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Outcomes Before and After Total Knee Arthroplasty Compared to Healthy Adults

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Abstract

STUDY DESIGN—Prospective cohort study.

OBJECTIVES—To measure changes in muscle strength, range of motion, and function from 2 weeks before to 6 months after total knee arthroplasty (TKA) and compare outcomes with data from a control group consisting of healthy adults.

BACKGROUND—Total knee arthroplasty successfully alleviates pain from knee osteoarthritis, but deficits in function can persist long term. How impairments and functional limitations change over the first 6 months after TKA, compared to data from healthy adults, has not been well reported in the literature.

METHODS—Twenty-four patients who underwent a primary unilateral TKA were compared to healthy adults ($n = 17$). All patients participated in a standardized rehabilitation program following surgery. Isometric quadriceps torque was assessed using an electromechanical dynamometer. Range of motion was measured actively and passively. Functional performance was assessed using the stair-climbing test, timed up-and-go test, 6-minute walk test, and single-limb stance time. Patients underwent testing at 2 weeks preoperatively and at 1, 3, and 6 months postoperatively.

RESULTS—Compared to healthy older adults, patients performed significantly worse at all times for all measures ($P < .05$), except for single-limb stance time at 6 months ($P > .05$). One month postoperatively, patients experienced significant losses from preoperative levels in all outcomes. Patients recovered to preoperative levels by 6 months postoperatively on all measures, except knee flexion range of motion, but still exhibited the same extent of limitation they did prior to surgery.

CONCLUSION—The persistent impairments and functional limitations 6 months after TKA with standard rehabilitation suggest that more intensive therapeutic approaches may be necessary to restore function of patients following TKA to the levels of healthy adults.

Keywords

joint replacement; older adults; osteoarthritis; rehabilitation

Arthritis is the leading cause of disability in America.⁵ Osteoarthritis (OA) is the most common type of arthritis and affects nearly 27 million Americans.¹⁷ Total knee arthroplasty

(TKA) is routinely performed to alleviate the pain associated with knee OA. In 2006, the number of TKA surgeries performed in the United States was 516 000,¹ and this number is projected to grow to 3.48 million by the year 2030 because of an increasing number of older adults, increasing prevalence of obesity, and increasing utilization of this surgery.¹⁶

Total knee arthroplasty reliably reduces pain and improves health-related quality of life in 90% of patients.²⁴ Yet, functional performance in patients 1 year after TKA remains lower than for healthy adults, with reports of an 18% slower walking speed, 51% slower stair-climbing speed, and deficits of nearly 40% in quadriceps strength.⁴³ One year after TKA, patients report having greater difficulty with kneeling, squatting, moving laterally, turning, cutting, carrying loads, stretching, performing lower extremity strengthening exercises, playing tennis, dancing, gardening, and participating in sexual activity, when compared to healthy adults.²⁵

Although there have been numerous studies on patients after TKA with a comparison to healthy adults, many of these studies were cross-sectional in nature or, if longitudinal, examined only long-term (greater than 6 months postoperative) outcomes.^{2-4,8,12,25,31,35,43-44} Thus, inference into how and when impairments and functional limitations develop in the first 6 months after TKA is lacking. A better understanding of impairments and functional limitations preoperatively and how these change postoperatively would help clinicians design rehabilitation programs that more fully restore physical function in patients after TKA to the levels of their healthy peers.

To date, there have been only 2 longitudinal studies that have assessed impairments and functional limitations during the 6-month interval after TKA.^{22,44} However, both studies had limitations. In the study by Mizner et al,²² there was no comparison of patients with healthy adults. Thus, the magnitude of deficits compared to healthy adults was not documented. The second study had limitations in generalizability because of (1) strict inclusion criteria (lower body mass index [BMI] and at least neutral knee extension), (2) small sample size ($n = 12$), and (3) no measurements earlier than 3 months after TKA.⁴⁴

The purpose of this study was to assess muscle strength, range of motion (ROM), and functional performance of patients prospectively from before to after TKA for comparison with healthy older adults. Our hypothesis was that patients would perform more poorly preoperatively and at 6 months postoperatively on muscle strength, ROM, and functional tests compared to healthy adults. Furthermore, we hypothesized that patients would experience significant losses in all outcomes 1 month postoperatively and then recover to preoperative levels by 6 months.

METHODS

Study Design

This was a prospective cohort study of patients undergoing TKA, evaluated at 2 weeks preoperatively, as well as at 1, 3, and 6 months postoperatively, with a cross-sectional comparison to a cohort of healthy adults. The 6-month time point was chosen because patients recovering from TKA typically plateau in strength and functional gains by this time point.^{7,15,22} The study was approved by the Colorado Multiple Institutional Review Board. Informed consent was obtained from all participants and the rights of participants were protected.

Participants

Twenty-four patients (12 females, 12 males) who underwent a primary unilateral TKA were compared to a healthy cohort of 17 adults (8 females, 9 males). Patients undergoing TKA

were consecutively recruited from 3 orthopaedic surgeons at the University of Colorado Hospital from June 2006 to June 2008 and were control subjects in an ongoing clinical trial. Patients were included if they were between the ages of 50 and 85 years and were undergoing a primary unilateral TKA for end-stage knee OA. Patients undergoing TKA were excluded if they had uncontrolled hypertension, uncontrolled diabetes, BMI greater than 35 kg/m², significant neurologic impairments, significant contralateral knee OA (as defined by pain greater than 4/10 with activity), or other unstable, lower extremity orthopaedic conditions. All patients participated in a standardized rehabilitation program following surgery. Inpatient rehabilitation at the University of Colorado Hospital was conducted twice daily for an average $\pm$ SD length of stay of 3.2 ± 1.1 days (APPENDIX). Following discharge from the hospital, patients were treated in the home setting for 2 weeks (6 to 7 visits), after which patients were treated in outpatient physical therapy for 11.5 ± 6.2 visits. All home health and outpatient physical therapists followed a standardized rehabilitation protocol as previously described (APPENDIX).²¹ Interventions targeted knee ROM, incision mobility, pain control, gait deviations, and strength of the quadriceps, hamstrings, hip abductors, hip extensors, and ankle plantar flexors. Both weight-bearing and non-weight-bearing exercises were initiated with 2 sets of 10 repetitions and then progressed to 3 sets of 10 repetitions. For strengthening exercises, weights were increased to maintain a 10-repetition maximum targeted intensity level. Patients were also given a home exercise program to be performed twice daily that consisted of end-range knee flexion and extension stretching, as well as weight-bearing and non-weight-bearing strengthening exercises for the quadriceps, hamstrings, hip abductors, hip extensors, and ankle plantar flexors. The intensity of the home exercise program was similar to that performed during the supervised home and outpatient physical therapy sessions. No patients were lost to follow-up evaluation.

Healthy adults were consecutively recruited from the community from December 2008 to March 2009. Healthy adults were included if they exercised a minimum of 3 days per week for at least 30 minutes per day and were between the ages of 50 and 85 years. Healthy adults were excluded if they had any of the exclusion criteria listed above for the patients receiving TKA or if they had knee pain greater than 2/10 on an intermittent basis or average knee pain greater than 0/10 with daily activities based on self-report. Both right and left lower extremities were tested for the unilateral measurements of quadriceps strength and ROM.

Outcomes

Isometric Muscle Torque Testing—To test isometric quadriceps muscle torque, patients were seated and stabilized on a HUMAC NORM (CSMi, Stoughton, MA) electromechanical dynamometer with 60° of knee flexion. Following 2 warm-up contractions, a practice maximal voluntary isometric contraction (MVIC) was performed against the dynamometer's force transducer. Data were acquired using a Biopac data acquisition system (Biodex Systems, Inc, Goleta, CA) at a sampling frequency of 2000 Hz, and analyzed using AcqKnowledge software, Version 3.8.2 (Biodex Systems, Inc), which allowed for gravity correction. Verbal encouragement was given during each maximum attempt. Visual torque targets were set on the feedback monitor at slightly higher torques than those produced during the practice MVIC trial. Data for 3 maximum trials were collected, unless maximal torque for the second trial was within 5% of the first trial, in which case only 2 trials were performed. Immediately following each MVIC, pain was recorded using an 11-point verbal numerical pain rating scale from 0 (no pain) to 10 (worst pain imaginable). Torque from quadriceps MVIC was normalized to body weight for between-subject comparisons.

Range of Motion—Knee ROM was measured in the supine position, both actively and passively, using a longarm goniometer. The proximal arm of the goniometer was aligned with the greater trochanter, and the distal arm was aligned with the lateral malleolus. For active knee extension, the heel was placed on a raised block and the participant was cued to actively extend the knee. This was followed by passive overpressure for measurement of passive knee extension ROM. For active knee flexion, the participant was cued to actively flex the knee as far as possible, keeping the heel on the supporting surface. This was followed by passive overpressure for measurement of passive knee flexion ROM. There is excellent intrarater reliability for measurements of knee flexion (intraclass correlation coefficient [ICC] = 0.97–0.99) and knee extension (ICC = 0.91–0.97), as well as excellent interrater reliability for knee flexion (ICC = 0.91–0.99) and modest interrater reliability for knee extension (ICC = 0.64–0.71).³² Negative values of extension represent hyperextension.

Functional Performance Measures—Measures of functional performance included the timed up-and-go test (TUG), stair climbing test (SCT), 6-minute walk test (6MW), and single-limb stance (SLS) time. The TUG measures the time to rise from an arm chair (seat height, 46 cm), walk 3 m, turn, and return to sitting in the same chair, without physical assistance.²⁸ This test has excellent interrater and intrarater reliability, with an ICC of 0.99, as measured in a group of 60 community-dwelling older adults.²⁸ The SCT measures the time to ascend and descend a flight of stairs. The SCT measures a higher level of activity and has been shown to correlate to the TUG test.¹³ Because this test is considered more challenging than the TUG, it reduces the possibility of a ceiling effect. Patients were tested on 1 of 2 staircases during the study due to a change in facilities. Nine patients were tested on a 10-step stair case with 17.1-cm step height. Fifteen patients and all healthy adults were tested on a 12-step staircase with 17.1-cm step height. The absolute times of the 10-step data were adjusted by a factor of 1.2 to allow for comparison between groups. The 6MW measures the total distance walked in meters over 6 minutes. This test has been used extensively to measure endurance and has been validated as a measure of functional performance following knee arthroplasty.²⁶ The 6MW test has excellent test-retest reliability, with ICCs from 0.95 to 0.97, and a low coefficient of variation (10.4%).³⁶ Single-limb stance time was used to assess static postural control of the surgical side. The test duration was limited to a maximum of 30 seconds, and the longest duration of the 2 trials was recorded. This measure is used commonly for clinical assessment and has test-retest reliability of 0.78.²⁹

Statistical Methods

The sample size estimate for the healthy adults was determined utilizing published normative values for the TUG and 6MW test in elderly adults.³⁶ Utilizing 6-month outcome data from our patients after TKA, an α level of .05, and a 2-tailed null hypothesis, calculations indicated that we needed 14 healthy adults for 80% power to determine an anticipated group difference in means of 1.1 seconds on the TUG at 6 months. Only 3 healthy adults were necessary for 80% power on the 6MW to determine an anticipated difference of 122 m between group means. Seventeen healthy adults were recruited to ensure that we were powered to detect differences.

Statistical analysis of differences between groups was carried out using an independent samples unequal variance *t* test, except for sex distribution between groups, which was tested using a Pearson chi-squared statistic. SAS Version 9.2 (SAS Institute Inc, Cary, NC) was used for all statistical analyses. There were no differences in the right and left lower extremities of healthy controls ($P > .05$). After establishing that there were no differences between sides, all analyses between groups for strength and ROM were done using the right side of the healthy adults. Only patients with complete data for a given time point were used

for comparison to healthy adults. Missing data were present when patients declined to participate in a particular test at a given time point, secondary to either discomfort or a limitation in time available for testing. Comparisons of the preoperative and 1-, 3-, and 6-month postoperative data for patients were performed utilizing a 1-way repeated-measures analysis of variance (ANOVA). If a significant effect of time was found, post hoc testing was performed using linear contrasts of pairwise comparisons. Unless specified, mean values are reported with standard deviation. For all statistical tests, the α level was set to .05.

RESULTS

There were no differences between healthy adults and patients receiving TKA for age or sex ($P>.05$). BMI was greater in patients receiving TKA by an average of 3.5 kg/m^2 ($P<.05$) (TABLE 1). Average testing time postoperatively for the 1-month time point was 25.6 ± 2.7 days, 92.2 ± 7.9 days for the 3-month time point, and 186.8 ± 18.9 days for the 6-month time point.

Average verbal numerical pain rating scores for patients during quadriceps MVIC testing (0–10) were 2.3 ± 2.7 preoperatively, 2.8 ± 2.5 at 1 month, 0.4 ± 0.8 at 3 months, and 0.5 ± 1.3 at 6 months postoperatively. Pain was similar preoperatively and 1 month postoperatively ($P>.05$), then decreased at 3 months postoperatively ($P<.05$). Pain levels then remained similar between 3 and 6 months postoperatively ($P>.05$). None of the healthy adults experienced pain during quadriceps MVIC testing.

Compared to healthy adults, patients awaiting TKA had $36.1\% \pm 24.7\%$ less quadriceps torque, $19.7^\circ \pm 10.9^\circ$ less active knee flexion, and $4.6^\circ \pm 4.5^\circ$ less active knee extension (TABLE 2), and were $74.7\% \pm 42.4\%$ slower on the TUG, had $160.0\% \pm 150.2\%$ longer SCT times, walked $31.0\% \pm 16.1\%$ less distance on the 6MW, and had $29.0\% \pm 35.6\%$ shorter SLS times ($P<.05$) (TABLE 3) (FIGURES 1–2).

One month after surgery, compared to preoperative levels, patients decreased in quadriceps torque by 55.9% (95% CI: 42.7, 69.1), lost 24.0° of active knee flexion (95% CI: 19.2, 28.8), lost 2.6° of active knee extension (95% CI: 0.4, 4.8), took 49.0% longer on the TUG (95% CI: 36.2, 61.8), had 87.9% longer SCT times (95% CI: 59.5, 116.3), walked 38.5% less distance on the 6MW (95% CI: 30.1, 46.9), and decreased in SLS time by 25.2% (95% CI: 2.4, 48) ($P<.05$).

Three months after surgery, compared to their preoperative levels, patients still exhibited decreased quadriceps strength by 20.0% (95% CI: 6.8, 33.2), as well as decreased active knee flexion by 8.5° (95% CI: 3.7, 13.3) ($P<.05$). However, patients did recover to preoperative levels of active knee extension, as well as to preoperative performance levels on the TUG, SCT, 6MW, and SLS tests ($P>.05$).

Six months after surgery, compared to preoperative levels, patients recovered to preoperative levels of quadriceps strength ($P>.05$) but still exhibited deficits in active knee flexion of 6.6° (95% CI: 1.8, 11.4) ($P<.05$). There was no further recovery of active knee flexion between 3 and 6 months ($P>.05$). Furthermore, between 3 and 6 months, patients had reached a plateau in recovery of their active knee extension and performance on the TUG, SCT, 6MW, and SLS tests ($P>.05$).

Compared to healthy adults, at 6 months after surgery, patients had a mean $\pm$ SD of $40.9\% \pm 23.1\%$ less quadriceps torque, $26.3^\circ \pm 7.5^\circ$ less active knee flexion, $2.6^\circ \pm 4.6^\circ$ less active knee extension, took $62.9\% \pm 35.1\%$ longer on the TUG, had $105.0\% \pm 87.7\%$ longer SCT times, and walked $27.9\% \pm 15.8\%$ less distance on the 6MW ($P<.05$). Patients did not differ from healthy adults in SLS time ($P>.05$).

DISCUSSION

This study examined outcomes of patients 2 weeks before and 1, 3, and 6 months after TKA compared to healthy older adults. There were still significant deficits in quadriceps strength, knee ROM, stair-climbing speed, TUG time, and 6MW distance in patients 6 months after TKA compared to healthy adults. Patients were able to recover to their preoperative levels by 6 months postoperatively for all measures except knee flexion ROM. Patients in this study completed a standardized rehabilitation program following surgery. Although there are minimal data on referral patterns following TKA, Lingard et al¹⁸ reported that only 26% of patients receive outpatient physical therapy after TKA. Because physical therapy is not routinely prescribed following TKA, it is possible that the patients in the current study represented a group of individuals with higher functional levels than those previously reported in cross-sectional comparison studies.¹⁸

The outcome measures chosen for this study are common clinical measures and their associated impairments are theoretically addressable by targeted rehabilitation techniques. Although sex, age, BMI greater than 40 kg/m², comorbidities, and social support can affect outcomes following TKA, these variables are not as easily addressable in the physical therapy setting.^{9,14,37,43} Most previous studies that compared patients after TKA with healthy controls used self-reported measures of function, such as the Medical Outcomes Study Short Form-36, Western Ontario and McMaster University Osteoarthritis Index, Lower Extremity Activity Profile, Knee Society Scores, or Knee Outcome Survey activities of daily living.^{3,8,25,35,44} However, these self-report measures are based on patient perceptions of function and have not been shown to relate well to objective measures of physical performance.^{23,38–39,41} An overly optimistic perception of functional ability is likely to result from decreased pain levels after TKA.⁴¹ Therefore, the current study focused on impairment and functional outcome measures. Previous studies have also assessed quadriceps strength and functional outcomes at 1 year or more following TKA.^{2–4,31,35,43} Our data add to the literature by focusing on the preoperative and early postoperative periods to characterize recovery and by including comparisons with healthy, older adults without knee pain. Additionally, this study examined a variety of impairment and functional outcome measures that will help to evaluate the effectiveness of future studies examining different physical therapy interventions for patients after TKA.

At all time intervals of assessment, patients with TKA demonstrated decreased quadriceps strength compared to healthy adults. The greatest deficits in strength occurred 1 month after surgery. Although patients recovered to preoperative levels by 6 months after TKA, they still exhibited the same level of limitation that they did prior to surgery. This is consistent with previous studies that found decreased quadriceps strength of the surgical limb at 6 months,¹² 1 year,^{43–44} 2 years,³⁵ and 3 years² after TKA. The failure to achieve normal levels of strength is particularly important because quadriceps strength is highly correlated with functional performance.²² Based on the present findings and those of previous cohort studies, current TKA rehabilitation strategies are ineffective in restoring muscle strength to normal levels, and research efforts should be directed at designing more-effective programs to address these deficits. There is a profound loss of quadriceps strength in the first month following surgery, suggesting that this period may be an appropriate target for more aggressive strategies to mitigate the early decline in muscle function. The use of neuromuscular electrical stimulation to the quadriceps within the first month after TKA may help mitigate this force loss.²¹ More aggressive early intervention may allow for a more rapid recovery of function and also enable patients to achieve higher levels of function.

Preoperatively and at 6 months, knee ROM was limited both actively and passively when compared with healthy controls. Patients were able to recover their knee extension ROM by

6 months compared to preoperative ROM; however, knee flexion did not recover to preoperative levels by 6 months. The average active knee flexion observed in this study (113.4°) is enough to complete most activities of daily living, except squatting and getting into a bath.³³ If patients achieve higher than 125° postoperatively, they can further optimize stair-climbing performance, as well as squatting and getting into a bath, but this may not lead to higher self-report of function.¹⁹ Although ROM is often the focus of rehabilitation programs, strength appears to be a more limiting factor than ROM for the recovery of function.

Function, as assessed by the TUG, SCT, and 6MW, decreased in the first month after TKA and then recovered to preoperative levels by 3 months. However, at all time points, patients with TKAs performed more poorly on all functional tests than healthy adults. This is consistent with the results of previous studies by Walsh et al⁴³ and Boonstra et al,³ who found decreased performance in gait speed, increased TUG times, and increased stair climbing times at 1 year or more after TKA compared to healthy adults. In contrast, Yoshida et al⁴⁴ found that 1 year after TKA, patients had equivalent scores on the TUG, SCT, and 6MW compared to healthy adults. However, Yoshida et al used a small sample size ($n = 12$), matched patients and healthy adults using BMI, and excluded patients with decreased knee ROM, which decreased the generalizability of their results. In the current study, patients had substantially poorer performance 1 month after surgery on all 3 of these functional measures compared to the preoperative time point. This suggests that an increased focus on functional training in the early postoperative period may help to restore function more quickly in this group.

Patients with knee OA are at risk for falls, and 24.7% of patients will fall in the first year following TKA.⁴⁰ Previous studies on balance following TKA have focused on joint proprioception, as well as positional sway.^{10–11,42} To our knowledge, this was the first study to examine change in SLS duration over time in patients undergoing TKA. In this study, SLS duration was decreased compared to healthy adults prior to surgery and increased to the level of healthy adults by 6 months following TKA. Knowing that individuals after TKA are at increased risk for falls, demonstrate increased postural sway, and have decreased knee proprioception, it is likely that they also exhibit decreased static postural control. However, this was not seen in this experiment utilizing SLS time. This could be due to a possible ceiling effect from our 30-second cut-off time, as well as the need for a more challenging test to clinically assess these deficits.

A potential limitation of this study was the length of time patients were followed postoperatively. With a longer follow-up, some patients might have continued to recover. However, it has been shown that patients generally plateau in their recovery by 6 months and that function begins to decline by 2 years after their surgery.^{7,15,22,30} In this study, we found that patients plateau in their recovery from 3 to 6 months on most measures; nevertheless, patients could have shown some improvements beyond this point with continued rehabilitation. This study demonstrated that patients undergoing TKA do not recover to normal levels of function by 6 months. A persistent deficit in functional abilities can lead to premature disability, risk for falls, and loss of independence. Moreover, incomplete recovery of function could be an important factor in the development of contralateral knee pain and subsequent joint replacement. In a previous study of patients undergoing primary TKA, 50% had pain in their contralateral knee prior to surgery, and this prevalence increased to 69% by 12 months after surgery.⁶ The most common joint to be replaced in the body following unilateral primary knee replacement is the contralateral knee, followed by the contralateral hip.³⁴ More research is needed to determine if recovery of normal levels of function is not only possible, but also protective of future deterioration of other joints in the lower extremities.

Another potential limitation of the current study is the lack of a detailed assessment of activity level for both patients and healthy adults. It is possible that the healthy adults in the present study represent a population of older adults that are higher functioning than average but, nevertheless, still at a functional level that is worth attempting to achieve in patient recovery.

Current rehabilitation strategies in patients after TKA typically focus heavily on ROM exercises and underemphasize resistance training or functional training.²⁰ A recent study demonstrated that a more intensive rehabilitation program that incorporated resistance training and functional training can lead to better results.²⁷ However, the program was initiated 1 month after surgery and comparisons were made to a cohort of patients who received community rehabilitation. The results of the current study suggest that by 1 month, the deficits in function and strength are significant. Thus, it is important to determine whether rehabilitation programs can be effective in attenuating the large declines in the first month to enable faster and perhaps better long-term recovery.

CONCLUSIONS

This study indicates that, preoperatively, individuals with unilateral knee OA have deficits in strength, ROM, balance, and function compared to healthy adults. Following TKA, deficits in strength, ROM, and function became dramatically worse at the 1-month time point, despite initiating a standard rehabilitation protocol the day after surgery. Patients recovered to preoperative levels by 6 months after TKA in all measures except knee flexion ROM. However, they still exhibited the same level of limitation that they did prior to surgery, compared to healthy adults.

Physical therapy for patients recovering from TKA beyond the acute care setting is not routinely prescribed in the United States.¹⁸ Even when therapy is prescribed, as it was in this study, outcomes are still suboptimal. Given the substantial impairment and functional deficits present prior to knee surgery, along with the additional trauma of surgery itself, more aggressive rehabilitation may be needed to remediate these impairments and functional deficits to the levels of healthy adults. More interventional research following TKA is needed to address how this can most effectively be accomplished.

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APPENDIX

Inpatient Rehabilitation Exercise Program

Postoperative day 1

- Bedside exercises: ankle pumps, quadriceps sets, gluteal sets, hip abduction (supine), short-arc quads, straight-leg raise (if able)
- Knee range of motion (ROM): heel slides
- Bed mobility and transfer training (bed to/from chair)

Postoperative day 2

- Exercises for active ROM, active-assisted ROM, and terminal knee extension
- Strengthening exercises (eg, ankle pumps, quadriceps sets, gluteal sets, heel slides, short-arc quads, straight-leg raises, supine hip abduction), 1–3 sets of 10 repetitions for all strengthening exercises, twice per day
- Gait training with assistive device on level surfaces and functional transfer training (eg, sit-to/from-stand, toilet transfers, bed mobility)

Postoperative days 3–5 (or on discharge to rehabilitation unit)

- Progression of ROM with active assisted exercises and manual stretching, as necessary
- Progression of strengthening exercises to the patient's tolerance, 1–3 sets of 10 repetitions for all strengthening exercises, twice per day
- Progression of ambulation distance and stair training (if applicable) with the least restrictive assistive device
- Progression of activities-of-daily-living training for discharge to home

Outpatient Rehabilitation Exercise Program

Range of motion

- Exercise bike (10–15 min), to be started with forward and backward pedalling with no resistance until enough ROM for full revolution
 - Progression: lower seat height to produce a stretch with each revolution
- Active assisted ROM for knee flexion, sitting or supine, using other lower extremity to assist
- Knee extension stretch with manual pressure (in clinic) or weights (at home)
- Patellar mobilization as needed

Strength

- Quad sets, straight leg raises (without knee extension lag), hip abduction (sidelying), hamstring curls (standing), sitting knee extension, terminal knee extensions from 45° to 0°, step-ups (5- to 15-cm block), wall slides to 45° knee flexion, 1–3 sets of 10 repetitions for all strengthening exercises

- Criteria for progression: exercises are to be progressed (eg, weights, step height, etc) only when the patient can complete the exercise and maintain control through 3 sets of 10 repetitions

Pain and swelling

- Ice and compression as needed

Incision mobility

- Soft tissue mobilization until incision moves freely over subcutaneous tissue

Functional activities

- Ambulation training with assistive device, as appropriate, with emphasis on heel strike, push-off at toe-off, and normal knee joint excursions
- Emphasis on heel strike, push-off at toe-off, and normal knee joint excursions when able to walk without assistive device
- Stair ascending and descending step over step when patient has sufficient concentric/eccentric strength

Cardiovascular exercise

- 5 min of upper body ergometer until able to pedal full revolutions on exercise bicycle, then exercise bicycle
 - Progression: duration of exercise progressed up to 10–15 min as patient improves endurance; increase resistance as tolerated

Monitoring vital signs

- Blood pressure and heart rate monitored at initial evaluation and as appropriate

Reproduced from Mintken PE et al.²¹

KEY POINTS**FINDINGS**

Individuals with unilateral knee OA exhibit significant impairments and limitations compared to healthy adults. These impairments and limitations become dramatically more pronounced by 1 month following surgery, despite initiating rehabilitation within the first day after surgery. Patients recovered to preoperative levels by 6 months after TKA, but still exhibited the same level of limitation that they did prior to surgery.

IMPLICATION

Current rehabilitation methods do not effectively restore patients to the level of their healthy peers. Moreover, current rehabilitation methods do not prevent the dramatic decrease in strength and function in the first month after TKA. New rehabilitative methods need to be developed to more effectively rehabilitate this patient population.

CAUTION

Limited long-term follow-up may limit the strength of conclusions from this study.

FIGURE 1.

Comparison of timed up-and-go and stair-climbing test over time to healthy adults. Lower times on the TUG and SCT tests indicate improved function. Abbreviations: SCT, stair climbing test; TUG, timed up-and-go test.

* Different from healthy adults ($P<.05$). Error bars indicate SD.

FIGURE 2.

Comparison of 6-minute walk test distance over time to healthy adults.

* Different from healthy adults ($P<.05$). Error bars indicate SD.

TABLE 1

Patient Characteristics at the Preoperative Time Point

Variable	TKA Group (n = 24)	Healthy Adults (n = 17)	Differences (95% CI)
Age (y)	65.0 ± 9.4 [*]	66.8 ± 6.5 [*]	1.8 (−3.50, 7.15)
Sex (female, male)	12, 12	8, 9	
BMI (kg/m ²)	30.7 ± 4.1 [*]	27.2 ± 3.5 [*]	−3.5 (−5.95, −1.00) [†]

Abbreviations: BMI, body mass index; CI, confidence interval; TKA, total knee arthroplasty.

^{*} Values are mean ± SD.

[†] Different at $P < .05$

TABLE 2

Impairments in Patients Before and After TKA Compared to Healthy Adults*

Variable	Healthy Adults (n = 17)	TKA Preoperative (n = 24)	Difference From Healthy Adults at Preoperative (95% CI)	TKA at 1 mo (n = 24)	TKA at 3 mo (n = 24)	TKA at 6 mo (n = 24)	Difference From Healthy Adults at 6 mo (95% CI)
Normalized quadriceps torque (Nm/kg)	2.1 ± 0.5	1.3 ± 0.5	-0.8 (-1.1, -0.4) [†]	0.6 ± 0.3	1.1 ± 0.5	1.2 ± 0.5 [‡]	-0.9 (-1.2, -0.5) [‡]
Active knee flexion (°)	139.7 ± 4.6	120.0 ± 13.6	-19.7 (-25.8, -13.6) [†]	96.1 ± 13.0	111.5 ± 10.2	113.4 ± 8.9	-26.3 (-30.7, -22.0) [‡]
Passive knee flexion (°)	143.4 ± 5.0	123.3 ± 12.6	-20.1 (-25.9, -14.3) [†]	99.6 ± 13.1	114.8 ± 10.7	117.8 ± 8.6 [§]	-25.6 (-29.9, -21.1) [‡]
Active knee extension (°)	-0.9 ± 2.0	3.7 ± 5.6	-4.6 (-7.2, -2.0) [†]	6.4 ± 5.1	2.3 ± 4.1 [‡]	1.7 ± 5.8 [‡]	-2.6 (-5.3, -0.05) [‡]
Passive knee extension (°)	-3.7 ± 2.9	1.3 ± 5.5	-5.0 (-7.7, -2.3) [†]	3.8 ± 4.9	-0.3 ± 4.0 [‡]	-0.3 ± 6.7 [‡]	-3.4 (-6.6, -0.3) [‡]

Abbreviations: CI, confidence interval; TKA, total knee arthroplasty.

* All values are reported as mean ± SD, except for differences between groups, which are mean (95% CI).

[†] Different from healthy adults ($P < .05$).

[‡] Recovered to preoperative level ($P > .05$).

[§] n = 23.

TABLE 3
Functional Limitations of Patients Before and After TKA Compared to Healthy Adults*

Variable	Healthy Adults (n = 17)	TKA Preoperative (n = 24)	Difference from Healthy Adults at Preoperative (95% CI)	TKA at 1 mo (n = 24)	TKA at 3 mo (n = 24)	TKA at 6 mo (n = 24)	Difference from Healthy Adults at 6 mo (95% CI)
TUG (s)	5.6 ± 1.0	9.8 ± 3.2	4.2 (2.7, 5.6) [†]	14.6 ± 12.3	9.7 ± 2.7 [‡]	9.1 ± 2.4 [‡]	3.5 (2.4, 4.6) [‡]
SCT (s)	8.9 ± 1.7	23.1 ± 17.3	14.2 (6.9, 21.6) [†]	43.4 ± 24.4	18.8 ± 8.4 ^{‡§}	18.2 ± 10.1 ^{‡§}	9.3 (4.9, 13.8) [‡]
6MW (m)	600.1 ± 76.0	414.1 ± 109.1 ^{//}	-185.9 (-248.5, -123.4) [†]	255.4 ± 156.2	412.9 ± 109.7 [‡]	432.6 ± 106.7 ^{‡§}	-165.7 (-229.0, -106.0) [‡]
SLS (s)	26.6 ± 7.6	18.8 ± 10.6 ^{//}	-7.8 (-13.7, -1.9) [†]	14.1 ± 12.9 [¶]	20.9 ± 11.4 ^{‡¶}	21.6 ± 10.4 ^{‡¶}	-5.0 (-11.0, 1.0)

Abbreviations: 6MW, 6-minute walk test; CI, confidence interval; SCT, stair climbing test; SLS, single-limb stance; TKA, total knee arthroplasty; TUG, timed-up-and-go test.

* All values are reported as mean ± SD, except for differences between groups, which are mean (95% CI).

[†] Different from healthy adults ($P < .05$).

[‡] Recovered to preoperative level ($P > .05$).

[§] n = 23.

^{//} n = 22.

[¶] n = 21.