# Knee Extensor Function Before and 1 Year After Simultaneous Bilateral Total Knee Arthroplasty: Is There Asymmetry Between Limbs?

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## Abstract

**One year after unilateral total knee arthroplasty (TKA), there is interlimb knee extensor function asymmetry. In the study reported here, we investigated whether there was knee extensor function "asymmetry" between limbs 1 year after simultaneous bilateral TKA.**

**Fourteen patients volunteered to participate in this study before undergoing simultaneous bilateral TKA secondary to knee osteoarthritis. One year after surgery, 8 patients agreed to participate in follow-up testing. Torque production, work, and range of motion of knee extensors were assessed isokinetically at 1.047 radians·second$^{-1}$.**

**Before surgery, there was no difference between limbs in peak torque, work, or range of motion during isokinetic testing. One year after surgery, this pattern persisted.**

**The strength asymmetry evident in patients 1 year after unilateral TKA did not exist in patients who underwent simultaneous bilateral TKA. There is a symmetrical pattern between limbs for knee extensor function 1 year after the bilateral procedure.**

A person who has knee osteoarthritis and is waiting to undergo total knee arthroplasty (TKA) cannot generate knee extensor force on the involved limb compared with the uninvolved side.[1-3] Thirty days to 1 year after TKA, the ability to generate knee extensor force improves. However, this improvement is relative to presurgical knee extensor strength.[1,2] Despite such improvement after unilateral TKA, interlimb differences in knee extensor force production persist months and years after surgery.[1,4-6]

Within the first 30 days after unilateral TKA, force production of knee extensors decreases from presurgical levels; then, within 60 days, there is a slow return of force-generating capability.[1-3] The "dip" in strength at 30 days has been confirmed in patients who undergo simultaneous bilateral TKA.[7] From before surgery to 1 year after unilateral TKA, the ability to generate force on the involved limb is far less than on the uninvolved side.[1,4-6] In other words, over the course of a year, knee extensor force production on the involved side never "catches up" to that in the uninvolved or healthy limb.

Interestingly, in the first few months after bilateral TKA, the interlimb knee extensor asymmetry evident in unilateral involvement does not exist.[7] It is important to evaluate the strength of the knee extensors after TKA, as studies have shown a relationship between knee extensor strength and mobility.[8,9] Moreover, knee extensor function after unilateral TKA is related to load-bearing during functional tasks.[10]

As force production of knee extensors had not been evaluated more than 2 months after bilateral TKA, we set out to evaluate knee extensor function and determine whether there is "asymmetry" between limbs 1 year after simultaneous bilateral TKA.

## Materials and Methods

### Test and Rationale

To determine whether there is knee extensor function asymmetry between limbs before and 1 year after simultaneous bilateral TKA, we evaluated the ability to generate knee extensor torque under an isokinetic condition, the total work produced, and the range of motion (ROM) achieved during the isokinetic strength assessment. Isokinetic testing of knee extensors has been successfully used to evaluate torque production 3 to 12 months after TKA.[2-6,11] The Cybex isokinetic system (Cybex International, Medway, Massachusetts) was used to determine knee extensor isokinetic torque production

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**Table I. Patient Characteristics Before and 1 Year After Surgery**

| | Mean | SEM | Minimum | Maximum |
|---|---|---|---|---|
| **Before Surgery (n = 14)** | | | | |
| Age, y | 74.57 | 1.47 | 63.00 | 83.00 |
| Height, cm | 169.91 | 2.52 | 154.90 | 190.50 |
| Weight, kg | 76.42 | 2.63 | 64.00 | 99.00 |
| BMI, kg/m$^2$ | 26.47 | 0.69 | 23.15 | 30.44 |
| **1 Year After Surgery (n = 8)** | | | | |
| Age, y | 73.13 | 1.92 | 63.00 | 78.00 |
| Height, cm | 165.74 | 2.33 | 154.90 | 176.50 |
| Weight, kg | 71.13 | 1.68 | 64.00 | 79.00 |
| BMI, kg/m$^2$ | 25.99 | 0.93 | 23.46 | 30.42 |

Abbreviations: BMI, body mass index; SEM, standard error of the mean.

and total work at 1.047 radians·second$^{-1}$ before and 1 year after surgery on both limbs. The first dependent variable was maximum torque (N·m) over 3 trials, and the second and third dependent variables were total work produced (joules) and ROM (degrees) during the trial producing the maximum torque.

### Patients

Fourteen patients (8 men, 6 women) volunteered to participate in this study before undergoing simultaneous bilateral TKA secondary to knee osteoarthritis. All patients were selected consecutively from an outpatient orthopedic practice as a sample of convenience. All patients provided written consent, which was approved by our institutional review board. Patient characteristics are presented in Table I.

All patients were discharged home after acute care services with continued outpatient physical therapy. All TKAs were completed by the same orthopedic surgeon, and all were tricompartmental posterior cruciate ligament–sacrificed designs. Before surgery, all patients required an assistive device (ie, cane, walker) secondary to disabling pain. Exclusion criteria were past hip arthroplasty; severe osteoarthritis of ankle or hip joints; cardiovascular problems, such as uncontrolled heart disease; any neuromuscular disease; any long-term disease processes, such as cancer; or any other pathology or disease process that could affect muscular strength, including clinically significant back pain.

One year after simultaneous bilateral TKA, patients were called and asked to participate in follow-up testing. Of the 14 patients called, 8 (5 men, 3 women) agreed to participate in the 1-year follow-up. These 8 patients were tested within 2 weeks before or after their 1-year anniversary of surgery. One year after surgery, all patients were active at home and within the community and did not require an assistive device. No changes in comorbidities were reported, and all patients continued to meet the inclusion criteria. No patient received physical therapy services since discharge from outpatient rehabilitation, and no patient reported knee pain or discomfort during isokinetic testing.

### Procedure

During each day of testing, the Cybex system was calibrated, and the force arm was validated to a known weight according to manufacturer instructions. Patients were seated in the Cybex chair with the axis of the dynamometer corresponding to the knee axis (lateral femoral condyle in frontal plane). Once positioned, patients were secured with Velcro straps over the waist, shoulder, and thigh of the testing limb. Each patient was instructed to complete full ROM starting in full available flexion and then moving into full available extension. Each patient was given a warm-up at 2.094 radians·second$^{-1}$ and 1.047 radians·second$^{-1}$ for 5 repetitions at each speed, with a 2-minute rest between speeds. After the rest period, each patient was asked to perform 3 repetitions "as hard and as fast as they could" at a speed of 1.047 radians·second$^{-1}$. Patients were then given a 5-minute rest before the opposite side was tested using the same procedure. This protocol was used before surgery and 1 year after surgery.

After surgery, all patients received physical therapy in the hospital (mean stay, 3 days). Acute care rehabilitation included continuous passive motion, passive and active ROM, resistive therapeutic exercise, gait, transfer, and bed mobility training. Within 10 days after hospital discharge, all patients began outpatient physical therapy and were full weight-bearing. Physical therapy was given 3 times per week for 8 weeks. Specific resistive exercises have been reported previously.[6,7]

### Analysis

Because of the small sample size, we used nonparametric statistics to assess for interlimb differences. We used the Wilcoxon paired test to determine interlimb differences in peak torque, total work, and ROM at 1.047 radians·second$^{-1}$ before and 1 year after surgery. Alpha was set at 0.05.

## Results

Baseline and 1-year follow-up data are presented in Table II. There was no difference between limbs in peak torque, work, or ROM before simultaneous bilateral TKA; 1 year after surgery, there was no difference between limbs for each outcome measure (Table III).

**Table II. Outcome Measures Before and 1 Year After Simultaneous Bilateral Total Knee Arthroplasty**

| Dependent Variable | Mean | SEM | Minimum | Maximum |
|---|---|---|---|---|
| **Before Surgery (n = 14)** | | | | |
| ROM extension L,° | 5.36 | 0.77 | 2.00 | 10.00 |
| ROM extension R,° | 6.64 | 0.54 | 4.00 | 10.00 |
| ROM flexion L,° | 97.93 | 2.93 | 67.00 | 111.00 |
| ROM flexion R,° | 95.71 | 2.60 | 75.00 | 110.00 |
| Peak torque L, N·m | 62.78 | 8.16 | 31.19 | 132.89 |
| Peak torque R, N·m | 65.57 | 11.41 | 29.83 | 158.65 |
| Work extension L, J | 70.29 | 7.30 | 15.00 | 113.00 |
| Work extension R, J | 71.79 | 10.28 | 19.00 | 133.00 |
| **1 Year After Surgery (n = 8)** | | | | |
| ROM extension L,° | 7.00 | 0.76 | 5.00 | 10.00 |
| ROM extension R,° | 7.75 | 0.75 | 5.00 | 10.00 |
| ROM flexion L,° | 100.13 | 2.21 | 90.00 | 108.00 |
| ROM flexion R,° | 99.88 | 2.50 | 90.00 | 111.00 |
| Peak torque L, N·m | 104.22 | 7.80 | 82.72 | 150.52 |
| Peak torque R, N·m | 107.08 | 7.13 | 89.50 | 149.60 |
| Work extension L, J | 88.63 | 7.40 | 64.00 | 130.00 |
| Work extension R, J | 91.00 | 6.69 | 73.00 | 133.00 |

Abbreviations: L, left; R, right; ROM, range of motion; SEM, standard error of the mean.

**Table III. Differences Between Limbs Before and 1 Year After Simultaneous Bilateral Total Knee Arthroplasty**

| Dependent Variable | Mean Difference (Left–Right) | Wilcoxon (2-Tailed) |
|---|---|---|
| **Before Surgery (n = 14)** | | |
| Work knee extension, J | –1.50 | 1.00 |
| Peak torque, N·m | –2.79 | 0.73 |
| ROM extension,° | –1.28 | 0.16 |
| ROM flexion,° | 2.22 | 0.22 |
| **1 Year After Surgery (n = 8)** | | |
| Work knee extension, J | –2.37 | 1.00 |
| Peak torque, N·m | –2.86 | 0.09 |
| ROM extension,° | –0.75 | 0.57 |
| ROM flexion,° | 0.25 | 0.94 |

Abbreviation: ROM, range of motion.

## Discussion

The current body of knowledge indicates that knee extensor strength is related to mobility and weight-bearing after TKA, which makes knee extensor function an important factor to measure after this procedure.[8-10] There is strength asymmetry between limbs before and many months after unilateral TKA.[1-6,11] However, patients who undergo simultaneous bilateral TKA do not have this asymmetry before surgery or over the 60 days after surgery.[7] The goal of our study was to determine whether patients have an asymmetrical strength pattern between limbs 1 year after TKA. Our results indicated that the strength asymmetry evident in patients 1 year after unilateral TKA does not exist in patients who undergo simultaneous bilateral TKA. Not only is there a symmetrical pattern between limbs for knee extensor torque production 1 year after a bilateral procedure, but total work and ROM do not differ between limbs.

Patients many months after unilateral TKA also present with a weight-bearing asymmetry during tasks, such as rising from a chair and climbing stairs.[10] In other words, patients with unilateral involvement rely on their "good" or healthy limb to complete functional tasks. Patients after simultaneous bilateral TKA attempt to use both limbs in a symmetrical fashion when attempting activities of daily living.[12] This symmetrical pattern of use may minimize the possibility of placing excess demand on a specific side. People after unilateral TKA favor the involved lower extremity[10]; therefore, there may be less demand on the surgical limb, potentially increasing muscular dysfunction (caused by disuse) of the involved side and compounding interlimb strength asymmetry.

We reported that mean knee extension short of full extension for both limbs before surgery was approximately 6°. Mean extension short of full extension before unilateral TKA has been reported to be 3° (Mizner and colleagues[1]) and approximately 8° (Rodgers and colleagues[13]). These results are comparable; patients with bilateral involvement and patients with unilateral involvement presented with similar knee extension. Mizner and colleagues[1] reported mean presurgical knee flexion to be 119° in unilateral cases, and Rodgers and colleagues[13] reported mean presurgical flexion to be approximately 113°. Our mean flexion of approximately 97° is lower than in these studies.

In their investigation, Rodgers and colleagues[13] reported that, by 3 months after surgery, mean knee extension had improved approximately 3° to 5° short of full, and mean flexion was 111°. In addition, Mizner and colleagues[1] reported that, by 6 months, mean extension had improved 2° to 1° short of full and, interestingly, that mean flexion had decreased approximately 3° to 116°.

Lavernia and colleagues[14] reported that knee ROM, measured by physical therapists approximately 1 year after unilateral TKA, ranged from approximately 7°

**Table IV. Quadriceps Strength Deficit of Involved and Uninvolved Limbs After Total Knee Arthroplasty**

| Author | Time | Test Mode | Units | Involved | Uninvolved |
|---|---|---|---|---|---|
| Anchuela et al[16] | Before surgery | Isokinetic 60°/s | N·m | 71.33±2.42 | 97.50±22.45 |
| | 6 mo after surgery | | | 57.88±2.70 | 68.50±25.11 |
| | 12 mo after surgery | | | 62.66±2.42 | 89.15±22.45 |
| Berman et al[5] | Before surgery | Isokinetic 60°/s | ft-lb | 26.21±7.0 | 44.17±7.9 |
| | 3-6 mo after surgery | | | 28.90±6.8 | 49.43±8.1 |
| | 7-12 mo after surgery | | | 37.21±7.0 | 52.33±7.9 |
| | 13-23 mo after surgery | | | 41.22±7.1 | 51.00±7.8 |
| | 24+ mo after surgery | | | 41.99±7.0 | 50.27±7.0 |
| Lorentzen et al[3] | Before surgery | Isokinetic 30°/s | N·m | 57.0 | 67.0 |
| | 3 mo after surgery | | | 55.0 | 78.0 |
| | 6 mo after surgery | | | 67.0 | 79.0 |
| | Before surgery | Isokinetic 120°/s | N·m | 37.0 | 52.0 |
| | 3 mo after surgery | | | 39.0 | 52.0 |
| | 6 mo after surgery | | | 42.0 | 53.0 |
| Rodgers et al[13] | Before surgery | Isokinetic 60°/s | ft-lb | 74.6 | 102.4 |
| | 1.5 mo after surgery | | | 56.9 | 101.7 |
| | 3 mo after surgery | | | 73.9 | 103.4 |
| Berth et al[24] | Before surgery | Isometric 90° KF | N·m | 66.3±33.4 (MVIC) | 81.9±38.1 (MVIC) |
| | 33 mo after surgery | | | 84.8±35.5 (MVIC) | 79.4±30.5 (MVIC) |
| Lorentzen et al[3] | Before surgery | Isometric 75° | N·m | 66.0 | 87.0 |
| | 3 mo after surgery | | | 55.0 | 92.0 |
| | 6 mo after surgery | | | 65.0 | 92.0 |
| Mizner et al[1] | Before surgery | Isometric 75° KF | N | 18±8 (MVIC) | 23±10 (MVIC) |
| | 1 mo after surgery | | | 7±4 (MVIC) | 22±9 (MVIC) |
| | 2 mo after surgery | | | 11±5 (MVIC) | 23±9 (MVIC) |
| | 3 mo after surgery | | | 15±6 (MVIC) | 23±10 (MVIC) |
| | 6 mo after surgery | | | 18±8 (MVIC) | 23±10 (MVIC) |

Abbreviations: KF, knee flexion; MVIC, maximal voluntary isometric contraction.

short of full extension to approximately 100° of flexion across different practitioners. Miner and colleagues[15] reported mean preoperative flexion of 108° and mean extension approximately 6° short of full. They also noted that, by 12 months, flexion was 110° and extension was 1° short of full. Our ROM results are similar to those in other studies, yet it can be noted that our patients had less total ROM than patients with unilateral involvement. One possible reason for this finding is that, in unilateral patients, ROM is wider because the uninvolved side is healthy, thus allowing more excursion on both limbs during functional tasks, such as getting in and out of a car or rising from a chair. However, this explanation needs further scientific investigation.

In the studies that found the interlimb knee extensor force producing asymmetry after unilateral TKA, the involved side generated less output than the uninvolved side (Table IV). The torque produced by both limbs before surgery in our study was similar to that in studies of the torque production of the knee extensors in unilateral involvement. Our knee extensor peak torque, assessed at 60°/s before surgery, was similar to that reported by Anchuela and colleagues[16] and Rodgers and colleagues[13] but much larger than what Berman and colleagues[5] found. Numerous studies have shown that, 1 year after unilateral TKA, knee extensor force production asymmetry remains. However, in our study, patients 1 year after bilateral TKA did not have knee extensor force production asymmetry between limbs, and there was more knee extensor force production in our patients 1 year after bilateral TKA than in the involved limb of patients with unilateral involvement.[5,16] One explanation could be that patients who undergo bilateral arthroplasty do not favor an "involved side" and appear to complete tasks symmetrically, potentially distributing body weight equally on both legs. Such a hypothesis cannot be confirmed with our data, but it opens the door for further investigation. Concerning frequency and duration of rehabilitation, Mizner and colleagues[1] reported that, beginning 4 weeks after surgery (2 to 3 weeks of home care initially after hospital discharge), physical therapy was given 2 to 3 times per week for 6 weeks. Outpatient rehabilitation in our study was similar; however, patients in the Mizner investigation received home care before outpatient physical therapy.

One limitation of our study is that we did not gather information on perceived abilities, general health, and activity levels. We did not use tests to assess locomotor abilities before and after surgery. However, our goal was to evaluate at the impairment level before and after simultaneous bilateral TKA. Another limitation is the small sample size, which makes generalizations to the

overall population tenuous and increases the probability of committing type II errors. Despite these limitations, our data provide valuable information regarding knee extensor function 1 year after bilateral TKA. Although we previously documented our physical therapy protocol,[6,7] we did not monitor the home exercise program in the period from 60 days after surgery to 1 year after surgery.

Other investigators have reported that, compared with patients who have unilateral TKA, patients who undergo a simultaneous bilateral procedure self-report better function and general health 1 year after surgery.[17] Furthermore, complication rates and clinical outcomes are similar between unilateral TKA patients and simultaneous bilateral arthroplasty patients.[18] Some patients who need a TKA on both limbs do not undergo a simultaneous procedure, but, rather, a staged procedure (2 separate surgeries, 1 for each knee). As a simultaneous procedure involves only 1 surgery, hospital costs would be expected to be lower than those for a staged bilateral procedure.[19,20]

Given that a large percentage of the population will be entering later adulthood, demands on health care will rise as well. The number of knee arthroplasties was projected to increase through the year 2030.[21,22] Although risks are higher with a bilateral procedure,[23] this intervention is safe and effective and can minimize recovery time and hospital costs (1 vs 2 surgeries). Our study at the impairment level has shown that knee ROM and knee extensor function (total work, torque production) do not differ between limbs 1 year after simultaneous bilateral TKA.

## Conclusions

Unlike patients after a unilateral TKA, patients 1 year after simultaneous bilateral TKA have knee extensor function "symmetry" between limbs. We recommend that longitudinal prospective studies document the short- and long-term history of knee extensor and lower limb function, mobility, and perceived function after simultaneous procedures. Investigations should attempt to assess the strength symmetry between limbs after simultaneous bilateral TKA and the implications for balance and function over the long term. Moreover, well-detailed exercise protocols, including prescribed home exercises and patient-directed exercises, must be documented in longitudinal investigations so that the relationship between postrehabilitation exercises and functional outcomes can be established. Studies also should investigate the costs of staged and simultaneous procedures in an effort to determine the most cost-effective methods for maximizing rehabilitation and obtaining positive functional outcomes.

## Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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