The Effect on Leg Strength of Tourniquet Use During Anterior Cruciate Ligament Reconstruction: A Prospective Randomized Study

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Purpose: The purpose of this study was to prospectively evaluate the effect of tourniquet use during endoscopic anterior cruciate ligament (ACL) reconstruction surgery on dorsiflexion strength, plantarflexion strength, quadriceps strength, and calf and thigh girth. **Type of Study:** The study was a prospective, double-blind, randomized clinical trial. **Methods:** Forty-eight patients were prospectively randomized into 2 groups: (1) tourniquet use during surgery (T) and, (2) no tourniquet use during surgery (NT). Within 1 week before ACL reconstruction, all patients were evaluated for isometric plantarflexion and dorsiflexion strength, thigh strength, and thigh and calf girth. These same measurements were repeated 3 weeks postoperatively. At 6 months, isokinetic quadriceps strength was evaluated at 60° per second. All patients underwent ACL reconstruction using a patella-tendon autograft and a tourniquet was placed on the affected extremity. In all 25 T patients, the tourniquet was inflated to 300 mm Hg. The average tourniquet time was 85 ± 7 minutes (range, 51 to 114 minutes). **Results:** ACL reconstruction resulted in a significant decrease in thigh girth ($P < .01$), calf girth ($P < .01$), dorsiflexion strength ($P < .01$), and plantarflexion strength ($P < .05$) at 3 weeks postoperatively in both groups. The T group had a greater decrease in thigh girth than the NT group ($P < .05$). Tourniquet use did not have an effect on calf girth ($P = .53$), dorsiflexion strength ($P = .17$), or plantarflexion strength ($P = .32$) at 3 weeks postoperatively. Tourniquet use also had no effect on quadriceps strength at 6 months postoperatively ($P = .78$). **Conclusions:** Tourniquet use of less than 114 minutes during ACL reconstruction had no effect on the strength of the lower extremity after surgery. **Key Words:** Tourniquet—Anterior cruciate ligament—Reconstruction—Strength.

The pneumatic tourniquet was first proposed in 1904 and its use is now a standard procedure in extremity surgery.[1] The advantage of using a tourniquet is that it creates a bloodless operative field that improves visualization and may decrease operative time. However, complications such as neuropathies, muscle weakness, muscle atrophy, and delayed postoperative strength recovery have all been reported after surgery.[2-5] Additionally, histological studies have shown ultrastructural changes in muscles and nerves, as well as altered contractile properties of muscle when subjected to a tourniquet.[6-8] These changes can reflect neuromuscular injury beneath and distal to the pneumatic tourniquet. Several authors have documented neuromuscular changes after tourniquet use but have not shown whether motor function is affected distal to the compression.[9-11] Guanche[12] reported a case of tibial nerve palsy following anterior cruciate ligament (ACL) reconstruction that resulted in the loss of active ankle movement.

Despite aggressive rehabilitation, ACL reconstruction often results in significant weakness and atrophy of the involved extremity beyond 6 months after surgery.[13,14] Several studies have been published looking at the effects of tourniquet use during ACL recon-

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struction and have focused on the return of quadriceps strength and electromyographic (EMG) changes.[9,10,12] However, no studies have evaluated muscle strength distal to the tourniquet following ACL reconstruction. The purpose of this study was to prospectively evaluate the effect of tourniquet use during ACL reconstruction surgery on dorsiflexion strength, plantarflexion strength, quadriceps strength, and calf and thigh girth. The main hypothesis was that the use of a tourniquet during ACL reconstruction would result in lower leg strength deficits at 3 weeks but not at 6 months, and quadriceps weakness at 6 months.

METHODS

Forty-eight patients diagnosed with an ACL tear were scheduled for reconstruction using a central one-third patella-tendon autograft. Patients were prospectively randomized into 1 of 2 groups based on the use of a tourniquet (T, n = 25) or no tourniquet (NT, n = 23) during surgery. Exclusion criteria included history of peripheral neuropathy, lumbar radiculopathy, or surgery to the injured or contralateral knee. Informed consent was obtained from all patients and approval from the institutional review board at the Nicholas Institute of Sports Medicine and Athletic Trauma.

All patients underwent preoperative testing by 1 of 2 experienced physical therapists 2 weeks before surgery. This examination included isometric strength testing of plantarflexor and dorsiflexor muscle groups of the lower extremity and isokinetic quadriceps strength testing. Additionally, thigh and calf girths were measured. Three weeks after surgery, patients were evaluated for isometric plantarflexion and dorsiflexion strength and thigh and calf girths. Quadriceps strength testing was not performed at this time due to pain inhibition. Six months postoperatively, patients were tested for isokinetic quadriceps strength at 60° per second. Data were excluded if pain was reported during strength testing. There were 2 patients in each group who could not be tested because of anterior knee pain. The examiners were blinded as to which group patients were in.

Girth Measurements

Quadriceps girth was measured by calculating the distance in centimeters from the anterior superior iliac spine to the superior border of the patella for the affected extremities. The circumference of the thigh was measured at one third the distance above the superior pole of the patella. The calf circumference was measured one third of the distance from the lateral joint line to the lateral malleolus.

Strength Testing

Isometric plantarflexion and dorsiflexion strength of both extremities were measured using the Biodex Dynometer (Biodex, Shirley, NY). Patients were tested in a beach chair position with the knee flexed to 30° and the ankle in the neutral position. All patients underwent a warmup exercise of 10 isometric repetitions for both plantarflexion and dorsiflexion. Next, patients performed 2 sets of 3 maximum repetitions with 30 seconds of rest between each set, and the highest peak torque was recorded. Isokinetic testing of the quadriceps was performed on both lower extremities at 60° per second in the seated position, and the peak torque was recorded.

Surgical Technique

All patients were brought to the operating room and had a pneumatic tourniquet placed on the proximal thigh of the affected extremity. Randomization (stratified by surgeon) was done by sealed white envelopes. Patients were administered general or epidural anesthesia (depending on their own preference). Patients underwent a single-incision, central-third, endoscopic ACL reconstruction. A superior lateral inflow portal was made so not to interfere with the vastus medialis oblique. Patients in the T group had the cuff inflated to 300 mm Hg and tourniquet use was recorded in minutes for each patient. In the NT group, 1:100,000 epinephrine was injected into each 1,000-mL bag of saline used during surgery to help reduce bleeding. Interference screw fixation was used on both the femoral and tibial side. The patellar defect was grafted with autogenous tibial bone and the patellar tendon defect was closed. All reconstructed knees were braced and locked in extension. Patients began early motion with use of a continuous passive motion machine and were told to bear weight as tolerated with axillary crutches. Formal physical therapy began 1 week after surgery.

Data Analysis

The primary statistic used in this study was repeat measures analysis of variance with treatment group (T *v* NT) as the between-subject factor, and time (preoperative, 3-week follow-up) as the within-subjects factor. Means are reported with 95% confidence interval. Strength measurements are reported as the percent deficit and were calculated by subtracting the

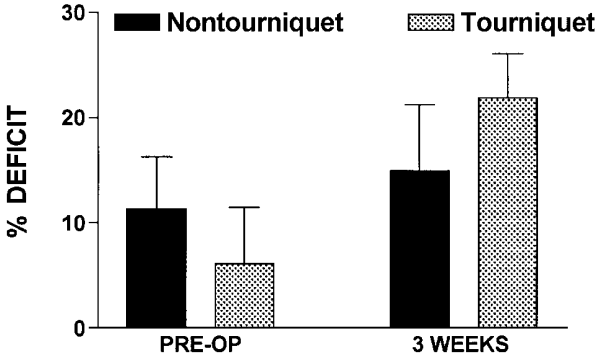

FIGURE 1. Effect of tourniquet use on dorsiflexion strength deficit following ACL reconstruction. The decrease in strength after surgery was not different between groups ($P = .17$).

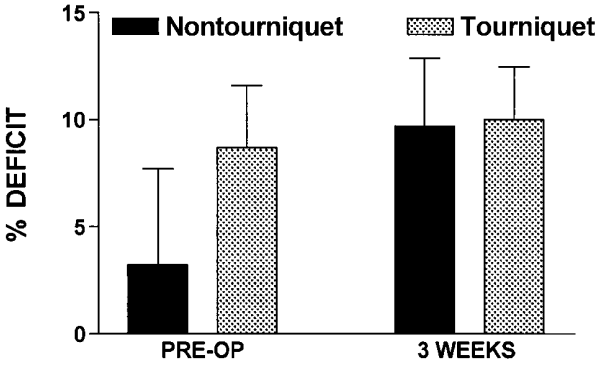

FIGURE 2. Effect of tourniquet use on plantarflexion strength deficit following ACL reconstruction. The decrease in strength after surgery was not different between groups ($P = .34$).

noninvolved minus involved divided by the noninvolved. A linear regression analysis was used to examine the relationship between tourniquet time and calf and quadriceps strength.

RESULTS

In the NT group, there were 16 men and 7 women with a mean age of 32 ± 9 years, mean height of 157 ± 37 cm, and a mean weight of 76.7 ± 16.3 kg. The T group included 13 men and 12 women with an average age of 33 ± 7 years. The average height was 165 ± 25 cm and the average weight was 72.3 ± 14.7 kg. There were no differences between groups in age, height, and weight. General anesthesia was used in 38 patients, and 16 patients received epidural anesthesia with sedation. The average tourniquet time was 85 ± 7 minutes (range, 51 to 114 minutes). There were no reported neuropathies or complications.

Strength Measurements

Before surgery, both patient groups had slight strength deficits in the dorsiflexors of 9% (range, 2% to 16%; $P < .01$) and plantarflexors of 6% (range, 2% to 11%; $P < .05$). Three weeks after surgery, these strength deficits had increased to 18% (range, 11% to 26%) in the dorsiflexors and 10% (range, 5% to 14%) in the plantarflexors. The strength loss following surgery was not different between the T and NT groups for either dorsiflexion strength: T = 21% (range, 13% to 30%), NT = 15% (range, 2% to 30%) ($P < .17$) (Fig 1), or plantarflexor strength: T = 10% (range, 5% to 15%), NT = 9% (range, 2% to 16%) ($P < .34$) (Fig 2).

Patients had significant preoperative knee extension weakness of 26% (range, 18% to 31%; $P < .01$) as well as 6 months following surgery of 33% (range, 26% to 41%; $P < .01$). At 6 months, deficits in knee extension strength were comparable between groups: T = 32% (range, 26% to 45%) and NT = 35% (range, 21% to 43%) ($P = .59$).

Girth Measurements

Before surgery, patients had minimal calf atrophy (0.3 cm; range, 0.015 to 0.55 cm) side-to-side difference ($P < .05$), and thigh atrophy (1.4 cm; range, 0.92 to 1.8 cm) difference ($P < .01$). At 3 weeks postoperatively, greater atrophy was evident in both the calf (1.4 cm; range, 1.1 to 1.6 cm) difference and thigh (3.2 cm; range, 2.5 to 4.0 cm) difference. The decrease in calf girth after surgery was not different between groups: NT = 1.0 cm (range, 0.5 to 1.5 cm), T = 1.1 cm (range, 0.5 to 1.6 cm) ($P = .78$) (Fig 3). The

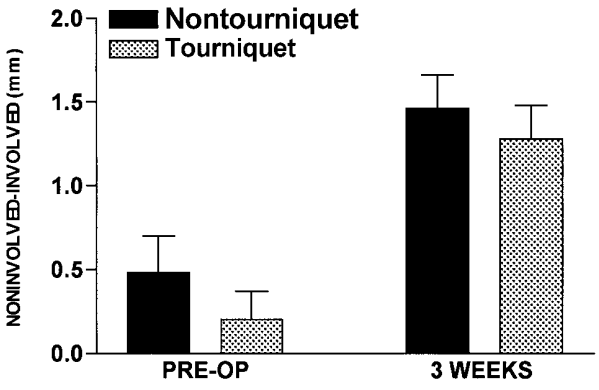

FIGURE 3. Effect of tourniquet use on calf girth following ACL reconstruction. The decrease in calf girth after surgery was not different between groups ($P = .78$).

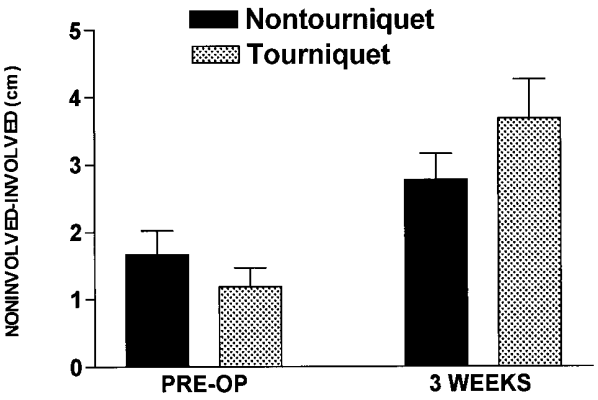

FIGURE 4. Effect of tourniquet use on thigh girth following ACL reconstruction. The decrease in thigh girth after surgery was greater for the tourniquet group compared with the nontourniquet group ($P < .05$).

decrease in thigh girth following surgery was greater in the T group: T = 2.5 cm (range, 1.3 to 3.7 cm), NT = 1.1 cm (range, 0.4 to 1.8 cm) ($P < .05$ (Fig 4).

Tourniquet Time and Strength

Tourniquet compression time was unrelated to the quadriceps strength deficit 6 months after surgery ($P = .380$). Tourniquet compression time was unrelated to the dorsiflexion and plantarflexion strength deficit at 3 weeks ($P = .293$ and $P = .248$, respectively).

Anesthesia

The choice of anesthesia used during surgery did not affect strength recovery or girth measurements.

DISCUSSION

The results of this prospective randomized study show that tourniquet compression around proximal neural structures does not affect lower extremity strength following ACL reconstruction. Surgery resulted in a significant decrease in dorsiflexion strength, plantarflexion strength, and calf girth 3 weeks after surgery in both groups, but no differences between the groups. Tourniquet use had a significant effect on thigh girth 3 weeks following surgery. However, this did not seem to have any lasting effect on quadriceps strength, which was similar between groups at 6 months.

Previously, tourniquet compression has been shown to result in neuromuscular changes in both animal models and humans.[3,9,12,15] Rorabeck and Kennedy[16] reported tourniquet-induced EMG and nerve-conduction velocity changes in the common peroneal and tibial nerves immediately after knee ligament surgery. Functional deficits remained in these patients for up to 6 months. Similarly, functional deficits in a patient with tibial nerve palsy were reported for up to 6 months following a tourniquet-assisted ACL reconstruction.[12] In the present prospective randomized study, no lower-leg functional strength deficits were present in either group 3 weeks after ACL reconstruction. Although tourniquet-induced nerve palsy is a known complication of ACL reconstruction, it was not seen in this study.

Previous studies have evaluated the effect of tourniquet use on quadriceps function.[9-11] Daniel et al.[10] found that a greater isometric knee extension strength deficit existed in a tourniquet group compared with a nontourniquet group at 12 weeks. However, at 1-year follow-up, there was no difference in isokinetic strength between the 2 groups. The presence of pain during isometric testing at 12 weeks after ACL reconstruction was not reported and may have influenced the results of the study. In the present study, we waited to measure isokinetic knee extension strength until 6 months after surgery to avoid the influence of pain. Our isokinetic quadriceps strength testing revealed no difference in recovery of quadriceps strength between groups 6 months following the surgery. However, quadriceps weakness remained in both groups.

Arciero et al.[9] reported results of a prospective, randomized study evaluating tourniquet use in 40 patients who had arthroscopically assisted, autogenous bone–patellar tendon–bone ACL reconstructions. Twenty patients underwent this procedure with the use of a tourniquet inflated for an average of 87 minutes, with an average pressure of 269 mm Hg. One month postoperatively, the authors found by measuring thigh girth 10 cm proximal to the medial joint line, that there was more atrophy in the tourniquet group. Similarly, our results showed a significant decrease in quadriceps girth for both groups following surgery, with a greater decrease in thigh girth in the T group. Furthermore, Arciero et al. reported that abnormal EMG recordings were evident 3 weeks after surgery, but that they had returned to normal by 6 months. However, these authors did not evaluate muscular strength changes distal to the tourniquet in the early postoperative period. We found that tourniquet use did not affect strength distal to the site of compression. Similar to the present study, these authors found no difference in the recovery of isokinetic quadriceps strength in the group using a tourniquet during ACL

reconstruction. In addition, Kirkley et al.[17] found no effect of tourniquet use during routine knee arthroscopy on isokinetic knee strength testing, functional testing, time to return to activities, or health quality of life. However, their results did suggest that tourniquet use offers the advantage of improved visualization and decreased technical difficulty.

Epinephrine as an alternative to tourniquet use was a satisfactory method of establishing a bloodless field. There were no complications with use of epinephrine reported in this study. Similarly, Furia and Zambetti[18] found no significant difference in postoperative complications, length of hospital stay, operative time, and quality of visual fields when comparing tourniquet use with epinephrine injections into the knee joint. They also found that the epinephrine injection group required less postoperative pain medication.[17] The injection technique consisted of subcutaneous injections of 20 mL of 1% lidocaine with 1:100,000 epinephrine into the operative sites while a 60-mL 1:1 mixture of 0.5% bupivacaine and 0.5% lidocaine with 1:200,000 epinephrine was injected into the knee joint before surgery. The use of a long-lasting local anesthetic could have resulted in less need for pain medication, although the authors did speculate that tourniquet use may have produced local tissue trauma to the underlying muscles and induced more thigh pain.

It has been suggested that longer tourniquet times predispose one to higher risk of neuromuscular complications.[11,15,19] The average tourniquet time in the present study was 85 minutes (range, 51 to 114 minutes). This relatively short tourniquet time may be the reason for the lack of strength differences between the groups. Even though quadriceps strength was unaffected by the use of a tourniquet, neuromuscular changes may occur beneath and distal to the compression. Saunders et al.[11] reported EMG abnormalities 3 to 4 weeks after knee arthrotomy with the use of pneumatic tourniquet. Eighty-five percent of patients displayed abnormalities when the tourniquet was inflated for 60 minutes or longer, whereas only 22% of patients with tourniquet times of less than 15 minutes displayed EMG abnormalities. However, they did not measure quadriceps strength. Rorabeck and Kennedy[16] reported neuromuscular deficits in a patient following 45 minutes of tourniquet use during knee ligament surgery. However, these previous studies did not prospectively examine the effect of tourniquet time on lower extremity strength. Our analysis to determine if longer tourniquet times result in increased neuromuscular deficits was unable to show a relationship between longer tourniquet time and greater postoperative strength deficits. Nevertheless, tourniquet use resulted in a greater decrease in thigh girth, which indicates that the tourniquet may have compressed the thigh musculature without compromising the neurovascular structures.

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