http://dx.doi.org/10.2106/JBJS.L.01488

TABLE E-1 Total Knee Arthroplasty Patient Responses from the Orthopaedic Practice (N = 73)*

	Pre-Surgery Responses *(%)*		Post-Surgery Responses *(%)*	
Questions	Full Benefit	Limited Benefit	Full Benefit	Limited Benefit
Walk a quarter of a mile	48	52	90	10
Walk up 10 steps	64	36	92	8
Sit for about 2 hr	85	14	100	0
Reach up over your head	96	4	99	1
Stand or be on your feet for about 2 hr	49	51	81	19
Stoop, bend, or kneel	33	67	75	25
Lift or carry 10 lb	74	26	93	7
Push or pull large objects (e.g., chair)	63	37	89	11

*All differences between mean pre-surgery and post-surgery scores were significant at the $p < 0.001$ level. Some response percentages may not add up to 100% because of rounding.

TABLE E-2 Annual SSI Disability Payments*

Age *(yr)*	Male *($)*	Female *($)*
18-39	8816	9090
40-44	14,296	7619
45-49	16,741	12,824
50-54	17,500	12,824
55-59	17,566	9578
60-64	21,208	11,052
65-69	13,896	9587
≥70	15,667	8756

*Source: 2011 Current Population Survey.

http://dx.doi.org/10.2106/JBJS.L.01488

Appendix

The Direct and Indirect Costs to Society of Treatment for End-Stage Knee Osteoarthritis

This technical appendix describes our approach to estimating the effects of total knee arthroplasty on the indirect costs associated with end-stage osteoarthritis of the knee. Our approach for estimating indirect costs was based on the methods and data reported by Dall et al.[28]. That approach infers the indirect economic benefits of interventions when direct data do not exist by linking data on (1) the effectiveness of musculoskeletal treatment, and (2) the impact of functional impairment on economic outcomes. A brief description of this approach as well as our approach to converting Medicare reimbursement rates to all-payer reimbursement levels are presented below.

Framework for Estimating Indirect Costs

NHIS data were used to generate regression coefficients that described the statistical relationship between physical function status and economic outcomes. The regression coefficients were then applied to surgical outcome data obtained from a survey of patients treated at a multi-practice orthopaedic surgeon group to estimate the effect of surgery on income, missed workdays, and the probability of receiving disability payments (SSI). These findings were incorporated into a Markov decision model to estimate total societal savings resulting from total knee replacement.

The NHIS, which is used to monitor the health of the U.S. population, is one of the major data collection programs of the National Center for Health Statistics (NCHS), which is part of the Centers for Disease Control and Prevention (CDC). The NHIS covers the civilian noninstitutionalized population residing in the U.S. and has an expected sample size (completed interviews) of approximately 35,000 households each year.

Estimating the Relationship Between Functional Limitations and Indirect Costs

The NHIS collects information from a stratified random sample of the U.S. population regarding physical function, economic factors such as employment status and income, and other characteristics[38]. Our analysis combined the 2003 through 2010 NHIS files to increase the sample size, resulting in a sample of 185,813 adults (eighteen years of age or older) living in noninstitutional settings. The NHIS asks respondents:

By yourself and without using any special equipment, how difficult is it for you to:

Walk a quarter of a mile—about three city blocks?
Walk up 10 steps without resting?
Sit for about 2 hours?
Reach up over your head?
Stand or be on your feet for about 2 hours?
Stoop, bend, or kneel?
Lift or carry something as heavy as 10 pounds such as a full bag of groceries?
Push or pull large objects like a living room chair?

Responses to each question include (1) not at all difficult, (2) only a little difficult, (3) somewhat difficult, (4) very difficult, and (5) can't do at all. Our analysis focused only on activity limitations in which the respondent indicates that back pain, bone or joint injury, or arthritis contributed to his or her limitations.

Regression analysis was used to compare the probability of being employed, household income, missed worked days, and the probability of receiving disability payments between two groups: adults with and adults without activity limitations. Responses to physical function questions were made independent of the questions by creating a binary variable (1 = yes, 0 = no) for each of the possible responses (e.g., "not at all difficult," "only a little difficult," "somewhat difficult," "very difficult," and "can't do at all,") to each question. Individuals claiming that the physical function task was "not at all difficult" were used as the comparison group. The following control variables were included in each model: age (age groups of eighteen to thirty-nine, forty to forty-four, forty-five to forty-nine, fifty to fifty-four, fifty-five to fifty-nine, sixty to sixty-four, sixty-five to sixty-nine, and seventy years or more), sex, highest educational attainment (high school diploma, baccalaureate degree, post-baccalaureate degree), and occupation (for analysis of household income and missed workdays).

Logistic regression was used for the models involving employment and disability payment status. In the employment model, the dependent variable took on a value of 1 if a survey respondent reported that he or she had a job in the last week. For the disability payment model, the dependent variable took on a value of 1 if a survey respondent reported that he or she was currently receiving SSI. Ordinary least-squares regression was used to quantify the impact of activity limitations on household income, and a negative binomial model was used for missed workdays. The models for income and missed workdays only included respondents who reported that they had been employed in the last week. Regression results for the functional outcome variables are given in Dall et al.[28].

Total Knee Arthroplasty Patient Outcome Data from the Physician Group (Table E-1)

Predicted values for indirect cost components were obtained by utilizing patient-reported data collected by a physician group practice with multiple locations. Electronic questionnaires were sent to 310 patients who received a total knee arthroplasty from September 2010 to April 2011. A total of seventy-three responses were received and were used in the analyses. The survey contained questions regarding an individual's socioeconomic status and functional ability (using the same questions on functional status used in the NHIS) prior to undergoing surgery and after undergoing surgery. Functional questions included the following possible answers: "no difficulty," "only a little difficult," "somewhat difficult," "very difficult," and "cannot do." Numerical values of 1 through 5 were assigned to the responses, with "no difficulty" assigned a value of 1 and "cannot do" assigned a value of 5. Patients were categorized as receiving full benefit from the total knee arthroplasty if their mean post-surgery response for all functional questions was 3 (somewhat difficult) or less and as limited benefit otherwise. The results of this characterization of the survey responses are shown in Table E-1. Assuming this response categorization allowed us to match the distribution of patients experiencing full benefit in the study by Losina et al.[3], which was 88%.

As noted, the response rate for our survey was approximately 24%. There are three issues that may arise from the survey's low response rate: insufficient statistical power, recall bias, and non-response bias. A power test, based on the physical function component of the WOMAC[41] scores in a published study[4] (mean [and standard deviation], 46.6 ± 18.1 preoperatively and 36.2 ± 17.6 postoperatively), was conducted prior to survey collection. The test indicated that forty-seven participants would be needed in the preoperative and postoperative groups to attain a power of 0.80, and seventy-seven participants would be needed to attain a power of 0.95. We obtained responses from seventy-three patients who underwent total knee replacement; thus, our results show sufficient statistical power.

The two potential biases mentioned above raise the concern that our respondents may not be representative of the true population of individuals with end-stage knee osteoarthritis who undergo total knee arthroplasty. We believe that, despite the low response rate, this is not the case. The WOMAC function subscore resembles the questions in our survey with respect to the questions and the response scales. (Our questions are a subset of the WOMAC function questions and maintain a five-point response scale for each question, ranging from no difficulty to unable to do). When converted to the WOMAC scale typically utilized in the literature (0 to 100, with a higher score indicating better function), the means calculated from our survey data (n = 73) were 48.0 preoperatively and 74.3 postoperatively. Lingard et al.[34] analyzed the responsiveness of the Knee Society Clinical Rating System, WOMAC, and Medical Outcomes Study Short Form-36 (SF-36) in a prospective observational study of 697 patients undergoing total knee arthroplasty for osteoarthritis of the knee who had a twelve-month duration of follow-up. The mean preoperative and postoperative WOMAC function scores in that cohort were 46.4 and 74.6, respectively. Similarly, Jones et al.[12] reported mean preoperative and postoperative WOMAC scores of 43 ± 18 and 72 ± 18 for patients younger than eighty years and 38 ± 12 and 66 ± 17 for patients eighty years of age and older. The cohort in that study had a six-month duration of follow-up. The mean preoperative function scores in our survey were thus comparable with the corresponding WOMAC subscores in both Lingard et al. and Jones et al. (The mean change in the function scores was also comparable with the values in those studies.)

Methods for Combining Indirect Cost Components and Patient Outcome Data

The relationships between functional status and indirect costs were determined by regression analysis as described above. The results from the models allowed us to determine changes in an individual's probability of being employed, number of missed workdays, household income, and disability payments conditional on his or her level of functional ability in a given year.

Data from the seventy-three patients who underwent total knee arthroplasty from 2009 to 2011 allowed us to determine changes in functional measures used to assess total knee arthroplasty recipients. For each observation from the patient outcome data, functional responses were held constant while age was allowed to vary from forty to ninety-nine years. This allowed us to obtain predicted values for assumed ages from forty to ninety-nine years for the probability of being employed, probability of being disabled, income (in dollars), and missed workdays. These predicted values were generated for the pre-surgery and post-surgery periods. Individuals older than seventy-five years were assumed to have a probability of employment of 0. Thus, there were fifty-nine observations, varied only by age, for each observation in the patient survey, resulting in a total of 59 × 73 observations. The predicted probabilities for employment, disability, predicted income, and missed workdays were then averaged at each age.

Once the mean employment probability by age was obtained, the expected income change from undergoing total knee arthroplasty was calculated as: Expected Income = (Estimated Income After Surgery × Probability of Being Employed After Surgery) – (Estimated Income Before Surgery × Probability of Being Employed Before Surgery).

The change in the annual value of missed worked days as a result of a total knee arthroplasty was calculated as: Expected Value of Missed Workdays = (Estimated Income After Surgery × Probability of Being Employed After Surgery) × (Missed Workdays After Surgery)/240 – (Estimated Income Before Surgery × Probability of Being Employed Before Surgery) × (Missed Workdays Before Surgery)/240.

Additionally, we assumed that workers lost a mean of forty days as a result of a total knee arthroplasty. To account for income lost during this period, the mean predicted income according to age was multiplied by the individual's probability of being employed. Changes in the expected disability payment as a result of an arthroplasty were calculated by multiplying the change in probability of being disabled by the SSI payment according to sex and age.

The change in the disability payment was calculated as: Expected Disability Payment = (Estimated Disability Payment × Probability of Being on Disability After Surgery) – (Estimated Disability Payment × Probability of Being on Disability Before Surgery).

Disability payments were determined as a function of age and sex, as shown in Table E-2, and were taken from the 2011 Current Population Survey.

Combining the patient-reported outcomes and the NHIS data indicated that the age-weighted mean expected change in income for the first year following surgery was a gain of $6502 for individuals in the full-benefit state and a loss of $2924 for individuals in the limited-benefit state because of a decrease in functional status. The expected first-year change in income for an individual gaining full benefit from total knee arthroplasty ranged from $13,739 for those forty to forty-four years of age to $1249 for those seventy to seventy-four years of age. For individuals younger than sixty-five years in the full-benefit group, the mean probability of being employed increased by a mean of 23.3% relative to the nonsurgical cohort. Similarly, full-benefit individuals missed fewer workdays, valued at $36 per day, and received $740 less in SSI disability payments. The expected decrease in income for individuals receiving limited benefit from the total knee arthroplasty ranged from $7604 for the youngest age group to $339 for patients seventy to seventy-four years of age. Limited-benefit patients experienced almost no change in missed workdays and an increase of $184 in expected disability payments relative to patients who did not choose to undergo total knee arthroplasty.

Converting Medicare Costs to All-Payer Costs

Cost estimates based on Medicare payment rates may underestimate payments made by private insurers and overestimate payments made by Medicaid and self-insured and uninsured patients. To reconcile these differences, we adjusted our estimates of direct medical costs by determining payment rates for other insurers (expressed as a percentage of the Medicare rate) and then weighting the results by the national distribution of payers for total knee arthroplasty. We set the payment rates for Medicaid and self-pay patients as 80% and 50% of the Medicare rate, respectively. For private insurers, we used payment rates reported in the literature. Ginsburg estimated that, on average, private insurers paid 139% of Medicare payment rates for inpatient care nationally in 2008[39]. The same study also indicated private insurer payments as a percentage of Medicare rates for outpatient services in selected areas; these ranged from 193% in Cleveland to 368% in San Francisco. We used the median of the reported range, which is 280%, to adjust the costs of outpatient services. The Medicare Payment Advisory Commission (MedPAC) estimated that the private rate for physician services averaged 123% of the Medicare rate across all services and areas in 2003[40]. For all other patients, including those with claims paid by Workers' Compensation, we assumed the rate to be equal to the mean of the rates of Medicare and private insurers. ■