/s (0° Knee Flexion)	67.5 ± 45.0	67.4 ± 45.8	0.00	.99
3.	Maximum PF Strength at 20° at 120°/s (0° Knee Flexion)	82.3 ± 18.4	86.4 ± 31.0	0.13	.73
4.	Maximum PF Strength at 35° at 120°/s (0° Knee Flexion)	64.6 + 40.2	78.6 + 55.3	0.42	.53
5.	Maximum PF Strength at 20° at 60°/s (90° Knee Flexion)	89.5 ± 25.6	81.8 ± 30.1	0.37	.55
6.	Maximum PF Strength at 35° at 60°/s (90° Knee Flexion)	107.9 ± 71.5	96.2 ± 36.3	0.21	.65
7.	Maximum PF Strength at 20° at 120°/s (90° Knee Flexion)	85.9 ± 17.9	84.5 ± 21.4	0.03	.88

Table 5 continued:

Parameter (D.V.)	Open Repair Technique	Percutaneous Repair	F ratio	P
8. Maximum PF Strength at 35° at 120°/s (90° Knee Flexion)	92.3 + 39.6	91.1 + 11.9	0.01	.93
9. Mid-Calf Girth	98.8 ± 2.6	96.5 ± 2.4	4.53	.05
10. Tendon Girth	97.4 ± 10.2	100.9 ± 3.07	1.08	.31
11. Maximum PF Active (0° Knee Flexion)	94.2 ± 9.34	97.0 ± 9.79	0.43	.52
12. Maximum PF Active ROM (90° Knee Flexion)	99.3 ± 9.29	102 ± 7.48	0.51	.48
13. Ankle Proprioception (90° Knee Flexion)	-.05 ± 2.02	-1.25 ± 1.34	2.45	.13
14. Ankle Proprioception (0° Knee Flexio)	-0.5 ± 3.36	0 ± 2.54	0.14	.71

*P<.01

(a) All expressed values are ratios calculated by the following general formula: (postsurgical limb value/contralateral normal limb value) x 100.

were archetypical Achilles tendon patients (Beskin et al., 1987; Carden et al., 1987; Gilles & Chalmers, 1970).

The causes of Achilles tendon injury in this group of subjects are similar in many ways to etiologies found in patient populations of studies conducted by Beskin et al. (1987) and Carden et al. (1987). The majority of the injuries in the present study occurred from a sudden forceful dorsiflexion, jumping, or pushing off. Carden et al. (1987) reported similar findings in a group of 103 Achilles patients. Hooker (1963) observed that men who engage in occasional strenuous physical activity are highly susceptible to Achilles tendon rupture. In the present study, all 20 subjects were middle-aged men who ruptured their Achilles tendon while engaging in occasional strenuous activity.

The results of the subjective questionnaire revealed that 7 of 10 subjects in the percutaneous group and 60% of the open repair group (N=6) perceived their Achilles surgery as a "complete success." Only 80% (N=8) of those patients whose Achilles tendon was repaired percutaneously indicated that they would recommend the procedure to a friend, while 100% (N=10) of those that received the open repair stated that they would recommend the procedure. These findings suggest that subjects in both operative groups believed their surgeries to be successful.

Each subject was also asked to rate the overall condition of his postsurgical Achilles tendon using a 10-point rating scale, with "10" being a perfect score. The percutaneous group reported a mean

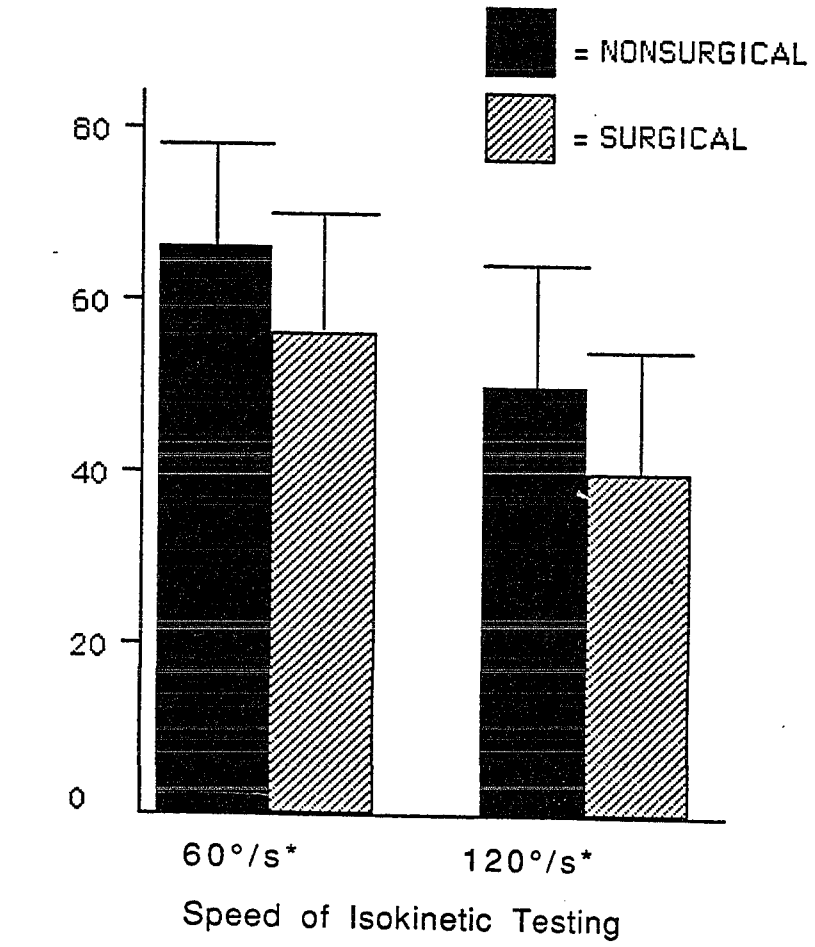
score of 8.0 ± 3.6, while the open repair group had a mean score of 7.5 ± 2.4. Given the large percentage of patients who viewed their surgical outcomes as completely successful (65%), these high postsurgical Achilles tendon ratings were somewhat expected. While the patients' subjective assessments of their postsurgical status were highly satisfactory, the objective findings of this study presented a somewhat different perspective of the surgical outcomes.

The results of the paired T-tests revealed the presence of long-term functional disabilities following Achilles tendon surgery, irrespective of surgical technique. Figures 4 and 5 graphically illustrate the significant differences ($P<.01$) between plantarflexion strength for the postsurgical and contralateral normal limbs when the knee was positioned at 0° of flexion in order to isolate the contribution of the gastrocnemius to plantarflexion. Average postsurgical limb plantarflexion strength deficits ranging from 18 to 38% were present in the maximum torque values at 20° and 35° of plantarflexion.

It is a common clinical practice to release a patient from physical therapy when isokinetic strength in the injured extremity returns to within 10% of the contralateral normal limb (Harter, Osternig, & Standifer, 1990; Knight, 1980; Slagle, 1979). Individual rehabilitation records of patients were not available for analysis; however, all patients underwent formal physical therapy procedures following Achilles tendon repair. The average duration of

Figure 4

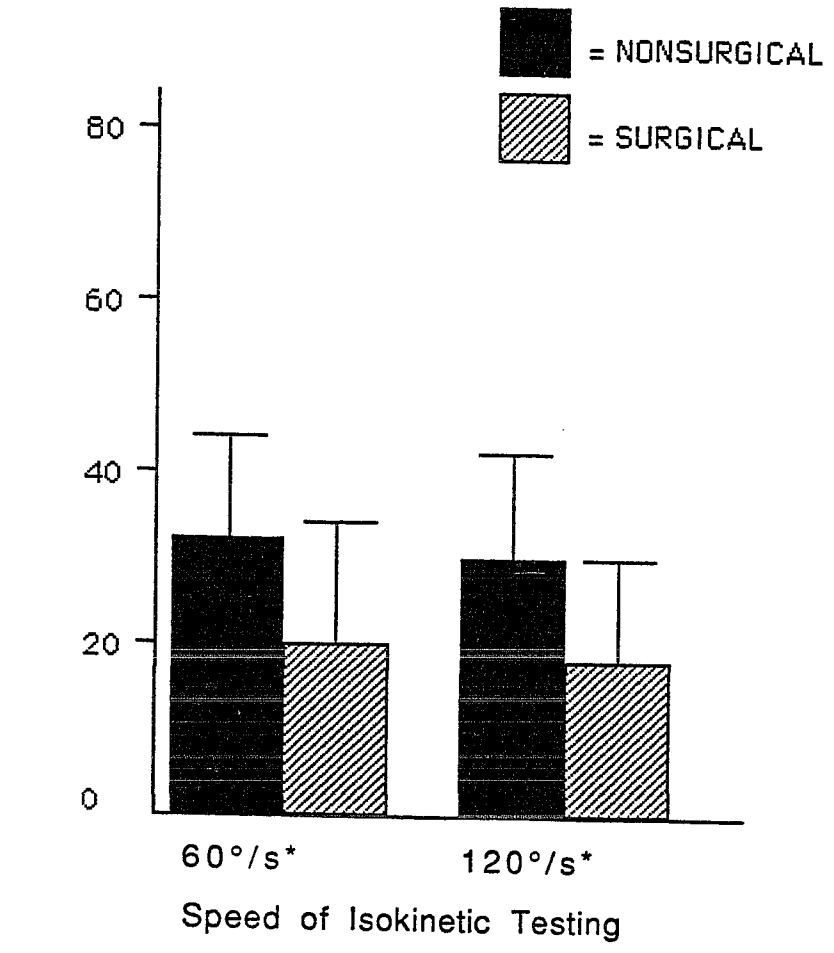
Average ± SD Maximum Postsurgical Versus Nonsurgical Limb Plantarflexion Torque Values at 20° of Ankle Plantarflexion (0° knee Flexion)



*P<.01

Figure 5

Average ± SD Maximum Postsurgical Versus Nonsurgical Limb Plantarflexion Torque Values at 35° of Ankle Plantarflexion (0° Knee Flexion)



*P<.01

postoperative physical therapy was 13.6 ± 3.3 months, with a minimum of nine months and maximum of 24 months. The postsurgical isokinetic strength deficits present suggest either an incompleteness of rehabilitation, or more likely the physiologic inability to regain full plantarflexion strength following percutaneous and/or open surgical repair of the Achilles tendon.

It should be noted that average maximum plantarflexion torque values at the 35° position were affected by the fact that some subjects were unable to generate significant torque at the near end-range position due to limited ranges of motion in their postsurgical Achilles.

In the only published study of percutaneous repairs, Ma and Griffith (1977) reported an 86% return of strength (14% deficit) in the 12 patients they studied one year postoperatively, and 89% (11% deficit) two years postoperatively. In the present study, the average postoperative period was 22.6 ± 8.2 months. Patients experienced strength returns ranging from 67.4% ± 45.8% (32.6% deficit) when tested with the knee in 0° of flexion at 35° of ankle plantarflexion at 60°/s, to 96.2% ± 36.3% (3.8% deficit) when tested with the knee in 90° of flexion at 35° of ankle plantarflexion at 60°/s. (Table 5).

While previous studies have analyzed only peak torque values (Beskin et al., 1987; Kellam et al., 1985; and Nistor, 1981), the current study employed preselected angles of 20° and 35° of plantarflexion to determine maximum voluntary torque at those specific positions. Osternig, Hamill, Sawhill, and Bates (1983)

found that with faster isokinetic speeds, it is necessary for the limb to "catch up" to the predetermined speed of the dynamometer. This phenomenon results in a peak torque that may be higher then the actual torque being generated at any given speed. In the present study, the average position of peak torque was 8.2° ± 1.4° (range, 3 to 17) at 60°/s, and 13.6° ± 2.7° (range, 5 to 18) at 120°/s with 0° of knee flexion. With the knee at 90° of flexion, the average position that peak torque occurred was 16.6° ± 4.7° (range, 6 to 21) at 60°/s, and 21.0 ± 5.2 (range, 14 to 33) at 120°/s. Although the angles at which peak torque occurred are close to the 20° position rather than the 35° angle of plantarflexion, maximum torque values at 35° revealed several subjects who were unable to produce significant torque at this position in the range of motion [normal plantarflexion ROM = approximately 50° (Hoppenfeld 1976; Magee, 1987)].

Subjects' isokinetic strength was also evaluated with the knee at 90° in effort to isolate the contribution of the soleus muscle to plantarflexion (figure 6 and 7). Results revealed a 15% deficit at the 20° position and a 9% deficit at the 35° position of plantarflexion at 60°/s when comparing the subjects' postsurgical to nonsurgical limbs. When evaluated at the isokinetic speed of 120°/s, subjects demonstrated 14% and 12% deficits at the 20° and 35° positions of plantarflexion, respectively. An exhaustive review of literature revealed no previous studies having evaluated isokinetic plantarflexion strength with the knee positioned at 90°

Figure 6

Average ± Maximum Postsurgical Versus Nonsurgical Limb Plantarflexion Torque Values at 20° of Ankle Plantarflexion (90° knee Flexion)

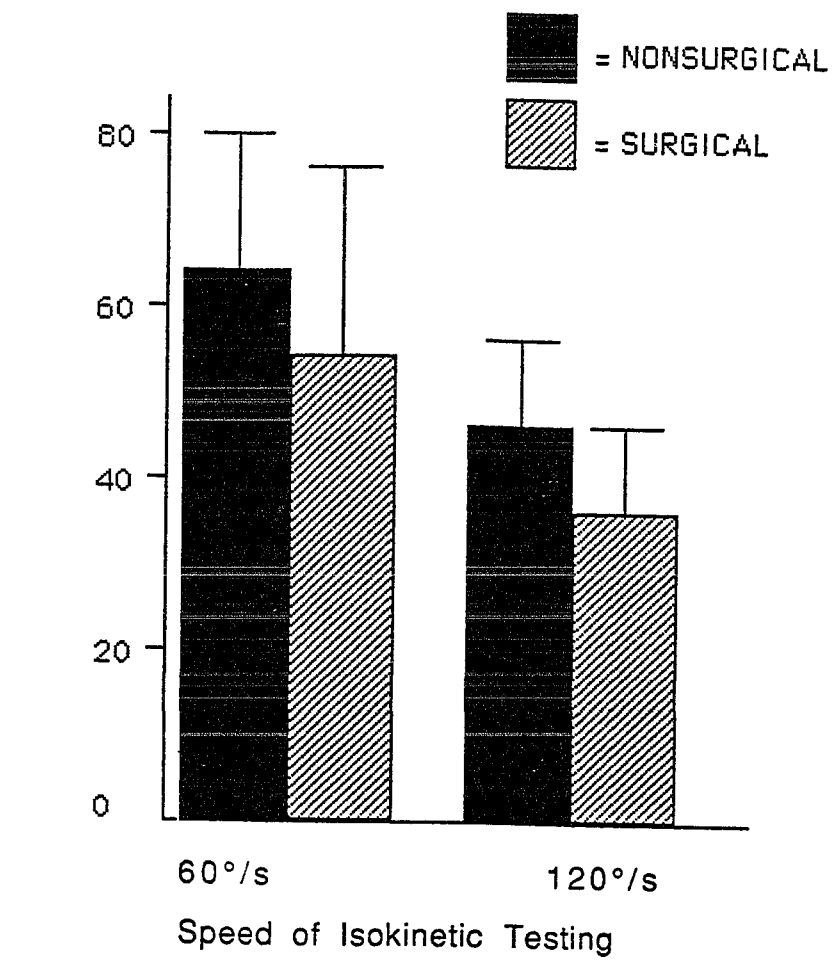
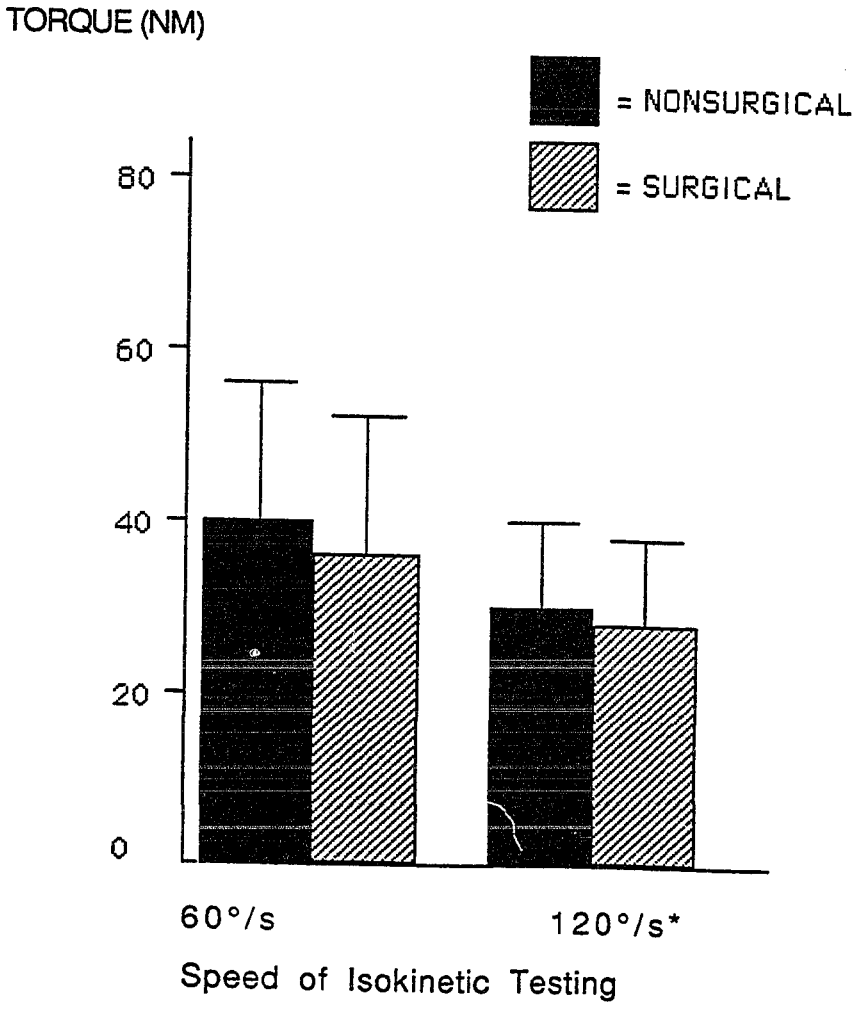


Figure 7

Average ± SD Maximum Postsurgical Versus Nonsurgical Limb Plantarflexion Torque Values at 35° of Ankle Plantarflexion (90° Knee Flexion)



*P>.01

flexion, thus no direct comparisons of these measurements can be made at this time.

In the present study, the isokinetic plantarflexion strength of subjects in the open repair group was evaluated with the knee in 0° of flexion. These subjects were found to have a 22% strength deficit at 20° plantarflexion and 33% deficit at 35° plantarflexion at 60°/s. Shields et al. (1978) studied 33 subjects that underwent open repair, and reported a 16.5% deficit in plantarflexion strength at 120°/s. In the present study at 120°/s the open repair group demonstrated an 18% strength deficit and a 36% deficit at 20° and 35° of plantarflexion, respectively. Inglis and Sculco (1981) studied 50 patients treated with the open repair, and reported postsurgical average peak plantarflexion torque values of 101% of the normal contralateral limb values. Beskin et al. (1987) reported a 26% deficit in plantarflexion isokinetic strength at 180°/s at one year postoperatively, and an average deficit of 15% two years postoperatively.

Barnes and Hardy (1986) stated that following surgical repair of the Achilles tendon, calf-wasting almost always persists. While the paired t-tests revealed a statistically significant difference ($P<.01$) between the subjects' post surgical and contralateral normal mid-calf girth measurements in the present study, the average difference between limbs was less then 1.0 cm. Ma and Griffith (1977) reported that 50% (N=6) of their percutaneous repair subjects had less than 0.5 cm surgical limb calf atrophy 12 months

or more postoperatively. Beskin et al., (1987) reported an average difference of calf girth of 0.7 cm in those treated early with the open repair, and 1.2 cm in the late repair group. Inglis and Sculco (1979) also noted a 0.5 to 1.3 cm difference in mid-calf girth. Therefore, the mid-calf girth measurements obtained in the current study were judged to be consistent with the findings of several previous studies. Determination of the functional significance of mid-calf girth differences of this magnitude was beyond the scope of this study.

Surgical limb ankle joint proprioception, as measured by reproduction of a passive position, was not significantly different ($P>.01$) between postsurgical and nonsurgical limbs, nor between surgical techniques. Although no other studies to date have examined ankle joint proprioception following Achilles tendon repair, these findings suggest that either: (a) rupture and subsequent surgical repair of the Achilles tendon had no direct effect on ankle proprioception, or (b) any ankle proprioceptive deficits caused by Achilles tendon rupture and surgical repair were accommodated for prior to follow-up evaluation at an average of 22.9 $\pm$ 8.3 months postsurgery. Only through use of a prospective experimental design can the existence of ankle proprioception deficits be confirmed or denied.

Ideally, with any operative procedure postoperative complications are to be minimized or prevented altogether. A number of studies have reported numerous postoperative

complications with the open surgical repair of the Achilles tendon (Beskin et al., 1987; Edna, 1980; Gilles & Chalmers, 1970). In the present study, two reruptures of the Achilles occurred in patients treated with the open repair, while two other subjects reported postsurgical infections following their open surgical repair. One case of nerve entrapment was reported by a patient in this study who received a percutaneous repair. Despite continued improvement in surgical technique, there are still postsurgical complications associated with the open surgical repair of the Achilles tendon.

The lack of significant differences between the two surgical groups on orthopedic parameters commonly used in the clinical setting to evaluate the functional abilities of patients following Achilles tendon surgeries, in itself, is perhaps the most significant finding of this study. As this study was the first to directly compare the outcomes of the percutaneous and open surgical repairs of the Achilles tendon, these findings cannot truly be supported or contradicted by any other study. The results of the ANOVAs suggest that the two techniques were equally effective in the patient population studied. The percutaneous technique, being less invasive and requiring less hospitalization, appears to be a viable alternative surgical procedure to the more traditional open repair of the Achilles tendon.

Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Injuries to the Achilles tendon are one of the most common acute problems in the lower leg. The Achilles tendon, the distal attachment of the triceps surae, is responsible for the pushoff during normal gait and can be ruptured by a forceful and sometimes unexpected plantarflexion of the ankle. Currently, there are various types of medical treatment employed for repair of a torn Achilles tendon, with no clear consensus of opinion regarding the most effective technique.

The purpose of this retrospective study was to evaluate the results of two methods of surgical treatment of acute closed ruptured Achilles tendons, specifically the percutaneous repair and the primary open repair procedures, utilizing the following objective measures: (a) ankle joint range of motion; (b) plantarflexion isokinetic strength at 60 and 120°/s; (c) mid-calf and tendon girth; and (d) ankle joint proprioception. As a secondary purpose, the frequency of reruptures and postsurgical complications associated with the two methods of treatment was compared.

A total of 30 surgical patients who had been treated for acutely ruptured Achilles tendons at the Sports Orthopedic and Rehabilitation Medical Associates clinic in Portola Valley, California between 1986 and 1989 were identified through a review of medical records. Twenty-eight patients were contacted by

telephone and with a follow-up letter, requesting their participation in the study. Twenty male patients (mean age, 44.0 $\pm$ 9.4 yrs) volunteered to participate in the study, and were tested at Santa Clara Sports Therapy (SCST) in Santa Clara, California during the period from May 15, 1990 to June 15, 1990. All subjects read and signed an informed consent form prior to testing, in accordance with San Jose State University's Institutional Review Board for Human Subjects policy.

A one-way analysis of variance (ANOVA) was performed on each of the thirteen isokinetic parameters. The results of the ANOVA's revealed no significant differences ($P>.01$) between the percutaneous repair and open surgical repair groups for any of the measures of isokinetic strength, muscle girth, active plantarflexion range of motion, and proprioception. Chi-square analysis performed to assess subjects attitudes toward the functional outcome or their surgical procedure also failed to show any statistical significance ($P>.05$). Paired T-tests performed revealed significant differences ($P<.002$) between the subjects' surgical and normal contralateral limbs for 7 of 14 parameters.

Conclusions

Based upon the results of the study, the following conclusions were drawn.

1. Subjects exhibited significant ($P<.01$) residual functional disabilities following Achilles tendon surgical repair, irrespective of surgical techniques. Significant deficits in postsurgical

plantarflexion isokinetic strength and mid-calf girth suggests an incompleteness of rehabilitation or the physiologic inability to regain these characteristics postoperatively.

2. The two Achilles tendon surgical repair techniques evaluated, the percutaneous and the open techniques, produced similar functional outcomes in the patient population studied. The percutaneous technique, by design, is intended to be less invasive and result in fewer surgical complications, appears to be a viable alternative surgical procedure to the more traditional open surgical repair of the Achilles tendon.

3. The fewer number of postsurgical complications in the percutaneous repair patient group (1 nerve entrapment, 10%) favorably reflects upon the efficacy and safety of this procedure in deference to the open surgical repair, in which a higher number of postoperative complications occurred (2 cases of infection; 20%) in an equal size sample.

Recommendations

Based on the findings of this study the following are recommendations for future studies.

1. As additional patients are treated with the percutaneous technique, replicate this study with a larger population of subjects.

2. Retest the subjects who participated in this study at a later date to determine if residual functional disabilities currently present at follow-up examination persist.

3. Expand the experimental paradigm of this study to a two-way (3x2) ANOVA in order to include a functional analysis of patients whose torn Achilles tendons were treated with a closed (equinus casting) technique, at intermediate (2 yrs) and long-term (4-6 yrs) postoperative periods.

References

Barfred. T. (1971). Kinesiological Comments on Subcutaneous Ruptures of the Achilles Tendon. Acta Ortop. Scand., 152, 397-405.

Barnes. M.J., Hardy A.E. (1986). Delayed Reconstruction of the Calcaneal Tendon. The Journal of Bone and Joint Surgery., 68 B, 121-124.

Beskin, J.L., Sanders, R.A., Hunter, S.C., & Hughston, J.C. (1987). Surgical Repair of Achilles Tendon Ruptures. The American Journal of Sports Medicine, 15,1-8.

Carden, D.G., Noble, J., Chalmers, J., & Ellis, P.L. (1987). Rupture of the Calcaneal Tendon. The Journal of Bone and Joint Surgery, 69 B, 416-420.

Cybex Handbook (1983). New York: Division of Lumex Inc., Ronkonkoma, 75-78.

CDRC Manual (1983). New York Division of Lumex Inc., Ronkonkoma, 18-21.

Edna, T.H. (1980). Non-Operative Treatment of Achilles Tendon Ruptures. Acta Orthopaedic Scandinavian, 51, 991-993.

Gardner, E., Gray, D.J., & O'Rahilly, R. (1975). Anatomy (4th Ed.). Philadelphia: W.B. Saunders Company, 231-235.

Gillies, H., Chalmers, J. (1970). The Management of Fresh Ruptures of the Tendo Achillis. The Journal of Bone and Joint Surgery, 52 A, 337-343.

Harter, R.A., Osternig, L.R., & Standifer, L.W. (1990). Isokinetic Evaluation of Quadriceps and Hamstring Symmetry Following Anterior Cruciate Ligament Reconstruction. Archives of Physical Medicine and Rehabilitation, 16, 465-468.

Hooker, C.H. (1963). Rupture of the Tendo Calcaneus. The Journal of Bone and Joint Surgery, 45 B, 360-363.

Hoppenfeld, S. (1976). Physical examination of the spine and extremities. New York: Appleton-Century-Crofts, 218, 230-31.

Inglis, A.E., Scott, W.N., Sculco, T.P., & Patterson, A.H. (1976). Ruptures of the Tendo Achillis. The Journal of Bone and Joint Surgery, 58 A, 990-993.

Inglis, A.E., & Sculco, T.P. (1981). Surgical Repair of Ruptures of the Tendo Achillis. Clinical Orthopaedics and Related Research, 156,160-169.

Keene, J.S., Lash, E.G., Fisher, D.R., & DeSmet, A.A. (1989). Magnetic Resonance Imaging of Achilles Tendon Ruptures. The American Journal of Sports Medicine, 17, 333-337.

Kellam, J.F., Hunter, M.B., & McElwain, J.P. (1985). Review of the Operative Treatment of Achilles Tendon Rupture. Clinical Orthopaedics and Related Research, 201, 80-83.

Knight, K.L. (1980). Strength Imbalance and Knee Injury. The Physician and Sportsmedicine, 8, 140.

Lea, R.B., & Smith, L. (1972). Non-Surgical Treatment of Tendo Achillis Rupture. The Journal of Bone and Joint Surgery, 54 A, 1398-1407.

Leekam, R.N., Salsberg, B.S., Bogoch, E., & Shankar, L. (1986). Sonographic Diagnosis of Partial Achilles Tendon Rupture and Healing. Journal of Ultrasound Medicine, 5, 115-116.

Lildholdt, T., & Munch-Jorgensen, T. (1976). Conservative Treatment of Achilles Tendon Rupture. Acta Orthopaedic Scandinavian, 47, 454-485.

Ma, G.W.C., & Griffith, T.G. (1977). Percutaneous Repair of Acute Closed Ruptured Achilles Tendon. Clinical Orthopaedics and Related Research, 128, 247-255.

Magee, D.J. (1987). Orthopedic physical assessment. Philadelphia: W.B. Saunders, 319-334.

Nistor, L. (1976). Conservative Treatment of Fresh Subcutaneous Rupture of the Achilles Tendon. Acta Orthopaedic Scandinavian, 47, 459-462.

Nistor, L. (1981). Surgical and Non-Surgical Treatment of Achilles Tendon Rupture. The Journal of Bone and Joint Surgery, 63 A, 394-399.

Osternig, L.R. (1986). Isokinetic dynamometry: implications for muscle testing and rehabilitation. Exercise and Sport Sciences Reviews, 14, 45-80.

Osternig, L.R., Hamill, J., Sawhill, J.A., & Bates, B.T. (1983). Influence of Torque and Limb Speed on Power Production in Isokinetic Exercise. American Journal of Physical Medicine, 58, 163-171.

Pickrell, K., Thompson, L., Nichol, T., & Kasdan, M. (1970). The surgical treatment of varicose ulcers. The American Surgeon, 13, 55-60.

Quenu J, Stoianovitch (1929). Les ruptures du tendon d'Achille. Review Chir Paris, 67, 647-678.

Reinig, J.W., Dorwart, R.H., & Roden, W.C. (1985). MR Imaging of a Ruptured Achilles Tendon. The Journal of Computer Assisted Tomography, 9, 1131-1134.

Schepsis, A.A., & Leach, R.E. (1987). Surgical Management of Achilles Tendinitis. The American Journal of Sports Medicine, 308-315.

Shields, C.L., Kerlan, R.K., Jobe, F.W., Carter, V.S., & Lombardo, S.J. (1978). The Cybex II Evaluation of Surgically Repaired Achilles Tendon Reruptures. The American Journal of Sports Medicine, 15, 369-372.

Slage, G.W. (1979). The Importance of Pre-testing the Knee joint. Athletic Training, 14, 225-226.

Stein, S.R., & Luekens, C.A. (1976). Closed Treatment of Achilles Tendon Ruptures. Orthopedic Clinics of North America, 7, 241-246.

Thomas, C.L. (Ed). (1985). Taber's cyclopedic medical dictionary. Fifteenth Edition. F.A. Davis Company, Philadelphia, 1257.

Thompson, T.C., Doherty, J.H. (1962). Spontaneous rupture of tendon of Achilles: a new clinical diagnostic test. Journal of Trauma, 2, 126-129.

Tortora,G,J., & Anagnostakos, N.P. (1984). Principles of anatomy and physiology (4th ed.). New York: Harper & Row, Publishers.

Tripp, E. (1970). Meridian handbook of classical mythology. NewYork: Harper & Row, pp. 6-9.

Williams, J.G.P. (1986). Achilles Tendon Lesions in Sport. Sports Medicine, 3, 114-135.

Winter, D.A. (1979). Biomechanics of Human Movement. New York: John Wiley & Sons, 35.

APPENDIX A

TELEPHONE CONVERSATION SCRIPT

TELEPHONE CONVERSATION SCRIPT

Hello,

My name is Greg Steele. I'm a student at San Jose State University. I'm working on my masters degree and I am in the process of finishing up my thesis on Achilles tendon repairs. I received your number from the doctors at the SOAR Clinic. The reason I'm calling is to inquire whether or not you would be interested in taking part in the study that I'm conducting. Should you be interested, I will be sending you further information and a consent form to sign. If you should decide to partake in the study, you will be asked to go to Santa Clara Sports Therapy in Santa Clara for a one time visit lasting approximately 30 minutes. The visit may be scheduled at any time, so to fit your schedule. You will be asked to do various Cybex testing to determine your level of strength, endurance, range of motion, and proprioception.

I sincerely hope that you will consider being part of this study, as it will greatly help in my efforts to complete my masters degree, as well as give you an idea of exactly how well you have recovered from your surgery. The doctors of SOAR are also very interested in the results of this study, and they would greatly appreciate your involvement.

I will be happy to answer any questions you may have at this time?

Thank you for your time.

APPENDIX B

SUBJECT PARTICIPATION LETTER

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

School of Applied Arts and Sciences • *Department of Human Performance*
One Washington Square • San Jose, California 95192-0054 • 408/924-3010

Dear,

My name is Gregory J. Steele from San Jose State University and I am conducting a research study that is investigating the postsurgical results of Achilles tendon repair. The results of this study should further our understanding of the various methods of Achilles tendon repair, and help us to determine whether or not one method may in fact be superior to another. Your participation in this study would greatly appreciated and would help in the understanding of Achilles tendon repair, and possibly benefit those who have future Achilles tendon repairs.

Should you decide to participate in the study, you will be tested one time. You will be tested for strength, endurance, range of motion, and proprioception in both of your ankles. The entire testing procedure will take approximately 30 minutes. The testing may be done at any time, so to fit your schedule.

Filling out and returning to me the enclosed letter implies that you have given informed consent for participating in my study. The results from this study may be published, but any information from this study that can be identified with you will remain confidential and will be disclosed only with your permission. You may choose not to participate in this study without prejudice to your relations with SJSU or SOAR.

For any questions about this study, please feel free to call me collect at (408) 725-8454. Complaints about the procedures may be presented to Rod A. Harter, Ph.D., A.T.,C. at (408) 924-3015. For questions or complaints about research subject's rights contact Serena Stanford, Ph.D. (Associate Academic Vice President for Graduate Studies and Research) at (408) 924-2480.

Thank you for your time and effort in this study.

Sincerely,

Gregory J. Steele, A.T.,C.

APPENDIX C

SAMPLE ANKLE EVALUATION FORM

SAMPLE ANKLE EVALUATION FORM

Subject Number _____
DATE _____/_____/_____
AFFECTED ANKLE R/L

Objective Evaluation:

GIRTH LEFT RIGHT DIFFERENCE
- Mid-Calf
- Malleoli

PROPRIOCEPTION
Knee @ 0°
- 20° (PF)
- 35° (PF)

Knee @ 90°
- 20° (PF)
- 35° (PF)

Maximal ROM
Knee @ 0°
- Plantarflexion

Knee @ 90°
- Plantarflexion

Strength @60°/s

Knee @ 0°
- 20° (PF)
- 35° (PF)

Knee @ 90°
- 20° (PF)
- 35° (PF)

Strength @120°/s
Knee @ 0°
- 20° (PF)
- 35° (PF)

Knee @ 90°
- 20° (PF)
- 35° (PF)

APPENDIX D

SUBJECTIVE QUESTIONNAIRE

SUBJECT QUESTIONNAIRE

Subject Number _____ Age ____ Date of Birth _____/_____/_____

Gender _____ Dominant Leg _____ Leg Injured _____

Date of Initial Injury _____/_____/_____

Date of Injury Requiring Surgery _____/_____/_____

Did you receive any physical therapy? yes _____ no _____

Length of time in physical therapy, _____ weeks, _____ times/week.

Physical therapy clinic attended _____

Date that you began physical therapy _____/_____/_____

Date of discharge from physical therapy _____/_____/_____

Occupation _____

Cause of injury _____

Section I. After each of the following statements, please circle the number of the response that best represents your opinion regarding each statement. A Likert-type scale is given, with 1 = strongly agree, 3 = neutral (neither agree nor disagree), and 5 = strongly disagree:

Statements	strongly agree	agree	neutral	disagree	strongly disagree
1. I believe that my Achilles tendon surgery was a complete success.	1	2	3	4	5
2. I would recommend the surgical procedure that I underwent to a friend.	1	2	3	4	5
3. My repaired Achilles tendon causes me discomfort in my daily activities.	1	2	3	4	5

Section II: For each question, check pain level that applies for each ankle.
Check only one box for each ankle.

1. What pain do you have when doing strenuous sports or heavy work (construction)?
   SURGICAL ANKLE __ None or Slight __ Definite Pain, Causing Limitation
   NON-SURGICAL ANKLE __ None or Slight __ Definite Pain, Causing Limitation

2. What pain do you have when doing light/recreational sports or moderate work (police officer, mechanic)?
   SURGICAL ANKLE __ None or Slight __ Definite Pain, Causing Limitation
   NON-SURGICAL ANKLE __ None or Slight __ Definite Pain, Causing Limitation

3. What pain do you have when doing living activities (walking) or light work (office)?

SURGICAL ANKLE	__ None or Slight	__ Definite Pain/ Mild Limitations	__ Definite Pain/ Moderate Limitations Relieved by Rest	__ Definite Pain/ Severe Limitations Pain is Constant
NON-SURGICAL ANKLE	__ None or Slight	__ Definite Pain/ Mild Limitations	__ Definite Pain/ Moderate Limitations Relieved by Rest	__ Definite Pain/ Severe Limitations Pain is Constant

---

Section III: For each category , check all boxes that apply for your SURGICAL (S) and NON-SURGICAL (NS) ankle.

TYPE OF PAIN:		PAIN OCCURS ON:	
S	**NS**	**S**	**NS**
__	__ Sharp	__	__ Stairs
__	__ Aching	__	__ Standing
__	__ Intermittent	__	__ Walking
__	__Consistent	__	__ Running/Jumping
__	__ No Pain	__	__ No Pain

Section IV: When you do the following highlighted activities, check the level of problems you experience with both your SURGICAL (S) and NON-SURGICAL (NS) ankle. Check only one box in each category for your right and left ankle.

WALKING

S	NS	
__	__	Normal, no problem
__	__	Slight/mild problem
__	__	Moderate problem: smooth surface okay up to one-half mile
__	__	Severe problem: only 2-3 blocks possible
__	__	Severe problems: requires cane, crutches

STAIRS

__	__	Normal, No problems
__	__	Slight/mild problem
__	__	Moderate problem: only 10-15 steps possible
__	__	Severe problems: requires support
__	__	Severe problem: only 1-5 steps possible

RUNNING

S	NS	
__	__	Normal, no problem: fully competitive, strenuous
__	__	Slight/mild problem: run half-speed
__	__	Moderate problem: only 1-2 miles possible
__	__	Severe problem, only 1-2 blocks possible
__	__	Severe problem, only a few steps

JUMPING OR TWISTING ACTIVITIES

__	__	Normal, no problem: fully competitive, strenuous
__	__	Slight /mild problem: some guarding, but sports okay
__	__	Moderate problem: gave up strenuous sports; recreational sports okay
__	__	Severe problem: affects all sports, must constantly guard
__	__	Severe problem: only light activity possible (golf, swimming)

Section V: Rate the overall condition of your ankles (10 = normal)

Surgical Ankle

1 2 3 4 5 6 7 8 9 10

Non-Surgical Ankle

1 2 3 4 5 6 7 8 9 10

APPENDIX E

INFORMED CONSENT FORM

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

School of Applied Arts and Sciences • *Department of Human Performance*
One Washington Square • San Jose, California 95192-0054 • 408/924-3010

AGREEMENT TO PARTICIPATE IN RESEARCH
SAN JOSE STATE UNIVERSITY

RESPONSIBLE INVESTIGATOR: Gregory J. Steele, A.T.,C.

TITLE OF PROTOCOL: Postsurgical Evaluation of Two Methods of Treatment for Acutely Ruptured Achilles Tendons.

I have been asked to participate in a research study that is investigating two surgical methods for repairing the Achilles tendon. The results of this study should further our understanding of the effectiveness of various operative procedures for repairing the Achilles tendon.

I understand that

1) I will be asked to perform isokinetic testing to determine my strength, range of motion, and proprioception. As well as be measured for muscle girth in the calf, and fill out a questionnaire. I understand that this will take place at Santa Clara Sports Therapy in Santa Clara, California, and take approximately 30 minutes.

2) the possible risks of this study are general muscle fatigue as a results of the isokinetic testing.

3) the possible benefits of this study to me are, knowing how well I recovered from my surgery, as well as knowing that the results from this study may help future patients in determining which operative procedure they choose.

4) the results from this study may be published, but any information from this study that can be identified with me will remain confidential and will be disclosed only with my permission or as required by law.

School of Applied Arts and Sciences • *Department of Human Performance*
One Washington Square • San Jose, California 95192-0054 • 408/924-3010

5) any questions about my participation in this study will be answered by Gregory J. Steele, A.T.,C. at (408) 725-8454. Complaints about the procedures may be presented to Dr. Rod A. Harter, Ph.D., A.T.,C. at (408) 924-3015. For questions or complaints about research subject's rights, or in the event of research-related injury, contact Serena Stanford, Ph.D. (Associated Academic Vice President for Graduate Studies & Research) at (408) 924-2480.

6) my consent is given voluntarily without being coerced; I may refuse to participate in this study or in any part of this study, and I may withdraw at an time, without prejudice to my relations with SJSU or SOAR.

7) I have received a copy of this consent form for my file.

I HAVE MADE A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE READ THE INFORMATION PROVIDED ABOVE AND THAT I HAVE DECIDED TO PARTICIPATE.

_____ _____

DATE SUBJECT'S SIGNATURE

_____

INVESTIGATOR'S SIGNATURE

APPENDIX F

VERBAL CUES
(RELATED TO ISOKINETIC PROTOCOL)

VERBAL CUES

(RELATED TO ISOKINETIC TESTING)

STRENGTH TESTING:

"This test will determine your strength in plantarflexion and dorsiflexion. When I tell you to begin, I want you to push as hard and as fast as you can, and then pull up as hard and as fast as you can."

VERBAL CUES TO BE GIVEN FOR EACH REPETITION:

Rep #1. "Ready, begin"
Rep #2. "Push, all the way down, good"
Rep #3. "Pull, all the way up"
Rep #4. "Last one, your doing good!"

ENDURANCE TESTING:

"This test will determine the endurance in each of your ankles. You might feel some fatigue, but it is important for you to work hard for the 20 repetitions."

VERBAL CUES TO BE GIVEN FOR EACH REPETITION:

Rep #1. "Ready, begin"
Rep # 5. "Looking good, keep it up"
Rep #10. "Good job, your half way there."
Rep #15. "Only five more, push"
Rep #16. "Come on, 4 more you can do it"
Rep #17. "Push it"
Rep #18. "Only 2 more to go."
Rep #19. "Come on 1 more"
Rep #20. "Last one, give it all you've got."

APPENDIX G

LATIN SQUARE DESIGN

LATIN SQUARE DESIGN

1	2	3	4	5	6	7	8
8	1	2	3	4	5	6	7
7	8	1	2	3	4	5	6
6	7	8	1	2	3	4	5
5	6	7	8	1	2	3	4
4	5	6	7	8	1	2	3
3	4	5	6	7	8	1	2
2	3	4	5	6	7	8	1

1 = Right Knee in full extension at 60°/sec.

2 = Right Knee in full extension at 120°/sec.

3 = Right Knee in 90° Flexion at 60°/sec.

4 = Right Knee in 90° Flexion at 120 °/sec.

5 = Left Knee in full extension at 60°/sec.

6 = Left Knee in full extension at 120°/sec.

7 = Left Knee in 90° Flexion at 60°/sec.

8 = Left Knee in 90° Flexion at 120 °/sec.

APPENDIX H

SUMMARY OF QUESTIONNAIRE RESPONSES

Subject Responces to Questionnaire

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Surgery a Success?	7 (70%)	3 (30%)	0	0	0
	6 [60%]	3 [30%]	1 [10%]	0	0
2. Recommend Procedure?	8 (80%)	2 (20%)	0	0	0
	10 [100%]				
3. Does Surgery cause discomfort?	1 (10%)	1 (10%)	0	2 (20%)	6 (60%)
	0	0	1 [10%]	3 [30%]	6 [60%]

	None or Slight	Definite Pain
4. Type of pain w/strenuous activity?		
Surgical	9 (90%)	1 (10%)
	10 [100%]	0
Non-Surgical	10 (100%)	0
	9 [90%]	1 [10%]
5. Type of pain w/light activity?		
Surgical	10 (100%)	0
	10 [100%]	0
Non-Surgical	10 (100%)	0
	9 [90%]	1 [10%]

( ) = Percutaneous Values [ ] = Open Repair Values

	None or Slight	Mild limitation	Moderate limitation	Severe limitation
6. Type of pain w/daily living activities?				
Surgical	10	0	0	0
	9 [90%]	1 [10%]	0	0
Non-Surgical	10 (100%)	0	0	0
	10 [100%]	0	0	0

	Sharp	Aching	Intermittent	Consistent	No Pain
7. Type of pain?					
Surgical	0	1 (10%)	4 (40%)	0	5 (50%)
	1 [10%]	1 [10%]	1 [10%]	0	7 [70%]
Non-Surgical	1 (10%)	0	0	0	9 (90%)
	1 [10%]	0	0	0	9 [90%]

	Stairs	Standing	Walking	Running	No Pain
8. Pain occurs on?					
Surgical	1 (10%)	0	0	3 (30%)	6 (60%)
	0	0	0	3 [30%]	7 [70%]
Non-Surgical	0	0	0	0	10 (100%)
	1 [10%]	0	0	0	9 [90%]

	No Pain	Mild Pain	Moderate Pain	Severe Pain	Walking Aide Required
9. Walking Causes?					
Surgical	8 (80%)	2 (20%)	0	0	0
	6 [60%]	4 [40%]	0	0	0
Non-Surgical	10 (100%)	0	0	0	0
	10 [100%]	0	0	0	0

( ) = Percutaneous Values [ ] = Open Repair Values

	No Pain	Mild Pain	Moderate Pain	Severe Pain	Walking Aide Required
10. Running Causes?					
Surgical	6 (60%)	2 (20%)	2 (20%)	0	0
	5 [50%]	5 [50%]	0	0	0
Non-Surgical	9 (90%)	1 (10%)	0	0	0
	10 [100%]	0	0	0	0
11. Stairs Cause?					
Surgical	7 (70%)	3 (30%)	0	0	0
	8 [80%]	2 [20%]	0	0	0
Non-Surgical	10 (100%)	0	0	0	0
	10 [100%]	0	0	0	0
12. Jumping Causes?					
Surgical	6 (60%)	3 (30%)	1 (10%)	0	0
	4 [40%]	3 [30%]	3 [30%]	0	0
Non-Surgical	10 (100%)	0	0	0	0
	10 [100%]	0	0	0	0

	1-6	7	8	9	10
13. 10-pt. rating scale (10=Normal)					
Surgical	0	3 (30%)	3 (30%)	1 (10%)	3 (30%)
	0	2 [20%]	5 [50%]	3 [30%]	0
Non-Surgical	0	0	2 (20%)	1 (10%)	7 (70%)
	0	1 [10%]	2 [20%]	1 [10%]	6 [60%]

( ) = Percutaneous values [ ] = Open Repair Values

APPENDIX I

ANALYSIS OF VARIANCE SUMMARY TABLES

APPENDIX I-1. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 60°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	33.11	1	33.11	0.09	0.76
WITHIN	6409.87	18	356.10		
TOTAL	6442.98	19			

APPENDIX I-2. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 35° PF/0° Knee Flexion @ 60°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	0.13	1	0.13	0.001	0.99
WITHIN	37142.63	18	2063.48		
TOTAL	37142.76	19			

APPENDIX I-3. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 120°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	82.81	1	82.81	0.13	0.73
WITHIN	11744.23	18	652.46		
TOTAL	11827.04	19			

APPENDIX I-4. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 120°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	979.88	1	979.88	0.42	0.53
WITHIN	42153.88	18	2341.88		
TOTAL	43133.75	19			

APPENDIX I-5. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 60°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	291.73	1	291.73	0.37	0.55
WITHIN	14049.06	18	780.50		
TOTAL	14340.79	19			

APPENDIX I-6. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 60°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	690.0	1	690.0	0.21	0.65
WITHIN	57968.38	18	3220.47		
TOTAL	58658.39	19			

APPENDIX I-7. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 120°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	9.73	1	9.73	0.03	0.88
WITHIN	7012.23	18	389.57		
TOTAL	7021.96	19			

APPENDIX I-8. ANOVA Summary Table for Plantarflexion Strength Surgical vs Nonsurgical Limbs @ 20° PF/0° Knee Flexion @ 120°/s By Operative Procedure

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	6.91	1	6.91	0.01	0.93
WITHIN	15350.24	18	852.79		
TOTAL	15357.16	19			

APPENDIX I-9. Mid-Calf Girth Ratio (Index)

Surgical/Nonsurgical

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	26.45	1	26.45	4.17	0.056
WITHIN	114.1	18	6.34		
TOTAL	140.55	19			

APPENDIX I-10. Tendon Girth Ration (Index)

Surgical/Nonsurgical

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	61.25	1	61.25	1.084	0.31
WITHIN	1017.3	18	56.52		
TOTAL	1078.55	19			

APPENDIX I-11. Plantarflexion Range of Motion

@ 0° Knee Flexion (Index)

Surgical/Nonsurgical

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	39.2	1	39.2	0.43	0.52
WITHIN	1649.6	18	91.64		
TOTAL	1688.8	19			

APPENDIX I-12. Plantarflexion Range of Motion

@ 90° Knee Flexion (Index)

Surgical/Nonsurgical

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	36.45	1	36.45	0.51	0.48
WITHIN	1280.1	18	71.12		
TOTAL	1316.55	19			

APPENDIX I-13. Proprioception Mean Absolute Error

@ (20° PF + 35° PF)

0° Knee Flexion

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	1.25	1	1.25	0.14	0.71
WITHIN	159.5	18	8.86		
TOTAL	160.75	19			

APPENDIX I-14. Proprioception Mean Absolute Error

@ (20° PF + 35° PF)

90° Knee Flexion

SOURCE	SS	DF	MS	F	SIGNIFICANCE
BETWEEN	7.2	1	7.2	2.45	0.135
WITHIN	52.85	18	2.94		
TOTAL	60.05	19			