Research Report

Assessing Recovery and Establishing Prognosis Following Total Knee Arthroplasty

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Background and Purpose

Information about expected rate of change after arthroplasty is critical for making prognostic decisions related to rehabilitation. The goals of this study were: (1) to describe the pattern of change in lower-extremity functional status of patients over a 1-year period after total knee arthroplasty (TKA) and (2) to describe the effect of preoperative functional status on change over time.

Subjects

Eighty-four patients (44 female, 40 male) with osteoarthritis, mean age of 66 years (SD=9), participated.

Methods

Repeated measurements for the Lower Extremity Functional Scale (LEFS) and the Six-Minute Walk Test (6MWT) were taken over a 1-year period. Data were plotted to examine the pattern of change over time. Different models of recovery were explored using nonlinear mixed-effects modeling that accounted for preoperative status and gender.

Results

Growth curves were generated that depict the rate and amount of change in LEFS scores and 6MWT distances up to 1 year following TKA. The curves account for preoperative status and gender differences across participants.

Discussion and Conclusion

The greatest improvement occurred in the first 12 weeks after TKA. Slower improvement continued to occur from 12 weeks to 26 weeks after TKA, and little improvement occurred beyond 26 weeks after TKA. The findings can be used by physical therapists to make prognostic judgments related to the expected rate of improvement following TKA and the total amount of improvement that may be expected.

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Knee osteoarthritis (OA) is one of the most frequent causes of disability.[1] For patients with end-stage OA, which is characterized by severe pain and poor functional status, total knee arthroplasty (TKA) is recognized as a highly beneficial and cost-effective treatment.[2–4] Despite the benefits and the rise in utilization of this procedure,[5] questions remain unanswered, particularly in the area of rehabilitation services. The National Institutes of Health consensus statement on total knee replacement indicates that the use of rehabilitation services is one of the most understudied aspects of the perioperative management of this population.[6]

One issue that clinicians face when treating patients with TKA is the decision as to which outcome measures to use for assessment of functional recovery. A growing body of literature indicates that self-report measures of function provide different information than physical performance measures in people with OA or arthroplasty.[7–11] Physical performance and self-report measures may assess different aspects of physical function.[12] In the arthroplasty literature, many studies have used only self-report measures, with the Medical Outcomes Study 36-Item Short-Form Health Survey questionnaire (SF-36) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) cited most frequently.[13] Although performance-based measures appear to provide more information about actual physical ability, consensus is still needed on what activities should be included for patients with hip or knee OA.[14] Previously, Kennedy et al[15] investigated the measurement properties of the Six-Minute Walk Test (6MWT), the Timed "Up & Go" Test (TUG), a fast self-paced walk test, and a stair performance measure in subjects with arthroplasty.

The expected rate of change in functional status following surgery is of significant interest to both researchers and clinicians. Researchers can apply this information to schedule optimal outcome assessment points in a randomized trial, and clinicians can use this knowledge to benchmark progress and to make prognostic decisions related to rehabilitation needs. Studies investigating exercise-based interventions have often assessed outcome up to 1 year after arthroplasty.[16–18] Long-term follow-up is essential for some interventions specific to arthroplasty to prevent problems such as prosthetic failure. However, extended follow-up times are likely not necessary for interventions that lead to rapid changes in a patient's status over a relatively short period of time. In a study examining the first 4 months of recovery in patients following hip and knee replacement, Kennedy et al[12] found that the greatest period of postoperative change occurred in the first 9 weeks.

Numerous studies[7,12,19–26] have examined recovery patterns after TKA with differing periods of follow-up. Several authors[19,21,23] provided graphical representations of recovery for the WOMAC and SF-36 but did not include performance measures. The study by Mizner et al[24] provided recovery curves for quadriceps femoris muscle strength (force-generating capacity), knee range of motion, the TUG, a timed stair-climbing test, SF-36 summary scores, and the Knee Outcome Survey–Activities of Daily Living Scale at 1, 2, 3, and 6 month postoperative time points. Two studies[12,22] examined recovery in the first 4 months after total hip and knee arthroplasty using hierarchical linear modeling to illustrate trajectories of change. Significant differences in the patterns and predictors of recovery were found when comparing the WOMAC and the Lower Extremity Functional Scale (LEFS) with the TUG, a timed stair test, and the 6MWT. In the case of the WOMAC and LEFS, site of arthroplasty was not a predictor and preoperative levels of function were met and exceeded much earlier (1–3 weeks) than what was observed for the performance measures (6–9 weeks postoperatively). A ceiling effect around 9 to 10 weeks was observed with respect to the TUG, indicating that this measure is not useful for detecting improvement beyond 3 months. A limitation of these studies was the inability to predict when patients had reached their maximal functional levels as measured via self-report or gait performance. We found no other studies that determined the specific time point of maximal functional return following knee arthroplasty.

The purpose of this study, therefore, was to build on the existing work by profiling the change in lower-extremity functional status of participants during the first year following primary TKA using the 6MWT and the LEFS. Although the WOMAC is one of the leading outcome measures for people with arthroplasty, the LEFS has demonstrated cross-sectional and longitudinal validity equal to or better than that of the WOMAC physical function subscale.[27] Clinicians find the LEFS easy to administer in busy clinic settings, and data are published on its score interpretation to a greater extent than for the WOMAC.[28–30] Our choice to report LEFS scores also was influenced by the growing body of evidence indicating that the WOMAC lacks factorial validity.[31–34] We chose the 6MWT because it is recognized as a useful measure of functional status and exercise capacity in elderly adults.[35–38] Speed and distance abilities are both important considerations for community mobility in older adults. Older adults need to be able to walk, on average, 300 m during the performance of instrumental activities of daily living.[39]

The specific study goals of this study were: (1) to describe the pattern of change in lower-extremity functional status as measured by the LEFS and 6MWT of participants over a 1-year period after TKA and (2) to explore the effect of preoperative functional status on the pattern of change. Clinicians need prognostic evidence to educate their patients about expected time to reach their maximal recovery. Having this knowledge allows patients and their family members to judge progress over time and have realistic expectations.[40] We provide a brief illustration using a hypothetical clinical vignette to illustrate how the study results can be applied to assist clinicians in making prognostic decisions when treating patients following TKA.

Clinical Practice Vignette

Mr Smith, a 67-year-old with a longstanding history of OA of the right knee, is referred for rehabilitation 2 weeks after a right TKA. As part of the initial assessment, you administer the LEFS and the 6MWT and obtain values of 28 LEFS points and 261 m, respectively. These values are substantially lower than Mr Smith's preoperative values of 40 points for the LEFS and 507 m of the 6MWT. Mr Smith mentions that he has a vacation cruise scheduled in 8 weeks and asks what his function is likely to be at that time. He also wonders what his maximum functional status is likely to be and when he will reach this level of functioning. Questions arising from the assessment include the following: (1) How much change is required in these measures to be reasonably certain that a true change has occurred? (2) What factors should be considered in scheduling the next assessment, and when should it occur? (3) What is Mr Smith's lower-extremity functional status likely to be in 8 weeks? (4) What is Mr Smith's maximum functional status likely to be? (5) When is Mr Smith likely to reach his maximum functional level?

Method

All data were collected as part of a larger observational study conducted at a tertiary care orthopedic facility in Toronto, Canada, from November 2001 to February 2004. Designated a Centre of Excellence for hip and knee replacement, the facility is one of the largest-volume arthroplasty sites in the country. Patients were recruited prospectively either at point of consultation with the orthopedic surgeon or at the preadmission visit prior to surgery. Only those patients with follow-up for the first year postoperatively were eligible for this study. During the larger study, there were periods of interruption of recruitment and tracking, such as with the outbreak of severe acute respiratory syndrome in Toronto from April to June 2003. At the height of the outbreak, thousands of people were quarantined, and there were significant restrictions on patient-related activities in hospitals for several months. None of the patients took part in other interventional studies. However, the current sample overlaps samples described in earlier publications, which used data from the same observational study.[10,12,15,22]

Participant eligibility criteria included the following: diagnosis of OA, scheduled for primary TKA; sufficient language skills to communicate in written and spoken English; and absence of neurological, cardiac, or psychiatric disorders or other medical conditions that would significantly compromise physical function. Ethics approval for the study was received from the institution's research ethics review board, and all participating patients provided written informed consent. Patients received standardized inpatient treatment following a primary total knee care pathway. All patients were permitted to be full weight bearing and participated in a progressive program of range of motion, strengthening exercises, proprioceptive exercises, and functional training. At the time of this study, the majority of the patients were transferred from the acute care floor on the fourth or fifth postoperative day to the on-site short-term rehabilitation unit to continue the aforementioned program for a maximum length of stay of 7 days. All patients were discharged with a home exercise program, and some patients received additional physical therapy treatment in the community.

Subjects

Preoperatively, 88 patients consented to participate in the study; however, only 84 patients contributed LEFS and 6MWT data following arthroplasty. Table 1 provides a summary of the participants' characteristics. Female participants had a greater body mass index ($t_{82}=-2.05$, $P_2=.042$); male participants had higher LEFS scores ($t_{82}=3.02$, $P_2=.003$) and walked greater distances in 6 minutes ($t_{82}=5.28$, $P_2<.001$).

Design

We applied a prospective study design with repeated measurements over a period of approximately 1 year following arthroplasty. To provide an accurate model of change over time, participants' follow-up measurements were not standardized to be at the same time points during the first 4 postoperative months, the period of greatest change.[7,12] When measurements take place at the same spaced time points, the shape of the curve is dictated by the choice of time points. Three assessments were planned during this time frame, and subsequently participants were assessed at points corresponding to the next surgeon follow-up appointments, which typically might fall at 6 or 9 months and then 12 months postoperatively. As noted earlier, this scheduling of assessments facilitated obtaining good estimates of the rate of change as well as the limit values or point of maximal return.

Measures

Previous work[7,8,10] has suggested that self-report and performance-based measures capture different, but related, aspects of lower-extremity functional status. Accordingly, we chose 2 measures of lower-extremity functional status—one a self-report measure and the other a performance-based measure.

LEFS. Conceived by Binkley and colleagues,[28] the LEFS is a 20-item self-report measure of lower-extremity functional status. It includes items that assess the disablement concepts of functional limitation (activity limitation) and disability (participation restriction).[41,42] Each item is scored on a 5-point scale (0–4). Accordingly, total LEFS scores can vary from 0 to 80 points, with higher scores being associated with greater levels of functional status. Considerable support for this measure's reliability, validity, and ability to detect change exists both for general lower-extremity conditions[43–45] and specific to patients with OA progressing to knee or hip arthroplasty.[27,29,46] The test-retest reliability estimate (intraclass correlation coefficient, type 2,1) for the LEFS derived from a sample of patients following arthroplasty was .85, the standard error of measurement (SEM) was 3.7 LEFS points, and the minimal detectable change at the 90% confidence level (MDC_{90}) was estimated to be 9 LEFS points.[28] In patients undergoing knee or hip arthroplasty, the LEFS has been shown to detect change as well as or better than the WOMAC physical function subscale.[27,46]

6MWT. Originally conceived as an outcome measure for people with respiratory problems, the standardized 6MWT has become a popular measure of lower-extremity functional limitation for patients with OA of the lower extremity and those progressing to arthroplasty.[7,8,15,47,48] Participants were instructed to cover as much distance as possible during the 6-minute time frame. The test was conducted on a measured 46-m uncarpeted rectangular indoor circuit. The course was marked off in meters, and the distance traveled by each participant was measured to the nearest meter. Standardized encouragement—"You are doing well, keep up the good work"—was provided at 60-second intervals.[49] The outcome was the distance walked in 6 minutes. A previous investigation with a similar group of subjects demonstrated the reliability and validity of data for this measure (intraclass correlation coefficient=.94 for test-retest reliability, SEM=26.3 m, and MDC_{90}=61.34 m).[15]

Table 1.
Preoperative Descriptive Statistics Expressed as Quartile Values (25th, 50th, 75th)

Measure	Female Participants (n=44)	Male Participants (n=40)
Age (y)	60, 64, 71	61, 67, 74
Body mass index (kg/m^2)	29, 32, 34	27, 29, 32
Prearthroplasty Lower Extremity Functional Scale score	21, 27, 38	26, 38, 45
Prearthroplasty Six-Minute Walk Test distance (m)	312, 353, 416	397, 501, 552

Data Analysis

Before beginning the modeling, we plotted the data to gain an impression of the pattern of change over time. Although one of the benefits of using mixed-effects modeling is that it does not require the number and timing of observations to be the same across all participants, missing data are still important. Bias will result if the cause of the missing data points is related to the outcome that would have been observed. For example, it would not be a problem if a patient following arthroplasty missed an appointment due to a change in his or her schedule; however, it would be a problem if the patient missed the appointment because of poor functioning due to an increase in pain. Therefore, we also examined the pattern of missing data across the time points.

Based on the plotted data, we developed and tested several nonlinear models of change that related the dependent variable of functional status—either LEFS scores or 6MWT distances—to the independent variable of number of weeks after arthroplasty.[50] The equation for our nonlinear change model (model 1) was:

$$\text{Functional status (LEFS or 6MWT)} = \text{limit} + (\text{y0} - \text{limit}) \times e(-e(\text{lnchange rate}) \times \text{weeks}),$$

where the *functional status* variable is the LEFS or 6MWT value, *e* is the base of natural logarithms (approximately 2.71828), *weeks* is the number of weeks after arthroplasty; *y0* is the parameter that represents the y-intercept value; *limit* is the parameter that represents the asymptote or maximum LEFS or 6MWT value, and *lnchange rate* is the natural log of the change rate ("change rate" refers to the rate of improvement at which patients approach their maximum functional status). We esti-

Table 2.
Summary of Nonlinear Analysis Without Covariates

	Female Participants (n=44)	Male Participants (n=40)
Lower Extremity Functional Scale analysis		
Parameters of average change[a]		
Limit (SE)	54.0 (2.3)	60.4 (2.3)
Y-intercept (SE)	10.4 (2.6)	19.0 (2.7)
Change rate (SE)	−1.7 (0.1)	−1.8 (0.1)
Standard deviation of individual differences from average		
Limit	12.1	11.6
Y-intercept	7.9	10.2
Within-patient variation	7.6	6.7
6-Minute Walk Test analysis		
Parameters of average change		
Limit (SE)	467.3 (15.4)	577.7 (18.2)
Y-intercept (SE)	154.7 (22.2)	185.7 (22.9)
Change rate (SE)	−2.0 (0.1)	−1.7 (0.1)
Standard deviation of individual differences from average		
Limit	84.7	94.6
Y-intercept	84.5	68.7
Within-patient variation	40.7	48.8

[a] Parameters of average change=fixed effects. Some parameters (ie, change rate) have only fixed effects, indicating that there are no significant individual differences. SE=standard error.

mated the parameters using the nonlinear mixed-effects modeling package in S-Plus.[50] A mixed-effects approach indicates that some parameters have both fixed and random effects. The fixed effects describe the average change in the population (in this case, the sample of participants who underwent TKA), and the random effects describe the individual differences among participants. We explored different models, and our final model specified the limit, y-intercept, and change rate parameters as fixed effects and the limit and y-intercept as random effects. Next, we examined the effect of including preoperative LEFS scores and 6MWT distances on the limit, y-intercept, and change rate coefficients. Finally, because previous work has shown that functional status levels differ by gender,[22,51] we created separate models for female and male participants.

Results

All participants completed baseline preoperative assessments and had a minimum of 2 visits postoperatively. To summarize, 31 participants were assessed 3 times, 18 were assessed 4 times, 9 were assessed 5 times, and 2 had 6 visits, with the rest of the sample having 2 visits. Supplemental Figures 1 and 2 (available online only at www.ptjournal.org) provide spaghetti plots showing the data points and change profiles for each participant.

All knee prostheses were posterior stabilized, with the majority cemented. At our institution, the perioperative management and rehabilitation protocols are not influenced by prosthesis selection or method of fixation. Postoperatively, one participant developed a documented deep vein thrombosis. None of the participants required revision surgery within the 1-year follow-up period.

Sixty-seven of the 84 participants composing the study sample were assessed within 17 days of arthroplasty. Of these 67 participants, 66 completed the LEFS and 44 performed the 6MWT during this 17-day period. The mean (±SD) preoperative LEFS score for those participants who contributed LEFS data within 17 days of arthroplasty was 32.3 points (SD=12.1) compared with 33.1 points (SD=14.4) for those participants who were not assessed within this period (t_{82}=0.22, P_2=.83). Similarly, the mean preoperative distance for those participants who contributed 6MWT data within 17 days of arthroplasty was 428.4 m (SD=114.8) compared with 393.4 m (SD=105.8) for participants who did not contribute 6MWT data within this period (t_{82}=1.46, P_2=.15). Finally, the mean LEFS score assessed within 17 days of arthroplasty was 26.0 points (SD=10.7) for the participants who contributed 6MWT data during this period compared with 16.7 points (SD=10.2) for the participants who were assessed during this interval but not able to contribute 6MWT data (t_{64}=3.45, P_2=.001). Post-arthroplasty assessments following the 3-week mark yielded approximately equal representation of LEFS and 6MWT data points.

Table 2 reports the fixed-effects parameter values and the variation in random-effects parameter values for the LEFS and 6MWT obtained from model 1. Also reported in Table 2 are the standard deviations of individual differences from the estimated average parameter values. For example, the standard deviation of individual differences from the average LEFS limit value for the female participants was 12.1. Accordingly, 68% of the female participants displayed limit values from 42 to 66 LEFS points. The curves shown in Figure 1 were generated by substituting the parameter estimates reported in Table 2 into model 1. This figure shows that most of the change occurred in the first 16 weeks after arthroplasty.

Our exploration of the effect preoperative functional status scores had on limit values, y-intercept, and change rate coefficients revealed that limit values only were significantly affected. This finding indicates that preoperative levels of function help to predict the maximal functional status that patients attain postoperatively. Better preoperative scores will be associated with patients attaining higher maximum postoperative levels of function. Accordingly, our revised model (model 2) was as follows:

$$\begin{aligned}\text{Functional status (LEFS or 6MWT)} \\ &= (\text{limit} + \beta \times \text{preoperative function}) \\ &\quad + (\text{y0} - \text{limit} + \beta \\ &\quad \times \text{preoperative function}) \\ &\quad \times e(-e(\text{lnchange rate}) \times \text{weeks}),\end{aligned}$$

where β is the regression coefficient associated with preoperative functional status level. Gender- and measure-specific coefficients are reported in Table 3. Figures 2 and 3 display the change curves for the LEFS and 6MWT adjusted for preoperative scores. The 3 curves presented in each figure depict the gender- and measure-specific change curves based on the preoperative quartile values reported in Table 1. For example, the top curve in Figure 2A represents LEFS scores for male participants with a preoperative LEFS score of 45 points (ie, third quartile value reported in Tab. 1). The 16-week value of 61 points on this curve was obtained by substituting the coefficient values reported in Table 3 into model 2 and applying a preoperative value of 45 points. Again, these figures show that most of the change occurred within the first 16 weeks after arthroplasty.

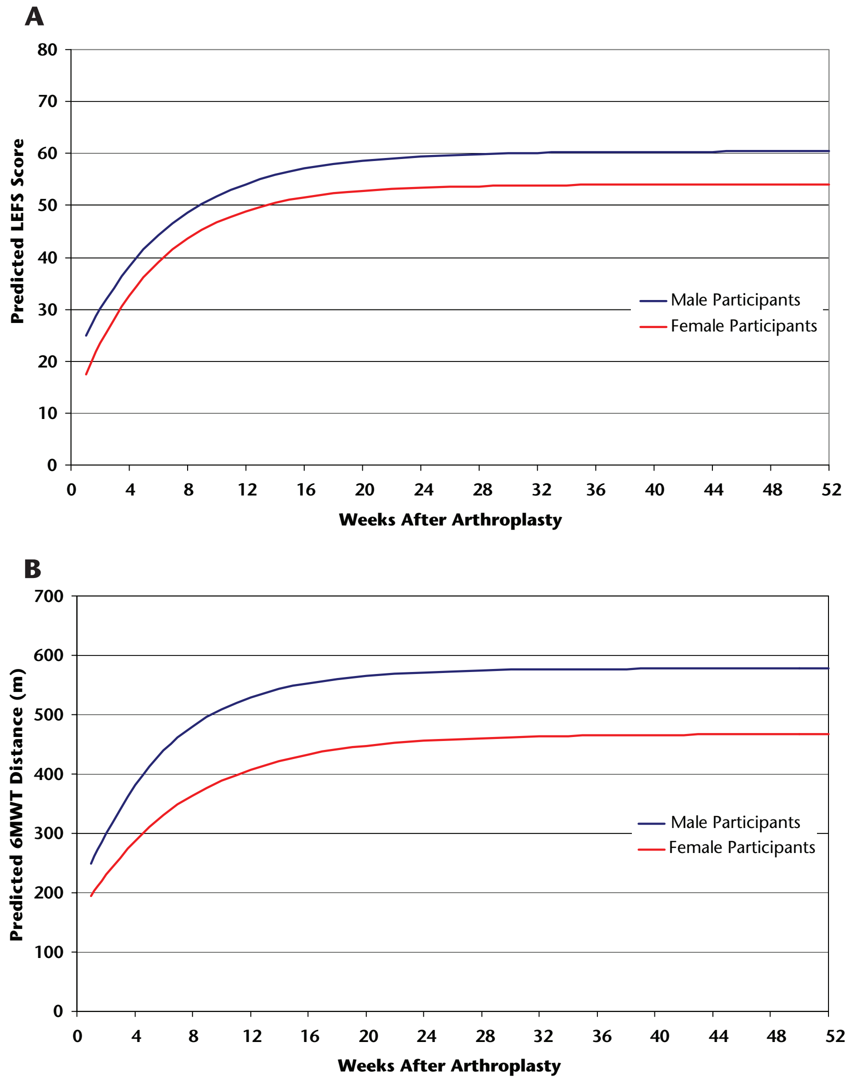

Figure 1.
(A) Change in Lower Extremity Functional Scale (LEFS) scores over time. (B) Change in 6-Minute Walk Test (6MWT) distances over time.

Discussion

Our goal was to describe the change in lower-extremity functional status over a 1-year period for patients who underwent TKA and received standardized inpatient physical therapy care for 1 to 2 weeks (acute and subacute short-term rehabilitation). The subsequent discussion will first provide a synthesis of our findings and then illustrate applications of this information by referring to the vignette introduced early in this article.

To our knowledge, this is the first study to sample patients at different time points over a 1-year period after TKA and to apply a nonlinear mixed-

Table 3.
Summary of Nonlinear Analysis With Preoperative Score as a Covariate

	Female Participants (n=44)	Male Participants (n=40)
Lower Extremity Functional Scale analysis		
Parameters of average change		
Limit (SE)[a]	38.1 (5.3)	42.2 (5.6)
Preoperative (β) (SE)	0.50 (0.1)	0.50 (0.1)
Y-intercept (SE)	10.3 (2.6)	19.0 (2.7)
Change rate (SE)	−1.7 (0.1)	−1.8 (0.1)
Standard deviation of individual differences from average		
Limit	10.4	9.8
Y-intercept	7.5	10.0
Within-patient variation	7.7	6.7
6-Minute Walk Test analysis		
Parameters of average change		
Limit (SE)	277.2 (55.0)	326.2 (56.9)
Preoperative (β) (SE)	0.6 (0.1)	0.5 (0.1)
Y-intercept (SE)	154.7 (22.2)	188.6 (22.8)
Change rate (SE)	−2.0 (0.1)	−1.7 (0.1)
Standard deviation of individual differences from average		
Limit	64.0	71.2
Y-intercept	83.7	71.5
Within-patient variation	41.1	48.5

[a] SE=standard error.

effects analysis to model change. Previously, members of our team have applied hierarchical linear modeling and a second-degree polynomial to model LEFS scores and 6MWT distances over the first 16 weeks after arthroplasty.[12,22,30] Participants' LEFS scores and 6MWT distances increased rapidly over this period, and a second-degree polynomial fit the data well within this interval. However, a second-degree polynomial specifies a parabola that clearly does not represent the change pattern of LEFS scores or 6MWT distances over a 1-year period, and it is for this reason that we applied a nonlinear mixed-effects analysis. The current study's results over the initial 16 weeks after TKA compare favorably with those modeled using a second-degree polynomial in patients who similarly received a mixed-effects model of physical therapy intervention with unknown parameters including outpatient treatment and natural recovery.[22,30]

Our study also explored the effect of preoperative LEFS scores and 6-MWT distances as potential predictors of y-intercept, change rate, and limit values. Maximal LEFS scores and 6MWT distances were influenced only by their respective preoperative values. Accordingly, it is important that clinicians take the preoperative value into account when making a prognosis concerning a patient's final level of lower-extremity functional status.

As illustrated in the section on responses to the clinical practice vignette, we believe that graphical representations of recovery can be very useful in assisting clinicians to benchmark recovery. The graphs can be used to compare measured scores obtained on patients with the predicted scores to monitor progress and guide treatment decisions. Normative scores for the measures in similar populations also are available to enable further benchmarking.[52,53] The recovery curves in our study also facilitate determination of the critical time points for measuring change. For example, if researchers were interested in determining the effect of interventions on improving the rate of recovery and the maximum level of function attained, they could apply these graphs to assist in their decision making. More studies are needed to determine the effect of various postoperative physical therapy interventions on recovery. Frequently cited assessment points are 3, 6, and 12 months after arthroplasty[13]; however, based on the information from the current study, to assess the effect of interventions, it would be important to assess patients more frequently in the first 3 months. In addition, because most of the recovery has occurred by 6 months, researchers might decide to not assess individuals beyond this point to avoid unnecessary costs.

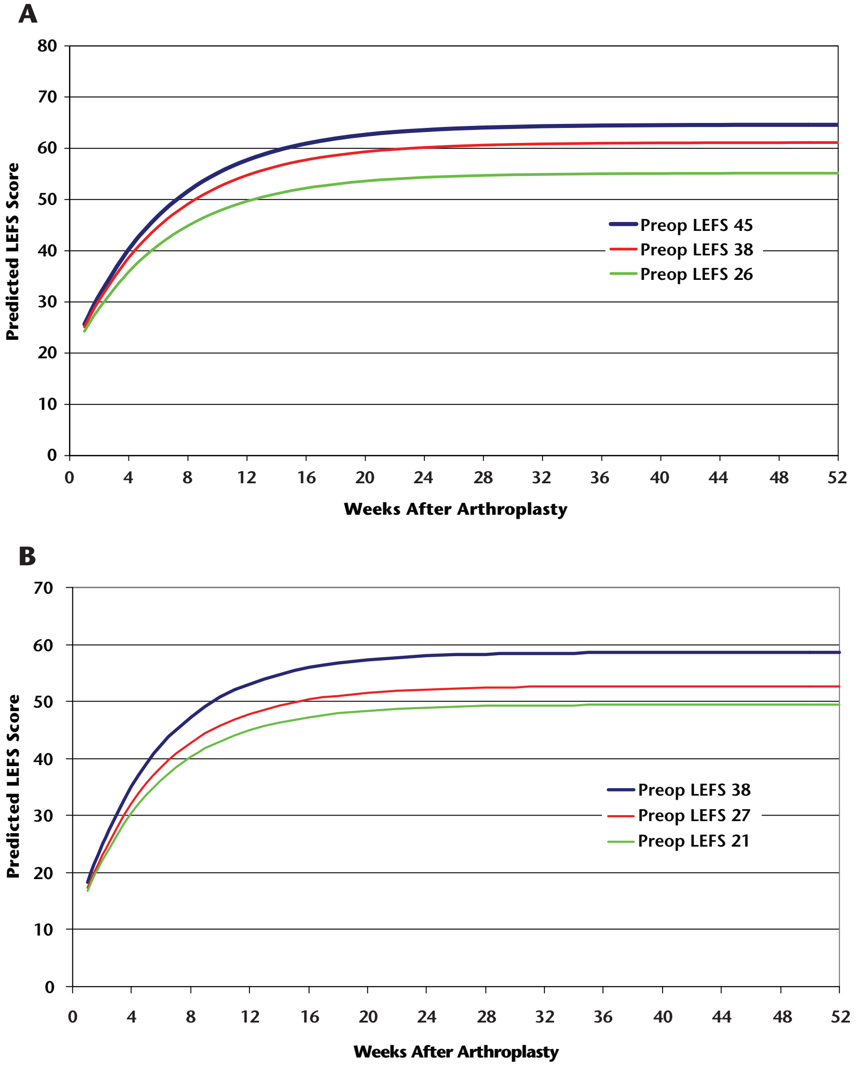

Figure 2.
(A) Change in Lower Extremity Functional Scale (LEFS) scores for male participants, adjusted for preoperative (preop) LEFS scores. (B) Change in LEFS scores for female participants, adjusted for preoperative LEFS scores.

Responses to the Clinical Practice Vignette

How confident can the clinician be in the measured values of 28 points on the LEFS and 261 m on the 6MWT, and how much change is required in these measures to be reasonably certain that a true change has occurred? To answer these questions, the results from 2 other studies that examined the reliability of data for the LEFS[29] and 6MWT,[15] whose estimates are reported in the Method section, are used. For example, the 90% confidence level (ie, 1 SEM × 1.65) for an estimate of the "true score" is ±6.1 points for the LEFS and 43.4 m for the 6MWT. We can say with 90% confidence that Mr Smith's true LEFS score is likely to fall between 21.9 and 34.1 points and that his true 6MWT distance is likely to lie between 222.9 and 304.4 m. To identify the minimal detectable change (MDC), the confidence values reported are multiplied by the square root of 2. For example, 90% of patients who are truly stable will display random fluctuations, when assessed on multiple occasions, of less than 9 points on the LEFS and 61.3 m on the 6MWT. Accordingly, a change of 9 points or more on the LEFS and of 61.3 m or more on the 6MWT is interpreted as evidence of a true change. Estimates obtained from this approach often are referred to as MDC with the confidence value subscripted (eg, MDC_{90}).[54]

What factors should the clinician consider in scheduling the next assessment, and when should it occur? Clearly, many factors, including feasibility, influence the choice of reassessment interval. Two factors specific to the context of this article are MDC and the interval over which a typical patient is likely to achieve a change equal to the MDC. Mr Smith's 2-week postoperative LEFS value was 28, and the MDC_{90} is a change of 9 points. This information is coupled with the curve for patients with a preoperative LEFS value of 38 (ie, the curve closest to Mr Smith's value). Referring to the middle curve presented in Figure 2A, it appears that a change of 9 LEFS points occurs between 2 and 4 weeks postoperatively. Accordingly, the interval between assessments for this specific instance is approximately 2 weeks. Applying the same approach to 6MWT distance, it appears that a minimum interval of 1 week is required for an expected change of 61.3 m.

What is Mr Smith's lower-extremity functional status likely to be in 8 weeks? To answer this question, the clinician can inspect the predicted functional status values for 10 weeks after TKA (the first assessment occurred at the 2-week mark). For a person with Mr Smith's preoperative values, the expected LEFS and 6MWT scores are approximately 52 points and 520 m, respec-

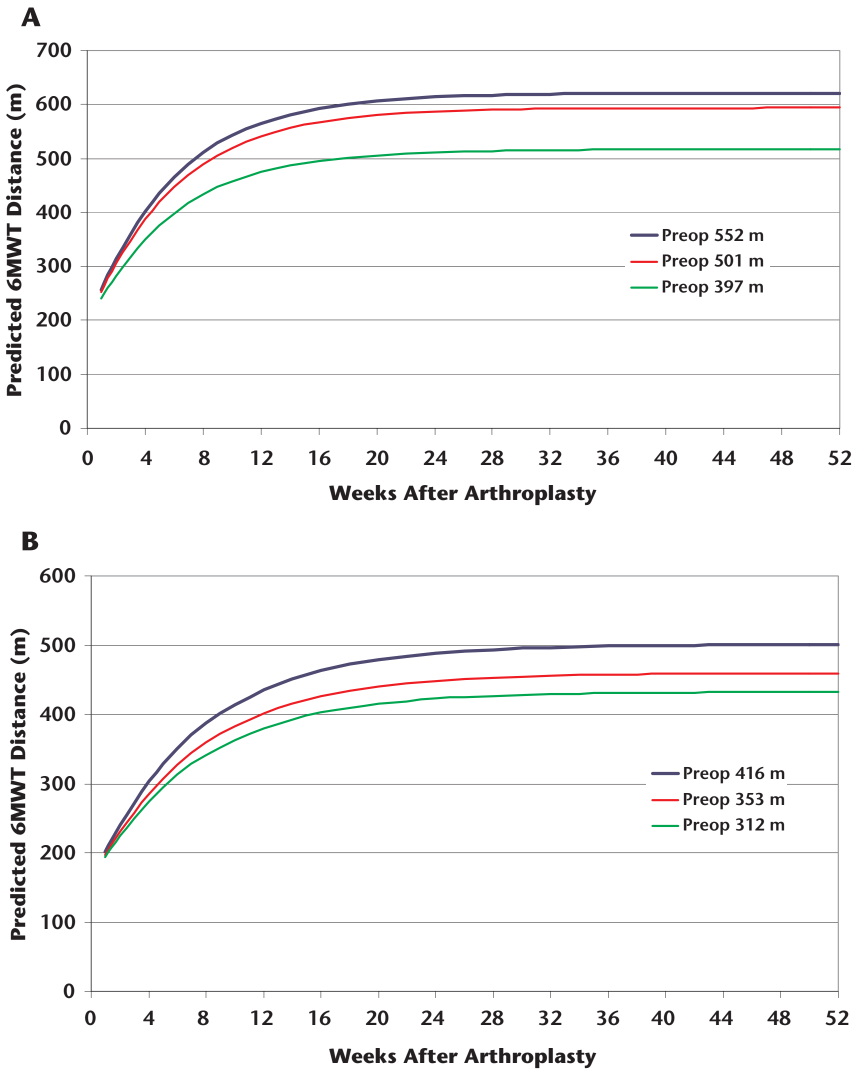

Figure 3.
(A) Change in 6-Minute Walk Test (6MWT) distances for male participants, adjusted for preoperative (preop) 6MWT distances. (B) Change in 6MWT distances for female participants, adjusted for preoperative (preop) 6MWT distances.

tively. Although the meaning of 520 m is straightforward, the interpretation of an LEFS score of 52 points is not intuitively obvious, and the clinician will need to translate this number into a narrative. Based on information provided in a previous article,[30] a person with an LEFS score of approximately 52 points will have: (1) "moderate difficulty" with heavy activities around the house, recreational activities, walking a mile, or standing for 1 hour; (2) "a little bit of difficulty" with going up or down 10 stairs or lifting an object such as a bag of groceries from the floor; and (3) "no difficulty" sitting for 1 hour, putting on shoes or socks, or walking short distances. These data will likely assist the clinician in advising Mr Smith on what he can expect regarding his mobility, which will likely assist Mr Smith in deciding whether he should consider rescheduling his trip.

What is Mr Smith's maximum functional status level likely to be? Recalling that a patient's preoperative level of function is a determinant of his or her postoperative maximal function level, Figures 2A and 3A are referenced to answer this question. Because Mr Smith had a preoperative score of 40 points on the LEFS, the middle curve is selected, and this would lead to a prediction that Mr Smith would have a terminal LEFS score of just over 60 points. In terms of the 6MWT, using a similar approach, the maximal distance that Mr Smith would be able to cover would be around 600 m.

When is Mr Smith likely to reach his maximum functional level? In both the case of the LEFS and 6MWT, Mr Smith would reach his maximum functional level sometime between 6 and 7 months.

Study Limitations

One limitation is that all participants in the change study were able to complete the LEFS and 6MWT preoperatively. Accordingly, the generalizability of our findings are restricted to patients who are able to complete these tests preoperatively and who have preoperative characteristics similar to those reported in Table 1. A second limitation is that fewer participants provided 6MWT data than LEFS data within a few weeks of arthroplasty. Our analysis showed that participants who were assessed within 17 days of arthroplasty and who did not contribute 6MWT data during this period had significantly lower LEFS scores at this time point. A consequence of this missing value pattern is that the predicted 6MWT distances over the first several weeks after arthroplasty are not applicable to the entire sample, but rather are restricted to those participants who were capable of performing the 6MWT within this time frame. This could have resulted in overestimation of the predicted scores for the 6MWT during this time frame.

Although mixed-effects modeling will stabilize the estimates of patients who have limited data by anchoring them to the group average, it should be noted that 66% of the participants in this study were assessed only 2 or 3 times. More than 50% of the participants were not assessed for both LEFS and 6MWT near to or at the end of the study termination. Finally, it was not possible to describe with accuracy the patients who were potentially eligible for the study due to study interruptions such as the outbreak of severe acute respiratory syndrome.

Conclusion

Our findings demonstrated that the greatest improvement for the LEFS and 6MWT occurred in the first 12 weeks after TKA. Improvement continued to occur from 12 to 26 weeks after TKA, although at a slower rater, and little improvement occurred beyond 26 weeks after TKA. The maximum scores obtained on the LEFS and 6MWT were influenced by their respective preoperative scores. Clinicians can use the recovery curves to make prognoses concerning the rate of improvement in functional status after TKA and the expected time-specific and maximal functional status scores. This information is critical to identifying rehabilitation needs and assisting patients to set realistic goals and plan their lives accordingly.

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