

Physical Activity and Risk of Revision Total Knee Arthroplasty in Individuals with Knee Osteoarthritis: A Matched Case-Control Study

DINA L. JONES, JANE A. CAULEY, ANDREA M. KRISKA, STEPHEN R. WISNIEWSKI, JAMES J. IRRGANG, DAVID A. HECK, C. KENT KWOH, and LAWRENCE S. CROSSETT

ABSTRACT. Objective. To determine if physical activity was a risk factor for revision arthroplasty after primary total knee arthroplasty (TKA) due to osteoarthritis (OA) within the previous 15 years.

Methods. This was a matched case-control study. The cases had primary TKA followed by revision arthroplasty. Controls had primary TKA and no revision arthroplasty. Cases and controls were matched for age, sex, number of knees replaced, and date of primary TKA. Standardized telephone interviews were conducted to assess historical leisure activity, occupational activity, and instrumental activities of daily living after primary TKA in metabolic equivalent (MET)-hours per week. Conditional logistic regression was performed to identify the variables that predicted the need for revision arthroplasty.

Results. Seventeen female and 9 male pairs, aged 47 to 85 years, participated. Most of the reported activity was of low impact and low or moderate intensity. Cases reported a median of 44.5 (range 0 to 137) MET-hours of total historical physical activity per week compared with controls' 55.1 (range 0 to 278) MET-hours. Total historical physical activity was not associated with the risk of revision arthroplasty (OR 0.99, 95% CI 0.99–1.01). Participants with primary TKA (controls) consistently reported more MET-hours of leisure and occupational activity than those with revision arthroplasty (cases) regardless of the number of knees replaced or whether or not walking was accounted for.

Conclusion. This study quantified and described patterns of physical activity in a population with TKA. Physical activity did not appear to be a risk factor for revision arthroplasty. Our results suggest that individuals undergoing primary TKA should be encouraged to remain active after surgery. (J Rheumatol 2004;31:1384–90)

Key Indexing Terms:

PHYSICAL ACTIVITY
PRIMARY

OSTEOARTHRITIS
REVISION

TOTAL KNEE ARTHROPLASTY
KNEE

Osteoarthritis (OA) of the knee is more likely to lead to disability than OA in any other joint^{1,2}. Total knee arthroplasty (TKA) is a frequently utilized treatment option that

can improve pain, function, and the quality of life³⁻⁷. Although good to excellent results have been reported in more than 90% of individuals after knee replacement, roughly 1% require revision arthroplasty per year⁶⁻¹². The escalating rate of primary TKA, coupled with the increase in longevity, will most likely lead to a greater number of revision procedures in the future.

Few studies have examined risk factors for prosthetic failure. Factors such as male sex, younger age, greater height and weight, longer length of hospital stay, and a higher number of surgical complications have been associated with an increased risk of revision arthroplasty^{10,13-15}. Physical activity has been suggested as a possible risk factor for prosthetic failure, through aseptic loosening or polyethylene wear of the primary prosthesis as a result of high-impact activities, or wear of the weight-bearing surfaces due to repetitive mechanical loading of the prosthetic knee joint^{10,16-18}. Understanding the relationship between physical activity and prosthetic failure is necessary because improving activity levels is an important patient expectation after TKA¹⁹.

Most surgeons recommend avoiding intense and/or high-

From the Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania.

Supported by the Arthritis Foundation and the Foundation for Physical Therapy.

D.L. Jones, PhD, PT, Research Associate, Division of Rheumatology and Clinical Immunology, Department of Medicine, and Clinical Assistant Professor, Department of Physical Therapy, School of Health and Rehabilitation Sciences; J.A. Cauley, DrPH, MPH, Associate Professor; A.M. Kriska, PhD, Associate Professor; S.R. Wisniewski, PhD, Assistant Professor; J.J. Irrgang, PhD, PT, ATC, Assistant Professor, Vice-Chairman Clinical Services, Department of Physical Therapy, School of Health and Rehabilitation Sciences; D.A. Heck, MD, Professor, Department of Orthopaedic Surgery, Indiana University; C.K. Kwoh, MD, Professor of Medicine and Epidemiology, Division of Rheumatology and Clinical Immunology, Department of Medicine, University of Pittsburgh, Center for Health Equity Research and Promotion, Veterans Administration Pittsburgh Health Care System; L.S. Crockett, MD, Assistant Professor, Department of Orthopaedic Surgery, University of Pittsburgh.

Address reprint requests to Dr. D.L. Jones, Division of Rheumatology and Clinical Immunology, University of Pittsburgh, 3500 Terrace Street, S727 Biomedical Science Tower, Pittsburgh, PA 15261. E-mail: DLjst4@pitt.edu

Submitted January 20, 2003; revision accepted January 23, 2004.

impact activities after TKA; however, little evidence is available to support such advice^{17,20}. Several studies recommend certain leisure/sports activities after TKA, or report the frequency with which people returned to such activities after surgery^{17,20,21}. Another study reported an increased risk of polyethylene failure in individuals who were more active, based on their occupation or retirement status¹⁰. Physical activity was not a risk factor for revision arthroplasty in a longterm study of younger individuals (aged 55 yrs or less) with primary TKA who were followed for an average of 8 years⁶.

Although physical activity comprises a spectrum of components that includes leisure activities, sports, occupational activities, and activities of daily living (basic and instrumental), previous studies assessed only limited components of physical activity after TKA (such as walking or sports activities)^{18,21-24}. Other studies classified activity after TKA with ordinal rating scales that combined the various components of physical activity, without providing information on the frequency, duration, and intensity of activity^{6,10}.

Our purpose was to determine if physical activity was a risk factor for revision arthroplasty after primary TKA due to OA. Specifically, we quantified the frequency, duration, and intensity of physical activity after TKA across the entire activity spectrum. A matched case-control study design was used to test the hypothesis that individuals with higher physical activity levels after primary TKA have a greater risk of revision arthroplasty than individuals with lower physical activity levels.

MATERIALS AND METHODS

Participants were recruited for the study between October 1999 and September 2000 at one community hospital and 3 tertiary hospitals after approval by the respective institutional review boards. Eligible participants were identified from the medical records of 12 orthopedic surgeons at 4 group practices. Recruitment materials and a consent form were mailed to all eligible participants. All participants provided written informed consent before enrolling in the study.

The cases and controls were aged 25 years or older. The cases had had primary TKA within the past 2 to 15 years and had also undergone revision arthroplasty. The controls had had primary TKA within the same time and no history of revision arthroplasty. Primary TKA was defined as at least one bicompartamental or tricompartmental knee replacement due to OA. Both cases and controls had primary TKA at least 2 years prior to study entry to allow one year for recovery and one year to assess physical activity at a stable level. Cases and controls were matched on 4 criteria: age (within 5 yrs), sex, number of knees replaced (unilateral vs bilateral), and the date of primary TKA (within 3 yrs).

Revision arthroplasty was defined as revision of at least the tibial or femoral component due to aseptic loosening or mechanical failure within the past 5 years, with a minimum of 2 years between primary and revision surgery. The indications for revision arthroplasty were classified based on a review of surgical and radiographic reports. Individuals who experienced prosthetic failure within 2 years after primary TKA were excluded from the study in order to eliminate those who required early revision arthroplasty due to serious postoperative complications. In order to minimize recall bias in the cases due to pain or recent surgery, the cases must have had revision surgery at least 3 months prior to enrolling in the study. Individuals with a

history of knee infection, resection arthroplasty, lower extremity arthrodesis, lower extremity amputation, or more than one revision arthroplasty were excluded from the study.

Surgical data related to primary TKA were obtained by a retrospective review of medical records. Information was collected on the number of knee compartments replaced, the method of prosthetic fixation for each component (cemented vs cementless), the anatomic class of prosthesis (based on the posterior cruciate ligament), thickness of the tibial polyethylene spacer, and number of postoperative complications. Inpatient medical records were reviewed to determine the presence or absence of 16 potential postoperative complications according to Heck, *et al*²⁵. The number of complications was summed to provide the total number of complications during the hospitalization for primary TKA.

Each participant completed a structured telephone interview to obtain information on sociodemographic, clinical, functional, and physical activity variables. The interviewers were blinded to the participants' case/control status. Self-reported height and weight were used to calculate body mass index²⁶. The presence of comorbid conditions was determined using the comorbidity index of the Lower Limb Questionnaire from the American Academy of Orthopaedic Surgeons' Lower Limb Outcomes Data Collection Questionnaires^{27,28}. The comorbidity index has shown satisfactory reproducibility and validity for predicting health status^{29,30}. The comorbidity index can range from a score of 0 (no comorbidities) to 100 (highest level of comorbidities)²⁸. Separate questions were used to assess the history of knee injury or knee surgery prior to primary TKA based on participant self-report.

Ambulation was categorized according to whether or not a participant required assistance (an assistive device or assistance from at least one person) to ambulate on level surfaces and stairs. Participants were also asked if their usual physical activity level 2 years after primary TKA was more, less, or the same as it was 2 years before surgery in order to assess the change in activity between pre- and postoperative primary TKA. Two years was chosen as the timeframe because there were differences among the matched pairs in the length of time from primary to revision arthroplasty, and 2 years after primary TKA was a common point in time for all pairs.

The measurement of historical leisure (including sports) and occupational activity in the cases included activity from the second year after primary TKA through either the fifteenth year after primary TKA or the time of revision surgery, whichever occurred first. For the matched control, leisure and occupational activity were assessed from the second year after primary TKA until the time of revision surgery in the matched case.

The leisure activity section of the Modifiable Activity Questionnaire (MAQ) was used to measure historically the average number of hours per week of participation in 39 leisure and sports activities²². The MAQ has been shown to be reliable in adults and adolescents through field testing and comparison with activity monitors (leisure activity $r = 0.69-0.85$; occupational activity $r = 0.88$)^{31,32}. To weight each activity by its relative intensity, the average number of hours per week for each activity was multiplied by the activity's metabolic equivalent (MET) and summed across all activities to provide the average number of MET-hours per week of historical leisure activity^{22,33-36}.

The MAQ was also used to assess historical occupational activity based on the physical demands and work schedule of each job²². Occupations such as student, homemaker, and volunteer, or being retired, disabled, or unemployed, were also included. The energy demands of each job were categorized as light, moderate, or hard. The number of hours per week in each category was weighted by its relative intensity (i.e., 1.5 MET for light, 4 MET for moderate, and 7 MET for hard) and summed to provide the average number of MET-hours per week of historical occupational activity.

The work, yard work, and caretaking sections of the YALE Physical Activity Survey were used to assess retrospectively the number of hours per week spent performing 15 instrumental activities of daily living (IADL) during the past month²². The 2-week reproducibility of the instrument has

been reported ($r = 0.42\text{--}0.65$)³⁷. The number of hours spent on each activity was multiplied by an intensity code and summed over all of the activities to provide the total number of kilocalories per week, which were then converted to MET-hours per week.

Statistical methods. Descriptive statistics were calculated for all variables. The median and range were also calculated for the physical activity variables due to the non-normal distribution of the data.

Univariate analyses for matched data were conducted between the outcome variable (revision/no revision) and each potential predictor variable using paired *t* tests and signed-rank tests where appropriate. Ordinal and nominal data were analyzed with either the McNemar test or the Bowker test of symmetry. Because the time spent walking for exercise has been found to be unreliable in many populations, the historical leisure activity variable was analyzed both with and without the inclusion of any time spent walking²². All results include walking as a leisure activity except where noted.

The leisure activities were also categorized according to the level of impact at the knee based on the literature to determine if there were differences in the amount of high-impact leisure activity between the cases and controls^{17,38,39}. The activities were classified as no (e.g., swimming), low/moderate (e.g., walking), or high-impact (e.g., jogging). In addition, the leisure and occupational activities were stratified based on intensity level to examine if the amount of high-intensity activity differed between cases and controls. Activities that required ≥ 6 MET in energy expenditure were classified as high-intensity activities^{31,40,41}.

Odds ratios (OR, based on a one MET-hour change in physical activity per week) and 95% confidence intervals (CI) were calculated for the leisure, occupational, and IADL variables. The physical activity variables were analyzed separately, as well as with leisure and occupational activity combined as a total historical physical activity variable. The total historical physical activity variable was analyzed as both discrete and continuous data. For discrete data, the total historical physical activity variable was stratified into high and low activity groups based on the sex-specific median of the distribution (men 51.9 MET-hours, women 49.8 MET-hours) to determine if high versus low physical activity was associated with the need for revision arthroplasty.

After the predictor variables were identified, a stepwise conditional logistic regression analysis for matched data was performed to identify the variables that predicted the need for revision arthroplasty. To avoid excluding any potentially important predictor variables, variables that had a univariate significance level ($p \leq 0.15$), were clinically meaningful, or had non-missing data were entered into the model⁴². The total historical physical activity variable was forced to remain in the model. A significance level (p) of 0.10 was used as the entry and stay criteria in the stepwise model⁴². The hypotheses for all of the statistical tests were 2-tailed except for the physical activity analyses. All statistical tests were conducted with a Type I error rate of 0.05 using the SAS software package (version 8.0; SAS Institute, Cary, NC, USA).

RESULTS

One hundred eighty-nine patients met the eligibility criteria, of whom 64 (34%) were identified as cases and 125 (66%) as controls. Thirty-eight of the eligible cases (59%) and 52 of the eligible controls (42%) enrolled in the study. Reasons for nonenrollment included: failure to respond to the mailings (cases 16%, controls 30%), declined participation in the study (cases 19%, controls 15%), no available forwarding address (cases 3%, controls 8%), and deceased (cases 3%, controls 5%). Enrolled and nonenrolled cases and controls were similar with respect to sex, number of knees replaced, number of months since primary TKA, and mean age, except that enrolled controls were significantly younger

than the nonenrolled controls [enrolled 71 (SD 7.4) yrs; not enrolled 75 (SD 8.1) yrs; $p = 0.001$].

Twenty-six case-control pairs were identified and included 17 female (65%) and 9 male (35%) pairs with a mean age of 70.5 (SD 8.9) years (range 47–85 yrs). Twelve (46%) of the pairs had both knees replaced. Primary TKA in the cases and controls was performed an average of 6.4 (SD 2.3) years previously (range 2–11 yrs). The mean time to prosthetic failure from primary to revision arthroplasty in the cases was 5 (SD 2.3) years (range 2–11 yrs). The indications for revision arthroplasty were polyethylene failure (42%), component loosening (38%), patellar instability (12%), arthrofibrosis (4%), and oversize components (4%). Revision arthroplasty in the cases was performed a mean of 2.6 (SD 1.5) years prior to study entry (range 4 mo to 5 yrs).

The sociodemographic, clinical, surgical, and functional characteristics of the case-control pairs are presented in Table 1. Cases reported a history of knee surgery prior to TKA 3 times more frequently than the controls ($p = 0.02$). Cementless femoral components were implanted during primary TKA more often in the cases than the controls ($p = 0.01$). After primary TKA, there were no statistically significant differences between the cases and controls in ambulation on level surfaces; however, the cases were more likely than controls to need assistance to ascend and descend stairs ($p = 0.02$). There was a tendency for the cases to report a reduction in their usual physical activity level after primary TKA more often than the controls, although the differences were not statistically significant ($p = 0.07$).

Physical activity was assessed historically over an average period of 4 (SD 2.0) years in the matched cases and controls (range 1–10 yrs). The most frequently reported leisure activity was walking in the cases (65%) and gardening/yardwork in the controls (77%). No case and only 2 controls (8%) engaged in high-impact leisure activities, therefore analyses examining the influence of activity type (high vs low-impact) on risk of revision arthroplasty were not conducted. Retirement was the most frequently reported occupational activity (cases 42%, controls 54%) followed by serving as a homemaker (cases 39%, controls 23%).

The controls reported more median MET-hours per week of historical leisure and occupational activity than the cases, and similar median MET-hours of high-intensity leisure and occupational activity (Table 2). There was no association, however, between leisure or occupational activity (historical or high-intensity) and the risk of revision arthroplasty. At the lower-intensity end of the activity spectrum, the controls again reported more median MET-hours per week of IADL than the cases (Table 2). Participation in IADL was not a risk factor for revision arthroplasty.

The controls reported more MET-hours of total historical physical activity per week than the cases (Table 2). Total historical physical activity was not associated with the risk of revision arthroplasty. Similar results were obtained when

Table 1. Sociodemographic, clinical, surgical, and functional characteristics.

	Cases, n = 26	Controls, n = 26
Self-reported race: white, n (%)	26 (100)	23 (88)
Marital status, n (%)		
Married	19 (73)	19 (73)
Other*	7 (27)	7 (27)
Annual income†, n (%)		
< \$20,000	9 (45)	6 (30)
\$20,000–40,000	5 (25)	8 (40)
> \$40,000	6 (30)	6 (30)
Highest level of education, n (%)		
High school or less	13 (50)	11 (42)
College experience or degree	13 (50)	15 (58)
Body mass index, kg/m ² , mean (SD)	30.3 (6.4)	30.3 (8.4)
Comorbidity index (0–100), mean (SD)‡	16.9 (9.0)	14.9 (9.0)
History of knee injury, n (%)	7 (27)	9 (35)
History of knee surgery, n (%)§	13 (50)	4 (15)
Compartments replaced: tricompartmental, n (%)	24 (92)	26 (100)
Component fixation: cemented, n (%)		
Femoral§	6 (23)	18 (69)
Tibial	15 (58)	26 (100)
Patellar	19 (73)	26 (100)
Anatomic class of prosthesis, n (%)¶		
PCL-retaining	20 (80)	13 (52)
PCL-sacrificing	1 (4)	0 (0)
PCL-substitution (posterior stabilized)	4 (16)	9 (36)
Constrained	0 (0)	3 (12)
Thickness of tibial polyethylene, mm, mean (SD)	11.3 (2.8)	11.1 (2.4)
Number of postoperative complications, n (%)#		
0	5 (21)	5 (21)
1	11 (46)	13 (54)
> 2	8 (33)	6 (25)
Required assistance, n (%)		
Ambulate on level surface	11 (42)	5 (19)
Ascend/descend stairs§	21 (81)	13 (50)
Usual physical activity level, n (%)**		
More	4 (15)	10 (39)
Same	9 (35)	10 (39)
Less	13 (50)	6 (23)

* Included single (never married), separated, divorced, or widowed. † n = 20 pairs. ‡ 0 = no comorbidities.

§ Comparison significant at $p < 0.05$. PCL: posterior cruciate ligament. ¶ n = 25 pairs. # n = 24 pairs. ** Usual physical activity level 2 years after primary TKA compared to 2 years before TKA.

walking was excluded from the leisure activity component of total activity.

The controls reported more median MET-hours of total historical physical activity than the cases regardless of whether one knee [cases 48.9 (range 13.9–125.2), controls 60.8 (range 0–194.4)] or both knees [cases 27.2 (range 0–137), controls 32.8 (range 10.2–278)] were replaced during primary TKA. In addition, men reported more median MET-hours of total historical physical activity per week than women [men 51.9 (range 0–278), women 49.8 (range 0–125.2)]. The risk of revision arthroplasty in participants with high levels of total historical physical activity was 33% lower than in those with low levels of total activity; however, this finding was not statistically significant (OR 0.67, 95% CI 0.67–1.93).

The following variables were entered into the multivariate model along with the total historical physical activity variable: history of knee surgery before primary TKA, fixation of femoral component, ambulation on stairs, ambulation on level surfaces, and change in usual physical activity. In the final model (Table 3), total historical physical activity was not associated with the risk of revision arthroplasty after adjusting for the other 2 variables in the model. The risk of revision arthroplasty was significantly increased in participants who reported a history of knee surgery before undergoing primary TKA and in those who experienced a reduction in usual activity level after surgery.

DISCUSSION

The purpose of this matched case-control study was to test

Table 2. Components of physical activity.

		Mean, MET-hours/wk	SD, MET-hours/wk	Median*, MET-hours/wk	Range*, MET-hours/wk	OR [†]	95% CI
Leisure							
Historical	Cases	16.6	17.7	11.2	0.0–70.4	0.99	0.99–1.02
	Controls	20.0	21.5	12.6	0.0–83.6		
High-intensity [‡]	Cases	1.7	4.9	0.0	0.0–19.4	0.96	0.88–1.05
	Controls	3.6	10.1	0.0	0.0–48.8		
Occupational							
Historical	Cases	34.2	28.3	27.7	0.0–120.0	0.99	0.99–1.01
	Controls	43.2	51.2	30.9	0.0–258.5		
High-intensity [‡]	Cases	15.7	33.7	0.0	0.0–120.0	1.00	0.99–1.01
	Controls	22.1	57.1	0.0	0.0–258.5		
IADL							
Past month	Cases	69.4	66.5	45.7	4.2–334.8	1.00	1.00–1.01
	Controls	58.6	40.9	48.6	5.7–162.8		
Total historical**							
With walking	Cases	50.8	34.6	44.5	0.0–137.0	0.99	0.99–1.01
	Controls	63.2	59.2	55.1	0.0–278.0		
Without walking	Cases	44.5	33.8	33.4	0.0–137.0	0.99	0.99–1.00
	Controls	60.2	59.2	50.6	0.0–276.8		

* Median and range presented because physical activity data were not normally distributed. [†] Odds ratio of needing revision arthroplasty per one MET-hour change in physical activity per week. [‡] Activities required ≥ 6 MET in energy expenditure. ** Historical leisure and occupational activity combined. IADL: instrumental activities of daily living.

Table 3. Total historical physical activity and risk of revision arthroplasty.

	OR**	95% CI
Total historical physical activity*	0.99	0.99–1.01
History of knee surgery before primary TKA [†]	23.7	1.11–504.10
Reduction in usual activity level after primary TKA [‡]	4.5	1.02–19.93

* Historical leisure and occupational activity combined. [†] History of knee surgery: yes or no. [‡] Activity level: more, less, or the same. ** Odds ratio of needing revision arthroplasty per one MET-hour change in physical activity per week.

the hypothesis that physical activity was a risk factor for revision arthroplasty after primary TKA due to OA. Our results showed that participants who reported a higher number of MET-hours per week of leisure activity, occupational activity, or IADL after primary TKA did not have an increased risk of revision arthroplasty. In addition, men reported more total historical physical activity than women in a pattern consistent with previous studies^{24,43,44}.

To our knowledge, this is the first study that quantified activity across the physical activity spectrum in a population with total knee replacement. Our study took the physical activity assessment one step further by quantifying the frequency, duration, and intensity of participation in a wide range of activities. Further, we were able to match the cases and controls on 4 important characteristics (age, sex, number of knees replaced, and date of primary TKA) that could potentially confound the relationship between physical activity and revision arthroplasty. Although surgeon and hospital characteristics have been reported to influence

outcomes after TKA^{25,45}, we chose not to match on these factors because they have not been linked to physical activity levels.

While physical activity was not related to revision arthroplasty, 2 other variables emerged as potential risk factors for revision surgery. Participants who reported a history of surgery in their knee before primary TKA were more likely to undergo revision arthroplasty than those who did not. Thus, prior surgery (e.g., arthrotomy or arthroscopy) may increase the risk of revision; however, this relationship is a complex issue and requires further study.

Participants who reported a reduction in their usual physical activity level after primary TKA were also more likely to undergo revision arthroplasty than those who reported that their activity levels were unchanged or had improved. Activity levels after knee replacement may have been related to the success of the surgery in restoring function⁴⁶. The cases may have curtailed their activity levels after primary TKA due to symptoms or functional limitations

associated with their knee. Because this was a retrospective study, data were not available on the preoperative functional status or attainment of postoperative rehabilitation milestones in the participants. Self-reported preoperative pain and functional status were not collected because patient recall of this information postoperatively has been found to have only poor to moderate agreement with information reported prospectively⁴⁷.

In the univariate analyses, participants with cementless femoral components implanted during primary TKA had a greater risk of revision arthroplasty than those with cemented components. Cementless prostheses generally have lower cumulative survival rates than cemented prostheses, and therefore have a greater risk of component loosening due to failure at the bone-implant interface^{15,48,49}.

The absence of a significant relationship between physical activity and revision arthroplasty may have been due to limited statistical power. Nevertheless, we were able to identify several potential risk factors for revision arthroplasty. More important, we were able to quantify and describe patterns of physical activity in an older population with total knee replacement. Participants with primary TKA (controls) consistently reported more MET-hours of leisure and occupational physical activity than participants with revision arthroplasty (cases) regardless of the number of knees replaced or whether or not walking was accounted for. With respect to the type of physical activities that were performed, there was not enough variability in our sample to examine the influence of high-impact activity on the need for revision arthroplasty.

Physical activity in this study was assessed by self-report, instead of direct evaluation, due to the retrospective design of the study. The physical activity estimates obtained by the questionnaires have been found to be reliable and valid, and allowed us to rank individuals within a group from the least to most active²². Because this was a retrospective study, the historical assessment of physical activity may have been subject to recall bias. The cases, who were interviewed after revision arthroplasty, may have remembered their past physical activity differently than the controls, who did not undergo a second surgery. To minimize any potential recall bias due to pain or recent surgery, we waited at least 3 months after revision arthroplasty before enrolling cases in the study. Recall of physical activity may also have been limited in the controls because the physical activity assessment period was framed by only one specific event (primary TKA), compared to 2 events in the cases (primary and revision TKA).

Based on these results, individuals undergoing primary TKA should be encouraged to remain active after surgery, especially women. Although there are no evidence-based guidelines available for determining which activities are appropriate after surgery, there is general agreement on the recommendation for participation in lower intensity and

low-impact activities, with avoidance of high-impact activities^{6,17,21,50}. Most of the activity reported in this study was of low impact and low or moderate intensity.

Although physical activity was not a significant risk factor for revision arthroplasty in this study, individuals with primary TKA (controls) consistently reported more leisure and occupational activity than those with revision TKA (cases). Further research is required to confirm this observation.

ACKNOWLEDGMENT

We thank Edward J. McClain III, MD; Raj K. Sinha, MD, PhD; Peter Z. Cohen, MD; Anthony M. DiGioia III, MD; Mark A. Goodman, MD; Rodney G. Gordon, MD; Gregory L. Hung, MD; Paul H. Resnick, MD; and Spiro N. Papas, MD, for their assistance in identifying potential participants for this study. We also thank Elizabeth Dames, Keelan R. Enseki, Sheri Anne Hale, Jayme Elizabeth Klein, and Brian M. Klucinec for their assistance with data collection.

REFERENCES

1. Yang SS, Nisonson B. Arthroscopic surgery of the knee in the geriatric patient. *Clin Orthop Rel Res* 1995;316:50-8.
2. Hannan MT, Felson DT, Anderson JJ, Naimark A, Kannel WB. Estrogen use and radiographic osteoarthritis of the knee in women. The Framingham Osteoarthritis Study. *Arthritis Rheum* 1990;33:525-32.
3. Mancuso CA, Ranawat CS, Esdaile JM, Johanson NA, Charlson ME. Indications for total hip and total knee arthroplasties. Results of orthopaedic surveys. *J Arthroplasty* 1996;11:34-46.
4. Dieppe P, Basler HD, Chard J, et al. Knee replacement surgery for osteoarthritis: effectiveness, practice variations, indications, and possible determinants of utilization. *Rheumatology* 1999;38:73-83.
5. Belmar CJ, Barth P, Lonner JH, Lotke PA. Total knee arthroplasty in patients 90 years of age and older. *J Arthroplasty* 1999;14:911-4.
6. Diduch DR, Insall JN, Scott NW, Scuderi GR, Font-Rodriguez D. Total knee replacement in young, active patients: long-term follow-up and functional outcome. *J Bone Joint Surg Am* 1997;79:575-82.
7. Gill GS, Chan KC, Mills DM. 5- to 18-year follow-up study of cemented total knee arthroplasty for patients 55 years old or younger. *J Arthroplasty* 1997;12:49-54.
8. Spector TD, Hart DJ. How serious is knee osteoarthritis. *Ann Rheum Dis* 1992;51:1105-6.
9. Callahan CM, Drake BG, Heck DA, Dittus RS. Patient outcomes following tricompartmental total knee replacement: a meta-analysis. *JAMA* 1994;271:1349-57.
10. Heck DA, Clingman JK, Kettelkamp DG. Gross polyethylene failure in total knee arthroplasty. *Orthopedics* 1992;15:23-8.
11. Lonner JH, Siliski JM, Scott RD. Prodromes of failure in total knee arthroplasty. *J Arthroplasty* 1999;14:488-92.
12. Rathjen KW. Surgical treatment: total knee arthroplasty. *Am J Knee Surg* 1998;11:58-63.
13. Heck DA, Melfi CA, Mamlin LA, et al. Revision rates after knee replacement in the United States. *Med Care* 1998;36:661-9.
14. Johnson GVV, Worland RL, Keenan J, Norambuena N. Patient demographics as a predictor of the ten-year survival rate in primary total knee replacement. *J Bone Joint Surg Br* 2003;85:52-6.
15. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. *J Bone Joint Surg Am* 2003;85:259-65.
16. Hilding MB, Ryd L, Toksvig-Larsen S, Mann A, Stenström A. Gait affects tibial component fixation. *J Arthroplasty* 1999;14:589-93.

17. McGrory BJ, Stuart MJ, Sim FH. Participation in sports after hip and knee arthroplasty: review of literature and survey of surgeon preferences. *Mayo Clin Proc* 1995;70:342-8.
18. McClung CD, Zehiri CA, Higa JK, Amstutz HC, Schmalzried TP. Relationship between body mass index and activity in hip or knee arthroplasty patients. *J Orthop Res* 2000;18:35-9.
19. Mancuso CA, Sculco TP, Wickiewicz TL, et al. Patients' expectations of knee surgery. *J Bone Joint Surg Am* 2001;83:1005-12.
20. Mallon WJ, Callaghan JJ. Total knee arthroplasty in active golfers. *J Arthroplasty* 1993;8:299-306.
21. Bradbury N, Borton D, Spoo G, Cross MJ. Participation in sports after total knee replacement. *Am J Sports Med* 1998;26:530-5.
22. Pereira MA, Fitzgerald SJ, Gregg EW, et al. A collection of Physical Activity Questionnaires for health-related research. *Med Sci Sports Exerc* 1997;29 Suppl 6:S1-205.
23. Zehiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty* 1998;13:890-5.
24. Schmalzried TP, Szuszczewicz ES, Northfield MR, et al. Quantitative assessment of walking activity after total hip or knee replacement. *J Bone Joint Surg Am* 1998;80:54-9.
25. Heck DA, Robinson RL, Partridge CM, Lubitz RM, Freund DA. Patient outcomes after knee replacement. *Clin Orthop Rel Res* 1998;356:93-110.
26. US Department of Health and Human Services, Public Health Service. Healthy People 2000 National Health Promotion and Disease Prevention Objectives. Washington, DC: US Department of Health and Human Services; 1990.
27. American Academy of Orthopaedic Surgeons, American Association of Hip and Knee Surgeons, American Orthopaedic Society for Sports Medicine, et al. Lower limb questionnaire. Version 2000. [Internet. Cited May 3, 2004] Available from: www3.aaos.org/research/normstdy/lwintr.cfm
28. Hunsaker FG, Cioffi DA, Amadio PC, et al. The American Academy of Orthopaedic Surgeons outcomes instruments: Normative values from the general population. *J Bone Joint Surg Am* 2002;84:208-15.
29. Sangha O, Stucki G, Fossel AH, Katz JN. A simplified method to assess comorbidity in clinical and health services research of rheumatic diseases [abstract]. *Arthritis Rheum* 1995;38 Suppl:S177.
30. Sangha O, Stucki G, Liang MH, Fossel AH, Katz JN. The Self-Administered Comorbidity Questionnaire: A new method to assess comorbidity for clinical and health services research. *Arthritis Rheum* 2003;49:156-63.
31. Kriska AM, Knowler WC, LaPorte RE, et al. Development of a questionnaire to examine relationship of physical activity and diabetes in Pima Indians. *Diabetes Care* 1990;13:401-7.
32. Kriska AM, Sandler KB, Cauley JA, LaPorte RE, Hom DL, Pambianco G. The assessment of historical physical activity and its relation to adult bone parameters. *Am J Epidemiol* 1988;127:1053-63.
33. Ainsworth BE, Haskell WL, Leon AS, et al. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* 1993;25:71-80.
34. Durnin JVGA, Passmore R. Energy, work, and leisure. London: Heinemann Educational Books Ltd.; 1967.
35. Passmore R, Durnin JVGA. Human energy expenditure. *Physiol Rev* 1955;35:801-40.
36. Wilson PWF, Paffenbarger RS Jr, Morris JN, Havlik RJ. Assessment of methods for physical activity and physical fitness in population studies: a report of a NHLBI workshop. *Am Heart J* 1986;111:1177-93.
37. DiPietro L, Caspersen CJ, Ostfeld AM, Nadel ER. A survey for assessing physical activity among older adults. *Med Sci Sports Exerc* 1993;25:628-42.
38. Kilgus DJ, Dorey FJ, Finerman GA, Amstutz HC. Patient activity, sports participation, and impact loading on the durability of cemented total hip replacements. *Clin Orthop Rel Res* 1991;269:25-31.
39. Jakes RW, Khaw KT, Day NE, et al. Patterns of physical activity and ultrasound attenuation by heel bone among Norfolk cohort of European Prospective Investigation of Cancer (EPIC Norfolk): population based study. *BMJ* 2001;322:140.
40. Taylor HL, Jacobs DR Jr, Schucker B, Knudsen J, Leon AS, Debacker G. A questionnaire for the assessment of leisure time physical activities. *J Chron Dis* 1978;31:741-55.
41. Blair SN, Haskell WL, Ho P, et al. Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. *Am J Epidemiol* 1985;122:794-804.
42. Hosmer DW, Lemeshow S. Applied logistic regression. 2nd ed. New York: John Wiley & Sons; 2000.
43. Caspersen CJ, Christenson GM, Pollard RA. Status of the 1990 physical fitness and exercise objectives — Evidence from NHIS 1985. *Publ Health Reports* 1986;101:587-92.
44. Stephens T, Jacobs DR Jr, White CG. A descriptive epidemiology of leisure-time physical activity. *Publ Health Reports* 1985;100:147-58.
45. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright J, Losina E. Association between volume and perioperative outcomes of primary and revision total knee replacement [abstract]. *Arthritis Rheum* 2003;48 Suppl:S220.
46. Jones DL, Cauley JA, Kriska AM, et al. The role of physical activity on the need for revision total knee arthroplasty in individuals with osteoarthritis of the knee. Pittsburgh: University of Pittsburgh; 2001.
47. Lingard EA, Wright EA, Sledge CB, Kinemax Outcomes Group. Pitfalls of using patient recall to derive preoperative status in outcome studies of total knee arthroplasty. *J Bone Joint Surg Am* 2001;83:1149-56.
48. Lotke PA, Garino JP. Revision total knee arthroplasty. Philadelphia: Lippincott-Raven Publishers; 1999.
49. Robertsson O, Knutson K, Lewold S, Lidgren L. The Swedish Knee Arthroplasty Register 1975-1997: An update with special emphasis on 41,223 knees operated on in 1988-1997. *Acta Orthop Scand* 2001;72:503-13.
50. Ritter MA, Eizember LE, Fechtman RW, Keating EM, Faris PM. Revision total knee arthroplasty. A survival analysis. *J Arthroplasty* 1991;6:351-6.