Published in final edited form as:
J Arthroplasty. 2011 April ; 26(3): 366–374.e1. doi:10.1016/j.arth.2010.02.006.

Higher Body Mass Index Is Not Associated with Worse Pain Outcomes After Primary or Revision Total Knee Arthroplasty (TKA)

Jasvinder A. Singh[1,2,3,4], **Sherine Gabriel**[1], and **David G. Lewallen**[2]

[1]Department of Health Sciences Research, Mayo Clinic School of Medicine, Rochester, Minnesota, USA

[2]Department of Orthopedic Surgery, Mayo Clinic School of Medicine, Rochester, Minnesota, USA

[3]Rheumatology Section, Medicine Service, VA Medical Center, Birmingham, Alabama, USA

[4]Division of Rheumatology, Department of Medicine, University of Alabama at Birmingham, Alabama, USA

Abstract

We assessed whether higher Body Mass Index (BMI) is associated with higher risk of moderate-severe knee pain 2- and 5-years after primary or revision Total Knee Arthroplasty (TKA). We adjusted for gender, age, comorbidity, operative diagnosis and implant fixation in multivariable logistic regression. BMI (reference, <25 kg/m^2) was not associated with moderate-severe knee pain at 2-years post-primary TKA (odds ratio (95% confidence interval): 25-29.9, 1.02 (0.75,1.39), p=0.90; 30-34.9, 0.93 (0.65,1.34), p=0.71; 35-39.9, 1.16 (0.77,1.74), p=0.47; ≥40, 1.09 (0.69,1.73), (all p-values ≥0.47). Similarly, BMI was not associated with moderate-severe pain at 5-year primary TKA and at 2- and 5-yr revision TKA follow-up. Lack of association of higher BMI with poor pain outcomes post-TKA implies that TKA should not be denied to obese patients for fear of suboptimal outcomes.

In the U.S., the number of Total Knee Arthroplasty (TKA) procedures is projected to grow by 673% from 0.5 million in 2005 to 3.48 million by 2030 [1]. Identification of predictors of sub-optimal outcomes post-TKA is important, since this information can help patients to have realistic expectations, and can allow surgeons to risk-stratify patients for pain outcomes, while searching for modifiable factors or interventions that might improve outcomes. Many important outcome predictors may be modifiable such as comorbidity and body mass index (BMI), while others such as gender and age are obviously not modifiable. Among the patient-reported outcomes after TKA, pain is perhaps the most important outcome [2].

Prior reports regarding predictors of outcomes following TKA had contradictory findings. Higher body mass index (BMI) was associated with worse post-TKA function/HRQoL outcomes in some studies [3-6], but not others [7-14]. With the exception of one study that examined pain as an outcome and found a borderline association of higher BMI with more pain (p=0.049), others were limited to function and HRQoL assessment. Pain is the most important reason for patients undergoing TKA and it is important to understand whether important factors such as higher BMI and comorbdiity impact pain outcomes post-TKA. Similarly, higher comorbidity was associated with worse post-TKA function/Health-related quality of life (HRQoL) outcomes in some [5,6,15], but not other studies [9,10,13,16,17]. Previously published studies have many limitations. First, the small sample sizes of most previous TKA studies, a highly successful surgery with low failure rate (few patients with severe pain, severe functional limitation or revision), makes them liable to type-II error, i.e., low power. Many studies did not include important covariates such as BMI and comorbidity in multivariable-adjusted analyses, limiting their interpretation. Most studies were also limited to short follow-up (<1 year). Recent data has revealed that knee pain continues to improve up to 1-year after knee arthroplasty [18]. Therefore, well-designed prospective studies of post-TKA that follow an adequate sample of patients for a duration of at least 2-5 years are needed to improve our understanding of short- and intermediate-term pain outcome post-TKA.

Gender was reportedly associated with pain outcome in some studies [6,15,17], but not associated in others [9,10,13,16,18-21]. Age associations were positive in some studies [6,19,20], but not others [10,16,18,21-23].

A 2003 NIH consensus statement on TKA concluded that "Research also should identify the patient-level factors affecting outcomes after surgery, including medical and sociodemographic characteristics……" [24]. We therefore conducted multivariable analyses to examine 12-year prospectively-collected data from the Mayo Clinic Total Joint registry. We hypothesized that BMI would be a significant predictor of moderate-severe knee pain 2- and 5- years post-primary TKA surgery, and 2- and 5-years post-revision TKA surgery, after adjusting for important confounders. Our secondary hypotheses were that higher comorbidity would predict worse pain outcomes and that our previously observed associations of age and gender with pain outcomes post-TKA [25] will be significant, after adjusting for additional important confounders.

METHODS

The Mayo Clinic Total Joint Registry prospectively captures data for all patients undergoing TKA using a validated standardized institutional questionnaire administered to patients by mail, phone call, or during an in-person clinic visit at 2- and 5-year time-points post-arthroplasty. These questionnaires have construct validity and reproducibility [26] and include questions assessing pain and function. This questionnaire is similar to the Knee Society Scale [27], a commonly used reasonably validated scale.

Eligibility Criteria

Patients were eligible for inclusion in this study if they had undergone a primary or revision TKA during 1993-2005 and were alive at the time of follow-up. Patient questionnaire data were used if the questionnaire was received within 6 months of their 2- or 5-year follow-up, subsequent to TKA (responders).

Predictors of Interest and Covariates

The main predictor of interest was BMI. Additional predictors of interest were comorbidity,,gender and age. The following information was abstracted from the registry: (1) demographic characteristics: age (categorized as ≤60, >60-70, >70-80, >80), gender, and body mass index (categorized as <25 (<18.5 collapsed into 18.5-24.9 category due to small numbers), overweight, 25-29.9, obese, 30-34.9, very obese, 35-39.9, or extremely obese, ≥40 as previously (8), as per WHO classification [28]); (2) Operative diagnosis:

osteoarthritis, rheumatoid/inflammatory arthritis, or other (avascular necrosis, fracture etc.) for primary TKA; loosening/wear/osteolysis, dislocation/bone or prosthesis fracture/instability/non-union or failed prior arthroplasty with components removed/infection; and (3) implant fixation: cemented or uncemented/hybrid for primary TKA only.

American Society of Anesthesiology (ASA) Physical Status score, categorized as class I-II vs. III-IV [29], a validated measure of peri-operative mortality and immediate post-operative morbidity [29,30], was retrieved by a database managed by the Department of Anesthesiology. Comorbidity was assessed by the Deyo-Charlson index [31], a validated measure of comorbidity, consisting of a weighted scale of 19 comorbidities (including cardiac, pulmonary, renal, hepatic disease, diabetes, cancer, hemiplegia, HIV etc.), expressed as a summative score [32,33]. It was calculated using diagnosis codes collected in Mayo Clinic's Hospital Adaptation of International Code for Diseases (H-ICDA) codes up to the index TKA [34]. Distance from medical center (0-100 miles, >100-500 miles, >500 miles) was calculated by using zip codes and country codes from the patients' registration records at the time of surgery (if available) or at present. Income category was calculated based on zip code using the census data for median household income for county from the respective year of surgery; categorized as ≤$35K, >$35K- $45K or >$45 K. Confounders/covariates chosen have been shown to impact post-TKA outcomes, including underlying condition [35], comorbidity [5,6,15], implant fixation [36], ASA score [37,38] and income [39]. Distance from medical center was included as a covariate, since Mayo Clinic is a tertiary referral center providing care to local as well as patients travelling from distance and these patients may differ in complexity and in the risk for poorer outcome.

Of the survey responders at 2- or 5-year follow-up, approximately half to two-thirds had also completed a similar pre-surgery questionnaire, since this is a clinical registry. Due to potential for further non-response bias, these were not included in the final multivariable models, but assessed in separate univariate analyses (appendix 1). These included: (1) pre-operative pain (moderate/severe vs. no/mild pain/walking and stairs/stairs only); (2) pre-operative functional limitation (moderate/severe vs. no/mild limitation); and (3) presence of ipsilateral hip joint involvement at follow-up.

Outcome of Interest

Patients answered the following pain question with nominal responses: "Do you have pain in the knee in which the joint was replaced?" The responses were: no pain, mild (occasional), stairs only, walking and stairs (all combined into reference category); moderate (occasional), moderate (continuous) and severe categories - combined into outcome variable, moderate-severe pain (2- and 5-years post-primary and post-revision TKA). This was based on an a priori clinical decision of the experienced orthopedic surgeon and the clinician, that moderate-severe knee pain after TKA was an undesired outcome. This question is similar to the pain question on the Knee Society Scale (KSS).

Statistical Analyses

All analyses were performed using logistic regression using a generalized estimating equations (GEE) approach to adjust the standard errors for the correlation between observations on the same subject due to both knees having been replaced and/or multiple operations on the same knee. Univariate models were used to assess the association between baseline demographic variables (BMI, age, gender, Deyo-Charlson Index, ASA score, median income, distance to the medical center and operative diagnosis), and whether a relevant questionnaire was received from the patient, i.e. responder assessment.

Univariate and multivariable models were used to assess the association of BMI, Deyo-Charlson Index, gender and age with the odds of moderate-severe pain (relative to none/mild/stairs/walking and stairs) at both 2- and 5-years post-primary and post-revision TKA. The main multivariable model included ASA score, implant fixation (for primary only), distance from medical center and operative diagnosis (**model 1**). To test the robustness of associations, we performed additional sensitivity analyses. Since income has been associated with TKA outcomes in one study [36], we performed additional multivariable regression analyses, which included the variables previously mentioned, as well as income category, categorized as ≤$35K, >$35K - $45K, >$45K (**model 2**). Another alternative model similar to **model 1** was analyzed by considering BMI and age as continuous (rather than categorical), again done for each time point and type of TKA (**model 3**). Another model adjusted for pre-operative pain severity (**model 4**). Odds ratios (ORs), 95% confidence intervals (CIs), and p-values are reported. The alpha-level was set at 0.05 for statistical significance.

Results are presented from multivariable models1 and 2 and since multivariable model 3 did not change any interpretation, these data are not shown.

RESULTS

Patient Characteristics and Non-Response Bias

Of the 11,294 primary TKAs, 10,957 were alive at 2-year follow-up; of these, 7,139 (65%) had completed a 2-year questionnaire, with 4,701 (43%) having completed both preoperative and 2-year questionnaires. 7,404 were alive and eligible for 5-year follow-up, with 4,234 (57%) having completed 5-year questionnaires, with 2,935 (40%) having completed both preoperative and 5-year questionnaires.

Of the 2,800 revision TKAs, 2,695 were alive and eligible for 2-year follow-up. Fifteen hundred thirty-three (57%) had completed a 2-year questionnaire, with 725 (27%) of these having both preoperative and 2-year questionnaires. 1,842 patients were alive and eligible for 5-year follow-up, with 881 (48%) having completed a 5-year questionnaire, with 393 (21%) having both preoperative and 5-year follow-up questionnaires.

For primary TKA 2- and 5-year follow-up, men and those with osteoarthritis were slightly more likely to respond and older age was associated with significantly greater odds of response (Appendix 1). Higher ASA class of 3 or 4 and higher Deyo-Charlson comorbidity index score were associated with slightly lower and distance of >500 miles from the Mayo Clinic with much lower odds of response. However, since only 9% of patients lived 500 miles or further, we postulated that estimates of association are unlikely to be affected by non-response based on distance from the center. Similar patterns were noted for revision TKA patients (Appendix 1).

Baseline Characteristics

Primary and revision TKA patients responding to the questionnaire had a mean age of 68 and 69 years, most were overweight (86-87%), with equal male:female distribution (Table 1). Osteoarthritis was the commonest underlying diagnosis in patients with primary TKA, 94% and 93% at 2- and 5-years, and loosening/wear/osteolysis in revision TKA, 57% and 61% and 2- and 5-years. 20% of primary TKAs at 2- and 23% at 5-years were simultaneous bilateral procedures.

The overall proportion of TKAs with moderate-severe pain was as follows: 2-year post-primary TKA, 7.3%; 5-year post-primary TKA, 8.1%; 2-year post-revision TKA, 22.2%; and 5-year post-revision TKA, 24.5%. The prevalence of moderate-severe pain was significantly higher at 2-years (p<0.0001) and 5-years (p<0.0001) post-revision TKA, compared to primary TKA.

BMI did not Independently Predict Moderate/Severe Pain after Primary TKA

Univariate and multivariable model estimates of the odds for moderate-severe pain 2-year post-primary TKA are shown in Table 2. Multi-variable adjusted estimates showed that BMI was not significantly associated with higher odds of moderate-severe knee pain at 2-year post-primary TKA (Table 2). Higher comorbidity, female gender and younger age were each significantly associated. Multivariable models with income (Table 2) or with BMI and age as continuous variables (data not shown) did not result in any meaningful change in odds ratios. After adjusting for pre-operative pain, comorbidity and younger age were still associated, and gender was not. Other variables significantly associated with higher odds of moderate-severe knee pain at 2-years were increased distance from medical center and use of a hybrid implant (data not shown).

At 5-years post-primary TKA, BMI was not significantly associated (Table 3). Older age showed lower odds, but results varied from borderline significance to non-significant (Table 3). Women had significantly higher odds of reporting moderate-severe knee pain, but comorbidity was not associated. Multivariable models with income (Table 3) or with BMI and age as continuous variables (data not shown) showed similar estimated odds of moderate-severe knee pain. After adjusting for pre-operative pain, gender was still significantly associated. Other variables significantly associated with higher odds of moderate-severe knee pain at 5-years were a higher ASA class of III or IV, increased distance from the medical center, and a hybrid or uncemented implant (data not shown).

BMI did not Independently Predict Moderate/Severe Pain after Revision TKA

BMI, comorbidity and gender were not significantly associated (Table 4). Older age, 61-70, 71-80 and >80 year (vs. <60), were associated with significantly lower odds of moderate-severe knee pain 2-years post-revision TKA. Multivariable models with income (Table 4) or with BMI and age as continuous variables (data not shown) showed similar results. Adjustment for pre-operative pain did not impact the age associations. Other variables significantly associated with higher odds were greater distance from the medical center or an underlying diagnosis of dislocation/fracture/instability/non-union (data not shown).

BMI, gender and comorbidity were not significantly associated (Table 5). Older age, 61-70 and 71-80 years was associated with significantly lower odds of moderate-severe knee pain at 5-years. Multivariable models with income (Table 5) or with BMI and age as continuous variables (data not shown) showed similar results. Due to small number of events, multivariable model could not adjust for pre-operative pain. Other variables significantly associated with higher odds were greater distance or diagnosis of dislocation/fracture/instability/ non-union (data not shown).

DISCUSSION

In this study, we describe one of the largest U.S. cohort of TKA patients followed for patient-reported pain outcomes. We found that a higher BMI was not associated with worse pain outcomes 2- and 5-years after primary or revision TKR. Higher comorbidity was associated with a greater likelihood of moderate-severe pain at 2-years. This study also confirmed our previous findings of association of female gender and younger age with moderate-severe pain at both 2- and 5-years after primary TKA [25]. We found that older patients were less likely to report moderate-severe pain 2- and 5-years after revision TKA. Other factors associated with moderate-severe pain following knee arthroplasty implant fixation (uncemented or hybrid) for primary TKA, the underlying diagnosis for revision TKA and greater distance from the medical center, for both. Uncemented knees have a higher rates of aseptic loosening [40] and revision than cemented knees [41,42], which may explain the higher prevalence of moderate or severe pain in patients receiving non-cemented implants.

One of the most remarkable finding in our study is that obesity was not associated with any higher prevalence of moderate-severe pain in either primary or revision TKA patients at 2- or 5-year follow-up. Previously published literature regarding BMI and TKA outcomes is contradictory. Most previous studies have examined the association of BMI with summary scores (not pain), mostly using the Knee Society Scale (KSS) total and objective/subjective scores, with most reporting lack of association [7-14], while few were positive [3-6]. All previous studies had <600 patients. The limited sample size in previous studies precluded use of WHO-recommended BMI categories. Most studies collapsed many BMI categories due to small number of poor outcomes. We are aware of only one small study of 67 TKA patients that examined association of obesity with pain outcomes [17]. BMI of 35-39.9 was significantly associated with pain scores (p=0.049) in multivariable-adjusted models that included age, gender and comorbidity [17]. Our study results are in contrast to this previous study, likely due to differences in patient population (67 years, 50% female vs. 75 years, 80% female), sample size (>800 patients for each of the four cohorts vs. 67 patients), covariates in multivariable model (income, distance, implant fixation vs. intra-operative, surgical, in-patient and postoperative clinical variables), or the type of regression analyses (model including all covariates vs. step-wise regression).

The large study sample size provided us with adequate number of patients in each BMI category (vs. 8 patients in previous study with BMI 35-39.9) to examine the link between presence and severity of obesity and pain. Our results and interpretations did not change depending on how the BMI was examined as a predictor in the analyses (i.e continuous or categorical). Due to a large sample size, negative findings are very unlikely due to type II error (i.e. missing an effect, when one exists due to lack of power). Our study adds to the post-primary TKA literature by showing that obesity is not associated with any higher risk of moderate-severe pain during short-intermediate-term follow-up post-TKA. To our knowledge, the findings of lack of BMI association with pain outcomes 2- and 5-years after revision TKA are new and add to existing knowledge of pain predictors. Several previous studies of smaller sample size have also reported similar HRQoL outcomes in patients with obese and non-obese patients undergoing TKA. This implies that TKA can (and should) be offered to patients across the range of BMI without concern for significant variation of pain relief.

It is possible that patients with higher BMI have lower level of activity and therefore despite greater forces across the joint, less frequent weight-bearing occurs. Our findings should reassure patients and surgeons that obesity is not by itself a risk for poor pain outcomes after primary or revision TKA. In conjunction with our recent finding of association of BMI≥40 with higher activity limitation 2- and 5-years after revision TKA from this cohort [43], this implies that higher BMI has different impact on pain versus function outcomes.

Another important observation from this study is the positive association between comorbidity and pain outcomes at 2-year post-primary TKA. Our findings agree with some studies [5,6,15] and are in contrast to studies that found no association [9,10,13,16,18-21]. There were no meaningful differences between follow-up durations between the studies with positive association (1-2 years) versus those finding no association (0.5-5 years). A higher comorbidity is associated with poorer post-operative outcomes [30,44,45]. Higher prevalence of moderate-severe pain at 2-year post-TKA in patients with more comorbidities may be due to higher complication rates, higher risk of pain with comorbidities such as diabetes and/or lower tolerance to pain. Future studies need to examine whether specific diseases, disease severity at baseline or change in severity during follow-up predicts pain and HRQoL outcomes. If optimization of comorbidity can lead to a better outcome, this may be indicated before an elective procedure like arthroplasty.

We found that older patients reported less moderate-severe pain after primary TKA compared to younger patients. This is in contrast to many studies [10,16,18,21-23], but in agreement with others [6,19,20] and our previous observation [25]. In most previous studies, age has been examined mostly as a continuous variable, which assumes that the increase in risk is the same across each year of increased age across the entire age spectrum. It is also difficult to interpret higher risk per 1-year increase in age. Two of the positive studies categorized age and reported that patients ≥75 years had better pain outcomes at 1-year [20] and <60 years worse pain outcomes at 5-years post-primary TKA [19]. We confirm these findings in a much larger cohort and extend them to other older age groups.

To our knowledge age associations have not been reported in detail in previous studies of revision TKA. Our findings in revision TKA add to the current literature: patients aged 61-70 years had better pain outcome at 2- and 5-years; 71-80 year-olds had better pain outcome at 2-years; and those older than 80 years had better pain at 2-years post-revision TKA. In fact, age had a consistent strong relationship with moderate-severe pain at both time-points in both primary and revision TKA. This may be due to lower activity level, better pain-coping skills and/or more self-efficacy in older patients.

It is not surprising that moderate-severe pain was found to be more prevalent after revision than after primary TKA in our study. This is similar to previously reported better HRQoL in patients with primary versus revision total hip arthroplasty [46]. Our study extends these findings to patients with TKAs.

Our study has several strengths and limitations. We report on the largest cohort of patients followed up to 5-years for clinical outcome and pain to date, (to our knowledge). As a result we have robust estimates of association allowing for the control of many important clinical and socio-demographic confounders/covariates. On the other hand, we were unable to control for pre-operative knee pain severity as was data available in only half of the sample, which could have lead to selection bias [15,18] We also were unable to control for the presence of anxiety/depression. Being a tertiary referral center, we did not think these would be accurately or completely captured in our records. Both preop pain and anxiety/depression are considered important predictors of post-operative pain and HRQoL and would be valuable additions to future studies.. The response rate for 2-year follow-up of 57-65%, although not perfect, is similar to that reported in large surveys of this size [47], and may even be considered very good for a clinical follow-up, considering this is for *every patient operated over 12-years*. Our estimates may be somewhat biased due to non-response; however, since non-responders were more likely to be female, and younger (associated with poorer pain outcome), our estimates are conservative and the differences would at least be as large or larger had all eligible patients responded. Despite a large sample size, the number of responders was lower at 5-years (than 2-year), making the 5-year estimates less precise. Our findings need to be confirmed in other large patient cohorts.

In conclusion, we found that obesity was not associated with worse pain outcomes after primary or revision TKA. Three-fold more patients report moderate-severe pain after revision compared to patients with primary TKA over the first five years after the surgery. Higher comorbidity predicted worse pain outcome after primary TKA. Female gender and younger age predicted worse pain outcome after primary TKA and younger age after revision TKA. A better understanding of patient- or disease-related factors that impact post-arthroplasty pain can help us better inform patients before surgery and in the case of modifiable predictors, assist efforts to target interventions or preventive programs to improve these outcomes. Further studies are needed to better understand these relationships.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We thank Scott Harmsen and Megan O'Byrne of the Mayo Clinic for their assistance in data extraction, programming and statistical analyses. We thank Ruth Brady, Amy Anderson and Perlita Ochoa of the Minneapolis VA medical center for their administrative assistance.

REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the united states from 2005 to 2030. J Bone Joint Surg Am. 2007; 89:780–5. [PubMed: 17403800]
2. Singh JA, Sloan JA. Challenges with health-related quality of life (hrqol) assessment in arthroplasty patients: Problems and solutions. Journal of American Academy of Orthopaedic Surgeons. 2009 (In Press).
3. Foran JR, Mont MA, Etienne G, Jones LC, Hungerford DS. The outcome of total knee arthroplasty in obese patients. J Bone Joint Surg Am. 2004; 86-A:1609–15. [PubMed: 15292406]
4. Foran JR, Mont MA, Rajadhyaksha AD, Jones LC, Etienne G, Hungerford DS. Total knee arthroplasty in obese patients: A comparison with a matched control group. J Arthroplasty. 2004; 19:817–24. [PubMed: 15483795]
5. Rajgopal V, Bourne RB, Chesworth BM, Macdonald SJ, McCalden RW, Rorabeck CH. The impact of morbid obesity on patient outcomes after total knee arthroplasty. J Arthroplasty. 2008
6. Fisher DA, Dierckman B, Watts MR, Davis K. Looks good but feels bad: Factors that contribute to poor results after total knee arthroplasty. J Arthroplasty. 2007; 22:39–42. [PubMed: 17823013]
7. Amin AK, Clayton RA, Patton JT, Gaston M, Cook RE, Brenkel IJ. Total knee replacement in morbidly obese patients. Results of a prospective, matched study. J Bone Joint Surg Br. 2006; 88:1321–6. [PubMed: 17012421]
8. Griffin FM, Scuderi GR, Insall JN, Colizza W. Total knee arthroplasty in patients who were obese with 10 years followup. Clin Orthop Relat Res. 1998:28–33. [PubMed: 9917664]
9. Hawker G, Wright J, Coyte P, et al. Health-related quality of life after knee replacement. J Bone Joint Surg Am. 1998; 80:163–73. [PubMed: 9486722]
10. Jones CA, Voaklander DC, Johnston DW, Suarez-Almazor ME. The effect of age on pain, function, and quality of life after total hip and knee arthroplasty. Arch Intern Med. 2001; 161:454–60. [PubMed: 11176772]
11. Krushell RJ, Fingeroth RJ. Primary total knee arthroplasty in morbidly obese patients: A 5- to 14-year follow-up study. J Arthroplasty. 2007; 22:77–80. [PubMed: 17823021]
12. Mont MA, Mathur SK, Krackow KA, Loewy JW, Hungerford DS. Cementless total knee arthroplasty in obese patients. A comparison with a matched control group. J Arthroplasty. 1996; 11:153–6. [PubMed: 8648308]
13. Naylor JM, Harmer AR, Heard RC. Severe other joint disease and obesity independently influence recovery after joint replacement surgery: An observational study. Aust J Physiother. 2008; 54:57–64. [PubMed: 18298360]
14. Spicer DD, Pomeroy DL, Badenhausen WE, et al. Body mass index as a predictor of outcome in total knee replacement. Int Orthop. 2001; 25:246–9. [PubMed: 11561501]
15. Lingard EA, Katz JN, Wright EA, Sledge CB. Predicting the outcome of total knee arthroplasty. J Bone Joint Surg Am. 2004; 86-A:2179–86. [PubMed: 15466726]

16. Fortin PR, Clarke AE, Joseph L, et al. Outcomes of total hip and knee replacement: Preoperative functional status predicts outcomes at six months after surgery. Arthritis Rheum. 1999; 42:1722–8. [PubMed: 10446873]
17. Nunez M, Nunez E, Segur JM, et al. Health-related quality of life and costs in patients with osteoarthritis on waiting list for total knee replacement. Osteoarthritis Cartilage. 2007; 15:258–65. [PubMed: 16962795]
18. Brander VA, Stulberg SD, Adams AD, et al. Predicting total knee replacement pain: A prospective, observational study. Clin Orthop Relat Res. 2003:27–36. [PubMed: 14646737]
19. Elson DW, Brenkel IJ. Predicting pain after total knee arthroplasty. J Arthroplasty. 2006; 21:1047–53. [PubMed: 17027550]
20. Fitzgerald JD, Orav EJ, Lee TH, et al. Patient quality of life during the 12 months following joint replacement surgery. Arthritis Rheum. 2004; 51:100–9. [PubMed: 14872462]
21. Roth ML, Tripp DA, Harrison MH, Sullivan M, Carson P. Demographic and psychosocial predictors of acute perioperative pain for total knee arthroplasty. Pain Res Manag. 2007; 12:185–94. [PubMed: 17717610]
22. Berend KR, Lombardi AV Jr. Adams JB. Obesity, young age, patellofemoral disease, and anterior knee pain: Identifying the unicondylar arthroplasty patient in the united states. Orthopedics. 2007; 30:19–23. [PubMed: 17549861]
23. Brander V, Gondek S, Martin E, Stulberg SD. Pain and depression influence outcome 5 years after knee replacement surgery. Clin Orthop Relat Res. 2007; 464:21–6. [PubMed: 17603386]
24. Nih consensus statement on total knee replacement december 8-10, 2003. J Bone Joint Surg Am. 2004; 86-A:1328–35. [PubMed: 15173310]
25. Singh JA, Gabriel S, Lewallen D. The impact of gender, age, and preoperative pain severity on pain after tka. Clin Orthop Relat Res. 2008; 466:2717–23. [PubMed: 18679762]
26. McGrory BJ, Morrey BF, Rand JA, Ilstrup DM. Correlation of patient questionnaire responses and physician history in grading clinical outcome following hip and knee arthroplasty. A prospective study of 201 joint arthroplasties. J Arthroplasty. 1996; 11:47–57. [PubMed: 8676118]
27. Lingard EA, Katz JN, Wright RJ, Wright EA, Sledge CB. Validity and responsiveness of the knee society clinical rating system in comparison with the sf-36 and womac. J Bone Joint Surg Am. 2001; 83-A:1856–64. [PubMed: 11741066]
28. WHO. Obesity; preventing and managing the global epidemic. Geneva: World health organization; 2000.
29. Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. JAMA. 1961; 178:261–6. [PubMed: 13887881]
30. Weaver F, Hynes D, Hopkinson W, et al. Preoperative risks and outcomes of hip and knee arthroplasty in the veterans health administration. J Arthroplasty. 2003; 18:693–708. [PubMed: 14513441]
31. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with icd-9-cm administrative databases. J Clin Epidemiol. 1992; 45:613–9. [PubMed: 1607900]
32. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. J Chronic Dis. 1987; 40:373–83. [PubMed: 3558716]
33. Charlson ME, Sax FL, MacKenzie CR, Braham RL, Fields SD, Douglas RG Jr. Morbidity during hospitalization: Can we predict it? J Chronic Dis. 1987; 40:705–12. [PubMed: 3110198]
34. Commission on professional and hospital activities, hospital adaptation of icda. 2nd ed. Vol. Vol. 1. Commission on Professional and Hospital Activities; Ann Arbor, MI: 1973.
35. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS. Factors affecting the durability of primary total knee prostheses. J Bone Joint Surg Am. 2003; 85-A:259–65. [PubMed: 12571303]
36. Jones CA, Voaklander DC, Suarez-Alma ME. Determinants of function after total knee arthroplasty. Phys Ther. 2003; 83:696–706. [PubMed: 12882610]
37. Schneider M, Kawahara I, Ballantyne G, et al. Predictive factors influencing fast track rehabilitation following primary total hip and knee arthroplasty. Arch Orthop Trauma Surg. 2009

38. Gordon SM, Culver DH, Simmons BP, Jarvis WR. Risk factors for wound infections after total knee arthroplasty. Am J Epidemiol. 1990; 131:905–16. [PubMed: 2321631]

39. Agabiti N, Picciotto S, Cesaroni G, et al. The influence of socioeconomic status on utilization and outcomes of elective total hip replacement: A multicity population-based longitudinal study. Int J Qual Health Care. 2007; 19:37–44. [PubMed: 17159197]

40. Chockalingam S, Scott G. The outcome of cemented vs. Cementless fixation of a femoral component in total knee replacement (tkr) with the identification of radiological signs for the prediction of failure. Knee. 2000; 7:233–8. [PubMed: 11104915]

41. Duffy GP, Berry DJ, Rand JA. Cement versus cementless fixation in total knee arthroplasty. Clin Orthop Relat Res. 1998:66–72. [PubMed: 9917669]

42. Robertsson O, Knutson K, Lewold S, Goodman S, Lidgren L. Knee arthroplasty in rheumatoid arthritis. A report from the swedish knee arthroplasty register on 4,381 primary operations 1985-1995. Acta Orthop Scand. 1997; 68:545–53. [PubMed: 9462354]

43. Singh JA, O'Bryne M, Harmsen S, Lewallen D. Predictors of moderate-severe functional limitation 2- and 5-years after revision total knee arthroplasty. J Arthroplasty. 2009 (In Press).

44. SooHoo NF, Lieberman JR, Ko CY, Zingmond DS. Factors predicting complication rates following total knee replacement. J Bone Joint Surg Am. 2006; 88:480–5. [PubMed: 16510811]

45. Wasielewski RC, Weed H, Prezioso C, Nicholson C, Puri RD. Patient comorbidity: Relationship to outcomes of total knee arthroplasty. Clin Orthop Relat Res. 1998:85–92. [PubMed: 9917672]

46. Patil S, Garbuz DS, Greidanus NV, Masri BA, Duncan CP. Quality of life outcomes in revision vs primary total hip arthroplasty: A prospective cohort study. J Arthroplasty. 2008; 23:550–3. [PubMed: 18514873]

47. Asch DA, Jedrziewski MK, Christakis NA. Response rates to mail surveys published in medical journals. J Clin Epidemiol. 1997; 50:1129–36. [PubMed: 9368521]

Table 1

Demographic and clinical characteristics of study cohort

	Primary TKA					Revision TKA			
	Entire Cohort		Cohort with both pre- and post-operative data			Entire Cohort		Cohort with both pre- and post-operative data	
	2-year (n=7139)	**5-year (n=4234)**	**2-year (n=4,701)**	**5-year (n=2,935)**		**2-year (n=1533)**	**5-year (n=881)**	**2-year (n=725)**	**5-year (n=393)**
Mean Age (±SD)	68±10	68±10	68±10	68±10		69±10	69±10	69±10	68±10
Men/Women (%)	44%/56%	45%/55%	44%/56%	45%/55%		49%/51%	51%/49%	51%/49%	53%/47%
Age groups n (%)									
≤60 yrs	18%	18%	18%	17%		20%	20%	19%	22%
>60-70 yrs	35%	37%	36%	39%		29%	31%	32%	29%
>70-80 yrs	38%	38%	38%	38%		42%	41%	40%	41%
>80 yrs	8%	7%	7%	6%		9%	8%	8%	7%
Body Mass index (in kg/m^2)									
<25	13%	13%	13%	13%		13%	14%	12%	11%
25-29.9	35%	36%	35%	36%		36%	39%	38%	38%
30-34.9	29%	43%	30%	30%		29%	27%	28%	29%
35-39.9	14%	7%	14%	14%		14%	14%	14%	14%
≥40	9%	7%	8%	7%		7%	5%	7%	7%
ASA Score									
Class I-II	58%	58%	59%	60%		50%	53%	55%	59%
Class III-IV	42%	41%	41%	40%		50%	47%	45%	41%
Cemented									
Yes	98%	99.5%	98%	99.7%					
Hybrid	2%	0.5%	2%	0.2%					
Underlying Diagnoses									

	Primary TKA					**Revision TKA**			
	Entire Cohort		**Cohort with both pre- and post-operative data**			**Entire Cohort**		**Cohort with both pre- and post-operative data**	
	2-year (n=7139)	**5-year (n=4234)**	**2-year (n=4,701)**	**5-year (n=2,935)**		**2-year (n=1533)**	**5-year (n=881)**	**2-year (n=725)**	**5-year (n=393)**
Rheumatoid Arthritis/ Other	4%	4%	3%	4%	Loosening/Wear or Osteolysis	57%	61%	62%	65%
Inflammatory arthritis conditions									
Osteoarthritis	94%	93%	95%	94%	Dislocation, Bone or Prosthesis Fracture, Instability, Non-Union	22%	20%	25%	24%
Other	2%	3%	2%	2%	Failed Prior Arthroplasty with Components Removed or Infection	21%	19%	13%	11%

Table 2

Association of BMI, comorbidity, age and gender with Moderate or Severe Knee Pain at 2-years post-Primary TKA.

		Univariate		Multivariable model 1		Multivariable model 2	
	n/N (%)	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
BMI (Ref, <25 kg/m^2)	70/916 (7.6%)						
25-29.9	166/2377 (7%)	0.91 (0.67,1.23)	0.53	1.02 (0.75,1.39)	0.91	1.02 (0.73,1.44)	0.90
30-34.9	132/2021 (6.5%)	0.84 (0.62,1.16)	0.29	0.95 (0.68,1.32)	0.75	0.93 (0.65,1.34)	0.71
35-39.9	75/949 (7.9%)	1.04 (0.73,1.48)	0.84	1.14 (0.78,1.66)	0.50	1.16 (0.77,1.74)	0.47
≥40	58/591 (9.8%)	1.32 (0.90,1.93)	0.16	1.27 (0.84,1.93)	0.26	1.09 (0.69,1.73)	0.71
Deyo-Charlson index (5-point increase)	n/a	1.23 (0.98,1.54)	0.08	**1.38 (1.09,1.74)**	**0.007**	**1.40 (1.09,1.79)**	**<.01**
Gender (Ref, Male)	184/3055 (6%)						
Female	321/3826 (8.4 %)	**1.43 (1.17,1.75)**	**<0.001**	**1.39 (1.12,1.71)**	**0.002**	**1.35 (1.08,1.70)**	**<.01**
Age (Ref, ≤60 yrs)	128/1278 (10 %)						
>60-70 yrs	153/2439 (6.3 %)	**0.60 (0.46,0.78)**	**<0.001**	**0.64 (0.48,0.84)**	**<0.001**	**0.66 (0.49,0.89)**	**<.01**
>.0170-80 yrs	172/2639 (6.5 %)	**0.63 (0.49,0.81)**	**<0.001**	**0.66 (0.50,0.88)**	**0.003**	**0.66 (0.49,0.90)**	**<.01**
>80 yrs	52/525 (9.9 %)	0.99 (0.70,1.40)	0.94	1.03 (0.70,1.52)	0.89	1.04 (0.69,1.57)	0.85

Multivariable model 1 adjusted for: gender, age, Deyo-Charlson index, BMI, ASA score, distance from medical center, operative diagnosis, type of implant (cemented, uncemented, hybrid); Multivariable model 2 = Model 1 plus **income category**

Table 3

Association of BMI, comorbidity, age and gender with Moderate or Severe Knee Pain at 5-years post-Primary TKA.

		Univariate		Multivariable model 1		Multivariable model 2	
	n/N (%)	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
BMI (Ref, <25 kg/m^2)	41/544 (7.5%)						
25-29.9	115/1471 (7.8%)	1.04 (0.70,1.54)	0.84	1.28 (0.84,1.94)	0.25	1.38 (0.87,2.18)	0.17
30-34.9	93/1216 (7.6%)	1.02 (0.68,1.52)	0.94	1.14 (0.74,1.77)	0.55	1.16 (0.72,1.86)	0.55
35-39.9	53/549 (9.7%)	1.31 (0.83,2.07)	0.24	1.26 (0.77,2.06)	0.36	1.40 (0.83,2.38)	0.21
≥40	29/297 (9.8%)	1.33 (0.78,2.27)	0.30	1.19 (0.66,2.14)	0.56	1.38 (0.74,2.58)	0.31
Deyo-Charlson index (5-point increase)	n/a	1.23 (0.92,1.63)	0.16	1.24 (0.91,1.69)	0.18	1.14 (0.81,1.61)	0.46
Gender (Ref, Male)	128/1847 (6.9%)						
Female	203/2247 (9%)	**1.33 (1.04,1.71)**	**0.02**	**1.37 (1.05,1.79)**	**0.02**	**1.47 (1.10,1.96)**	**0.01**
Age (Ref, ≤60 yrs)	72/723 (10%)						
>60-70 yrs	112/1531 (7.3%)	0.71 (0.51,1.00)	0.05	0.71 (0.49,1.02)	0.06	0.78 (0.52,1.17)	0.23
>70-80 yrs	122/1556 (7.8%)	0.77 (0.55,1.07)	0.12	**0.68 (0.47,0.99)**	**0.05**	0.76 (0.50,1.17)	0.21
>80 yrs	25/284 (8.8%)	0.87 (0.53,1.45)	0.60	0.78 (0.46,1.35)	0.38	0.93 (0.52,1.66)	0.80

Multivariable model 1 adjusted for: gender, age, Deyo-Charlson index, BMI, ASA score, distance from medical center, operative diagnosis, type of implant (cemented, uncemented, hybrid); Multivariable model 2 = Model 1 plus **income category**

Table 4

Association of BMI, comorbidity, age and gender with Moderate-Severe Knee Pain at 2-years post-REVISION TKA.

		Univariate		Multivariable model 1		Multivariable model 2	
	n/N (%)	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
BMI (Ref, <25 kg/m^2)	42/198 (21.2%)						
25-29.9	108/537 (20.1%)	0.94 (0.62,1.40)	0.75	1.00 (0.64,1.56)	0.99	1.08 (0.64,1.81)	0.78
30-34.9	99/427 (23.2%)	1.12 (0.73,1.71)	0.60	1.17 (0.74,1.84)	0.51	1.43 (0.85,2.40)	0.18
35-39.9	51/216 (23.6%)	1.15 (0.71,1.85)	0.57	1.19 (0.71,1.98)	0.51	1.21 (0.67,2.18)	0.53
≥40	29/106 (27.4%)	1.40 (0.81,2.43)	0.23	1.22 (0.68,2.18)	0.51	1.32 (0.67,2.59)	0.43
Deyo-Charlson index (5-point increase)	n/a	0.84 (0.56,1.25)	0.38	1.07 (0.72,1.60)	0.75	1.13 (0.73,1.73)	0.59
Gender (Ref, Male)	149/737 (20.2%)						
Female	183/757 (24.2%)	1.26 (0.97,1.63)	0.08	1.21 (0.92,1.60)	0.17	1.16 (0.85,1.58)	0.34
Age (Ref, ≤60 yrs)	102/299 (34.1%)						
>60-70 yrs	84/441 (19%)	**0.45 (0.32,0.65)**	**<0.001**	**0.48 (0.33,0.69)**	**<0.001**	**0.46 (0.31,0.71)**	**<0.01**
>70-80 yrs	125/624 (20%)	**0.48 (0.35,0.67)**	**<0.001**	**0.50 (0.35,0.70)**	**<0.001**	**0.48 (0.33,0.72)**	**<0.01**
>80 yrs	21/130 (16.2%)	**0.37 (0.21,0.65)**	**<0.001**	**0.42 (0.24,0.75)**	**0.003**	**0.39 (0.20,0.75)**	**<0.01**

Multivariable model 1 adjusted for: gender, age, Deyo-Charlson index, BMI, ASA score, distance from medical center, operative diagnosis, type of implant (cemented, uncemented, hybrid); Multivariable model 2 = Model 1 plus **income category**

Table 5

Association of BMI, comorbidity, age and gender with Moderate-Severe Knee Pain at 5-years post-REVISION TKA.

		Univariate		Multivariable model 1		Multivariable model 2	
	n/N (%)	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
BMI (Ref, <25 kg/m^2)	23/115 (20%)						
25-29.9	79/329 (24%)	1.26 (0.73,2.19)	0.40	1.44 (0.80,2.57)	0.22	1.36 (0.68,2.70)	0.39
30-34.9	51/233 (21.9%)	1.12 (0.63,2.00)	0.70	1.20 (0.65,2.22)	0.56	1.50 (0.74,3.06)	0.26
35-39.9	34/117 (29.1%)	1.64 (0.86,3.10)	0.13	1.72 (0.89,3.30)	0.11	1.52 (0.70,3.28)	0.29
≥40	17/45 (37.8%)	2.43 (1.11,5.32)	0.03	1.76 (0.77,4.03)	0.18	1.89 (0.71,5.01)	0.20
Deyo-Charlson index (5-point increase)	n/a	0.70 (0.36,1.34)	0.28	1.04 (0.53,2.04)	0.91	0.89 (0.44,1.80)	0.74
Gender (Ref, Male)	90/423 (21.3%)						
Female	117/421 (27.8%)	1.42 (1.02,1.98)	0.04	1.38 (0.98,1.96)	0.07	1.44 (0.97,2.14)	0.07
Age (Ref, ≤60 yrs)	61/166 (36.7%)						
>60-70 yrs	67/264 (25.4%)	**0.59 (0.38,0.90)**	**0.02**	**0.65 (0.41,1.03)**	**0.06**	**0.58 (0.34,0.98)**	**0.04**
>70-80 yrs	66/344 (19.2%)	**0.41 (0.27,0.62)**	**<0.001**	**0.46 (0.29,0.73)**	**<0.001**	**0.43 (0.26,0.71)**	**<.01**
>80 yrs	13/70 (18.6%)	**0.39 (0.20,0.78)**	**0.008**	0.50 (0.24,1.02)	0.06	0.47 (0.21,1.04)	0.06

Multivariable model 1 adjusted for: gender, age, Deyo-Charlson index, BMI, ASA score, distance from medical center, operative diagnosis, type of implant (cemented, uncemented, hybrid); Multivariable model 2 = Model 1 plus **income category**