Journal of Clinical Orthopaedics and Trauma 11 (2020) S164–S170

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

Clinical characteristics associated with depression or anxiety among patients presenting for knee surgery

Ashley La [a], Vidushan Nadarajah [b], Julio J. Jauregui [a], William P. Shield III [a], Shaun H. Medina [c], Andrew G. Dubina [a], Sean J. Meredith [d], Jonathan D. Packer [a], R. Frank Henn III [a, *]

[a] Department of Orthopaedic Surgery, University of Maryland School of Medicine, Baltimore, MD, USA
[b] Department of Orthopaedic Surgery, SUNY Downstate Medical Center, Brooklyn, NY, USA
[c] The Ohio State University College of Medicine, USA
[d] Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA

ARTICLE INFO

Article history:
Received 26 June 2019
Received in revised form
10 August 2019
Accepted 12 August 2019
Available online 12 August 2019

Keywords:
Knee
Patient-reported outcomes
PROMIS
Depression
Anxiety

ABSTRACT

Background: Preoperative depression and anxiety in patients undergoing surgery have been shown to be associated with increased postoperative complications, decreased functional improvement, and long-term dissatisfaction. The purpose of this prospective study was to measure the relationship between a diagnosis of depression or anxiety and Patient-Reported Outcomes Measurement Information System (PROMIS) domains, as well as determine which preoperative factors are associated with depression or anxiety in patients undergoing knee surgery. We hypothesized that preoperative depression and/or anxiety would be associated with worse preoperative pain, function, and general health status.
Methods: Three-hundred and eighty-six patients undergoing knee surgery between 2015 and 2017 were administered health-related quality of life measures preoperatively, and their medical records were reviewed for relevant medical history. A propensity matched analysis was performed to determine clinical factors independently associated with preoperative depression and/or anxiety.
Results: The overall study population consisted of 216 males and 170 females, with a mean age of 39.4 ± 16.2 years. From this overall cohort, 43 (11.1%) patients had a positive preoperative diagnosis of depression and/or anxiety. After controlling for covariate imbalances, preoperative depression/anxiety was independently associated with PROMIS Anxiety ($p = 0.018$), PROMIS Depression ($p < 0.019$), and Tegner pre-injury ($p = 0.013$) scores. Regression analysis also determined that preoperative depression/anxiety was independently associated with arthroscopic anterior cruciate ligament reconstruction (ACLR) ($p = 0.004$), total knee arthroplasty (TKA) ($p = 0.019$), and uni-compartmental knee arthroplasty ($p < 0.05$).
Conclusion: The results support our hypothesis that preoperative depression/anxiety is associated with worse preoperative pain, function, and general health status. Furthermore, PROMIS Anxiety and Depression tools offer a reliable means of measuring psychological distress in the orthopaedic knee population. Similar to other studies, we also noted psychological comorbidity to be independently associated with ACLR and TKA.

© 2019 Delhi Orthopedic Association. All rights reserved.

1. Introduction

The prevalence of knee surgeries in the United States has been steadily increasing each year, wherein it has increased from 0.13% in 1980 to 1.52% in 2010.[1] This trend is likely to continue as the average life expectancy of the U.S. citizen continues to rise.[2] The elderly population is often at a higher risk of requiring knee surgery, due to an increased risk for knee arthritis as a result of mechanical and biochemical cartilage deterioration.[3]

As with any surgical procedure, postoperative dysfunction and complications do occur after orthopaedic knee surgeries. The rate of complications, including hemarthrosis, pulmonary embolism, and deep vein thrombosis, has been estimated to be 4.7% for arthroscopic knee operations between 2003 and 2009.[4] Complications

* Corresponding author. University of Maryland Rehabilitation and Orthopaedic Institute, 2200 Kernan Drive, Baltimore, MD, 21207, USA.
E-mail address: FHenn@som.umaryland.edu (R.F. Henn).

https://doi.org/10.1016/j.jcot.2019.08.009
0976-5662/© 2019 Delhi Orthopedic Association. All rights reserved.

and dysfunction after surgery can result in higher financial burdens, slower recovery times, and lower quality of life.[5] Essential in minimizing the risk of complications is identifying and minimizing preoperative factors associated with poor postoperative outcomes. Several such factors have been identified in the literature, which include age, body mass index (BMI), preexisting comorbidities such as diabetes and cardiac disease, and American Society of Anesthesiologists (ASA) classification.[6,7]

Interestingly, psychological comorbidities, such as depression and anxiety, have been shown to be associated with increased postoperative complications, decreased functional improvement, lengthened rehabilitation, and long-term dissatisfaction.[8–16] The prevalence of major depressive disorder, the most common of all mood disorders, has been estimated to be 29.9% of the general population in 2012.[17] Thus, depression and anxiety may be common within orthopaedic surgery patients and negatively influence postoperative outcomes.

Recognition of preoperative risk factors, including depression and anxiety, may allow for intervention and optimization of postoperative outcomes. Patients with conditions requiring knee surgeries, in particular, could be at increased risk for psychological comorbidities due to fatigue, pain, and inability to carry out their usual activities due to lower extremity dysfunction.[18] However, there is a lack of data regarding depression and anxiety assessment in patients undergoing knee surgery, and that which is reported is limited to patients undergoing knee arthroplasty.

The Patient-Reported Outcomes Measurement Information System (PROMIS) domains have been created by the National Institutes of Health (NIH) to provide an assessment of patient-reported outcomes that is cost effective, time effective, and generalizable over a wide variety of clinical patients.[19,20] However, the data collected through PROMIS in orthopaedic patients is currently limited to foot, ankle, upper extremity, and spine injuries,[20–23] with a lack of data regarding the use of PROMIS for patients undergoing knee surgery.

The primary objective of this study was to determine the potential demographic associations of preoperative depression and/or anxiety in patients undergoing a variety of knee surgeries. The secondary purpose was to determine whether preoperative depression/anxiety was a significant independent predictor of health-related quality of life (HRQOL) measures, including PROMIS, in patients undergoing knee surgery. Our first hypothesis was that preoperative depression/anxiety would be associated with worse demographic and clinical measures. Our second hypothesis was that preoperative depression/anxiety would be significantly and independently associated with worse HRQOL measures, including function, pain, and satisfaction.

2. Patients and methods

The investigation was observational cross-sectional study. A prospective orthopaedic database was used to evaluate patients preoperatively from June 2015 to June 2017 at a single institution.[24] All patients undergoing knee surgery at our institution were eligible for enrollment into an institutional review board-approved registry. All study data was collected within 7 days prior to surgery using the Research Electronic Data Capture (REDCap™) data collection system. Inclusion criteria were as follows: (1) patient undergoing orthopaedic surgery, (2) age more than 12 years, and (3) English speaking.

Demographic data, including a diagnosis of depression and/or anxiety, was self-reported by each respondent. Income level was assessed as approximate family income including wages, disability payment, retirement income, and welfare. This was done so as to account for very young patients who may have no income (i.e students) and the elderly that may be retired. Each patient's medical record was reviewed for relevant medical history, including their American Society of Anesthesiologists (ASA) score and current medications.[24]

Patients enrolled in the registry were asked to complete an electronic baseline assessment of: (1) preoperative data, (2) six PROMIS (v1.2) computer adaptive testing tools (Domains: Physical Function, Pain Interference, Fatigue, Social Satisfaction, Anxiety, and Depression), (3) the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, (4) International Physical Activity Questionnaire (IPAQ), (5) Tegner activity measure (both prior to injury and preoperative), (6) Activity Rating Scale for the lower extremity (ARS), (7) Numeric Pain Scale (NPS, for the operative knee and body overall), and (8) pretreatment expectations (MODEMS, Musculoskeletal Outcomes Data Evaluation and Management System).

2.1. Statistical analysis

Descriptive statistics were used to analyze study variables (means, medians, standard deviations, and frequency). Demographic and clinical data were compared using the Wilcoxon rank sum test for continuous variables and the Pearson chi-squared test (or Fisher's exact test when more than 20% of cells had frequencies < 5) for categorical variables.

In addition, a propensity score matching analysis was implemented to reduce the effect of covariate bias and to better estimate the independent associations of preoperative depression and/or anxiety. Covariates that were previously reported to affect perioperative depression and anxiety, or that had a possible association with depression and/or anxiety in the current dataset were entered in the analysis. These covariates included: age, BMI, expectations overall, number of surgeries (ANY), gender, employment status, smoking status, preoperative opioid use, and ASA score.

The propensity score was the conditional probability for subjects who had depression/anxiety and those who did not as a function of predetermined covariates, added into a multiple logistic regression. Propensity scores derived from logistic regression models were determined. Using the calculated propensity scores, a 1-to-1 matched analysis was carried out by random selection of a patient who had depression/anxiety with one who did not using the closest calculated propensity score. The selected pair was suitable for matching if the propensity scores of the pair were within 0.6 standard deviation of all selected pairs. According to Cochran and Rubin, a caliper width of 0.6SD will remove almost 90% of the bias in observed confounders.[25] Those patients who did not have an acceptable range of propensity scores were excluded from analysis. Logistic regression models using propensity matched groups were used to identify independent association between each patient-reported outcome and preoperative depression/anxiety. A two-sided P value < 0.05 was considered statistically significant.

3. Results

From a total of 412 eligible patients between 2015 and 2017, medical record data regarding a preoperative diagnosis of depression and/or anxiety was available for 386 patients. The study population consisted of 216 males (56%) and 170 females (44%), with a mean age of 39.4 ± 16.2 years and mean BMI of 29.3 ± 5.7 kg/m^2. From this overall cohort, 43 (11.1%) patients had a positive preoperative diagnosis of depression and/or anxiety. The distribution of categorical variables of the patients studied, including demographic data, ASA score, drug use, and surgical history, is presented in Table 1. Bivariate analysis demonstrated that

Table 1
Categorical variables (n = 386).

	Depression and/or Anxiety				P value
	Yes		No		
	N	**%**	**N**	**%**	
	43	**11.1%**	**343**	**88.9%**	
Gender					
Male	10	23.3%	206	60.1%	**<.0001**
Female	33	76.7%	137	39.9%	
Ethnicity					
Hispanic or Latino	1	2.4%	18	5.4%	0.800
NOT Hispanic or Latino	41	97.6%	317	94.6%	
Race					
Black	12	27.9%	113	33.9%	0.706
White	27	62.8%	190	57.1%	
Other	4	9.3%	30	9.0%	
Education					
HS grad or above	42	97.7%	302	91.2%	0.284
Some HS or below	1	2.3%	29	8.8%	
Employment Status					
Employed for wages	21	48.8%	170	50.9%	**0.026**
Self-employed	2	4.7%	24	7.2%	
Out of work and looking for work	–	–	12	3.6%	
Out of work but not currently looking for work	–	–	6	1.8%	
Homemaker	2	4.7%	5	1.5%	
Student	2	4.7%	69	20.7%	
Military	–	–	1	0.3%	
Retired	7	16.3%	15	4.5%	
Unable to work	9	20.9%	27	8.1%	
Other	–	–	5	1.5%	
Income					
Less than $10,000	5	14.3%	28	12.6%	0.835
$10,000 - $19,999	2	5.7%	12	5.4%	
$20,000 - $29,999	–	–	15	6.7%	
$30,000 - $39,999	2	5.7%	18	8.1%	
$40,000 - $49,999	1	2.9%	17	7.6%	
$50,000 - $59,999	3	8.6%	15	6.7%	
$60,000 - $69,999	3	8.6%	9	4.0%	
More than $70,000	19	54.3%	109	48.9%	
Marital Status					
Single - never married	12	27.9%	168	50.1%	0.110
Married or domestic partnership	23	53.5%	135	40.3%	
Divorced, separated, or widowed	8	18.6%	32	9.6%	
Smoking Status					
Daily	6	14.0%	14	4.2%	**0.049**
Less than daily	3	7.0%	11	3.3%	
Quit smoking	11	25.6%	60	18.0%	
Never smoked	23	53.5%	249	74.6%	
Alcohol Consumption					
Never	16	39.0%	88	26.7%	0.814
Monthly or less	12	29.3%	94	28.5%	
2 to 4 times a month	6	14.6%	74	22.4%	
2 to 3 times a week	5	12.2%	51	15.5%	
4 or more times a week	2	4.9%	23	7.0%	
Recreational drug use					
No	38	90.5%	316	95.2%	0.592
Yes	4	9.5%	16	4.8%	
Preoperative Opioid Use					
No	28	65.1%	274	80.8%	**0.009**
Yes	15	34.9%	65	19.2%	
ASA score					
1	4	9.3%	156	45.7%	**<.0001**
2	33	76.7%	174	51.0%	
3	6	14.0%	11	3.2%	
Injury prior to surgery					
No	23	57.5%	118	35.3%	**0.018**
Yes	17	42.5%	216	64.7%	
Workers' compensation					
No	42	97.7%	331	96.5%	0.915
Yes	1	2.3%	12	3.5%	
Prior surgery on same knee					
No	22	52.4%	228	67.1%	0.192
Yes	20	47.6%	112	32.9%	

preoperative depression/anxiety was significantly associated with female gender ($p < 0.0001$), employment status ($p = 0.026$), smoking status ($p = 0.049$), preoperative opioid use ($p = 0.009$), ASA score ($p < 0.0001$), and the occurrence of an injury prior to surgery ($p = 0.018$).

The distribution of the continuous variables, including demographic data, preoperative expectations of surgical outcomes, and patient-reported outcome measures, are presented in Table 2. Bivariate analysis demonstrated multiple significant differences between those patients with a positive preoperative diagnosis of depression/anxiety and those without depression/anxiety. The average age of patients with preoperative depression/anxiety was 48.0 ± 14.4 years, while the average age of patients without depression or anxiety was 38.1 ± 16.1 years ($p = 0.0002$). Patients with preoperative depression/anxiety had a significantly worse mean Charlson Comorbidity Index (1.8 ± 1.7 vs. 0.8 ± 1.1; $p < 0.0001$) and significantly more prior surgeries of any type (4.3 ± 3.3 vs. 2.6 ± 3.2; $p < 0.0001$) than those patients without preoperative depression/anxiety. Patients with positive preoperative depression/anxiety had significantly worse scores across all PROMIS health domains, including Physical Function (37.8 ± 6.8 vs. 42.0 ± 8.1; $p = 0.0013$), Pain Interference (64.0 ± 6.5 vs. 59.8 ± 7.3; $p = 0.0005$), Fatigue (57.6 ± 10.1 vs. 51.7 ± 10.4; $p = 0.0006$), Social Satisfaction (39.6 ± 7.2 vs. 42.9 ± 9.4; $p = 0.015$), Anxiety (61.9 ± 7.6 vs. 54.4 ± 8.8; $p < 0.0001$), and Depression (54.7 ± 8.7 vs. 48.5 ± 9.0; $p < 0.0001$) (see Fig. 1). There were also significant differences in IKDC, IPAQ, Tegner pre-injury, ARS (lower extremity), and pain intensity (NPS, operative knee and overall body) scores between those patients with preoperative depression/anxiety and those without (Table 2).

After propensity matching to control for covariate imbalances, logistic regression analysis determined that PROMIS Anxiety ($p = 0.018$), PROMIS Depression ($p < 0.019$), and Tegner pre-injury ($p = 0.013$) scores were independently associated with a preoperative depression/anxiety. Logistic regression analysis also determined that preoperative depression/anxiety was independently associated with arthroscopic anterior cruciate ligament (ACL) surgery (CPT 29888; $p = 0.004$), total knee arthroplasty (CPT 27447; $p = 0.019$), and uni-compartmental knee arthroplasty (CPT 27446; $p < 0.05$) (see Table 3).

4. Discussion

Knee surgery successfully restores physical function and relieves pain in millions of Americans each year. Despite the overwhelming success of many orthopaedic knee procedures, functional improvement varies widely. Poor functional measures have been correlated with poor emotional health, such as anxiety, depression, poor coping skills, and poor social support.[26,27] This study identified several key associations of preoperative depression/anxiety in patients undergoing a variety of knee surgeries. Our primary hypothesis was supported as preoperative depression/anxiety was associated with multiple clinical factors including age, gender, employment, smoking, opioid use, worse comorbidities, and greater number of prior surgeries. Our secondary hypothesis was also supported as patients with preoperative depression/anxiety was associated with worse scores on all HRQOL measures. After adjusting for covariate imbalances, preoperative depression/anxiety demonstrated an independent association with PROMIS Depression, PROMIS Anxiety, Tegner pre-injury, ACL reconstruction, and knee arthroplasty.

Among the United States general population, the prevalence of depression is estimated between 3.4% and 29.9%,[17,28,29] and the prevalence of anxiety is estimated between 9% and 33.7%.[17,30] Comparatively, in our study the prevalence of depression and/or anxiety was 11.1%. Similar to the general U.S. population, our study identified preoperative depression/anxiety to be significantly associated with female gender, smoking, and opioid use.[17,28,30–37] However, many of the commonly noted associations of depression/anxiety, such as race, BMI, and socioeconomic status, were not

Table 2
Continuous variables (n = 386).

	Depression and/or Anxiety						P value
	Yes			No			
	Mean	SD	Median	Mean	SD	Median	
Age (years)	48.0	14.4	49.2	38.1	16.1	36.5	**0.0002**
BMI (kg/m^2)	30.4	5.9	30.1	29.1	5.8	28.6	0.0879
Charlson Comorbidity Index	1.8	1.7	1.0	0.8	1.1	0.0	**<.0001**
Expectations Overall (MODEMS)	4.3	0.8	4.5	4.4	0.7	4.7	0.3359
1. Relief from symptoms	4.4	0.8	4.6	4.5	0.8	5.0	0.2510
2. Household or yard activities	4.4	0.8	5.0	4.5	0.9	5.0	0.2628
3. Sleep	4.3	1.1	5.0	4.3	1.0	5.0	0.9168
4. Job	4.4	0.9	5.0	4.5	0.9	5.0	0.1061
5. Exercise recreational	4.4	0.9	5.0	4.5	0.8	5.0	0.1449
6. Future disability	4.2	1.0	4.5	4.3	0.9	5.0	0.2341
Number of surgeries (ANY)	4.3	3.3	3.0	2.6	3.2	2.0	**<.0001**
Number of orthopaedic surgeries	1.5	1.8	1.0	1.3	1.7	1.0	0.2396
Number of knee surgeries	1.4	0.6	1.1	1.4	0.6	1.2	0.4960
PROMIS Physical Function	37.8	6.8	36.5	42.0	8.1	41.4	**0.0013**
PROMIS Pain Interference	64.0	6.5	64.2	59.8	7.3	59.7	**0.0005**
PROMIS Fatigue	57.6	10.1	58.7	51.7	10.4	50.6	**0.0006**
PROMIS Social Satisfaction	39.6	7.2	38.7	42.9	9.4	42.4	**0.0150**
PROMIS Anxiety	61.9	7.6	61.8	54.4	8.8	54.1	**<.0001**
PROMIS Depression	54.7	8.7	55.4	48.5	9.0	48.2	**<.0001**
IKDC	30.1	15.2	31.0	40.3	18.1	39.1	**0.0008**
IPAQ (MET/week)	2186.5	2422.5	1542.7	3603.8	3906.5	2772.0	**0.0182**
Tegner Pre-Injury	5.3	2.6	5.3	7.2	2.1	7.0	**<.0001**
Tegner Current (preoperative)	2.3	2.3	2.0	2.5	1.9	2.0	0.1667
ARS (Lower Extremity)	4.4	5.6	1.1	7.5	6.4	8.0	**0.0034**
NPS (Operative Knee)	6.0	2.7	6.8	4.7	2.9	5.0	**0.0040**
NPS (Overall body)	2.8	2.7	2.0	1.3	2.3	0.0	**<.0001**

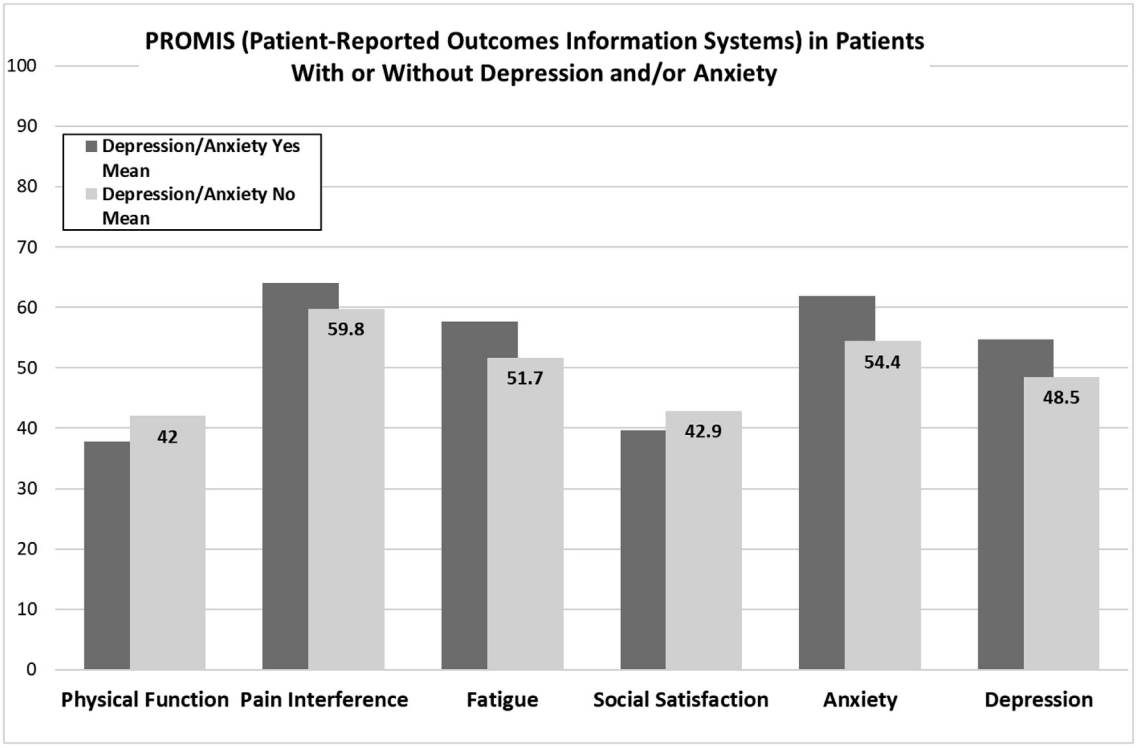

Fig. 1. PROMIS (Patient-Reported Outcomes Information Systems) in Patients with or without Depression and/or Anxiety.

Table 3
Top 10 most performed knee procedures.

CPT	Description	Count	P Value
29881	Arthroscopy, knee, surgical; with meniscectomy (medial OR lateral, including any meniscal shaving) including debridement/shaving of articular cartilage (chondroplasty), same or separate compartment(s), when performed	51	
29888	**Arthroscopically aided anterior cruciate ligament repair/augmentation or reconstruction**	**86**	**0.0036**
29876	Arthroscopy, knee, surgical; synovectomy, major, 2 or more compartments (eg, medial or lateral)	25	
29879	Arthroscopy, knee, surgical; abrasion arthroplasty (includes chondroplasty where necessary) or multiple drilling or microfracture	35	
29882	Arthroscopy, knee, surgical; with meniscus repair (medial OR lateral)	27	
20610	Arthrocentesis, aspiration and/or injection; major joint or bursa eg, shoulder, hip, knee joint, subacromial bursa)	2	
29877	Arthroscopy, knee, surgical; debridement/shaving of articular cartilage (chondroplasty)	10	
27447	**Arthroplasty, knee, condyle and plateau; medial AND lateral compartments with or without patella resurfacing (total knee arthroplasty)**	**30**	**0.0192**
29870	Arthroscopy, knee, diagnostic, with or without synovial biopsy (separate procedure)	32	
27446	**Arthroplasty, knee, condyle and plateau; medial OR lateral compartment**	**19**	**0.0484**

identified in our cohort of patients undergoing knee surgery.[28,38,39]

Patient-reported outcomes (PROs) are increasingly being combined with electronic medical records throughout orthopaedic clinical practices. PROs are not only a research tool but are becoming a standard means of capturing patient-oriented indicators,[22] and there has been growing interest in determining the capacity of PROs to predict which patients are the most suited to undergo specific orthopaedic treatments. Previous studies have identified multiple preoperative variables associated with worse outcomes after knee surgery, which include severity and chronicity of pain,[40–42] psychological disease,[26,43–46] and poor coping strategies.[41,47] Psychological disease in orthopaedics has historically been elicited using the Mental Component Score of Short Form-36 or -12 general health questionnaires which measure a combination of anxiety, depression, and poor social support. Other psychological measures used include the Beck Depression Index[45] and the Hospital Anxiety and Depression (HAD) scale.[48] However, these measures are often limited by high respondent-burden, lack of precision, and inefficiency in comparison to normative data.

PROMIS is a high-throughput PRO measure that has proven to be valid and accurate in multiple orthopaedic patient populations.[23,49–56] The growing body of literature supports the strength of PROMIS Physical Function as an orthopaedic PRO measurement,[54] but there is limited data regarding the use of PROMIS Depression and PROMIS Anxiety to measure psychological disease in the orthopaedic population,[22,57] particularly in patients undergoing knee surgery. After adjusting for covariate imbalances by using propensity score matching analysis, preoperative depression and/or anxiety was found to be independently associated with PROMIS Depression and PROMIS Anxiety. This finding strengthens the argument for utilizing the PROMIS questionnaires for assessing psychological distress in the orthopaedic knee population. However, further studies in other orthopaedic surgical populations are needed before widespread use.

Preoperative depression and/or anxiety was also found to be independently associated with patients undergoing ACL reconstruction, uni-compartmental and total knee arthroplasty. A recent study by Chen et al.[58] demonstrated that preoperative PROMIS

Physical Function, Pain Interference, and Depression scores were highly predictive of outcome in the early postoperative period. The authors found that patients undergoing ACL reconstruction with a preoperative PROMIS Physical Function (PF) score of <42.5, Pain Interference (PI) score of >56.2, or Depression score of >44.8 were more likely to reach a minimal clinically important difference (MCID) at 20 weeks postoperatively. Comparatively, we found a significant difference in PROMIS PF, PI and Depression scores between patients with and without preoperative depression/anxiety. Though our patients demonstrated preoperative scores within the cutoff for MCID established in Chen et al.,[58] given that our study population consisted of patients undergoing a variety of knee surgeries, the true MCID in a heterogenous population might differ.

Given that the prevalence of documented depression in the total joint replacement literature ranges from 6.4% to 33%, psychological distress is a common medical comorbidity in this patient population.[12,59] A recent study suggests that patients with preoperative depressive symptoms undergoing total joint arthroplasty have lower functional improvement and satisfaction compared to nondepressed patients postoperatively.[12] This study further reaffirms the association between mental health and joint arthroplasty by establishing an independent relationship between preoperative depression and/or anxiety and knee arthroplasty. Identifying and addressing psychological comorbidities in patients undergoing knee arthroplasty may improve knee pain and function and decrease postoperative risks of infection, anemia, psychosis, and pulmonary embolism.[10,42,60]

There are several limitations in this study. Participants filled out a series of questionnaires, which might have affected the quality of collected data secondary to respondent-fatigue. As a study based on cross-sectional data, we cannot infer causality from our identified associations. Although we examined many demographic and clinical characteristics, there may be others that were outside our scope that could possibly act as confounders. While the risk of selection bias must be noted, a propensity matching analysis was used to mitigate the effect of possible covariates. Thus, this study is useful for hypothesis generation of potential associations that can be confirmed or refuted in more rigorous study designs. Contrary to most studies in the orthopaedic literature, we reported on a heterogeneous group of procedures, which could also be considered a strength of this study. We included all knee procedures performed at a single institution, and this may not be applicable to other patient populations of specific, isolated procedures. Furthermore, our study population is an urban population, which may not be applicable to other patient populations.

5. Conclusion

The results support our hypothesis that preoperative depression/anxiety is associated with worse preoperative pain, function, and general health status. Furthermore, PROMIS Anxiety and Depression tools offer a reliable means of measuring psychological distress in the orthopaedic knee population. Similar to other studies, we also noted psychological comorbidity to be independently associated with ACLR and TKA.

Conflicts of interest

Dr. Henn reports non-financial research support from Arthrex, Inc., outside the submitted work.

All other authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Funding

This work was supported by a grant from The James Lawrence Kernan Hospital Endowment Fund, Incorporated.

Approval

This study was approved by the Institutional Review Board (IRB) at the University of Maryland, Baltimore (HP-00062261).

Acknowledgements

The authors thank J. Kathleen Tracy, PhD; Farshad Adib, MD; Craig Bennett, MD, and Michael Smuda, MSAT for their assistance with data collection.

References

1. Maradit Kremers H, Larson DR, Crowson CS, et al. Prevalence of total hip and knee replacement in the United States. *J Bone Joint Surg Am*. 2015;97:1386–1397.
2. Arias E, Rostron BL, Tejada-Vera B. United States life tables, 2005. *Natl Vital Stat Rep*. 2010;58, 1-132.
3. Ding C, Cicuttini F, Scott F, Cooley H, Jones G. Association between age and knee structural change: a cross sectional MRI based study. *Ann Rheum Dis*. 2005;64:549–555.
4. Salzler MJ, Lin A, Miller CD, Herold S, Irrgang JJ, Harner CD. Complications after arthroscopic knee surgery. *Am J Sports Med*. 2014;42:292–296.
5. Britteon P, Cullum N, Sutton M. Association between psychological health and wound complications after surgery. *Br J Surg*. 2017;104:769–776.
6. Santaguida PL, Hawker GA, Hudak PL, et al. Patient characteristics affecting the prognosis of total hip and knee joint arthroplasty: a systematic review. *Can J Surg*. 2008;51:428–436.
7. Belmont Jr PJ, Goodman GP, Waterman BR, Bader JO, Schoenfeld AJ. Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. *J Bone Joint Surg Am*. 2014;96:20–26.
8. Alattas SA, Smith T, Bhatti M, Wilson-Nunn D, Donell S. Greater pre-operative anxiety, pain and poorer function predict a worse outcome of a total knee arthroplasty. *Knee Surg Sport Traumatol Arthrosc*. 2017 Nov 1;25(11):3403–3410.
9. Ali A, Lindstrand A, Sundberg M, Flivik G. Preoperative anxiety and depression correlate with dissatisfaction after total knee arthroplasty: a prospective longitudinal cohort study of 186 patients, with 4-year follow-up. *J Arthroplast*. 2017;32:767–770.
10. Browne JA, Sandberg BF, D'Apuzzo MR, Novicoff WM. Depression is associated with early postoperative outcomes following total joint arthroplasty: a nationwide database study. *J Arthroplast*. 2014;29:481–483.
11. Cho CH, Seo HJ, Bae KC, Lee KJ, Hwang I, Warner JJ. The impact of depression and anxiety on self-assessed pain, disability, and quality of life in patients scheduled for rotator cuff repair. *J Shoulder Elb Surg*. 2013;22:1160–1166.
12. Duivenvoorden T, Vissers MM, Verhaar JA, et al. Anxiety and depressive symptoms before and after total hip and knee arthroplasty: a prospective multicentre study. *Osteoarthr Cartil*. 2013;21:1834–1840.
13. Mollon B, Mahure SA, Ding DY, Zuckerman JD, Kwon YW. The influence of a history of clinical depression on peri-operative outcomes in elective total shoulder arthroplasty: a ten-year national analysis. *Bone Joint Lett J*. 2016;98-B:818–824.
14. Stundner O, Kirksey M, Chiu YL, et al. Demographics and perioperative outcome in patients with depression and anxiety undergoing total joint arthroplasty: a population-based study. *Psychosomatics*. 2013;54:149–157.
15. Werner BC, Wong AC, Chang B, et al. Depression and patient-reported outcomes following total shoulder arthroplasty. *J Bone Joint Surg Am*. 2017;99:688–695.
16. Wu HH, Liu M, Dines JS, Kelly JD, Garcia GH. Depression and psychiatric disease associated with outcomes after anterior cruciate ligament reconstruction. *World J Orthop*. 2016;7:709–717.
17. Kessler RC, Petukhova M, Sampson NA, Zaslavsky AM, Wittchen HU. Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *Int J Methods Psychiatr Res*. 2012;21:169–184.
18. Driban JB, Morgan N, Price LL, Cook KF, Wang C. Patient-Reported Outcomes Measurement Information System (PROMIS) instruments among individuals with symptomatic knee osteoarthritis: a cross-sectional study of floor/ceiling

effects and construct validity. *BMC Muscoskelet Disord*. 2015;16:253.
19. Cella D, Yount S, Rothrock N, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH Roadmap cooperative group during its first two years. *Med Care*. 2007;45:S3–S11.
20. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. *J Clin Epidemiol*. 2010;63:1179–1194.
21. Beckmann JT, Hung M, Voss MW, Crum AB, Bounsanga J, Tyser AR. Evaluation of the patient-reported outcomes measurement information System upper extremity computer adaptive test. *J Hand Surg Am*. 2016;41:739–744 e734.
22. Brodke DJ, Saltzman CL, Brodke DS. PROMIS for orthopaedic outcomes measurement. *J Am Acad Orthop Surg*. 2016;24:744–749.
23. Ho B, Houck JR, Flemister AS, et al. Preoperative PROMIS scores predict postoperative success in foot and ankle patients. *Foot Ankle Int*. 2016;37:911–918.
24. Henn 3rd RF, Dubina AG, Jauregui JJ, Smuda MP, Tracy JK. The Maryland Orthopaedic Registry (MOR): design and baseline characteristics of a prospective registry. *J Clin Orthop Trauma*. 2017;8:301–307.
25. Gu XS, Rosenbaum PR. Comparison of multivariate matching methods: structures, distances, and algorithms. *J Comput Graph Stat*. 1993;2:405–420.
26. Ayers DC, Franklin PD, Ploutz-Snyder R, Boisvert CB. Total knee replacement outcome and coexisting physical and emotional illness. *Clin Orthop Relat Res*. 2005;440:157–161.
27. Ayers DC, Franklin PD, Trief PM, Ploutz-Snyder R, Freund D. Psychological attributes of preoperative total joint replacement patients: implications for optimal physical outcome. *J Arthroplast*. 2004;19:125–130.
28. Centers for Disease C, Prevention. Current depression among adults—United States, 2006 and 2008. *MMWR Morb Mortal Wkly Rep*. 2010;59:1229–1235.
29. Olfson M, Blanco C, Marcus SC. Treatment of adult depression in the United States. *JAMA Intern Med*. 2016;176:1482–1491.
30. Bandelow B, Michaelis S. Epidemiology of anxiety disorders in the 21st century. *Dialogues Clin Neurosci*. 2015;17:327–335.
31. Luppino FS, de Wit LM, Bouvy PF, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Arch Gen Psychiatr*. 2010;67:220–229.
32. Wiltink J, Michal M, Wild PS, et al. Associations between depression and different measures of obesity (BMI, WC, WHtR, WHR). *BMC Psychiatry*. 2013;13:223.
33. de Wit LM, Fokkema M, van Straten A, Lamers F, Cuijpers P, Penninx BW. Depressive and anxiety disorders and the association with obesity, physical, and social activities. *Depress Anxiety*. 2010;27:1057–1065.
34. Goesling J, Henry MJ, Moser SE, et al. Symptoms of depression are associated with opioid use regardless of pain severity and physical functioning among treatment-seeking patients with chronic pain. *J Pain*. 2015;16:844–851.
35. Martins SS, Fenton MC, Keyes KM, Blanco C, Zhu H, Storr CL. Mood and anxiety disorders and their association with non-medical prescription opioid use and prescription opioid-use disorder: longitudinal evidence from the National Epidemiologic Study on Alcohol and Related Conditions. *Psychol Med*. 2012;42:1261–1272.
36. Trosclair A, Dube SR. Smoking among adults reporting lifetime depression, anxiety, anxiety with depression, and major depressive episode, United States, 2005-2006. *Addict Behav*. 2010;35:438–443.
37. Weinberger AH, Kashan RS, Shpigel DM, et al. Depression and cigarette smoking behavior: a critical review of population-based studies. *Am J Drug Alcohol Abuse*. 2017;43:416–431.
38. Kessler RC, Berglund P, Demler O, et al. The epidemiology of major depressive disorder: results from the National Comorbidity Survey Replication (NCS-R). *J Am Med Assoc*. 2003;289:3095–3105.
39. Strine TW, Mokdad AH, Balluz LS, et al. Depression and anxiety in the United States: findings from the 2006 behavioral risk factor surveillance System. *Psychiatr Serv*. 2008;59:1383–1390.
40. Sullivan M, Tanzer M, Stanish W, et al. Psychological determinants of problematic outcomes following Total Knee Arthroplasty. *Pain*. 2009;143:123–129.
41. Forsythe ME, Dunbar MJ, Hennigar AW, Sullivan MJ, Gross M. Prospective relation between catastrophizing and residual pain following knee arthroplasty: two-year follow-up. *Pain Res Manag*. 2008;13:335–341.
42. Brander V, Gondek S, Martin E, Stulberg SD. Pain and depression influence outcome 5 years after knee replacement surgery. *Clin Orthop Relat Res*. 2007;464:21–26.
43. Scott CE, Howie CR, MacDonald D, Biant LC. Predicting dissatisfaction following total knee replacement: a prospective study of 1217 patients. *J Bone Joint Surg Br*. 2010;92:1253–1258.
44. Lingard EA, Riddle DL. Impact of psychological distress on pain and function following knee arthroplasty. *J Bone Joint Surg Am*. 2007;89:1161–1169.
45. Brander VA, Stulberg SD, Adams AD, et al. Predicting total knee replacement pain: a prospective, observational study. *Clin Orthop Relat Res*. 2003:27–36.
46. Faller H, Kirschner S, Konig A. Psychological distress predicts functional outcomes at three and twelve months after total knee arthroplasty. *Gen Hosp Psychiatry*. 2003;25:372–373.
47. Riddle DL, Wade JB, Jiranek WA, Kong X. Preoperative pain catastrophizing predicts pain outcome after knee arthroplasty. *Clin Orthop Relat Res*. 2010;468:798–806.
48. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand*. 1983;67:361–370.
49. Wong SE, Zhang AL, Berliner JL, Ma CB, Feeley BT. Preoperative patient-reported scores can predict postoperative outcomes after shoulder arthroplasty. *J Shoulder Elb Surg*. 2016;25:913–919.
50. Berliner JL, Brodke DJ, Chan V, SooHoo NF, Bozic KJ. Can preoperative patient-reported outcome measures Be used to predict meaningful improvement in function after TKA? *Clin Orthop Relat Res*. 2017;475:149–157.
51. Berliner JL, Brodke DJ, Chan V, SooHoo NF, Bozic KJ. John charnley award: preoperative patient-reported outcome measures predict clinically meaningful improvement in function after THA. *Clin Orthop Relat Res*. 2016;474:321–329.
52. Papuga MO, Beck CA, Kates SL, Schwarz EM, Maloney MD. Validation of GAITRite and PROMIS as high-throughput physical function outcome measures following ACL reconstruction. *J Orthop Res*. 2014;32:793–801.
53. Nadarajah V, Glazier E, Miller K, et al. Evaluation of preoperative pain using PROMIS pain interference in knee surgery patients. *J Knee Surg*. 2019.
54. Miles M, Nadarajah V, Jauregui JJ, et al. Evaluation of the PROMIS physical function computer adaptive test in patients undergoing knee surgery. *J Knee Surg*. 2019.
55. Medina SH, Nadarajah V, Jauregui JJ, et al. Orthopaedic surgery patients who use recreational marijuana have less pre-operative pain. *Int Orthop*. 2019;43:283–292.
56. Meredith SJ, Nadarajah V, Jauregui JJ, et al. Preoperative opioid use in knee surgery patients. *J Knee Surg*. 2019;32(7):630–636.
57. Papuga MO, Mesfin A, Molinari R, Rubery PT. Correlation of PROMIS physical function and pain CAT instruments with oswestry disability index and neck disability index in spine patients. *Spine (Phila Pa 1976)*. 2016;41:1153–1159.
58. Chen RE, Papuga MO, Voloshin I, et al. Preoperative PROMIS scores predict postoperative outcomes after primary ACL reconstruction. *Orthop J Sports Med*. 2018;6, 2325967118771286.
59. Rasouli MR, Menendez ME, Sayadipour A, Purtill JJ, Parvizi J. Direct cost and complications associated with total joint arthroplasty in patients with preoperative anxiety and depression. *J Arthroplast*. 2016;31:533–536.
60. Sorel JC, Veltman ES, Honig A, Poolman RW. The influence of preoperative psychological distress on pain and function after total knee arthroplasty. *Bone Joint Lett J*. 2019;101-B:7–14.