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# Relationship Between Baseline Patient-reported Outcomes and Demographic, Psychosocial, and Clinical Characteristics: A Retrospective Study

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## Abstract

**Introduction:** Alternative payment models in total lower extremity joint replacement (TJR) increasingly emphasize patient-reported outcomes (PROs) to link the latter to value-based payments. It is unclear to what extent demographic, psychosocial, and clinical characteristics are related to PROs measured preoperatively with the commonly used Hip/Knee Osteoarthritis Outcome Scores (HOOS/KOOS) and the Veterans RAND 12-Item Health Survey (VR-12) questionnaires. We aim to identify (1) the preoperative relationship between HOOS/KOOS and VR-12 scores and several demographic, psychosocial, and clinical patient characteristics and (2) the best modifiable factors for optimization, which may result in improved baseline PROs before TJR.

**Methods:** All TJR cases performed in 2017 at the two highest-volume hospitals within an urban academic health system were queried. Preoperative HOOS/KOOS and VR-12 surveys were administered through an e-collection platform. VR-12 physical and mental component scores (PCS, MCS) were generated. Patient information was extracted from the electronic health record. Bivariate and multivariate regression analyses were performed. Odds ratios (ORs) and 95% confidence intervals were reported.

**Results:** In univariate analysis, patients with HOOS/KOOS, VR-12 PCS, and MCS in the  $\leq 25$ th percentile group were more likely to have an ASA score of  $\geq 3$  compared with those with higher scores. In multivariate analysis, increased and decreased odds of low HOOS/KOOS were associated with a one-unit increase in Charlson Comorbidity Index (OR, 1.16) and VR-12 MCS (OR, 0.97), respectively. Increased odds of low baseline VR-12 PCS and MCS were associated with ASA class  $\geq 3$  (OR, 1.65 and 1.40). Decreased odds of a low MCS were associated with an increase in HOOS/KOOS (OR, 0.98) ( $P \leq 0.05$  for all).

**Conclusion:** Of the factors that are associated with low baseline PRO scores, preoperatively addressing mismanaged comorbidities, mental health, and physical function were identified as the best modifiable factors for optimization, which may result in improved baseline PROs before TJR.

Patient-reported outcomes (PROs) can be quantified by patient-reported outcome measures (PROMs), such as the Hip/Knee Osteoarthritis Outcome Score (HOOS/KOOS) and the Veterans RAND 12-Item Health Survey (VR-12), which measure patients' perceptions of their health in relation to their underlying musculoskeletal illness. PROMs are the most direct measure of a therapeutic intervention's impact on patient quality of life and thus signify what matters most to patients. The relevance of PROs is expected to increase as the focus on value-centered and patient-centered care increases, particularly in orthopaedics. This is further emphasized by including baseline collection of PROMs as a prerequisite for participation in alternative payment models such as the Comprehensive Care for Joint Replacement (CJR) bundled-payment model implemented by the Centers for Medicare and Medicaid Services in April 2016 for lower extremity total joint replacement (TJR).<sup>1</sup> Dramatically increasing demand and a common goal to control cost and improve quality in TJR procedures additionally underscore the roles of alternative payment models and PROMs.<sup>2,3</sup>

In anticipation of these developments, evaluating patient factors related to baseline PROs is crucial. This information may be used to preoperatively optimize particularly modifiable patient factors, which, in turn, will improve baseline PROs. Indeed, it has been shown that high baseline PROMs in TJR patients are predictive of lower postoperative pain and better functional ability.<sup>4-6</sup> To further increase value in the TJR episode, patients with poor baseline

statuses can be targeted for optimization because an improvement in baseline status may increase their likelihood for maximal improvement across the episode of care. Moreover, previous studies using orthopaedic cohorts have demonstrated baseline PROs to be associated with modifiable patient factors such as mental health issues, lower activity levels, and smoking.<sup>7</sup> However, data for TJR patients are lacking.

Therefore, using data from TJR patients in two academic hospitals within an urban area, we examined the association between low baseline HOOS/KOOS and VR-12 scores (defined as scores below or equal to the 25th percentile score) and a set of modifiable and nonmodifiable demographic, psychosocial, and clinical characteristics. We hypothesized that this exercise would identify potentially modifiable patient factors that can be targeted to improve baseline PROs before surgery and consequently increase a patient's potential for a large and sustained improvement in PROs across a TJR episode.

## Methods

### The Data Source and Defining the Cohort

All total hip and knee arthroplasty cases performed between January 1, 2017, and December 31, 2017, at the two highest-volume hospitals (1,171 and 505 beds, respectively) within an urban multihospital academic health system were queried ( $n = 2,108$ ). Patient demographic, psychosocial, and clinical data were manually extracted from the electronic health record. Exclusion cri-

teria included cases with missing information on demographic, psychosocial, and clinical variables or baseline PRO (HOOS, KOOS, VR-12 PCS, or VR-12 MCS) scores; 1,182 cases were excluded to yield a final study population of 926 TJR cases.

## Variables Collected

We referenced similar studies in orthopaedics that investigated the impact of patient factors on outcomes to determine which patient data to collect.<sup>7,8</sup> Demographic data included age, sex, ethnicity (white, black, Asian, and other/unknown), and insurance status (Medicare, commercial/self-pay, Medicaid, and other/unknown). Psychosocial characteristics included a history of depression, dementia, psychosis, obesity (body mass index [BMI], 30 to 40/>40 kg/m<sup>2</sup>), smoking, alcoholism, drug abuse, or opioid abuse as indicated by International Classification of Diseases (ICD)-9 codes. The assessment of comorbidity burden included individual Charlson comorbidities and other clinical diseases/variables namely a history of hypertension, heart disease (including a history of myocardial infarction, chronic heart failure, coronary artery disease, valvular disorder, and/or arrhythmia), vascular disease (including cerebrovascular disease, peripheral artery disease, coagulopathy, deep vein thrombosis and/or pulmonary embolism), diabetes, pulmonary disease, circulation disorder, renal failure/dialysis need, liver disease, malignancy/cancer, HIV, and anemia. In addition, the Charlson Comorbidity Index (CCI) score was calculated for each patient.<sup>9</sup> The American Society of Anesthesiologists

Dr. Koenig or an immediate family member serves as a board member, owner, officer, or committee member of AAOS Healthcare Systems. Dr. Jevsevar is the Executive Medical Director of Risalto Health. Dr. Moucha is on speaker panels for 3M and Biocomposites. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Mr. Bienstock, Mr. Snyder, Mr. Kroshus, Ms. Ahn, Dr. Molloy, Dr. Poeran.

Table 1

## Distribution of Preoperative Patient-reported Outcomes for the Inclusion Population

Percentile <sup>a</sup>	HOOS	KOOS	VR-12 PCS	VR-12 MCS
10th	5.7	0.0	17.3	30.9
25th	20.8	15.9	22.5	40.0
50th	32.7	31.3	28.8	49.5
75th	46.7	44.9	36.1	58.4
90th	58.9	54.8	42.7	64.0
Mean	34.2	30.9	29.5	48.6
MCID <sup>b</sup>	9.9	9.6	4.9	6.3

MCID = minimum clinically important difference, MCS = mental component score, PCS = physical component score, VR-12 = Veterans RAND 12-Item Health Survey

<sup>a</sup> Analysis includes patients for whom baseline HOOS/KOOS, VR-12 PCS, and VR-12 MCS were available (n = 926).

<sup>b</sup> Half SD is a distribution-based method for calculating the minimum clinically important difference.

Physical Status Classification (ASA class) was also obtained for each patient.

### Outcomes of Interest

Outcomes of interest were preoperative (ie, baseline) HOOS/KOOS scores and VR-12 PRO scores. The HOOS/KOOS survey is an extensively validated disease-specific PROM that consists of pain and physical function subscales and ranges in score from 0 to 100, with higher scores being indicative of less pain and better physical function.<sup>10</sup> The VR-12 is a generic PROM that generates physical and mental component scores (PCS, MCS) to measure the physical and psychological well-being of a patient. Both the VR-12 PCS and MCS are norm-based scales in which higher scores indicate better health and 50 represents the average score of a healthy population.<sup>7</sup> PRO surveys were administered to all patients before arrival for surgery using an e-collection platform (VisionTree). These continuous PROMs were dichotomized with a cutoff based on the 25th percentile score in our cohort because the main study objective was to identify patient factors associated with low PRO scores to better define patients in whom optimization of these factors may lead to higher baseline PRO scores.

### Statistical Methods

Statistical analysis was performed using SAS version 9.4 (SAS Institute). A two-tailed *P* value of 0.05 was considered significant. HOOS, KOOS, VR-12 PCS, and VR-12 MCS percentiles were determined from our study population, and estimates for minimal clinically important difference were calculated using a distribution-based method, which is based on the statistical characteristics of the sample. Specifically, the half SD distribution method was used wherein a clinically meaningful difference in the outcome was defined as 0.5 SDs of the sample<sup>11</sup> (Table 1). Bivariate analysis was then used to compare demographics, psychosocial, and clinical characteristics between patients with  $\leq 25$ th percentile and  $> 25$ th percentile HOOS/KOOS, VR-12 PCS, and VR-12 MCS; this threshold was chosen to provide adequate discrimination while preserving the sample size. Categorical variables were compared using chi-square tests and Fisher exact tests when necessary. Continuous variables were compared using Student *t*-tests and Mann-Whitney *U* tests when necessary. All study covariates were considered in a multivariate logistic regression with backward elimina-

tion (cutoff *P* = 0.15). Three separate models represented each of our main outcomes: HOOS/KOOS, VR-12 PCS, and VR-12 MCS, dichotomized using the same 25th percentile as cutoff. Odds ratios (ORs) and 95% confidence intervals are reported. Models were assessed for goodness of fit using the Hosmer-Lemeshow test and by calculating the *c*-statistic. When interpreting the *c*-statistic, models with a score greater than 0.7 are generally considered to have adequate discrimination.

## Results

### Descriptive Statistics for the Patient Population

Nine hundred twenty-six patients were included for analysis. Baseline 50th percentile HOOS, KOOS, VR-12 PCS, and VR-12 MCS were 32.7 (interquartile range [IQR] 20.8 to 46.7), 31.3 (IQR, 15.9 to 44.9), 28.8 (IQR, 22.5 to 36.1), and 49.5 (IQR, 40.0 to 58.4), respectively. Estimated minimal clinically important differences using the half SD distribution method for HOOS, KOOS, VR-12 PCS, and VR-12 MCS were 9.9, 9.6, 4.9, and 6.3, respectively (Table 1).

## Demographic, Psychosocial, and Clinical Characteristics Compared Between Patients with High and Low Baseline HOOS/KOOS and Veterans RAND 12-Item Health Survey Physical or Mental Component Scores

Patients with low-scoring HOOS/KOOS in the  $\leq 25$ th percentile group (compared with those in the  $> 25$ th percentile) were more likely to be women, to be on Medicaid or noncommercial insurance, to suffer from a pulmonary disease or circulation disorder, and were categorized in ASA class  $\geq 3$  (Table 2). Similarly, patients with low baseline VR-12 PCS scores in the  $\leq 25$ th percentile group were more likely to be morbidly obese, to suffer from a malignancy, and to be categorized as ASA class  $\geq 3$ . Patients with  $\leq 25$ th percentile baseline VR-12 MCS were more likely to be on Medicaid, classified as a smoker, obese, depressed, suffering from hypertension or vascular disease, and categorized as ASA class  $\geq 3$ , whereas they were less likely to suffer from a malignancy (all  $P < 0.05$ ).

## Factors Associated With Low ( $\leq 25$ th percentile) Baseline HOOS/KOOS and Veterans RAND 12-Item Health Survey Physical and Mental Component Scores

In multivariate analysis (Table 3), a one-unit increase in CCI (OR, 1.16) and nonwhite/unknown race (OR, 1.83) was associated with increased odds to be in the  $\leq 25$ th percentile HOOS/KOOS score group, whereas a one-unit increase in baseline VR-12 PCS (OR, 0.92), MCS (OR, 0.96), or age (OR, 0.97) and male sex (OR, 0.56) was associated with lower odds. In the multivariable model evaluating factors associated with

baseline VR-12 PCS, we found baseline VR-12 MCS (OR, 1.04), ASA class  $\geq 3$  (OR, 1.65), and smoking (OR, 1.74) to be associated with higher odds of being in the  $\leq 25$ th percentile group, whereas an increase in baseline HOOS/KOOS (OR, 0.96) was associated with lower odds. In the analysis evaluating factors associated with baseline VR-12 MCS in the  $\leq 25$ th percentile, we found depression (OR, 2.29), hypertension (OR, 1.97), Medicaid insurance (OR, 1.76), BMI 30 to 40 (OR, 1.47), and ASA class  $\geq 3$  (OR, 1.40) to be associated with higher odds, whereas an increase in baseline HOOS/KOOS (OR, 0.98) and cancer or a malignancy (OR, 0.50) was associated with significantly lower odds (all  $P < 0.05$ ).

## Discussion

Baseline PROMs are useful predictors of improvement in postoperative pain and functional ability after TJR.<sup>4</sup> As value-based payment systems such as CJR become more widespread, understanding the factors that are associated with and predict baseline PROMs will help identify patients who may benefit from preoperative optimization, which could help them increase their potential to achieve larger benefits from TJR. This study identified several modifiable and non-modifiable patient characteristics associated with baseline HOOS/KOOS and VR-12 scores. Specifically, preoperatively addressing mismanaged or untreated comorbidities, mental health issues, and physical function seem to offer the best opportunities as modifiable factors for improving outcomes. Optimizing these factors in patients with poor baseline statuses will likely increase the value and sustainability of the TJR episode.

## Factors Associated With Low Baseline HOOS/KOOS or Veterans RAND 12-Item Health Survey Physical Component Scores

A high preoperative physical function PROM score has been associated with better postoperative PROs after TJR.<sup>4</sup> Although patients who present with high baseline scores may have less to gain from surgery, those with poor baseline statuses can benefit from preoperative optimization such that they have the highest probability of having a maximal improvement in function after TJR. Specifically, Berliner et al<sup>12</sup> found that improving a patient's baseline KOOS to a threshold of 58 will make him/her more likely to experience a clinically meaningful improvement after total knee arthroplasty (TKA) as calculated by the half SD distribution method. However, it should be noted that patients with baseline KOOS above this threshold have a lower probability of attaining a meaningful improvement from surgery; patients with such high baseline function scores should not be targeted for optimization because there is little capacity to improve the value of their surgeries. Identifying modifiable factors that affect baseline functional status represents an important opportunity for providers to maximize a patient's potential for a large and sustained improvement across the TJR episode.

Our study shows that patients with higher ASA and increased chronic comorbidities (higher CCI) are more likely to have low baseline HOOS/KOOS and VR-12 PCS, which has been corroborated in other surgical fields.<sup>13</sup> The comorbidities that contribute to ASA classification and CCI are often chronic, progressive, and insidious in nature. With almost 50% of patients with chronic illness not taking their medication as prescribed,<sup>14</sup> identifying and addressing

Table 2

### Comparison of Clinical and Psychosocial Characteristics Among Patients With High Versus Low Baseline Patient-reported Outcomes

Total patients	Study Population	Preoperative HOOS/KOOS		P Value	Preoperative VR-12 PCS		P Value	Preoperative VR-12 MCS		P Value
	n (%)	>25th Percentile	≤25th Percentile		>25th Percentile	≤25th Percentile		>25th Percentile	≤25th Percentile	
Demographic characteristics										
Median age (IQR)	65 (58-72)	66 (59-72)	64 (56-71)	0.06	65 (59-72)	66 (56-72)	0.71	66 (59-72)	64 (57-71)	0.2
Male sex	352 (38%)	278 (41%)	74 (30%)	0.002	265 (38%)	87 (38%)	0.90	269 (39%)	83 (36%)	0.42
Ethnicity				0.0003			0.78			0.03
White	387 (42%)	306 (45%)	81 (33%)		295 (42%)	92 (40%)		308 (44%)	79 (34%)	
Black	201 (22%)	150 (22%)	51 (20%)		146 (21%)	55 (24%)		146 (21%)	55 (24%)	
Asian	37 (4%)	27 (4.0%)	10 (4%)		29 (4.1%)	8 (3.5%)		29 (4%)	8 (3.5%)	
Other/unknown	301 (33%)	194 (29%)	107 (43%)		225 (32%)	77 (33%)		211 (30%)	90 (39%)	
Insurance status				0.009			0.79			<0.0001
Medicare	462 (50%)	335 (49%)	127 (51%)		343 (49%)	119 (52%)		344 (50%)	118 (51%)	
Commercial/self-pay	323 (35%)	252 (37%)	71 (29%)		245 (35%)	79 (34%)		264 (25%)	59 (25%)	
Medicaid	139 (15%)	88 (13%)	51 (20%)		106 (15%)	33 (14%)		84 (12%)	55 (24%)	
Other/unknown	2 (0.2%)	2 (0.3%)	0 (0%)		1 (0.1%)	1 (0.4%)		2 (0.3%)	0 (0%)	
Psychosocial characteristics										
Smoker	82 (8.9%)	58 (8.6%)	24 (9.6%)	0.61	57 (8.2%)	25 (11%)	0.22	50 (7.2%)	32 (14%)	0.002
Alcoholic	5 (0.5%)	3 (0.4%)	2 (0.8%)	0.61	5 (0.7%)	0 (0%)	0.34	3 (0.4%)	2 (0.9%)	0.60
Drug abuse	6 (0.6%)	3 (0.4%)	3 (1.2%)	0.35	5 (0.7%)	1 (0.4%)	1.0	4 (0.6%)	2 (0.9%)	0.64
Opioid use	9 (1%)	4 (0.7%)	4 (1.6%)	0.26	8 (1.1%)	1 (0.4%)	0.33	5 (0.7%)	4 (1.7%)	0.24
Obesity										
Obese (30 ≥ BMI ≥ 40)	375 (40%)	268 (40%)	107 (43%)	0.35	285 (41%)	91 (39%)	0.58	262 (38%)	113 (49%)	0.003
Morbidly obese (BMI > 40)	93 (10%)	65 (9.6%)	28 (11%)	0.46	62 (9.0%)	31 (13%)	0.05	70 (10%)	23 (9.9%)	0.94
Depression	128 (14%)	87 (13%)	41 (16%)	0.16	99 (14%)	29 (13%)	0.52	74 (11%)	54 (23%)	<0.0001
Dementia/psychosis	6 (0.6%)	4 (0.6%)	2 (0.8%)	0.72	4 (0.6%)	2 (0.9%)	0.63	3 (0.43%)	3 (1.3%)	0.17
Clinical characteristics										
Hypertension	600 (65%)	433 (64%)	167 (67%)	0.38	448 (64%)	152 (66%)	0.71	424 (61%)	176 (76%)	<0.0001
Heart disease <sup>a</sup>	211 (23%)	154 (23%)	57 (23%)	0.96	151 (22%)	60 (26%)	0.18	150 (22%)	61 (26%)	0.14
Vascular <sup>b</sup>	80 (8.6%)	53 (7.8%)	27 (11%)	0.14	61 (8.8%)	19 (8.2%)	0.80	50 (7.2%)	30 (13%)	0.007
Diabetes	182 (20%)	133 (20%)	49 (20%)	0.99	135 (19%)	47 (20%)	0.76	129 (19%)	53 (23%)	0.16
Pulmonary disease/circulation disorder	174 (19%)	114 (17%)	60 (24%)	0.01	125 (18%)	49 (21%)	0.28	123 (18%)	51 (22%)	0.15
Renal failure/dialysis	1 (0.1%)	26 (3.8%)	11 (4.4%)	0.69	25 (3.6%)	12 (5.2%)	0.28	25 (3.6%)	12 (5.2%)	0.29
Liver disease	31 (3.3%)	18 (2.7%)	13 (5.2%)	0.05	25 (3.6%)	6 (2.6%)	0.46	20 (2.9%)	11 (4.7%)	0.17
Malignancy/cancer	80 (8.6%)	59 (8.7%)	21 (8.4%)	0.89	52 (7.5%)	28 (12%)	0.03	69 (9.9%)	11 (4.7%)	0.01
Immunocompromised/HIV	28 (3%)	15 (2.2%)	13 (5.2%)	0.02	18 (3.0%)	10 (4.3%)	0.18	21 (3.03%)	7 (3%)	0.99
Anemia	69 (7.5%)	48 (7.1%)	21 (8.4%)	0.49	49 (7.05%)	20 (8.6%)	0.42	55 (7.9%)	14 (6%)	0.34
ASA class ≥3	294 (32%)	200 (29%)	94 (38%)	0.02	201 (29%)	93 (40%)	0.001	199 (29%)	95 (41%)	0.0005
Median Charlson comorbidity index (IQR)	3 (2-4)	3 (2-4)	3 (2-5)	0.07	3 (2-4)	3 (2-5)	0.06	3 (2-4)	3 (2-4)	0.9

ASA class = American Society of Anesthesiology Physical Classification System, BMI = body mass index, HOOS = hip injury and osteoarthritis outcome score, IQR = interquartile range, KOOS = knee injury and osteoarthritis outcome score, MCS = mental component score, PCS = physical component score, VR-12 = Veterans RAND 12-Item Health Survey

<sup>a</sup> Defined as a history of myocardial infarction, chronic heart failure, coronary artery disease, valvular disorder, and arrhythmias.

<sup>b</sup> Defined as a history of cerebrovascular disease, deep vein thrombosis, pulmonary embolism, and peripheral artery disease, coagulopathy.

potentially neglected comorbidities represents an opportunity for care teams to improve a patient's preoperative functional status and maxi-

mize their likelihood of benefit from the TJR episode. This strategy has already shown to be successful in other surgical subspecialties.<sup>15</sup>

Future research should assess how preoperative optimization of comorbidities common in TJR populations affects baseline PRO scores

Table 3

Multivariate Analysis of Risk Factors for Lower Preoperative Patient-reported Outcomes			
Outcome/Risk Factor	OR (95% CI)	P Value	Model c-Statistic
≤25th percentile baseline HOOS/KOOS			0.76
Other/unknown race	1.83 (1.31-2.54)	0.0004	
Charlson comorbidity index	1.16 (1.06-1.27)	0.001	
Baseline VR-12 PCS	0.92 (0.90-0.94)	<0.0001	
Baseline VR-12 MCS	0.96 (0.95-0.97)	<0.0001	
Age	0.97 (0.95-0.98)	0.0002	
Male sex	0.56 (0.40-0.80)	0.002	
Smoker	0.62 (0.35-1.09)	0.1	
≤25th percentile baseline VR-12 PCS			0.74
Baseline VR-12 MCS	1.04 (1.02-1.05)	<0.0001	
ASA class ≥3	1.65 (1.17-2.32)	0.004	
Smoker	1.74 (1.02-2.97)	0.04	
Malignancy	1.60 (0.94-2.71)	0.08	
Baseline HOOS/KOOS	0.95 (0.94-0.96)	<0.0001	
Liver disease	0.41 (0.16-1.09)	0.07	
Other/unknown race	0.77 (0.54-1.09)	0.14	
≤25th percentile baseline VR-12 MCS			0.72
Depression	2.29 (1.50-3.50)	0.0001	
Hypertension	1.97 (1.37-2.83)	0.0003	
Medicaid insurance	1.76 (1.14-2.70)	0.01	
BMI 30-40	1.47 (1.06-2.02)	0.02	
ASA class ≥3	1.40 (0.99-1.97)	0.05	
Smoker	1.55 (0.91-2.64)	0.11	
Vascular disease	1.53 (0.91-2.58)	0.11	
Baseline HOOS/KOOS	0.98 (0.97-0.98)	<0.0001	
Malignancy	0.50 (0.25-0.99)	0.05	
Anemia	0.61 (0.32-1.17)	0.14	

ASA = American Society of Anesthesiology Classification System, BMI = body mass index, CI = confidence interval, HOOS = hip disability and osteoarthritis outcome score, KOOS = knee injury and osteoarthritis outcome score, MCS = mental component score, OR = odds ratio, PCS = physical component score, VR-12 = Veterans RAND 12-Item Health Survey

and how this optimization translates into sustained improvements in postoperative outcomes after the episode of care.

Smoking cessation may offer an additional opportunity for modifying low baseline physical function PROs. Although our study found no connection between smoking and baseline HOOS/KOOS, smoking was a predictor of low physical function as measured by baseline VR-12 PCS. However, the association between smoking and the pathogenesis of osteoarthritis leading to TJR is unclear; some studies

claim no association, whereas others report notable positive or negative associations between smoking and osteoarthritis.<sup>16</sup>

In our study, female sex was predictive of low baseline HOOS/KOOS. Other studies have similarly suggested a relationship between female sex and low baseline PROMs even after controlling for BMI, age, comorbidity, and mental health scores.<sup>17</sup> Some propose this finding may be due to women preferentially opting for surgery later in the course of their disease, having a risk-averse approach to treatment, barriers to

access, or their pressures to maintain caregiving responsibilities and decrease burden on others.<sup>18</sup> Investigators should determine whether any of the factors that drive women to have a tendency to score poorly on baseline PROMs could be addressed and modified preoperatively.

Increasing patient age was found to decrease the probability of scoring in the lowest 25th percentile of HOOS/KOOS. However, it has been shown that age does not predict preoperative PROs and that younger patients have better improvements in PROs postoperatively.<sup>19</sup>

## Factors Associated With Mental Health Status and the Impact of Mental Health on Patient-reported Outcomes

The relationship between a patient's preoperative pain level, functional ability, and baseline mental health has not yet been well established in the literature. In the present study, increasing baseline VR-12 MCS predicted higher (>25th percentile) baseline HOOS/KOOS and vice versa. The connection between these scores is logical; individuals with good mental health tend to be less sedentary<sup>20</sup> and would thus be more likely to report that they are at a higher functional level than those who are more sedentary. High pain levels also have been associated with psychological distress,<sup>21</sup> explaining why a lower HOOS/KOOS would be linked to a lower MCS. Although it is clear that an association between HOOS/KOOS and VR-12 MCS exists, future research is needed to determine whether the relationship is causative.

The relationship between preoperative mental health and postoperative outcomes has been a frequent topic of investigation in TJR. In a systematic review by Vissers et al,<sup>22</sup> impaired preoperative mental health was associated with lower scores on function and pain 1 year after TKA. Patients who score poorly on the VR-12 MCS have been shown to use more "catastrophizing" coping techniques, to report poorer pain control, and are at higher risk for dissatisfaction after surgery.<sup>23,24</sup> Mental health disorders including depression, anxiety, and schizophrenia have been associated with a low VR-12 MCS.<sup>25,26</sup> In a study of 2,425 patients in the Veteran's Health System, Kazis et al<sup>26</sup> found that depression lowered VR-12 MCS by eight points, a clinically notable difference. As expected, the results of our study corroborate this finding,

showing patients with depression to have a substantially decreased likelihood of achieving a high VR-12 MCS at baseline. The presence of physical comorbidities has also been found to affect MCS;<sup>27</sup> in the same study of Kazis et al<sup>26</sup>, hypertension was associated with a 0.5-point decrease in MCS, whereas malignancy was associated with almost a one-point increase in MCS. Hypertension was a risk factor for a low MCS in our study, whereas malignancy was associated with decreased odds of having a low baseline MCS. Aggregate analysis of the Surveillance, Epidemiology, and End Results–Medicare Health Outcomes Survey supports this finding, showing patients with malignancy to have a VR-12 MCS one point higher than the general population.<sup>28</sup> As CJR and other alternative payment models gain traction and baseline PROs become increasingly available, additional literature using larger samples and nation-wide data is required to further define the impact of comorbidities on baseline mental health scores. Identifying and addressing comorbidities that diminish MCS preoperatively has the opportunity to improve patients' mental health before surgery and increase their likelihood of sustaining high PRO scores after TJR.<sup>22</sup>

## Current Payment Models Incentivize Addressing Modifiable Risk Factors

Value-based alternative payment models such as CJR are evolving to reward providers for selecting TJR candidates who are most likely to achieve the greatest improvement in PROs per healthcare dollar spent and those that sustain that improvement with minimal complications long after surgery.<sup>29</sup> Addressing factors associated with low baseline PROs may increase the likelihood of maximal benefit from an episode of TJR

for a particular patient who is disabled. Of the factors identified in this study, preoperatively addressing comorbidities that are mismanaged or untreated, mental health, and physical function offer the best opportunities as modifiable factors for improving outcomes. Neglected comorbidities can be improved preoperatively through medical management, as performed in the Kaiser Permanente system.<sup>30</sup> Similarly, preadmission testing clinics can be used wherein patients are examined by a multidisciplinary team of medical professionals who identify comorbidities before surgery.<sup>31</sup> These clinics have been proven to dramatically decrease length of stay (LOS) in the high-dependency unit and admissions to the intensive care unit (ICU) and post-anesthesia care unit (PACU).<sup>32</sup> Preoperative testing can be included as part of a perioperative surgical home (PSH) model; comorbidities can be identified preoperatively and continuously be optimized through intervention and patient education throughout the surgical episode by an informed PSH team.<sup>33,34</sup> In addition to helping to sustain improvements in PROs from the TJR episode by mitigating the negative impact of comorbidities, implementing these changes to the pathway will likely result in reduced costs postoperatively because comorbidities have been associated with an increased risk of 30-day readmission after total hip arthroscopy (THA).<sup>30</sup>

Low baseline MCS should indicate patients for psychological intervention; a previous study found that patients who underwent a psychologically based pain management program before surgery reported markedly less pain preoperatively than those who did not undergo the intervention. After THA, these patients also displayed a greater improvement in function.<sup>35</sup> The Patient Health Questionnaire

(PHQ)-9 represents an additional useful tool to screen for and identify depression preoperatively.<sup>36</sup> Patients with poor PHQ-9 scores can be referred to primary care and mental health providers who can address the patients' depressive symptoms. When PHQ-9 scores and MCS improve, the patient can then be referred back to the surgeon for TJR. If mental health remains optimized postoperatively, the improvements in PROs from the episode of care will likely be more sustained. Surgeons and mental health providers should collaborate to build a framework that helps patients remain motivated postoperatively to maintain good mental health. Although allowing for time in the preoperative period to improve mental health will likely improve outcomes, the care team must also consider how an increased wait time before TJR can negatively affect the progression of the disease in the affected joint. Last, improving physical function PROs preoperatively will likely increase a patient's potential for high postoperative PROs.<sup>4</sup> In patients awaiting THA, exercise-based interventions, termed "prehabilitation," have been shown to reduce pain and increase physical function.<sup>37</sup> As soon as the patient enters the TJR pathway, a physical therapist should introduce them to targeted exercises that will improve their functional level even before surgery. Participation in preoperative physical therapy has been associated with a 29% reduction in postacute care use.<sup>38</sup> Because patients are often limited in the number of physical therapy appointments that they are allotted annually by insurers, they may be hesitant to commit some of their allotment to preoperative therapy. In these cases, online physical therapy exercise programs are a good alternative because they can be disseminated at a low cost and have been shown to be effective in

improving PROs in patients with knee osteoarthritis.<sup>1</sup>

The steps outlined above can occur before consultation with the surgeon. If implemented successfully, this enables the surgeon to be confident that the candidates he or she sees will have their maximal possible improvement in function after surgery. Downstreaming care in this manner is an important principle in value-based care delivery that allows the surgeon to practice at the "top of their license"; it ensures unnecessary appointments with poor candidates for surgery are avoided until their status improves, enabling practices to operate more efficiently.

### Limitations

There are several limitations of this study that must be acknowledged. First, a large portion of the initial study population (56%) was excluded because of missing preoperative PROs data. These patients tended to be older, on public insurance, and of Asian or other/unknown race. As such, the models described in this study may be overfit to populations more likely to complete PROMs (ie, younger, Caucasian patients on private insurance).<sup>39</sup> Inequities that perpetuate differences in PROM completion rates must be investigated and addressed before predictors of baseline PROs can be fully understood. Second, considering the relative homogeneity of patients undergoing elective THA and TKA, procedure type was not included as a variable in this analysis. Although this is a common approach that has been widely accepted in the literature, it is possible that baseline PROs differed between patients undergoing THA and TKA. Finally, the inclusion population for this study was drawn from two urban academic medical centers. Although this enabled a more granular study design, results

may not be generalizable to nonacademic institutions or institutions that treat a substantially different case-mix. Because the main outcomes in this study are based on percentile cutoffs from a distribution that is institution specific, institutions with different distributions may find different predictors of outcomes. Furthermore, the time point in the course of the disease at which baseline PROs were collected is dependent on each surgeon's decision to indicate a patient for TJR; there may be some inconsistency among surgeons regarding when this decision is made, and thus generalizability of these results may be impaired. To date, no national PRO data exist that would allow for more generalizable results. Although the scope of the present study excludes postoperative PROMs and changes in PROMs over the episode of care from the analysis, these variables are important to consider as indicators of the extent of a patient's improvement in function after surgery; the present analysis was only concerned with identifying factors that could be modified before surgery such that more successful outcomes are likely.

### Conclusion

Our study identified several modifiable and nonmodifiable patient factors that are predictive of low baseline HOOS/KOOS and VR-12 PCS and MCS in TJR patients. Specifically, we identified preoperatively addressing mismanaged or untreated comorbidities, mental health issues, and physical function as the best opportunities for optimization before TJR. Providers should consider addressing these factors preoperatively to ensure that their patients have the highest potential for large and sustained improvements in PROs across the TJR episode. Payors should

allocate specific resources for such optimizable initiatives.

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