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Longer tourniquet application time during knee surgery decreases the quadriceps muscle strength: a prospective study on 25 consecutive patients underwent total knee arthroplasty

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Abstract
The use of tourniquets in total knee arthroplasty (TKA) for patients with knee osteoarthritis is controversial. Although surgical techniques are more easily applied in a shorter time; there are some disadvantages associated with tourniquet use in orthopedic surgery. The aim of this study was to evaluate the effect of the tourniquet time on quadriceps strength by isokinetic muscle strength measurements in patients undergoing TKA. Prospective controlled study. Twenty-five knees of 25 patients with primary degenerative joint disease who underwent TKA were evaluated preoperatively and postoperatively at weeks 6 and 12 and month 6 by isokinetic knee extensor muscle strength testing at and American Knee Society Score (AKSS). The tourniquet time of all patients was recorded, and the preoperative results of all patients were compared with those postoperatively. The mean 60º/s angular velocity quadriceps peak torque was significantly lower postoperatively in patients with a longer tourniquet time. Isokinetic tests showed a significant negative correlation between the tourniquet time and mean muscle strength (week 6: $r = -0.718$, $p < 0.01$; week 12: $r = -0.651$, $p < 0.01$; month 6: $r = -0.672$, $p < 0.01$). The highest correlation with tourniquet time was obtained 6 weeks after surgery. Additionally, strong negative correlations were observed between the AKSS and tourniquet times (Knee Score: $r = -0.904$, $p < 0.01$; Knee Functional Score: $r = -0.878$, $p < 0.01$). Lower postoperative mean quadriceps strength in patients with a longer tourniquet time, suggesting that the tourniquet time affects the quadriceps muscle strength witl longer times resulting lower muscle strength.

Keywords: Knee osteoarthritis, muscle strength, quadriceps, tourniquet time

Introduction

TKA is frequently performed for patients with disabilities caused by osteoarthritis. TKA is also associated with substantial blood loss that sometimes causes hypotension, necessitating blood transfusion. The use of pneumatic tourniquets in orthopedic surgery is controversial. Using a tourniquet during TKA could reduce the amount of bleeding during surgery and thus decrease the incidence of cardiovascular complications, hemodynamic disorders, and peripheral vascular circulation problems[1]. Reduction of blood loss during surgery also provides a less hemorrhagic surgical field. Thus, surgical techniques are more easily applied and surgery is performed in a shorter time [2,3]. However, there are some disadvantages associated with tourniquet use in orthopedic surgery, including thigh pain, limb swelling, nerve palsy, rhabdomyolysis, vascular injuries, and reperfusion injury.

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A reduction in quadriceps strength after total knee replacement surgery has been reported[4,5]. Loss of muscle strength may be caused by tourniquet-associated ischemia and reperfusion. Prolonged operation and tourniquet times could intensify the loss of muscle strength. The performance of isokinetic muscle strength tests and muscle strength measurements would allow for the evaluation of this theory and potentially reveal more meaningful and objective results in the assessment of muscle strength[6].

Therefore, the aim of this prospective study was to evaluate the effect of the tourniquet time on quadriceps strength by isokinetic muscle strength measurements in patients undergoing TKA.

Materials and Methods

This prospective controlled study was approved by our Institutional Ethics Committee and was performed in accordance with the 2008 Helsinki Declaration. Informed consent was obtained from all study participants. Patients aged 60 to 70 years with primary osteoarthritis were included in this study. The exclusion criteria were neurological deficits, valgus deformities, ligament deficiencies, flexion contracture, rheumatologic disease, cardiovascular disease, a history of malignancy, cerebrovascular disease, and osteoporosis. The study group comprised 25 knees of 25 patients with primary degenerative joint disease who underwent TKA. The patients were evaluated with the American Knee Society Score and isokinetic quadriceps strength test. A cemented posterior cruciate ligament-retaining total knee replacement system was inserted in all patients by the same senior surgeon (E.E.S.). All procedures were performed using an inflatable tourniquet with the patients under regional anesthesia. Prophylactic low-molecular-weight heparin was administered to all patients. All patients also received intravenous prophylactic antibiotics for 72 h.

All patients underwent preoperative knee score determination and Cybex muscle testing. The strength of the quadriceps muscle was measured with a Cybex-350 isokinetic dynamometer system (Lumex, Ronkonkoma, NY, USA). Each patient underwent isokinetic testing of the quadriceps muscle. The patients were positioned on the Cybex chair with stabilization supports across the pelvis and distally over the thigh. The patients gripped the side of the chair and leaned back against the backrest, which was inclined posteriorly to an angle of 85º to the horizontal.

The isometric tests for knee extension and flexion were performed at 60º of knee flexion. A maximum of six attempts were made at each flexion degree, with a resting interval of 20 s between each attempt. The isokinetic tests for knee extension and flexion were performed at 60º/s (four repetitions), with a resting interval of 60 s between the tests.

All knees were surgically approached through a medial parapatellar incision. The tendinous part of the extensor mechanism was incised 5 mm lateral to the junction between the vastus medialis and rectus femoris. The quadriceps tendon was partially incised, leaving most of the tendon intact. The capsule and medial joint structures were opened along the medial border of the patella. The incision was carried parallel to the patellar tendon distally, ending 0.5 cm medial to the tibial tubercle.

Every patient stood at the bedside and began ambulating the day after surgery. Flexion-extension exercises were instituted on postoperative day 2. Neither a continuous passive-motion machine nor knee immobilizer was used.

The patients were evaluated at postoperative weeks 6 and 12 and at postoperative month 6 by isokinetic knee extensor muscle strength testing and American Knee Society Score (AKSS) which consist of two parts. (Knee score, function score) The tourniquet time of all patients was recorded, and the preoperative results of all patients were compared with those postoperatively.

Statistical analysis

All data are expressed as means ± standard deviation or median with minimum and maximum values. GPower software was used for sample size estimation and a sample size of 20 individuals is proposed to give 80% power to detect an effect size of 0.8 between preoperative and postoperative outcome variables of the study. Normality assumption was confirmed using Shapiro-Wilk test. Mann-Whitney U test, Wilcoxon signed rank test, Friedman test were used for statistical analyses where appropriate. Multiple comparisons were carried out by Wilcoxon signed rank test with Bonferroni correction. Correlations between the variables were estimated based on Spearman's rho correlation coefficient. All data were analyzed using the IBM SPSS Statistics 22.0 software package (SPSS, Inc., Chicago, IL, USA), and a p value of <0.05 was considered to indicate statistical significance.

Results

The patients comprised 19 females and 6 males with a median age of 66.1 ± 3.4 years (range, 60–70 years) and body mass index (BMI) of 31.1 ± 6.2 kg/m^2 (range, 23.0–45.0 kg/m^2). The average tourniquet time was 85.3 min (range, 0–135.0 min).

There was a significant difference between the preoperative and postoperative muscle strength and AKSS (Table 1). When the tourniquet times were grouped as <90 minutes and >90 minutes, a statistically significant difference in muscle strength with increasing tourniquet time was noted (Table 2).

Table 1. Preoperative and postoperative quadriceps muscle strength at 60°/s (Nm) and American Knee Society Score (AKSS) .

Variables	Mean ± SD
Preop Knee Score	36.60 ± 6.08
Postop Knee Score	78.80 ± 6.08*
Preop Knee Functional Score	35.80 ± 11.24
Postop Knee Functional Score	80.80 ± 11.24*
Muscle strength at 60°/s (Nm)	
Preop	74.84 ± 5.82
6 weeks postop	29.24 ± 7.64*
12 weeks postop	58.20 ± 9.21*
6 months postop	71.36 ± 7.87*

SD, standard deviation;Preop, preoperative; Postop, postoperative
*Significant difference between postoperative and preoperative muscle strength at 60°/s and knee scores ($p < 0.05$)

Table 2. Muscle strength at 60º/s (Nm) results after the groups were divided according to the tourniquet time.

Muscle strength at 60º/s (Nm)		Tourniquet time (0-90 min) (n =14)	Tourniquet time (>90 min) (n =11)	p
Preop	Median (min-max)	73 (65-84)	79 (66-82)	0.814
6 weeks postop		32 (22-44)	24 (16-35)	0.000*
12 weeks postop		63 (50-76)	52 (35-66)	0.004*
6 months postop		78 (63-84)	68 (51-76)	0.012*

SD: standard deviation; Preop: preoperative;Postop: postoperativen: Number of patients
*Significant difference between results of groups with longer tourniquet times.

The preoperative and postoperative isokinetic test results were investigated. Based on the results, for the 60º/s peak torque extension isokinetic tests, a significant negative correlation was noted between the tourniquet time and mean muscle strength (week 6: r = –0.718, p < 0.01; week 12: r = –0.651, p < 0.01; month 6: r = –0.672, p < 0.01) and the AKSS (Knee Score: r = –0.904, p < 0.01; Knee Functional Score: r = –0.878, p < 0.01). The highest correlation with tourniquet time was obtained 6 weeks after surgery.

Table 3. Preoperative and postoperative quadriceps muscle strength results for female and male patients.

			Tourniquet time (min)	Preop muscle strength at 60°/s (Nm)	6 weeks postop	12 weeks postop	6 months postop
Sex	Female (n = 19)	Mean ± SD	82.11 ± 33.88	73.37 ± 5.55	29.21 ± 7.76*	57.21 ± 8.67*	70.84 ± 8.21*
	Male (n = 6)		94.17 ± 49.54	79.50 ± 4.18	29.33 ± 7.97*	61.33 ± 11.00*	73.00 ± 7.13*

SD: standard deviation;Preop: preoperative;Postop: postoperative
*No significant difference between preoperative and postoperative results (p > 0.05)

There were no significant difference between male and female groups (Table 3). Also there was no significant correlation between BMI and muscle strength (week 6: r= –0.158, p=0.451; week 12: r= 0.322, p=0.116; month 6: r= 0.436, p=0.129).

Discussion

The results from this study suggest that the tourniquet time affects the quadriceps muscle strength which can be measured by isokinetic dynamometry.

Pneumatic tourniquets have been used for elective surgery for more than a century to reduce intraoperative blood loss and improve visibility in the surgical field [2,7,8]. Most orthopedic surgeons still inflate the tourniquet above the systemic blood pressure during total knee replacement surgery [9,10]. Proposed advantages of this practice include minimizing the amount of both intraoperative and postoperative blood loss, producing an intraoperative “bloodless” visual field, improving the cement–bone interdigitation, and reducing the operation time [8-10].

The theoretical disadvantages of tourniquet application include an increased risk of nerve palsy, vascular injury, muscle damage, postoperative swelling, and stiffness [11,15]. Cardiorespiratory function can also be affected by tourniquet inflation and deflation, which may lead to intraoperative cardiac arrest [16]. Reactive hyperemia upon tourniquet deflation has also been noted, which may cause substantial bleeding and prolong the operation time [17]. Tourniquets may also be associated with an increased incidence of early infection and wound healing disorders due to perioperative hypoxia and reduced postoperative tissue perfusion [18,19]. Total knee replacement has been associated with high rates of deep vein thrombosis and pulmonary thromboembolism [20].

Various studies have evaluated the measurement of muscle strength. Isokinetic muscle strength tests provide more meaningful and objective results with which to evaluate muscle strength. [6] Cila et al. compared the subvastus approach and median parapatellar approach with isokinetic muscle strength testing in 19 patients. The quadriceps strength was higher in the subvastus group in the early postoperative period, although no difference was noted between the two groups in the long term [21]. Fifty-two knees in normal healthy subjects and 32 knees more than 2 years after total knee arthroplasty were evaluated by Silva et al and they found isometric extension peak torque values in TKA patients were reduced by up to 30.7% [22]. Berman et al performed isokinetic testing of 68 patients with degenerative joint disease scheduled for unilateral TKA [4]. They found that hamstring peak-torque values were able to attain strength levels of the uninvolved knee within the period of seven to 12 months after surgery, whereas the quadriceps mechanism still showed a residual deficit at two years follow-up evaluation. Aquino et al used isokinetic muscle strength tests to compare patients’ knees that underwent TKA, using the contralateral knees as the controls; they found that the extensor muscle strength was lower on the operated side. Their study indicates that comparison of muscle strength changes between the operated knee and the contralateral knee is not accurate [5][5]. Therefore, in the present study, we compared patients’ muscle strength by calculating the average isometric extension peak torque (N/m) with the preoperative values. When we searched the literature, although we found many studies on isokinetic muscle strength testing for the measurement of muscle strength, we found no studies on the impact of tourniquet time on quadriceps muscle strength during total knee replacement. The present study is the first to address this topic.

We noted a decline in the quadriceps muscle strength in the postoperative period with a longer duration of tourniquet use. The most significant reduction in quadriceps strength was observed at 6 weeks postoperatively. This lower muscle strength at the first postoperative measurement suggests that the effect of tourniquet use on muscle strength is more prominent in the first 6 weeks postoperatively. This can be explained by tissue damage due to the reduction in the blood supply to tissues and impaired metabolism of soft tissue and muscle due to the operation in the early postoperative period [23,24].

Ongoing pain in the early postoperative period makes it difficult for patients to comply with the performance of muscle-strengthening exercises. With subsequent ongoing physiotherapy, increases in the patients' daily activities, greater mobilization, more repetitions of muscle-strengthening exercises, and improved compliance with these exercises, a significant increase in muscle strength was noted at 12 weeks and 6 months postoperatively compared with 6 weeks postoperatively. All patients' muscle strength failed to reach the preoperative levels at 6 months postoperatively; however, patients with a longer tourniquet time had less muscle strength than did patients with a shorter time. Decreases in muscle strength were observed at 6 weeks, 12 weeks, and 6 months postoperatively in patients with prolonged tourniquet times. These results suggest that a prolonged tourniquet time causes greater loss of muscle strength.

The use of a control group without tourniquets can provide a more meaningful assessment of the impact of a longer tourniquet time on muscle strength. In the present study, however, such a control group could not be utilized because of the routine application of tourniquets during TKA in our clinic.

The limitations of our study are the small number of patients, lack of long-term outcomes, and lack of a control group without tourniquets. Patients were still had limited range of motion; we didn't able to evaluate the the mean 180º/s angular velocity quadriceps peak torque. Studies with longer follow-up periods and larger numbers of patients are needed to fully assess the effect of tourniquet time on muscle strength.

In conclusion, tissue ischemia and reperfusion injury are known to occur due to tourniquet use in TKA [25,26]. Loss of muscle strength and rhabdomyolysis have also been reported in patients who have undergone TKA with a tourniquet [27]. To our knowledge, no studies have investigated the effects of tourniquet time on quadriceps muscle strength in patients undergoing TKA. In the present study, the mean 60º/s angular velocity quadriceps peak torque was significantly lower postoperatively than preoperatively in patients with a longer tourniquet time, suggesting that the tourniquet time affects the quadriceps muscle strength. Additionally, our study suggests that isokinetic dynamometry can be a sensitive and useful method with which to measure muscle strength.

Conflict of Interest Statement
All authors declare that they have no conflict of interest.

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The authors disclose no financial support or other benefits from commercial sources for the work reported on in the manuscript, or any other financial interests which could create a potential conflict of interest or the appearance of a conflict of interest with regard to the work.

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