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Original Research

Do You PROMIS (Patient Reported Outcomes Measurement Information System)? Physical Function and Pain Interference Scores After Total Knee and Hip Arthroplasty

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ABSTRACT

Background: Physical function and pain outcomes vary after arthroplasty. We investigated differences in postoperative Patient-Reported Outcomes Measurement Information System (PROMIS) physical function (PF) and pain interference (PI) scores for patients undergoing total knee arthroplasty (TKA) and total hip arthroplasty (THA). We aimed to identify preoperative factors that predict postoperative PROMIS scores.
Methods: Patients who underwent TKA and THA from 2014-2020 were eligible. Preoperative variables including demographics, comorbidities, and pain scores were obtained from the medical record. Patients completed surveys measuring postoperative PF and PI. Descriptive statistics and separate linear regression models for each anatomical location were performed to examine factors predicting postoperative PROMIS PF and PI scores.
Results: Surveys were completed by 2411 patients (19.5% response rate). Unadjusted mean PF postoperative scores were 47.2 for TKA and 48.8 for THA. Preoperative predictors of lower PF included female sex; body mass index and comorbidities for TKA and THA; and age, tobacco use, and non-White race for THA. Mean PI scores were 47.9 for THA and 49.0 for TKA. Preoperative predictors of increased PI included non-White race and increased body mass index for TKA and THA; higher preoperative pain for TKA; and female sex and increased comorbidity for THA.
Conclusions: Postoperative PROMIS scores were similar for TKA and THA, with THA having slightly higher PF and lower PI scores. Regression models using preoperative variables showed similar performance for TKA compared with THA. These findings suggest areas for future development of clinical decision support tools.

Introduction

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are among the most successful surgical interventions [1]. When a painful knee or hip with an end-stage degenerative condition severely limits function or quality of life, arthroplasty is considered for patients healthy enough to safely undergo surgery. Outcomes from total joint arthroplasty (TJA) have traditionally been assessed on implant survivorship and avoidance of postoperative complications. While these metrics are important, they do not fully capture improvements in quality of life, physical function (PF), or reduction in pain.

Outcomes vary significantly after arthroplasty. Reports in the literature range from 0% to 25% dissatisfaction with hip and knee arthroplasty, demonstrating differences based on the joint being replaced, preoperative expectations, and severity of arthritis [2,3]. Arthroplasty, especially THA, has been the gold standard for improvement in quality-adjusted life year scores [4], and recent studies show substantial increases in quality of life after primary TJA [5].

Patient-reported outcome measures provide feedback directly from patients and serve as a valuable resource for patient-centered outcome assessment in both research and clinical care [6]. The

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Patient-Reported Outcomes Measurement Information System (PROMIS), developed by the National Institutes of Health, has built a validated bank of survey measures including physical, mental, and social health domains relevant to multiple common conditions, including arthroplasty [5-7]. All PROMIS measures use a common metric of a T-score normalized to the United States general population, allowing scores to be compared across conditions and in relation to the general population. PROMIS measures are particularly beneficial in order to compare outcomes from TJA procedures between joints or other orthopaedic conditions. Not only are PROMIS measures validated in this population, but current research also suggests an increasing uptake of PROMIS measures across orthopaedics, with PF and pain interference (PI) as the most commonly reported domains [8].

Although PROMIS measures are valuable in clinical decision-making, they cannot be used alone to predict outcomes from surgery. There are factors that have been associated with worse outcomes, including PF and pain such as older age, female sex, lower income, higher body mass index (BMI), higher American Society of Anesthesiology score, some comorbid conditions, and smoking after TJA [9-14]. Additionally, psychological comorbidities such as anxiety and depression may also play an important role in arthroplasty outcomes [12,15,16]. Therefore, it is critical to understand how patient factors, along with patient-reported outcomes such as PROMIS, are associated with long-term outcomes from TKA and THA.

The purpose of this study was two-fold: first, to compare postoperative PROMIS PF and PI scores for patients who underwent TKA and THA; second, to explore the preoperative factors commonly recorded in the electronic health record (EHR) that are associated with postoperative PROMIS PF and PI scores for TKA and THA populations. This study aimed to add to the current literature on TJA by directly comparing postoperative outcomes between the 2 joints and identifying the preoperative factors commonly recorded in the EHR that can be used in future studies to predict outcomes in the 2 TJA regions. The end goal of this study is to identify common clinical variables that can be routinely collected as part of the standard of care to compare and predict outcomes across different TJA populations.

Material and methods

Participants and setting

Patients who underwent TKA and THA or related TJA procedures in a large academic health system in Durham, NC, between January 1, 2014, and January 31, 2020, were eligible for this study. We used

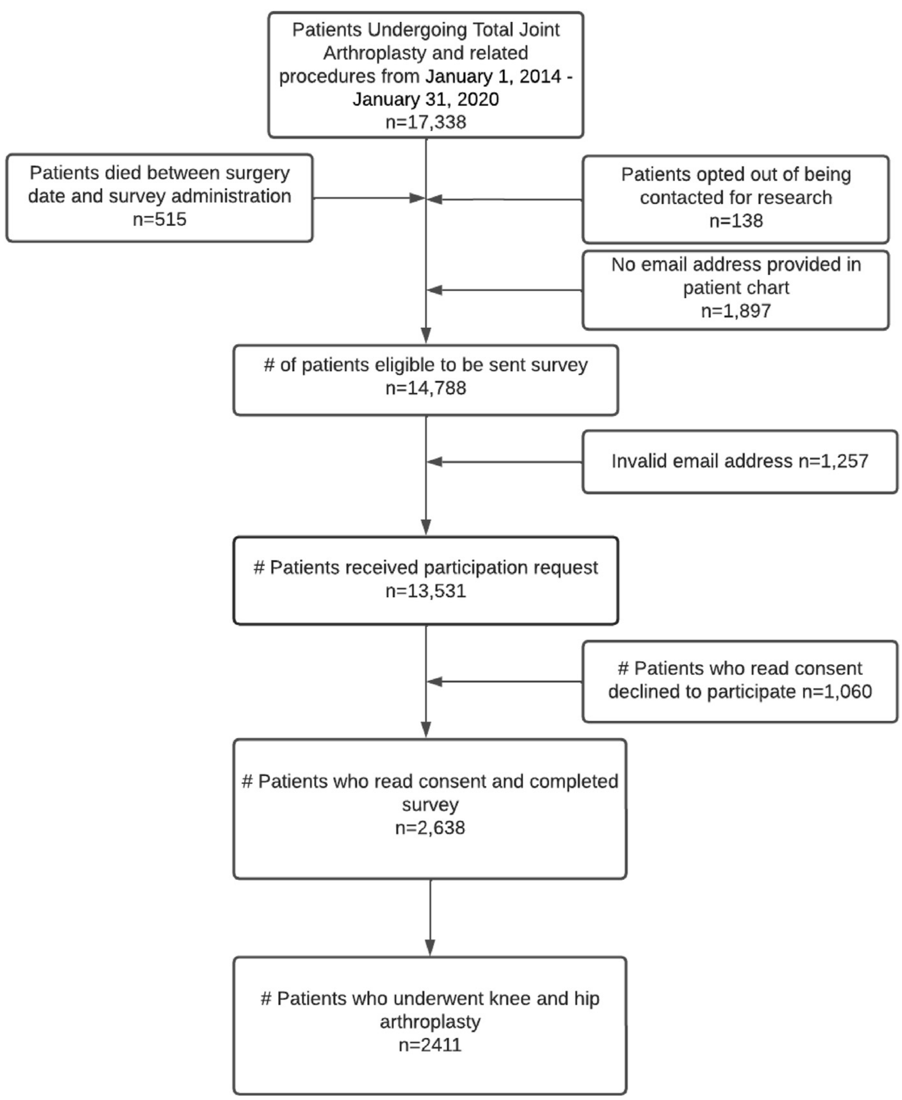

Figure 1. Survey flow diagram.

Current Procedural Terminology codes from the EHR to identify eligible patients (Supplemental File 1). The inclusion criteria for the study were undergoing a TJA-related procedure and having a valid email address listed within the EHR. Exclusion criteria included the death of the patient at the time of survey administration and an invalid email address listed within the EHR. The patient flow diagram and eligibility criteria can be found in Figure 1. This study was determined to be exempt by the Duke University Institutional Review Board.

Study design

We administered a cross-sectional survey through the Research Electronic Data Capture (REDCap) system to patients identified through the EHR who met eligibility criteria. Study data were collected and managed using REDCap electronic data capture tools hosted at Duke University [17,18]. This survey was designed to collect patient-reported information regarding the patients' postoperative health status including their state of PF, PI, and other metrics of interest.

Survey administration

The final eligible cohort was divided into groups by year of surgery. If patients underwent more than one surgery, the first surgery date was used for analysis. To avoid the influence of ordering effects, patients within each group were randomized by order of survey administration. The survey was administered in waves beginning July 6, 2021, and ending November 6, 2021.

Patients were contacted via email regarding study participation. If patients did not complete the questionnaire on the first contact, 2 follow-up emails were sent 3 days apart. If patients declined participation after reading the informed consent, they were not contacted again. In order to improve response rates, the research coordinator called any patient who had consented to participate but had not yet completed the survey. Patients who chose to participate consented electronically, and responses to the survey were recorded in the REDCap database.

Primary outcomes

Our primary outcomes in this study were postoperative scores for PROMIS PF and PI. PROMIS measures have been validated in the general population and in orthopaedic and arthroplasty populations [9,19]. Each PROMIS measure is standardized, such that the T-score has a mean of 50 and a standard deviation of 10 in the general US population, which enables comparison for clinical and research applications. We used a short-form survey instrument for the physical function (V.2.0, 4a) and pain interference (V.1.0, 4a) domains, and each survey instrument was scored on a T-score metric [20,21].

Covariates

Using the cohort of patients that completed the survey, the EHR was then queried for preoperative variables including sex, age at surgery, race, BMI, tobacco use, and the number of TJA surgeries patients underwent in the study period. The Charlson comorbidity index was used to determine comorbid disease status [22]. Preoperative comorbidities were then extracted by International Classification of Diseases (ICD-10) codes recording the presence or absence of 17 comorbid conditions, and a total score was calculated [23]. The preoperative pain score measured by the Numerical Pain Rating Scale was extracted from the EHR from their preanesthesia visit within 30 days preceding surgery [24]. We then calculated the time between the first surgical event and survey completion.

Data analysis

Data analysis was performed using SPSS (IBM SPSS Statistics for Windows, Version 25.1, Armonk, NY: IBM Corp.). Descriptive statistics were generated for the cohort with continuous measures (PF, PI, age, BMI, comorbidity, number of surgeries, and preoperative pain intensity) reported with mean and standard deviation. Categorical measures were dichotomized to allow for easier clinical interpretation, and these were reported with frequencies. The categorical measures included survey time (within 24 months of surgery vs greater than 24 months), race (White vs all others), tobacco history (no history vs current or prior history), and sex (male vs female). First, separate factorial general linear models investigated differences in PROMIS PF and PI scores by TJA location (TKA and THA) and sex (male vs female). Post hoc differences were reported when detected. Second, multiple linear regression predicted postoperative PROMIS PF and PI scores. Separate multivariable regression models were created for each TJA location (ie, TKA and THA were modeled separately), resulting in 6 different models. The same predictor variables were used for each regression model, and all predictor variables were included (ie, only full models were investigated and reported). The type I error rate was set at 0.01 for all analyses.

Results

Cohort and survey response rate

We identified 17,388 patients from the EHR with a Current Procedural Terminology code indicating they underwent TJA or a related procedure (Supplemental File 1). Exclusion criteria consisted of death prior to January 31, 2020 (n = 515), opting out of contact for research (n = 138), no email address on file (n = 1897), or invalid email address (n = 1257) (Fig. 1). After exclusion criteria were applied, 13,531 patients were contacted, and 2638 provided informed consent and completed the survey (19.5% response rate). Of the 2638 patients who responded to the survey, 2411 reported undergoing knee or hip arthroplasty.

Characterization of the cohort

Descriptive statistics are summarized in Table 1 for the entire cohort and also separately by TJA location. TKA and THA patients were similar demographically. We did not test for statistical differences in demographics because each variable was selected a priori to be included in the regression models for each TJA location.

PROMIS differences by arthroplasty location

Next, we wanted to examine the univariate differences in postoperative PROMIS PF and PROMIS PI between TJA locations. We found that PF scores were marginally lower for TKA (mean = 47.2, standard deviation [SD] 8.7) compared to THA (mean = 48.8, SD 8.6) ($P < .01$). THA patients also reported lower PI (mean 47.9, SD 8.6) compared to TKA patients (mean 49.0, SD 9.1) ($P < .01$). This data is summarized in Table 2 and Figure 2.

Prediction of postoperative physical function

The linear regression model predicting postoperative PF in TKA patients demonstrated 11.3% of the variance explained by the model. The linear regression model predicting postoperative PF in

Table 1
Descriptive statistics by total joint arthroplasty location.

Variables	All arthroplasty (n = 2411)	Total knee (n = 1265)	Total hip (n = 1146)
Sex (% female)	54.0%	54.3%	53.7%
Tobacco use (% no history)	56.9%	56.9%	56.9%
Race (% White/ Caucasian)	91.9%	92.1%	91.6%
Mean number surgeries (SD)	1.28 (0.57)	1.30 (0.56)	1.25 (0.58)
Survey time (% > 24 months)	72.5%	72.4%	72.6%
Mean preoperative pain (SD)	3.54 (2.8)	3.22 (2.8)	3.90 (2.9)
Mean age in years (SD)	64.2 (9.6)	65.5 (8.2)	62.7 (10.8)
Mean BMI (SD)	29.9 (5.6)	30.9 (5.5)	28.8 (5.6)
Mean comorbidity index (SD)	0.58 (0.92)	0.62 (0.95)	0.53 (0.88)

SD, standard deviation; BMI, body mass index.

THA patients demonstrated the best fit, with 13.5% of the variance explained by the model. The unstandardized and standardized coefficients for PF after THA and TKA are reported in Table 3.

The variables contributing independently for predicting postoperative PF in the TKA model were fewer than the model for THA. The variables included sex (males with higher PF), BMI (higher with lower PF), and the number of comorbidities (higher with lower PF). Based on the standardized regression coefficients reported in Table 3 for TKA, the strongest continuous variable was BMI, and the strongest categorical variable was sex.

The variables contributing independently for predicting postoperative PF in THA included sex (males with higher PF), age (older with lower PF), race (non-White/Caucasian with lower PF), BMI (higher with lower PF), comorbidity (higher with lower PF), and smoking (history of tobacco use with lower PF) status. Based on the standardized regression coefficients reported in Table 3 for THA the strongest continuous variable was BMI and the strongest categorical variable was sex.

Prediction of postoperative pain interference

The linear models for predicting postoperative PI explained less variance in outcome compared to the PF models with 6.8% variance explained in the knee models and 6.2% variance explained in the hip models. The unstandardized and standardized coefficients for PI after THA and TKA are reported in Table 4.

In the models for predicting postoperative PI in TKA, race (non-White/Caucasian with higher PI), BMI (higher with higher PI), and preoperative pain (higher with higher PI) contributed independently to the outcome. Based on the standardized regression coefficients reported in Table 4 for TKA, the strongest continuous variable was preoperative pain, and the strongest (only) categorical variable was race. In the model for THA, the variables contributing independently to the outcome included sex (males with lower PI), race (non-White/Caucasian with higher PI), BMI (higher with higher PI), and comorbidity (higher with higher PI). Based on the standardized regression coefficients reported in Table 4 for THA, the strongest continuous variable was BMI, and the strongest categorical variable was race.

Discussion

The findings of this study suggest that postoperative PF and PI are clinically similar between patients undergoing THA and TKA, with only small differences noted statistically. Patients undergoing THA had higher postoperative PF and lower PI scores when compared with patients undergoing TKA. Furthermore, BMI, sex, and comorbidities contributed statistically to PF regression models for patients undergoing TKA and THA, while age, race, and tobacco only contributed to THA. For the PI models, race and BMI contributed statistically to patients undergoing TKA and THA. Sex and comorbidities contributed to THA only and preoperative pain to TKA only.

In this cohort, preoperative pain intensity was a predictor variable for increased PI scores for those undergoing TKA but not THA. The clinical significance of this finding is unclear, as patients are often advised to delay surgery until the pain sufficiently impacts their quality of life. The presence of psychosocial factors (eg, depressive symptoms) may explain why TKA patients with higher preoperative pain were more likely to have higher PI scores postoperatively. However, this was not directly studied as part of this analysis, and the evidence is variable regarding the impact of depression on outcomes [25]. One possible hypothesis is that the severity of radiographic signs of arthritis required to recommend TKA to patients with knee pain may be different compared with THA. Less severe radiographic changes on preoperative radiographs prior to TKA [26] and THA [14] have been associated with decreased patient satisfaction after surgery and represent an interesting area for further research.

Of interest, the number of surgeries was not a significant predictor of outcomes in any of the models. Patients with more than one surgery during the study period were analyzed for their first operation. However, one limitation of the analysis is not knowing whether subsequent surgeries were on the same joint. Subsequent surgery may be performed on the same joint for complications such as infection or periprosthetic fracture, compared to patients who are satisfied with their first TKA and decide to have a subsequent contralateral TKA or a subsequent THA, for example. These effects would likely skew the results in different directions. Patients having repeat surgeries of the same joint for complications would likely have a lower PF and higher PI scores, corresponding to worse outcomes compared to patients who choose to have additional joints replaced because their first was a success. Additional research is needed to determine the impact of a number of surgeries on postoperative PF and PI.

A survey of TJA patients within a single health system collecting standardized metrics (ie, PROMIS) represents a notable strength of this study. However, there are important limitations. Because of the

Table 2
Difference in PROMIS scores by arthroplasty location.

PROMIS scores	All arthroplasty (n = 2411)	Total knee (n = 1265)	Total hip (n = 1146)	T-score
Pain interference T-score mean (SD)	48.5 (8.9)	49.0 (9.1)	47.9 (8.6)	2.9[a]
Physical function T-score mean (SD)	47.9 (8.7)	47.2 (8.7)	48.8 (8.6)	4.3[a]

[a] $P < .01$.

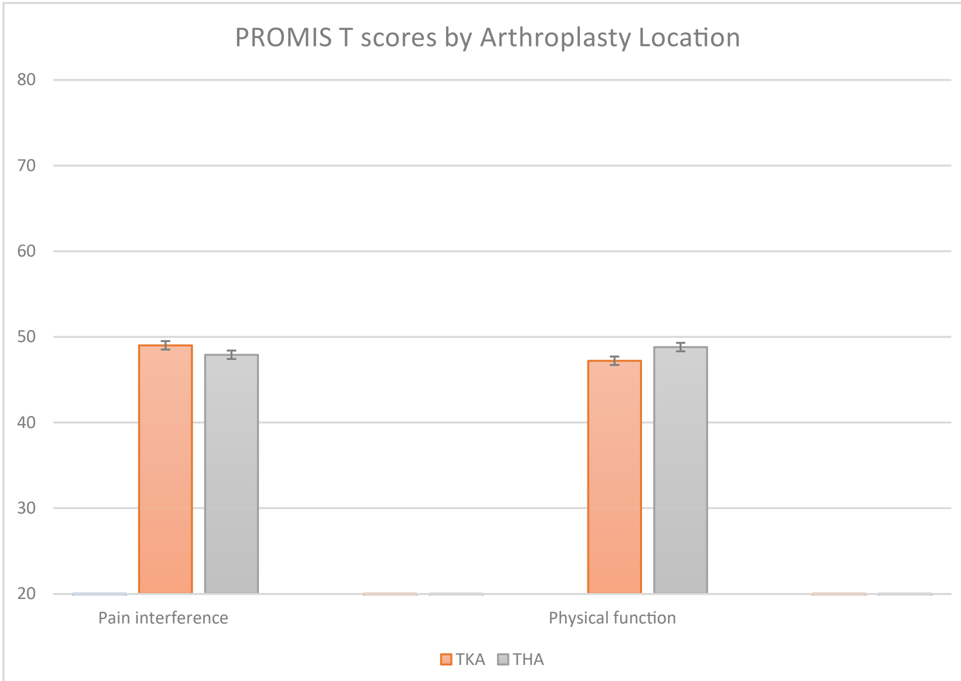

Figure 2. PROMIS pain interference and physical function scores by arthroplasty location.

cross-sectional design, this study identifies associations that may not be causative. Preoperative PROMIS scores were unavailable so other variables identified from the EHR preoperatively were used to predict postoperative status rather than directly assessing PROMIS score changes from preoperative to postoperative. The 19.5% response rate of patients contacted is an important limitation to acknowledge. As demonstrated in Figure 1, most patients did not reach the consent form. Multiple waves of reminder contacts were sent in an effort to boost participation. While this response rate seems low, it is in line with studies that have used similar approaches [27]. The application of a postoperative survey may cause patients who have strong opinions about their surgical outcome to be more likely to respond. Whether these perceptions are predominately positive or negative could influence the conclusions. The variability in time elapsed between surgery and the survey can also be a confounding factor causing recency bias. However, completing the survey within, compared to after, 24 months did not appear to be a significant predictive variable for any of the models. The homogeneity of our sample, being predominantly Caucasian/White, limited our ability to make inferences about race beyond Caucasian/White and non-Caucasian/White patients. Lastly, our primary method of data collection was electronic communication. In sensitivity analyses, we found that patients who were male, White/Caucasian race and had 2 or more surgeries were more likely to respond to the survey, but age was not found to affect whether patients completed the survey [28]. These limitations on data

Table 3
Linear regression models by TJA location for the PROMIS physical function domain.

Statistic	Knee		Hip	
Model summary (R-square)	0.113[a]		0.135[a]	
Adj R-square	0.105		0.125	
Constant	63.778		63.569	
Predictor variables	B	Beta	B	Beta
Sex	2.367[b]	0.136[b]	2.948[b]	0.174[b]
Age	−0.077	−0.072	−0.085[b]	−0.106[b]
Race	−2.403	−0.074	−2.535[b]	−0.086[b]
BMI	−0.328[b]	−0.206[b]	−0.313[b]	−0.203[b]
Comorbidity	−1.252[b]	−0.137[b]	−1.434[b]	−0.148[b]
Tobacco use	−0.847	−0.049	−1.773[b]	−0.104[b]
Preoperative pain	−0.250	−0.080	−0.140	−0.048
Number of surgeries	−0.091	−0.005	−0.045	−0.002
Survey time	−0.148	−0.008	1.226	0.067

B, Unstandardized coefficients (predict the outcome).
Beta, standardized coefficients (relative strength of each predictor).
BMI, body mass index.
Reference categories for binary variables: sex (female), race (White/Caucasian), tobacco use (no history), survey time (within 24 months of surgery).
[a] Models were $P < .001$.
[b] Predictor with $P < .01$.

Table 4
Linear regression models by TJA location for the PROMIS pain interference domain.

Statistic	Knee		Hip	
Model summary (R-square)	0.068[a]		0.062[a]	
(Adj R-square)	0.059		0.052	
Constant	41.046		42.260	
Predictor variables	B	Beta	B	Beta
Sex	−0.503	−0.028	−1.634[b]	−0.095[b]
Age	−0.013	−0.011	−0.021	−0.026
Race	3.744[b]	0.110[b]	3.456[b]	0.116[b]
BMI	0.198[b]	0.118[b]	0.205[b]	0.132[b]
Comorbidity	0.772	0.081	0.879[b]	0.090[b]
Tobacco use	0.586	0.032	1.096	0.063
Preoperative pain	0.430[b]	0.131[b]	0.059	0.020
Number of surgeries	0.107	0.005	0.636	0.028
Survey time	0.660	0.033	−0.806	−0.043

B, Unstandardized coefficients (predict the outcome).
Beta, standardized coefficients (relative strength of each predictor).
BMI, body mass index.
Reference categories for binary variables: sex (female), race (White/Caucasian), tobacco use (no history), survey time (within 24 months of surgery).
[a] Models were $P < .001$.
[b] Predictor with $P < .01$.

collection strategy should be considered when applying these findings to other patient populations.

PROMIS has been found to correlate with other commonly used measures to assess TKA and THA outcomes, such as Numeric Pain Scale, Knee Injury and Osteoarthritis Outcome Score, Hip Injury and Osteoarthritis Outcome Score, Harris hip score, and the Timed Up and Go [9,29-32]. We do not yet know the optimal functional data collection strategy to reduce the survey burden for patients while obtaining useful information to help predict who will achieve minimally clinically important differences after TJA [33]. In this analysis, we attempted to identify useful factors for 2 TJA locations. The factors identified in this study that are associated with an increased risk of worse outcomes, namely higher PI and lower PF scores, can be applied to help surgeons and patients make future decisions about surgery. They can also help explain some, but clearly not all, of the variability in outcomes seen in registries and other large studies.

Conclusions

In this large, single-institution cohort, PROMIS scores were clinically similar between postoperative THA and TKA patients. Statistically, THA had a higher postoperative PF and lower PI, but these differences were small. TKA and THA regression models for predicting PROMIS PF and PI predicted approximately 13% of the variance. These findings suggest areas for future research and may spur the development of clinical decision-support tools that consider patient-reported outcomes.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101208.

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Supplementary Material 1
Count of CPT codes by location.

Location	CPT code	Description	Count	% Of location
Knee n = 1265	27447	Arthroplasty, knee, condyle and plateau; medial AND lateral compartments with or without patella resurfacing (total knee arthroplasty)	1057	83.6%
	27446	Arthroplasty, knee, condyle and plateau; medial OR lateral compartment	116	9.2%
	27487	Revision of total knee arthroplasty, with or without allograft; femoral and entire tibial component	66	5.2%
	27486	Revision of total knee arthroplasty, with or without allograft; 1 component	17	1.3%
	27488	Removal of prosthesis, including total knee prosthesis, methylmethacrylate with or without insertion of spacer, knee	7	0.6%
	27440	Arthroplasty, knee, tibial plateau	1	0.1%
	27445	Arthroplasty, knee, hinge prosthesis (eg, Walldius type)	1	0.1%
Hip N = 1146	27130	Arthroplasty, acetabular and proximal femoral prosthetic replacement (total hip arthroplasty), with or without autograft or allograft	1031	90.0%
	27134	Revision of total hip arthroplasty; both components, with or without autograft or allograft	44	3.8%
	27132	Conversion of previous hip surgery to total hip arthroplasty, with or without autograft or allograft	42	3.7%
	27125	Hemiarthroplasty, hip, partial (eg, femoral stem prosthesis, bipolar arthroplasty)	9	0.8%
	27137	Revision of total hip arthroplasty; both components, with or without autograft or allograft	9	0.8%
	27091	Removal of hip prosthesis; complicated, including total hip prosthesis, methylmethacrylate with or without insertion of spacer	8	0.7%
	27138	Revision of total hip arthroplasty; femoral component only, with or without allograft	3	0.3%

CPT, Current Procedural Terminology.