Prognostic Factors for Functional Outcome of Total Knee Replacement: A Prospective Study

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Background. The objective was to investigate whether baseline physical functioning, medical, psychosocial, or demographic variables predict functional outcome in patients undergoing total knee replacement.

Methods. A prospective cohort study was performed between December 1991 and August 1993. Consecutive, unilateral tricompartmental total knee replacement patients aged ≥55 yr with osteoarthritis, who met criteria, were enrolled and evaluated one month before and 3 months after total knee replacement. The primary outcome measure was the Medical Outcome Study 36 Item Short Form Health Survey (known as the SF-36) Physical Functioning Scale score. The outcome evaluator was not involved in patient care.

Results. A hierarchical multiple regression analysis was performed to calculate the contribution of baseline variables to TKR outcome. Of the 27% of outcome variance explained by the model, demographic variables accounted for 4%, psychosocial variables (motivation, role functioning-emotional, and social functioning) for 19% (p = .013), medical variables (previous reconstruction, comorbidity, body mass index, bodily pain) for 2%, and baseline physical function for 2%.

Conclusions. Psychosocial variables are significantly related to total knee replacement functional outcome. Assessment of baseline psychological and social functioning may identify a subset of patients at risk for worse outcome. Specific interventions for these patients should be developed and evaluated as components of patient management prior to and after the procedure.

AN average of 95,000 total knee replacements (TKR) were performed each year in the United States between 1985 and 1989 (1). This figure rose to 129,000 in 1990, 160,000 in 1991, and 167,000 in 1992 (2). A 15.5% annual TKR rate increase has been calculated for the Medicare population (1). Despite this dramatic increase in procedures, little is known about prognostic factors predicting functional status outcome after TKR. Knowledge of these factors would allow specific intervention to optimize outcomes.

In the published literature, rarely have multivariate analytic techniques been applied to data prospectively collected for the purpose of identifying determinants of short- or long-term TKR outcome. Callahan and colleagues (3) conducted a meta-analysis of studies reporting patient outcomes following TKR, and concluded that anatomic classification of the prosthesis (posterior cruciate ligament sparing vs sacrificing or substituting), percent of enrolled patients with OA, publication year, and number of enrolled patients explained 27% of the variance in reported mean postoperative global rating scale scores. Such global scores, frequently used to describe TKR outcome in the published literature, do not necessarily reflect self-reported functional status, a better marker of patient satisfaction (4). Many potentially important factors (such as preoperative functional status, strength, comorbidity, weight, previous reconstructive surgery, motivation, psychosocial status, education, social support) could not be addressed in the meta-analysis because of inadequate data or study design limitations.

Recently, Kwoh and colleagues (5) reported that gender, type of arthritis, and comorbidity predicted short-term outcomes (e.g., the time to achieve defined physical therapy goals). Wolfe (6) found that gender and complications predicted length of stay and that age was related to hospital complications. In these reports, neither perceived physical functioning nor other aspects of health-related quality of life are described. Katz (7) retrospectively analyzed the effect of gender on functional TKR outcome, and found that women underwent TKR at a more disabled stage, had a larger improvement, and a similar complication rate.

In the following prospective cohort study, the relationship between each of several potential prognostic factors, including baseline physical, psychological, and social functioning,
gender, and other medical and demographic variables, and self-assessed TKR functional outcome assessed 3 months after surgery, was evaluated.

METHODS

Patient selection and study sample characteristics. — Consecutive osteoarthritis (OA) patients between 12/91 and 8/93, aged 55 or more, scheduled to undergo unilateral TKR by one surgeon (SDS) were prospectively enrolled. Because in these patients we also planned to assess whether the aging-related, variable decline in growth hormone was associated with TKR outcome, patients were excluded for the presence of conditions that might affect production of insulin-like growth factor 1 as a measure of integrated 24-hour serum growth hormone concentration, i.e., malnutrition, serious cardiac, renal, hepatic, neoplastic, or psychiatric disease, diabetes, abnormal thyroid, or adrenal state. Only 2 patients were excluded on this basis (1 with diabetes, 1 with chronic renal insufficiency). Inflammatory arthritis or body mass index (BMI) ≥ 51 also resulted in exclusion. During the study period, 114 patients (83 with OA) underwent unilateral TKR and 37 (26 with OA) bilateral TKR. Out of 83 with OA who underwent unilateral TKR, 66 met criteria for this study. Among the 17 who did not meet criteria, 10 had BMI ≥ 51, 4 were too young, one could not understand study activities, one had diabetes, and one had chronic renal insufficiency. Of the 66 who were eligible, 14 refused and 52 were enrolled. Forty-seven subjects, described in Table 1, completed the study and provided the data analyzed below. Of the remaining 5, one was dropped after a femoral neck fracture 35 days after TKR, and 4 refused to return for the second evaluation. Sample characteristics of these 5 did not differ from the group as a whole. Seven had complications (1 superficial infection, 2 manipulations, 1 blood loss, 1 dislocation, 1 gastrointestinal bleed, and 1 seizure).

Clinical care. — All subjects remained under the same surgeon’s care. Indications for TKR were pain and functional decline in spite of widely used modalities (nonsteroidal antiinflammatories, acetaminophen or propyphene napsylate/acetaminophen, strengthening and aerobic exercise) in the setting of advanced OA. The prosthesis used in all cases was the Continuum Knee System (Techmedica, Camarillo, CA). After TKR, patients received morphine by self-regulated pump for 36 hours, and subsequently, nonacetylated salicylates, supplemented by hydrocodone as needed. Inpatient therapy consisted of progressive passive, active, and resistance exercises, a stationary cycle, and gait training, increasing weight bearing as tolerated. Based on inability to achieve predetermined functional goals and the need for longer nursing assistance with self-care, 27 of the 47 subjects went to an inpatient rehabilitation unit. After discharge to home, each patient was seen 3 times per week by the physical therapist.

Study protocol. — Each patient was seen twice in the Clinical Research Center (CRC), one month before (“baseline visit”) and 3 months after TKR, by one rheumatologist (LS) and nurse. Evaluators used standardized forms and were not involved in care.

At the baseline visit, age, gender, insurance, income, education (years of schooling), and history of previous reconstructive surgery on the affected joint were recorded. A score (0–4) was assigned for social support with 1 point each given for: spouse; other relatives at home; relatives outside of home in the same town; friends. Medical comorbidity was scored using the Cumulative Illness Rating Scale (CIRS) (8), a validated method of summing organ-specific morbidity for a global score. At each visit, the following measurements were made:

- Physical, psychological and social function, and pain were assessed via the Physical Functioning, Bodily Pain, Mental Health, Role Functioning-emotional, and Social Functioning scales of the Medical Outcome Study 36-item short form Health Survey (SF36) (9, 10), a standardized and validated generic instrument widely used in the total joint replacement setting. The SF36 Physical Functioning scale, our primary TKR outcome measure, assesses health-related limitation of: bathing and dressing (1 item); walking (3 items); climbing stairs (2 items); bending, kneeling, or stooping (1 item); lifting or carrying groceries (1 item); moderate activities (1 item); and vigorous activities (1 item). Items are scored 1, 2, or 3 for “limited a lot,” “limited a little,” or “not limited,” respectively. For all SF36 scales, the summed raw score is transformed to a 0–100 scale with a higher score indicating a better state.

- Isometric quadriceps and hamstring strength were measured by one of two physical therapists in foot-pounds using a single Cybex isokinetic dynamometer, at mid-range, to eliminate the contribution of achievable range of motion, which was expected to vary between subjects, to the amount of force that could be generated. The mean of 3 measurements was recorded.

- Complications (cardiac, respiratory, or neurologic event, gastrointestinal bleed, persistent superficial or any deep infection of the surgical knee, blood loss requiring a transfusion, dislocation, requirement for manipulation, surgical or anesthetic complications) were recorded at the end of the TKR hospital stay and at the 3-month evaluation. The Self-Motivation Inventory (SMI) (11), a valid, reliable, and

<table>
<thead>
<tr>
<th>Table 1. Characteristics of Study Sample (N = 47)</th>
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<tbody>
<tr>
<td>Female gender (%)</td>
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<tr>
<td>Private insurance (%)</td>
</tr>
<tr>
<td>Previous reconstruction (%)</td>
</tr>
</tbody>
</table>

| Age | Mean 68.9 | Standard Deviation 7.0 | Range 55–83 |
| Body mass index | 30.8 | 6.0 | 21.1–50.5 |
| Comorbidity* | 1.5 | 1.2 | 0–4 |
| Income (x 1000) | 45.1 | 56.7 | 200–300 |
| Education (years) | 13.5 | 2.9 | 3–19 |
| Social support* | 2.4 | .8 | 1–4 |
| Motivation* | 156.6 | 23.6 | 94–200 |

*Refer to Methods for explanation of how these variables were measured.
stable measure of motivation (i.e., "dropout proneness," or the behavioral tendency to comply with a therapeutic exercise program), was completed during the hospital stay.

Calculations and statistical analysis. — The mean, standard deviation, and range were calculated for the demographic variables. Baseline and 3-month post-op mean were compared for strength and each of the SF36 scales, using a paired t-test. Below, unless otherwise noted, strength refers to the sum of hamstring and quadriceps strength.

To assess the role of gender in the timing of TKR, mean baseline Physical Functioning was calculated for men and for women. To compare TKR outcome by gender, effect size (12) (mean change in Physical Functioning scale score divided by the standard deviation of the change in score) was calculated for each gender.

To identify predictors of TKR outcome, a hierarchical regression analysis was performed in 4 steps with 3-month post-op Physical Functioning as the dependent variable. Variable sets were entered in the following order: (a) demographic (age, education, gender, and social support); (b) psychosocial (motivation, Role Functioning-emotional, and Social Functioning); (c) medical (previous reconstruction, comorbidity, BMI, Bodily Pain); and (d) baseline physical function (quadriceps strength and baseline Physical Functioning).

SF36 Mental Health score was initially included in the hierarchical analysis, but collinearity (i.e., its variance accounted for by other variables in the equation) resulted in its exclusion from the final model. This analysis was repeated, changing the order of entry to: (a) demographic; (b) physical function; (c) medical; and (d) psychosocial. For all the SF36 scale scores entered as independent variables, baseline score was used. The adjusted cumulative explained variance (i.e., adjusted $R^2$) in the dependent variable was tested for statistical significance on all steps of the regression. Also, the variance uniquely accounted for by the variables at each step (i.e., change in adjusted $R^2$) was tested for significance. All tests of significance were 2-tailed.

RESULTS

Strength and SF36 scores before and after TKR. — Improvement was seen in mean quadriceps strength, from 35.3 to 47.1 ($p < .0005$) and hamstring strength, from 29.3 to 33.7 ($p < .004$). Improvement was highly significant for Physical Functioning, Social Functioning, and Bodily Pain, but was not seen for Role Functioning-emotional and Mental Health (Table 2).

Gender differences. — Men had higher mean baseline Physical Functioning (39.3 vs 30.3 for women), but the difference was not statistically significant. The effect size for men was 0.94, and for women 1.06.

Predictors of TKR outcome. — The correlation coefficient for baseline Physical Functioning and TKR outcome (3-month post-op Physical Functioning) was .382.

The hierarchical multiple regression analysis performed to examine the extent to which the variance in TKR outcome could be explained by baseline (pre-op) variables is summarized in Table 3. In a hierarchical regression, as opposed to a full model multiple regression analysis (all variables are entered simultaneously), or to a stepwise regression (entry sequence determined by statistical significance), the ordering of variable entry is determined by the research goals. In the setting of potentially intercorrelated independent variables, this is the analytic method of choice for partitioning variance (13). Each variable or set is entered only after potentially confounding variables have been entered. Ideally, no variable set entering later should be a subspect of an earlier set. While it was clear that demographic variables should be entered first, establishing the remaining order was more difficult. The conservative sequencing recommended in this situation is to enter the variable set that is the focus of interest, in this case baseline physical functioning, last, after considering any variables that could contribute to its causality (13), like psychosocial factors. With this sequence, a non-significant 4% of the variance was accounted for by the demographic variables. Both the demographic and psychosocial variables explained a significant 23% of the variance $[F(7,35) = 2.80, p = .020]$. The psychosocial variables uniquely accounted for 19% of the variance $[F(3,35) = 4.14, p = .013]$. The partial correlation between Social Functioning and the dependent variable achieved significance, while the partial correlation for Role Functioning-emotional approached significance. In both instances, better psychosocial functioning was associated with better physical functional outcome. On step three, the demographic, psychosocial, and medical variables explained 25% of the variance $[F(11,31) = 2.25, p = .037]$. The medical variables uniquely accounted for 20% of the variance, and of these, only the partial correlation between comorbidity (CIRS) and the dependent variable approached significance ($p = .054$). Finally, step 4 of the regression analysis shows that 27% of the variance in 3-month post-op Physical Functioning was accounted for by the demographic, psychosocial, medical, and baseline physical function variables $[F(13,29) = 2.21, p = .037]$. Preoperative physical function uniquely accounted for a nonsignificant 2% of the variance in functional outcome of TKR.

### Table 2. Strength and SF36 Scores Before and After TKR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline*</th>
<th>3 Months Post-op*</th>
<th>p-value†</th>
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<tbody>
<tr>
<td>Strength:§</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps</td>
<td>70.3 (25.0)</td>
<td>81.1 (13.9)</td>
<td>.037</td>
</tr>
<tr>
<td>Hamstring</td>
<td>33.1 (12.0)</td>
<td>48.6 (21.8)</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>SF36 Health Survey:§</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Functioning</td>
<td>33.2 (19.0)</td>
<td>56.7 (22.4)</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>Mental Health</td>
<td>78.2 (15.4)</td>
<td>81.1 (13.9)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Role-Emotional</td>
<td>68.3 (39.0)</td>
<td>78.0 (36.3)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Social Functioning</td>
<td>70.3 (25.0)</td>
<td>87.8 (15.9)</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>Bodily Pain</td>
<td>33.1 (12.0)</td>
<td>48.6 (21.8)</td>
<td>&lt;.0005</td>
</tr>
</tbody>
</table>

*Values represent the mean followed by the standard deviation.
†P-value is related to Student’s paired t-test comparing the baseline and post-op means for each parameter.
§Units are foot-pounds.
$\$For all SF36 scales, the minimum score is 0 and the maximum 100. A higher score indicates a better health state.
We performed this analysis a second time, after changing the sequence of set entry (i.e., demographic variables first, baseline physical function variables second, medical variables third, and psychosocial variables last). Psychosocial variables continued to account for the largest portion of the variance, 15% \( F(3,29) = 3.19, p = .0387 \) in this model.

DISCUSSION

Of the baseline variables considered in our model, psychosocial variables (i.e., a set including Social Functioning, Role Functioning-emotional, and Motivation) most strongly predicted reported TKR physical functional outcome at 3 months. Some investigating orthopaedic outcomes have found a significant correlation between self-assessed physical functional status before and after surgery (14,15). These studies do not consider psychological factors. Our analysis revealed that after we controlled for demographic, psychosocial, and medical variables, baseline physical function variables accounted for only 2% of the variance in TKR outcome, while the psychosocial variables (Role Functioning-emotional, Social Functioning, and Motivation) uniquely accounted for 19% of the variance. This psychosocial variable set continued to be significantly associated with functional status after TKR, accounting for 15% of the variance, even when entered last into the analysis (i.e., after controlling for demographic, baseline physical function, and medical variables). The proportion of the variance explained by the physical function variables rose with this change in entry sequence, but remained smaller than that attributable to the psychosocial variables.

Overall, our results suggest that while the baseline level of physical function is important, psychological and social function may be more closely associated with TKR outcome. Prior to TKR, it is standard practice to optimize strength and physical functional status via physical therapy and home exercise. If our findings are confirmed in larger studies involving several surgeons, randomized controlled trials of specific psychosocial interventions (e.g., counseling to address depression or anxiety related to consequences of OA or surgery, use of support groups and patient networks) will be necessary to demonstrate an impact on outcome. Such programs are rarely provided currently.

Orthopaedic outcome assessment has evolved from anatomic measurements and global ratings (3) to the self-evaluation of the ability to perform specific activities, using health status questionnaires (12,16,17). Two knee-specific instruments were not found to be any more sensitive or specific than the generic SF36 to be any more sensitive or specific than the generic SF36 — to the self-evaluation of the ability to perform specific activities, using health status questionnaires (12,16,17). Two knee-specific instruments were not found to be any more sensitive or specific than the generic SF36 to be any more sensitive or specific than the generic SF36 . We used the SF36 because, as a generic measure (vs AIMS or HAQ), it allows comparison of the effect of different disease states or treatments on values such as physical functioning that are not restricted to one disease or intervention (19–21). Two knee-specific instruments were not found to be any more sensitive or specific than the generic SF36 battery in measuring physical functional status in TKR patients (22).
Enrollment of subjects from the practice of one surgeon may have limited the generalizability of results. The use of one practice actually offers certain advantages. Many difficult-to-measure variables that may have a large impact on self-assessed functional status are standardized in an individual practice, including those related to the process of care, specific nursing and other support staff, elements of surgical technique, etc. The medication and physical therapy programs before and after surgery, as well as other aspects of peri-operative care, did not differ from general practice. We were concerned that the association between SF36 psychosocial scores and the dependent variable, TKR outcome as measured by 3-month post-op SF36 Physical Functioning score, may reflect a systematic bias in the reporting of function (e.g., that those patients with a bright outlook select positive responses for all scales). Kantz found, however, in a group of patients 2 or more years after TKR for knee OA, only a weak correlation between Mental Health and Physical Functioning scales, but strong correlations between the Physical Functioning and Role Functioning-physical scales, and between the Mental Health and Role Functioning-emotional scales, supporting the distinction of physical and mental health concepts in the SF36 health status survey (22).

Other studies have demonstrated the important role of psychosocial status in OA outcome. Anxiety explained 34% of the variance in the Performance and Activity Scale, and depression 10% of the variance in AIMS Physical Functioning score (23) in OA patients. Summers (24) hypothesized that in OA, depression and anxiety decrease pain tolerance and lead to function impairment in a cycle of pain and inactivity. In 65 patients with knee or hip OA (24), depression was strongly correlated with impairment in almost all and anxiety in all areas assessed by Sickness Impact Profile (SIP) subscales. While radiographic severity accounted for 9% of the variance in SIP Physical Dimension score, depression and state anxiety accounted for 45%.

In one of few studies to evaluate the role of gender in TKR functional outcome beyond acute hospitalization, Katz (7) retrospectively detected a smaller TKR effect size for men (0.73) than women (1.12), using the intermediate activity of daily living physical function items of the FSQ. Prior to TKR, baseline functional status was worse for women even after controlling for other factors. We also found a larger effect size in women, though the gender discrepancy was smaller, and better baseline physical functional status in men. This may have reached statistical significance with a larger sample. Studies performed to analyze the contribution of independent variables to functional TKR outcome while controlling for the presence of other variables are rare in the published literature. In fact, none was identified by MEDLINE search (details available). In a recent abstract, Kwoh (5) reported that male gender, age 65 or older, marital status, type of arthritis, revision TKR, comorbidity, and no oral narcotics after the fifth post-operative day were significantly associated with a lower number of physical therapy sessions required to attain at least one functional milestone (i.e., supine to sit transfer, sit to stand transfer, or ambulation to 100 feet), in bivariate analyses. Gender, diagnosis, and comorbidity predicted the number of sessions required to attain all 3 milestones. The role of preoperative functional status and psychological variables is not described.

In conclusion, this study demonstrates that psychosocial factors play an important role in the reported functional result of TKR for advanced OA as assessed by the SF36 Physical Functioning scale. Psychological and social status evaluation may be used to identify patients at risk for worse outcome. Specific interventions should be developed, studied in controlled trials, and, if they improve outcome, incorporated into the multidisciplinary care provided in the preparatory, peri-operative, and rehabilitative phases of TKR.

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**REFERENCES**


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