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Patient-rated satisfaction and improvement following hip and knee replacements: Development of prediction models

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Abstract

Rationale: Effective preoperative assessments of determinants of health status and function may improve postoperative outcomes.

Aims and Objectives: We developed risk scores of preoperative patient factors and patient-reported outcome measures (PROMs) as predictors of patient-rated satisfaction and improvement following hip and knee replacements.

Patients and Methods: Prospectively collected National Health Service and independent sector patient data ($n = 30,457$), including patients' self-reported demographics, comorbidities, PROMs (Oxford Hip/Knee score (OHS/OKS) and European Quality of Life (EQ5D index and health-scale), were analysed. Outcomes were defined as patient-reported satisfaction and improvement following surgery at 7-month follow-up. Univariable and multivariable-adjusted logistic regressions were undertaken to build prediction models; model discrimination was evaluated with the concordance index (c-index) and nomograms were developed to allow the estimation of probabilities.

Results: Of the 14,651 subjects with responses for satisfaction following hip replacements 564 (3.8%) reported dissatisfaction, and 1433 (9.2%) of the 15,560 following knee replacement reported dissatisfaction. A total of 14,662 had responses for perceived improvement following hip replacement (lack of improvement in 391; 2.7%) and 15,588 following knee replacement (lack of improvements in 1092; 7.0%). Patients reporting poor outcomes had worse preoperative PROMs. Several factors, including age, gender, patient comorbidities and EQ5D, were included in the final prediction models: C-indices of these models were 0.613 and 0.618 for dissatisfaction and lack of improvement, respectively, for hip replacement and 0.614 and 0.598, respectively, for knee replacement.

Conclusions: Using easily accessible preoperative patient factors, including PROMs, we developed models which may help predict dissatisfaction and lack of

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improvement following hip and knee replacements and facilitate risk stratification and decision-making processes.

KEYWORDS
adverse outcomes, hip replacement, knee replacement, predictive modelling, PROMs, risk scores

1 | INTRODUCTION

Total hip and knee replacement procedures are performed to relieve pain, recover function and improve patient quality of life (QoL).[1,2] The last few decades have demonstrated an increase in the mean age and comorbidity burden for total hip replacement patients, leading to an increase in the complexity of these patients.[3] Rise in these procedures have been reported globally as they are increasingly renowned,[4,5] and outcomes have improved markedly.[3] However, the incidence of unfavourable outcomes are more common in patients with more functional comorbidities, in addition to the effects of gender and age.[6]

Functional status can be determined using patient-reported outcome measures[7] in identifying patient deficits. Patient-reported outcome measures (PROMs) facilitate assessing improvements in patient management initiatives pre- and postoperatively[8]; these take the form of self-reported questionnaires in better understanding how related factors, such as age and preoperative disease severity, affect surgical outcome.[2] Although traditionally used for governance and research purposes, they pose as relevant tools in assessing outcomes and delivery of care.[2] PROMs facilitate decision-making, and their collection has the potential to improve initiatives and refine policies in addition to improving endpoints of patients' interest.[2] The effective assessments of determinants of health, functional status, as well as the patient perception of health status may improve postoperative management and surgical outcomes.[8] Preoperative PROMs have demonstrated good predictors of functional outcome following surgery[9]; worse PROMs have demonstrated an association with higher risk of reoperation,[10] as well as the perception of surgical success and dissatisfaction with procedures.[11] Preoperative symptoms measured by Oxford Hip/Knee scores (OHS and OKS) are reportedly associated with costs and QoL associated with total joint replacement.[12] Additionally, worse preoperative PROMs, patient comorbidities and social features have demonstrated an association with worse postoperative outcome[13]; combinations of comorbidities also increase the likelihood of postoperative complications.[14]

Whilst traditional PROMs have tended to focus on QoL and functional status, it is also increasingly recognized that ratings of postoperative success differ between patients and surgeons[15]; ratings of success from surgeons sometimes fail to align with patient satisfaction.[16] This has contributed to the drive-in evaluating outcomes such as patient-rated satisfaction and perceived improvement, and therefore, their continuous collection are recognized as necessary in improving outcomes.[17,18] Although there are numerous validated risk scores measuring hip and knee replacement outcomes,[15,19–25] there has been a lack of focus on investigating the predictors of self-reported satisfaction and perceived improvement following procedures.

The aims of this study were (i) to evaluate preoperative patient factors and PROMs in predicting patient-rated satisfaction and improvement following hip and knee replacements and (ii) to develop risk scores for patient satisfaction and improvement.

2 | METHODS

2.1 | Source of data

This study is a secondary analysis of routinely collected anonymous data as part of a service line evaluation in patients undergoing orthopaedic surgeries conducted across Nuffield Health between 2010 and 2020. As such, the project underwent the Nuffield Health Research Expert Advisory Group to provide approval for the use of the data in addressing our research objectives. Data were captured using standardized questionnaires reporting on PROMs and other patient factors (Supporting Information: Table I).

The development of prediction models in this study has been reported using guidance from the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) Checklist (Supporting Information: Table II).[26]

2.2 | Participants

These data were formed of two cohorts of patients undergoing primary hip and knee replacements: (i) National Health Service (NHS) referrals; (ii) private Nuffield Health patient referrals. Nuffield Health is a trading charity and one of the United Kingdom's largest independent care providers; purchase of elective care from the independent healthcare sector by the NHS is a fast-growing area of expenditure.[27] Self-reported data collected included: demographics, comorbidities, general health and disability and indication for surgery; patients self-reported pre- and postoperative PROMs questionnaires; other information pertaining to surgical and acute care, such as length of stay (LOS), living arrangements and assistance in completing questionnaires.

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2.3 | Outcome

Outcomes of interest were self-reported postoperative outcomes reported using the 6-month follow-up questionnaire: more specifically, patient-rated satisfaction and improvement. In determining satisfaction using the questionnaire, patients were asked 'How would you describe the results of your operation?' Five response options were provided: excellent; very good; good; fair; poor. Responses were subsequently grouped as previously reported[11,18]: satisfaction was defined by a response of 'excellent', 'very good' or 'good' and dissatisfaction was determined by a response of 'poor' or 'fair'. Patient perceived improvements following surgical procedures were sought by asking 'Overall, how are the problems now, compared to before your operation?' Similarly, five possible responses were provided: much better, a little better, about the same, a little worse, and much worse. Patient-rated improvement was defined as 'much better', 'a little better' and responses determined as a lack of improvement were 'about the same', 'a little worse' or 'much worse'.

Follow-up questionnaires also included self-reported clinical outcomes, such as subsequent readmission, further surgery, and experiences of allergies, bleeding, urinary problems and active wounds following their primary surgery (Supporting Information: Table III).[7]

2.4 | Predictors

In developing the prediction models, preoperative PROMs were included as they typically gauge patient perceptions of health status, impairment, disability and QoL; preoperative PROMs were administered at a median of 1-month before the procedures. Validated PROMs tools included the disease-specific OHS and OKS[28,29] and general health outcomes (European Quality of Life [EQ5D]).[1] The OHS and OKS consist of 12 questions: using a Likert scale, values ranged from 0 to 4 per question and a summative score was subsequently calculated on completion. Summative scores ranged from 0 (lowest, most symptomatic) to 48 (highest, least symptomatic). The EQ5D is a generic instrument in ascertaining health-related QoL and has two components: descriptive system (index) explores five dimensions of health (mobility, self-care, usual activities, pain/discomfort and anxiety/depression); visual analogue scale (health-scale) permits self-rating of health that ranges from 0 (worst health) to 100 (best health). Postoperative PROMs questionnaires were re-issued approximately 6 months postdischarge, allowing any effects of surgery to be identified (postoperative self-reported outcome measures were completed at a median of 7 months [interquartile ranges, IQR: 7, 8]); pre- and postoperative questionnaires were subsequently linked. Additionally included in the model development were patient-reported comorbidities of pre-existing heart disease, hypertension, leg pain when walking due to poor circulation, lung disease, diabetes, stroke, kidney disease, nervous system conditions, liver disease, cancer and depression (Supporting Information: Table I). Variables from Hospital Episode Statistics (HES) data set were additionally included.[30]

2.5 | Sample size

Based on a sample size calculation using *pmsampsize* in Stata, around 14,000 subjects were required for logistic regression with 10 parameters, c-index of 0.60 and outcome of the prevalence of 0.05.

2.6 | Missing data

Missing data were handled by using a complete-case analysis in the development of the prediction models. Participants in which there were no missing data for the variables of interest were included in our analysis.

2.7 | Statistical analysis methods

Descriptive statistics for patient demographics including age, sex, ethnicity, clinical features and social factors were summarized as medians (IQR) for continuous and numbers (proportions) for categorical data. PROMs scores at baseline and changes in PROMs scores (postintervention − pre-intervention) were compared between groups using Mann–Whitney test. Differences between proportions were evaluated using the χ^2 test.

Associations with outcomes were investigated using univariable and multivariable logistic regressions (using binary preoperative characteristics in the model selection process while continuous data were grouped as above or below their median values). Using a backwards stepwise approach, patient demographics, comorbidities and PROMs were entered into a univariable analysis, and variables with $p < 0.1$ were subsequently entered into another backwards stepwise selection to identify variables with $p < 0.05$. Significant variables from the selection process were entered into an age- and sex-adjusted complete-case multivariable logistic regression to determine associations with outcome, reported as odds ratios (ORs) with bootstrap 95% confidence interval (CI).

The discrimination of the prognostic models was estimated using the concordance index (c-index) ranging from 0.5 (no discrimination) to 1 (perfect discrimination). Nomograms were developed for each outcome using estimates from the multivariable logistic regression models.

Data analysis was performed in Stata 16 and stratified by procedure type.

3 | RESULTS

3.1 | Participants

Following the exclusion of patients with revision surgeries ($n = 133$) and no follow-up or missing PROMs response data ($n = 11,041$), data were available for 14,651 subjects who responded for satisfaction and 14,662 for perceived improvement in the hip replacement

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cohort and 15,560 and 15,588, respectively, for knee replacement (Figure 1).

In patients who had undergone hip replacement procedures, 14,087 (96.2%) were reportedly satisfied with their procedure: their median (IQR) age was 69 (62, 75) years and 8337 (59.2%) were female (Table 1). Of these patients, 2179 (15.5%) had >5 years preoperative symptom duration and 87% of patients had at least one comorbidity; following the procedure, 4188 (29.7%) patients had >3 days LOS. In subjects who underwent hip replacement, 564 (3.8%) were reportedly dissatisfied: age was 70 (63, 76) years and 356 (63.1%) were female. In the dissatisfied cohort, 101 (17.9%) subjects had >5 years preoperative symptom duration and 91% of subjects reported at least one comorbidity; following the procedure, 212 (37.6%) had >3 days LOS. Among the subjects with responses for perceived improvement that underwent hip replacements, 14,271 (97.3%) subjects [69 (62, 75) years; 8,447 (59.2%) female] perceived an overall improvement following their procedure, while 391 (2.7%) subjects [72 (63, 77) years; 256 (65.5%) female] reported a lack of improvement following their procedure. Symptom of duration >5 years was reported in 2222 (15.6%) subjects with a perceived overall improvement and in 62 (15.9%) with a perceived lack of improvement, and those with a perceived lack of improvement also reported higher comorbidity rates (91%); following the procedure, >3 days LOS (37.3%) was mainly reported in those with a perceived lack of improvement.

Following knee replacements, responses were obtained for satisfaction [n = 14,127 (90.8%); 70 (64, 76) years; 7,672 (54.3%) females] and dissatisfaction [n = 1433 (9.2%); 68 (61, 74) years; 783 (54.6%) females] and for perception of improvement [n = 14,496 (93.0%); 70 (64, 76) years; 7885 (54.4%) females] and lack of improvements [n = 1092 (7.0%); 69 (62, 74) years; 581 (53.2%) females] (Table 1). Preoperative symptom of duration >5 years was reported in 5814 (41.2%) and 627 (43.8%) subjects reporting satisfaction and dissatisfaction, respectively, while at least one comorbidity was reported in 90% and 93%, respectively. Following the procedure, 4432 (31.4%) subjects reporting satisfaction had >3 days LOS, whilst the corresponding figure in that reporting dissatisfaction was 516 (36.0%). In the cohort with a perceived lack of improvement, 492 (45.1%) subjects reported symptoms of duration >5 years and 92.9% had at least one comorbidity before the procedure, the corresponding figures in subjects with perceived improvement were 5953 (41.1%) and 90%. In the postoperative responses, 4568 (31.5%) subjects with perceived improvement and 399 (36.5%) subjects with lack of improvement reported >3 days LOS.

Among the self-reported patient comorbidities, high blood pressure was the most prevalent, irrespective of procedure type; osteoarthritis (hip joint and knee) was the main diagnosis for patients undergoing surgery (Table 1).

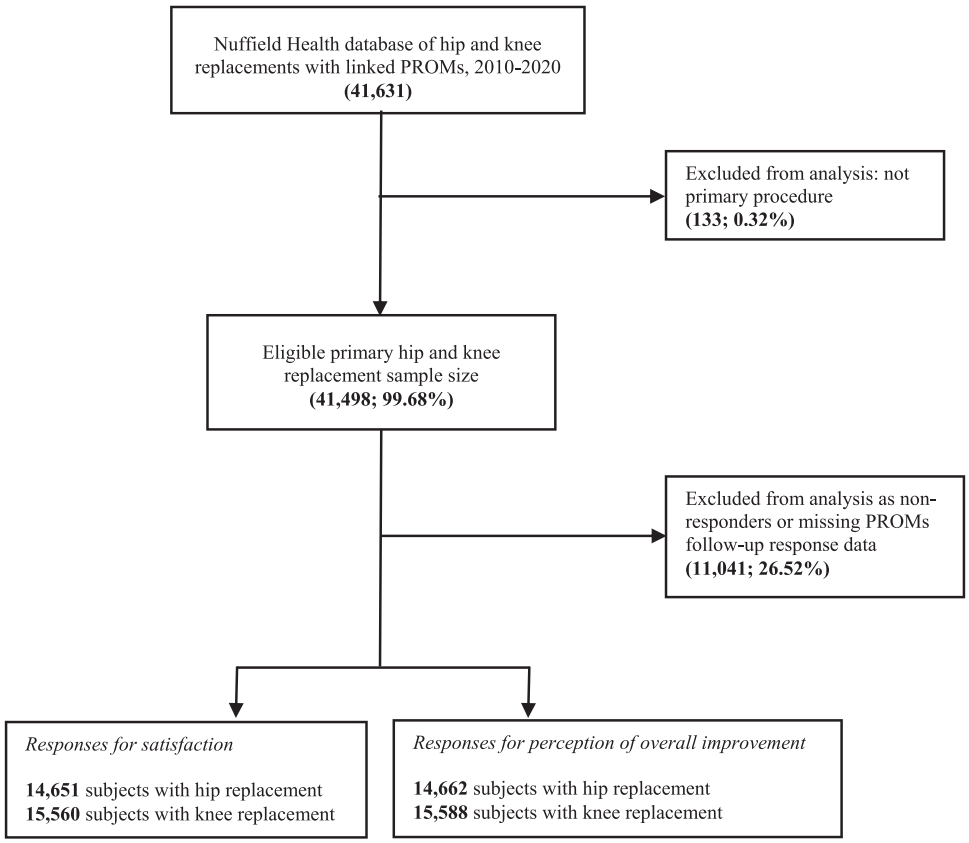

FIGURE 1 Flow diagram of subject selection for analysis. Selection of patients for analysis inclusion; responses for satisfaction and overall improvement are provided for each procedure type.

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TABLE 1 Characteristics of patients

Characteristic	Hip replacement				Knee replacement			
	Satisfied (*n* = 14,087)	Dissatisfied (*n* = 564)	Perceived improvement (*n* = 14,271)	Perceived lack of improvement (*n* = 391)	Satisfied (*n* = 14,127)	Dissatisfied (*n* = 1433)	Perceived improvement (*n* = 14,496)	Perceived lack of improvement (*n* = 1092)
Age, years	69 (62, 75)	70 (63, 76)	69 (62, 75)	72 (63, 77)	70 (64, 76)	68 (61, 74)	70 (64, 76)	69 (62, 74)
Sex, female	8337 (59.2%)	356 (63.1%)	8447 (59.2%)	256 (65.5%)	7672 (54.3%)	783 (54.6%)	7885 (54.4%)	581 (53.2%)
Preoperative PROMs (months)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)
Postoperative PROMs (months)	7 (7, 8)	7 (7, 8)	7 (7, 8)	7 (7, 8)	7 (7, 8)	7 (7, 8)	7 (7, 8)	7 (7, 8)
>3 days length of stay	4188 (29.7%)	212 (37.6%)	4261 (29.9%)	146 (37.3%)	4432 (31.4%)	516 (36.0%)	4568 (31.5%)	399 (36.5%)
White British	1393 (9.9%)	39 (6.9%)	1395 (9.8%)	39 (10.0%)	1081 (7.7%)	98 (6.8%)	1095 (7.6%)	84 (7.7%)
Index of multiple deprivation rank	20,981 (14,220, 26,980)	19,765 (13,317, 26,502.5)	20,985 (14,220, 27,020)	18,845 (11,779, 25,824)	20,110 (13,329, 26,263)	19,301 (11,349, 25,707.5)	20,079.5 (13,306, 26,226)	19,294 (11,221, 25,757)
>5 years preoperative symptom duration	2179 (15.5%)	101 (17.9%)	2222 (15.6%)	62 (15.9%)	5814 (41.2%)	627 (43.8%)	5953 (41.1%)	492 (45.1%)
NHS referral	11,259 (79.9%)	487 (86.4%)	11,447 (80.2%)	315 (80.6%)	11,804 (83.6%)	1265 (88.3%)	12,152 (83.8%)	942 (86.3%)
Previous surgery	396 (2.8%)	24 (4.3%)	404 (2.8%)	17 (4.3%)	513 (3.6%)	88 (6.2%)	532 (3.7%)	72 (6.6%)
Heart disease	668 (4.7%)	46 (8.2%)	676 (4.7%)	38 (9.7%)	761 (5.4%)	104 (7.3%)	782 (5.4%)	89 (8.2%)
High blood pressure	4928 (35.0%)	217 (38.5%)	5,002 (35.1%)	147 (37.6%)	5692 (40.3%)	579 (40.4%)	5859 (40.4%)	425 (38.9%)
Leg pain (when walking due to poor circulation)	341 (2.4%)	29 (5.1%)	345 (2.4%)	25 (6.4%)	456 (3.2%)	69 (4.8%)	468 (3.2%)	58 (5.3%)
Lung disease	748 (5.3%)	42 (7.4%)	765 (5.4%)	26 (6.6%)	862 (6.1%)	109 (7.6%)	897 (6.2%)	77 (7.1%)
Diabetes	899 (6.4%)	52 (9.2%)	921 (6.5%)	31 (7.9%)	1,239 (8.8%)	157 (11.0%)	1269 (8.8%)	127 (11.6%)
Kidney disease	154 (1.1%)	[a]	161 (1.1%)	[a]	161 (1.1%)	11 (0.8%)	158 (1.1%)	16 (1.5%)
Nervous system disease	64 (0.5%)	[a]	63 (0.4%)	[a]	115 (0.8%)	[a]	118 (0.8%)	[a]
Liver disease	41 (0.3%)	[a]	42 (0.3%)	[a]	62 (0.4%)	[a]	65 (0.4%)	[a]
Cancer	385 (3.4%)	27 (5.5%)	398 (3.5%)	17 (5.4%)	553 (3.9%)	58 (4.0%)	576 (4.0%)	41 (3.8%)
Depression	748 (5.3%)	53 (9.4%)	770 (5.4%)	32 (8.2%)	893 (6.3%)	151 (10.5%)	937 (6.5%)	107 (9.8%)
Disability	5802 (42.8%)	313 (57.6%)	5936 (43.3%)	188 (49.5%)	5605 (41.4%)	689 (50.3%)	5790 (41.7%)	515 (48.7%)
Hip joint osteoarthritis as main diagnosis	12,742 (90.5%)	500 (88.7%)	12,902 (90.4%)	349 (89.3%)	-	-	-	-

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TABLE 1 (Continued)

Characteristic	Hip replacement				Knee replacement			
	Satisfied (*n* = 14,087)	Dissatisfied (*n* = 564)	Perceived improvement (*n* = 14,271)	Perceived lack of improvement (*n* = 391)	Satisfied (*n* = 14,127)	Dissatisfied (*n* = 1433)	Perceived improvement (*n* = 14,496)	Perceived lack of improvement (*n* = 1092)
Knee osteoarthritis as main diagnosis	-	-	-	-	12,971 (91.8%)	1308 (91.3%)	13,322 (91.9%)	988 (90.5%)
Living arrangements								
Lives with family/friends	10,820 (77.5%)	415 (73.8%)	10,955 (77.4%)	285 (73.1%)	11,127 (79.5%)	1115 (79.3%)	11,396 (79.4%)	872 (81.1%)
Lives alone	3093 (22.2%)	143 (25.4%)	3139 (22.2%)	102 (26.2%)	2820 (20.2%)	287 (20.4%)	2909 (20.3%)	200 (18.6%)
Other	40 (0.3%)	[a]	42 (0.3%)	[a]	39 (0.3%)	[a]	40 (0.3%)	[a]
Assisted (preoperative)	2576 (18.5%)	105 (18.7%)	2610 (18.4%)	81 (20.9%)	2545 (18.2%)	248 (17.5%)	2618 (18.2%)	180 (16.6%)

Note: Shown are median (IQR) or number (%) for continuous and categorical variables, respectively; the Index of Multiple Deprivation ranks from 1 (most deprived area) to 32,844 (least deprived area).
Abbreviations: IQR, interquartile range; PROMs, patient-reported outcome measures.
[a]Suppressed as <10.

Preoperative values of and differences (Δ = post − pre) in EQ5D, OHS and OKS are shown in Table 2. Unfavourable outcomes were consistently associated with lower preoperative and improvements, apart from preoperative EQ5D and OHS for a perceived lack of improvement outcome following hip surgery. Additionally, the self-reported outcomes of dissatisfaction and lack of improvement following both knee and hip surgery were associated with reported clinical outcomes including higher rates of readmission, further surgery, allergy, bleeding, urine problems and wounds (Supporting Information: Table IV).

3.2 | Model development

A total of 14,049 individuals were included in the analysis determining the association of patient factors with dissatisfaction following hip replacement, of which 543 patients reported dissatisfaction. Following knee replacements, dissatisfaction was reported in 1361 (of 14,856) patients. Perceived lack of improvement were reported in 391 (of 14,662) and 1050 (of 14,885) patients following hip and knee replacement procedures, respectively.

3.3 | Model specification

Risk factors associated with unfavourable outcomes are summarized in Table 3: preoperative predictors of outcomes have been outlined with their associations and model discrimination ability. Nomograms to quantify the probabilities using the composite risk scores are shown in Figure 2.

Postoperative dissatisfaction following hip replacement was associated with a low preoperative EQ5D health-scale [≤70 vs. >70; OR 1.39 (95% CI: 1.16, 1.67)], heart disease [1.48 (1.06, 2.07)], depression [1.62 (1.22, 2.16)] and disability [1.63 (1.36, 1.94)] (Table 3).

For knee replacement, lower baseline EQ5D index [≤0.62 vs. >0.62; OR 1.20 (1.06, 1.35)] and EQ5D health-scale [≤75 vs. >75; 1.30 (1.16, 1.47)] were associated with postoperative dissatisfaction. This was in addition to: older age [0.68 (0.61, 0.77)]; disability [1.27 (1.13, 1.43)]; leg pain when walking due to poor circulation [1.35 (1.03, 1.78)]; heart disease [1.37 (1.10, 1.70)]; depression [1.37 (1.11, 1.67)]; White ethnicity [1.59 (1.14, 2.21)]; NHS referral [1.62 (1.24, 2.12)]; previous surgery [1.84 (1.44, 2.34)] and stroke [1.94 (1.23, 1.47)].

Patient-rated lack of improvement following hip replacement procedures were associated with preoperative PROMs and patient factors. Although a worse EQ5D index [≤0.587 vs. >0.587; OR 0.76 (95% CI: 0.61, 0.93)] reduced the odds of reporting a lack of improvement by 24%, a worse EQ5D health-scale [≤70 vs. >70; 1.34 (1.08, 1.67)], older age [>70 vs. ≤70 years; 1.58 (1.29, 1.93)], female sex [1.26 (1.02, 1.56)], depression [1.48 (1.02, 2.15)], leg pain when walking due to poor circulation [2.23 (1.46, 3.42)], and heart disease [1.86 (1.31, 2.65)] increased the odds of reporting a lack of improvement following surgery.

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TABLE 2 PROMs summary

Hip replacement			
	Satisfied (*n* = 14,087)	**Dissatisfied (*n* = 564)**	***p***
Preoperative OHS	19 (14, 25)	18 (13, 24)	0.02
OHS, Δ	23 (17, 29)	8 (2, 15)	<0.01
Preoperative EQ5D index	0.59 (0.06, 0.69)	0.52 (0.06, 0.62)	<0.01
EQ5D index, Δ	0.41 (0.24, 0.74)	0.1 (−0.03, 0.53)	<0.01
Preoperative EQ5D health-scale	70 (52, 80)	65 (50, 80)	<0.01
EQ5D health-scale, Δ	10 (0, 25)	0 (−15, 10)	<0.01
	Perceived improvement (*n* = 14,271)	**Perceived lack of improvement (*n* = 391)**	***p***
Preoperative OHS	19 (14, 25)	19 (14, 26)	0.30
OHS, Δ	23 (17, 29)	5 (−1, 10)	<0.01
Preoperative EQ5D index	0.59 (0.06, 0.69)	0.59 (0.06, 0.69)	0.87
EQ5D index, Δ	0.41 (0.24, 0.73)	0.00 (−0.07, 0.20)	<0.01
Preoperative EQ5D health-scale	70 (51, 80)	70 (50, 80)	<0.01
EQ5D health-scale, Δ	10 (0, 25)	−1 (−20, 10)	<0.01
Knee replacement			
	Satisfied (*n* = 14,127)	**Dissatisfied (*n* = 1433)**	***p***
Preoperative OKS	21 (16, 26)	19 (14, 25)	<0.01
OKS, Δ	18 (12, 24)	4 (−1, 10)	<0.01
Preoperative EQ5D index	0.62 (0.16, 0.69)	0.59 (0.09, 0.69)	<0.01
EQ5D index, Δ	0.31 (0.11, 0.59)	0 (−0.07, 0.36)	<0.01
Preoperative EQ5D health-scale	75 (60, 85)	70 (50, 80)	<0.01
EQ5D health-scale Δ	6 (0, 20)	−3 (−15, 10)	<0.01
	Perceived improvement (*n* = 14,496)	**Perceived lack of improvement (*n* = 1092)**	***p***
Preoperative OKS	21 (15, 26)	20 (14, 26)	<0.01
OKS, Δ	18 (12, 24)	2 (−3, 7.5)	<0.01
Preoperative EQ5D index	0.62 (0.16, 0.69)	0.59 (0.1, 0.69)	<0.01
EQ5D index, Δ	0.31 (0.11, 0.59)	0 (−0.1, 0.17)	<0.01
Preoperative EQ5D health-scale	75 (60, 85)	70 (50, 80)	<0.01
EQ5D health-scale, Δ	6 (0, 20)	−5 (−19, 10)	<0.01

Note: Change (Δ = postvalue − prevalue) and preoperative values are reported as median (IQR).

Abbreviations: Δ, change; EQ5D, European quality of life five dimensions; IQR, interquartile range; OHS, Oxford hip score; OKS, Oxford knee score; PROM, patient-reported outcome measure.

For knee replacement, a worse preoperative EQ5D health-score [≤75 vs. >75; 1.34 (1.17, 1.54)] and other patient factors were associated with a perceived lack of improvement, including: leg pain when walking due to poor circulation [1.52 (1.11, 2.08)]; depression [1.34 (1.08, 1.66)]; diabetes [1.33 (1.1, 1.62)]; >5 years preoperative symptom duration [1.13 (1.0, 1.29)]; disability [1.26 (1.1, 1.29)]; previous surgery [1.93 (1.48, 2.52)]; heart disease [1.55 (1.21, 1.98)]. However, older age [>70 vs. ≤70 years; 0.77 (0.67, 0.87)] and hypertension [0.86 (0.76, 0.98)] reduced the odds of reporting a lack of improvement following knee replacement.

3.4 | Model performance

The prognostic models for dissatisfaction showed a moderate discrimination ability with c-index values of 0.6130 (+0.0821

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TABLE 3 Risk predictors of outcomes following hip and knee replacements

Variables	Odds ratio (95% CI)	c-Index
Dissatisfaction		
Hip replacement (n = 543 of 14,049)		
Age > 70 years	1.15 (0.97, 1.37)	0.5309
Sex, female	1.13 (0.95, 1.34)	
Heart disease	1.48 (1.06, 2.07)	0.5462 (+0.0153)
EQ5D health-scale ≤ 70	1.39 (1.16, 1.67)	0.5702 (+0.0393)
Depression	1.62 (1.22, 2.16)	0.5472 (+0.0163)
Previous surgery	1.48 (0.96, 2.29)	0.5366 (+0.0057)
Stroke	2.20 (0.97, 4.99)	0.5366 (+0.0057)
Disability	1.63 (1.36, 1.94)	0.5864 (+0.0555)
Final model	-	0.6130 (+0.0821)
Knee replacement (n = 1361 of 14,856)		
Age > 70 years	0.68 (0.61, 0.77)	0.5432
Sex, female	0.96 (0.85, 1.08)	
Poor circulation	1.35 (1.03, 1.78)	0.5456 (+0.0024)
NHS referral	1.62 (1.24, 2.12)	0.5601 (+0.0169)
White British	1.59 (1.14, 2.21)	0.5457 (+0.0025)
EQ5D index ≤ 0.62	1.20 (1.06, 1.35)	0.5683 (+0.0251)
Depression	1.37 (1.11, 1.67)	0.5517 (+0.0085)
Disability	1.27 (1.13, 1.43)	0.5663 (+0.0231)
Previous surgery	1.84 (1.44, 2.34)	0.5530 (+0.0098)
Heart disease	1.37 (1.10, 1.70)	0.5480 (+0.0032)
EQ5D health-scale ≤ 75	1.30 (1.16, 1.47)	0.5680 (+0.0248)
Stroke	1.94 (1.23, 1.47)	0.5488 (+0.0056)
Final model	-	0.6137 (+0.0705)
Perceived lack of improvement		
Hip replacement (n = 391 of 14,662)		
Age > 70 years	1.58 (1.29, 1.93)	0.5752
Sex, female	1.26 (1.02, 1.56)	
EQ5D index ≤ 0.587	0.76 (0.61, 0.93)	0.5811 (+0.0059)
Depression	1.48 (1.02, 2.15)	0.5824 (+0.0072)
Poor circulation	2.23 (1.46, 3.42)	0.5877 (+0.0125)
EQ5D health-scale ≤ 70	1.34 (1.08, 1.67)	0.5862 (+0.011)
Heart disease	1.86 (1.31, 2.65)	0.5880 (+0.0128)
Final model	-	0.6175 (+0.0423)
Knee replacement (n = 1050 of 14,885)		
Age > 70 years	0.77 (0.67, 0.87)	0.5432
Sex, female	0.93 (0.82, 1.06)	
EQ5D health-scale ≤ 75	1.34 (1.17, 1.54)	0.5606 (+0.0174)
Poor circulation	1.52 (1.11, 2.08)	0.5409 (−0.0023)
Depression	1.34 (1.08, 1.66)	0.5424 (−0.0008)
Diabetes	1.33 (1.09, 1.63)	0.5406 (−0.0026)
Preoperative symptom period > 5 years	1.13 (1.00, 1.29)	0.5399 (−0.0033)
Disability	1.26 (1.10, 1.43)	0.5533 (+0.0101)
Previous surgery	1.93 (1.48, 2.52)	0.5435 (+0.0003)
Heart disease	1.55 (1.21, 1.98)	0.5404 (−0.0028)
High blood pressure	0.86 (0.76, 0.99)	0.5340 (−0.0092)
Final model	-	0.5981 (+0.0549)

Note: Differences in the c-index related to its value in the age and sex-adjusted; estimates obtained in complete-case models. Age and EQ5D (index and health-scale) have been dichotomized at their medians, and models report outcomes in only patients with data availability for all variables.

Abbreviations: CI, confidence interval; EQ5D, European quality of life five dimensions; poor circulation, leg pain when walking due to poor circulation.

compared to a model containing age and sex only) and 0.6137 (+0.0705) for hip and knee replacements, respectively (Table 3). Moreover, the risk score estimations of the full prognostic models identified a past medical history of stroke as the highest risk contributor for dissatisfaction following both hip replacement and knee replacement; nomograms to estimate the probability of dissatisfaction are shown in Figure 2.

Compared to the model with just age and sex, the c-index values for the overall prognostic models discrimination were 0.6175 (+0.0423) for hip replacement and 0.5981 (+0.0549) for knee replacements. Furthermore, a higher risk of reporting lack of improvement following surgery was mainly related to poor circulation (leg pain when walking) and previous surgery in hip and knee replacements, respectively; nomograms to estimate the probability of reporting a lack of improvement following surgery are shown in Figure 2.

4 | DISCUSSION

4.1 | Limitations

Importantly, a caveat of this study was the use of self-reported data. Self-report is a widely used method of collecting information on health status and thus reflects data that is readily available to the surgical team,[31] however, the rate of concordance, however, may vary over time. Whilst it is appreciated that these shortcomings can subsequently impact findings, this was an observational analysis of data, and cautious interpretations are warranted. Moreover, although

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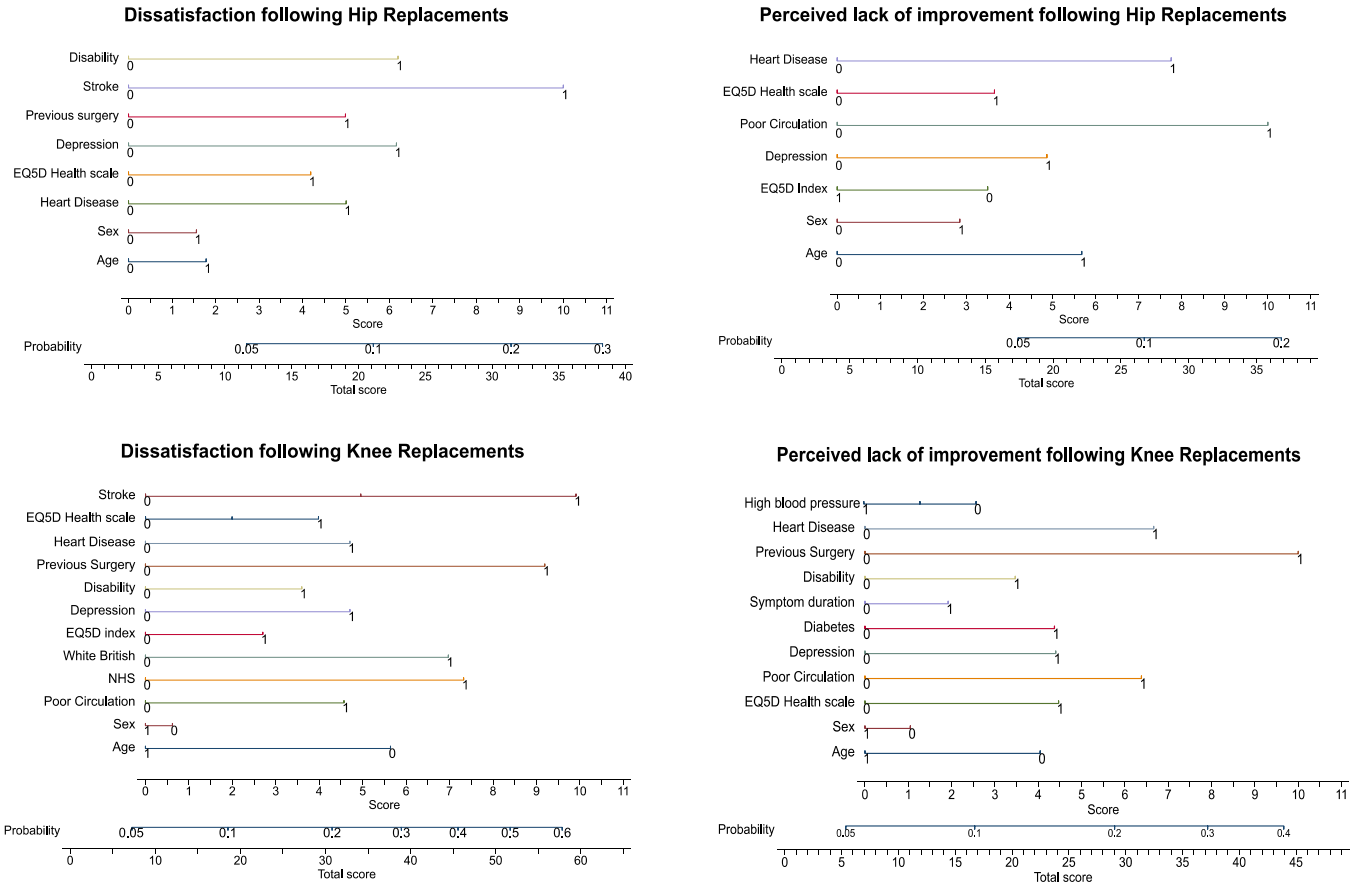

FIGURE 2 Risk scores (nomograms) for outcomes following hip and knee replacements. The score for each risk factor (Table 3) are shown for the hip and knee replacement outcomes; continuous variables (age; EQ5D index and health scale) have been dichotomized at their median values. The total score (and the corresponding probability—*Probability* in the graph) can be estimated as the sum of the score the risk factors. For *comorbidities*, values of 1 indicate the presence of comorbidity and 0 its absence; for *sex*, 1 indicates female and 0 indicates male; for *age*, 1 indicates >70 years and 0 indicates ≤70 years; for *EQ5D*, 1 indicates values ≤median and 0 indicates values >median; for *symptom duration*, 1 indicates symptom duration of >5 years and 0 indicates values ≤5 years; for *NHS*, 1 indicates NHS referral and 0 indicates no referral. EQ5D, European Quality of Life- 5 dimensions; NHS, National Health Service.

using risk scores estimated from the predictive models can facilitate clinical decision-making and ultimately improve outcomes,[32] contrarily to the use of validated and standardized measurements in ascertaining patient factors, there exist fundamental differences in patient characteristics and surgical techniques between the risk tool development and wider population cohorts.[33] Therefore, the present findings are mainly applicable to patients sharing similar characteristics as those included in the analysis; it is likely the risk prediction models will need validation in different patient populations to effectively translate these determinants of outcome into widely used clinical prediction tools.[34]

Furthermore, though the use of data collected in a clinical setting allows our findings to have immediate applicability within the general surgical practice, it is possible that other factors not routinely collected within these datasets, such as body mass index, may help to improve the performance of the risk prediction models. Therefore, primary data (i.e., prospective research datasets) are needed to complement these findings from 'real-world' datasets.

Moreover, whilst nonresponders to postoperative questionnaires were identified for hip and knee replacements, more effective methods to increase questionnaire responses within routine practice would better facilitate our understanding and generalizability of predictors of unfavourable outcomes. Strategies to increase responses have been previously suggested[35]; although a threshold of 60% for acceptable frequency for questionnaire responses have been recommended,[36] this present analysis had 73% suggesting there was sufficient data to derive conclusions. The effective generalizability of findings is particularly important in the application of results in real-world scenarios.

4.2 | Interpretation

Prediction models have previously been developed using easily accessible self-reported patient factors in determining clinical outcomes following hip and knee replacements, including physical

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function and pain,[33,37] discharge,[19,20] complications,[19,21] intensive care unit interventions,[19,22] LOS,[19,24] risk of reinfection[19,23] and long-term benefit of the procedure.[19,25] Predictive models have typically included preoperative factors including PROMs, both generic[25] and disease-specific.[38] In our analysis, it was interesting to note that generic PROMs (EQ5D) demonstrated usefulness as predictors of patient-reported dissatisfaction and a perceived lack of improvement following surgery; whereas disease-specific PROMs (OHS, OKS) were not associated with outcome and subsequently not included in developing risk scores. Along with EQ5D, we also observed that depression and patient comorbidities, particularly cardiovascular diseases, were important risk factors. This finding confirms previous hypotheses that patient health gains may be blunted by the presence of medical comorbid conditions,[39] along with previous findings that patients with no comorbidities are often more satisfied following surgery than their counterparts with at least one comorbidity.[17] The presence of comorbidities is considered to minimize postoperative improvements[40]; however, our results for patient-reported perceptions of improvement and satisfaction differ from evidence that has demonstrated little impact on surgery effectiveness,[41] suggesting the importance of comorbidities may differ by the outcome. Whilst comorbidities are present in addition to the index condition that results in joint replacement, as life expectancy is increasing globally, more people are living with multiple morbidities.[41] It is expected that the number of patients undergoing hip and knee replacement will have at least one comorbid condition,[41] as evidenced by our cohort whereby 87% of patients self-reported at least one comorbidity for hip replacement and 90% for knee replacement. Our findings suggest the increasing burden of chronic disease within joint replacement patients is likely to be an important factor in predicting patient experiences postsurgery.

Our study was aimed at risk prediction, however, as many of the factors that contributed to the prediction model are modifiable, it is possible that preoperative interventions targeted at factors such as depression, QoL or cardiovascular disease risk factors could lead to better outcomes.[42,43] Indeed, preoperative interventions including programmes pertaining to patient education, nutrition and preadmission exercises have been found to be effective tools in improving patient journey and minimizing postoperative burdens.[44–47] These have been considered to provide additional assurance as well as improve the understanding of the expectations of joint replacement surgery, which, in turn, improves outcomes related to satisfaction and perception of improvement, and overall health-related QoL.[48–51] Whether such interventions could be optimized for postoperative patient-reported satisfaction or perceived improvement needs further investigation, particularly as there have been reports of uncertainties in their overall benefits over usual care.[52]

4.3 | Implications

Patient-reported indicators of success have previously been recommended for inclusion in case-mix adjustment models,[36] and the importance of patient psychosocial and individual factors in determining outcomes are increasingly recognized.[33] Using a large data set, we build on previous published work and show that preoperative factors including age, sex, health status and generic PROMs scores are important prognostic indicators of patient-reported satisfaction and improvement following hip and knee replacements. Furthermore, patients who self-report dissatisfaction and a perceived lack of improvement following surgery had higher rates of poor clinical outcomes, including readmissions, further surgery, allergy, bleeding, urine problems and wound.

The use of preoperative patient factors including PROMs, specifically EQ5D, and comorbidities in demonstrating an association with the risk of patient-rated dissatisfaction and a perceived lack of improvement following hip and knee replacement has potential for application in clinical settings. Our risk prediction tools, developed from easily accessible preoperative patient factors, in addition to serving as a springboard for future research, may assist in risk stratification and facilitate decision-making processes.

AUTHOR CONTRIBUTIONS

Karen O. B. Appiah: Acquisition and analysis of data; drafting; final approval of the version to be published. **Kamlesh Khunti**, **Robert G. Middleton** and **Thomas W. Wainwright**: Interpretation of data; revising it critically for important intellectual content; final approval of the version to be published. **Benjamin M. Kelly**: Financial support; interpretation of data; revising it critically for important intellectual content; final approval of the version to be published. **Aidan Q. Innes, Zhining Liao** and **Michael Dymond**: Interpretation of data; acquisition of data; revising it critically for important intellectual content; final approval of the version to be published. **Thomas Yates**: Supervision of the project; interpretation of data; revising it critically for important intellectual content; final approval of the version to be published. **Francesco Zaccardi**: Supervision of the project; conception and design; interpretation of data for the work; revising it critically for important intellectual content; final approval of the version to be published

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CONFLICT OF INTEREST

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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