Determinants of outcome prior to and after total hip and knee arthroplasty

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Chapter III

Recovery trajectories after total hip and knee arthroplasty and early postoperative identification of patients at risk for unfavourable one-year outcome

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Submitted

Abstract

Background and purpose: Aims were to (i)evaluate the initial clinical recovery in relation to one-year outcomes of primary total hip or knee arthroplasty (THA or TKA) by the use of four clinical recovery trajectories of pain and function and (ii)to investigate if one-year pain/function can be predicted by the initial clinical recovery of pain/function and their preoperative values.

Methods: A longitudinal multicentre cohort study of 972 THA and 892 TKA patients. Self-reported pain and function were assessed preoperatively, six and 12 months after surgery with the Pain and ADL subscales of the HOOS and KOOS. Cut-off for unfavourable pain and function were based on the 20th percentile of its one-year outcomes. The initial recovery was assessed at six months. Prediction of one-year outcome by the initial clinical recovery of pain/function and their preoperative values was assessed with multivariate logistic regression and Receiver Operating Curves.

Results: Approximately 7% THA and 9% TKA patients had an initial unfavourable, yet favourable one-year pain outcome,14% of THA/TKA patients had initial and one-year unfavourable pain outcome. Similar results were found for function. Of the patients with initial unfavourable outcome, 33-46% attained favourable one-year outcome. For both THA and TKA, more initial clinical recovery and better preoperative pain/function (ORs approximately 0.9) predicted unfavourable one-year outcomes. The AUC's of full prediction models were approximately 0.89.

Interpretation: In conclusion, of the patients with initial unfavourable outcome, approximately one-third attained favourable outcome at one-year. Patients at risk for one-year unfavourable outcome could be identified six months postoperatively by initial clinical recovery and preoperative values.

Introduction

Total hip and knee arthroplasties (THA/TKA) are performed to reduce pain and improve function in patients with disabling hip and knee osteoarthritis (OA). However, persistent pain occurs in 7-23% of patients after THA and 10-34% of patients after TKA, according to patient reported outcome scores (PROs) (1). As for function, 14-36% of THA patients (2) and 11-67% of TKA patients have persistent functional limitations one-year postoperatively (3-6).

Most of the recovery after THA or TKA seems to occur in the first months after surgery and beyond three months only small clinical changes are to be expected (7-10). However, these findings are based on group averages. Individual patients could still attain substantial clinical improvements after the first postoperative months. More information on individual recovery trajectories after THA or TKA is necessary to detect if and what proportion of patients with persistent pain or functional limitations attain substantial improvements on the longer term. Early identification of patients at risk for unfavourable outcome (i.e. persistent pain or functional limitations) may enhance the outcome by timely interventions. In depressive patients it was shown that the initial clinical recovery could be a valuable, strong predictor of outcome (11, 12). Moreover, in TKA patients acute pain in the first postoperative days was found to be a predictor for postoperative pain at three or six months (13-15). Whether the initial clinical recovery could also predict one-year outcomes and if this also accounts for functional outcome and in THA patients remains to be evaluated. If the initial clinical recovery has an important predictive value, it could provide an opportunity for orthopaedic surgeons to select which patients should be invited to the outpatient clinic for extra monitoring. Currently, there are no international guidelines for the timing of routine follow-up visits.

Therefore the current study aims to investigate if one-year pain/function outcomes can be predicted by the initial clinical recovery of pain/function and their preoperative values. In addition, to evaluate the initial clinical recovery in relation to the outcomes at one-year by four clinically relevant recovery trajectories of pain and function will be visualized.

Methods

Setting

This study is part of the Longitudinal Leiden Orthopaedics Outcomes of Osteo-Arthritis study (LOAS; Trial ID NTR3348), which started in June 2012 and is an ongoing multi-center, longitudinal prospective cohort study (Level of Evidence II) (16). Ethical approval was obtained by the Medial Ethics Committee of the Leiden University Medical Center (registration number P12.047). Eligible patients are OA patients undergoing primary THA/TKA, who are able to complete Dutch questionnaires and are >18 years. Excluded are patients who have a physical or mental status not allowing participation. Patients are included once written informed consent is obtained according to the Declaration of Helsinki.

For the current study we used the data of patients recruited before June 2015. In total, 1274 THA and 1220 TKA patients returned the preoperative questionnaire. Of those, 302 THA (24%) and 328 TKA (27%) patients were lost to follow-up, resulting in 972 THA and 892 TKA in the present study (Figure 1).

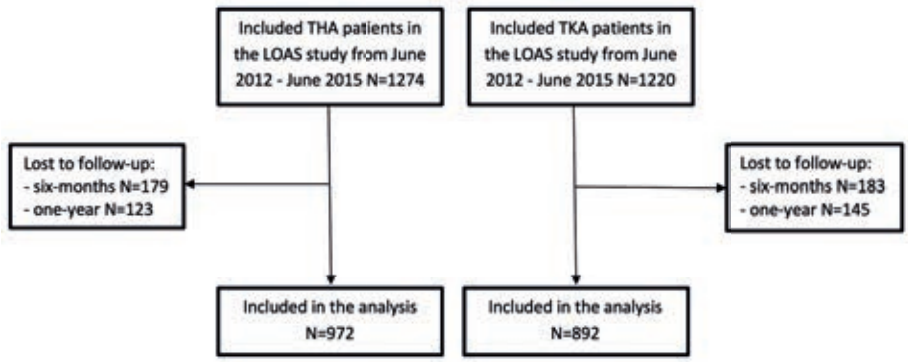

Figure 1. Flowchart of patients included in the Longitudinal Leiden Orthopaedics and Outcomes of Osteo-Arthritis Study (LOAS) from June 2012 up and until June 2015 undergoing Total Hip/ Knee Arthroplasty (THA/TKA). From a total of 1274 THA and 1220 TKA patients, 972 THA and 892 TKA patient were eligible for the present study. ‘

Assessments

Pain and Function

Preoperative, at six months and at one-year the Hip disability and Knee Injury Outcomes of Osteoarthritis Score (HOOS/KOOS) Pain and Activities

in Daily Living (ADL) subscale scores were used to assess pain and function in THA and TKA patients, respectively (17-19). For each subscale a normalized score (100 representing the best outcome) was calculated. The initial clinical recovery of the HOOS and KOOS pain or function scores was assessed as the difference between six-month postoperative scores and preoperative scores.

Currently no validated cut-off values for favourable/unfavourable HOOS/KOOS outcome after arthroplasty are available. However, proportions of THA and TKA patients with unfavourable postoperative one-year outcome approximate 20% (1-6). Therefore, for the current study, we have chosen cut-off values based on the 20th percentile scores. Unfavourable outcome was defined as all scores below the 20th percentile of the one-year outcome after THA/TKA and favourable outcome was defined as all scores above the 20th percentile. For the HOOS the cut-off was 75.0 for pain and 70.3 for function. For the KOOS these cut-offs were 72.2 and 70.3, respectively. Based on the dichotomized outcome at six months and one year, four clinical recovery trajectories were identified: 1) Patients with favourable initial- and one-year outcome, 2) patients with favourable initial- and unfavourable one-year outcome, 3) patients with unfavourable initial- and favourable one-year outcome and 4) patients with unfavourable initial- and one-year outcome.

In addition, a sensitivity analysis was performed to test the robustness of the results. A cut-off defined by the FORCE-TJR in preoperative knee osteoarthritis patients was used (20). This cut-off (a KOOS score of 70) was also applied to the KOOS function and the HOOS pain and function scores.

Sociodemographic characteristics
Preoperatively self-reported age, gender and height and weight to calculate body mass index (BMI) were assessed.

Quality of Life
Quality of life (QoL) was measured using the QoL subscale of the HOOS and KOOS questionnaires. Similar to the pain and ADL subscale scores, for the QoL subscale a normalized score (100 representing the best outcome) was calculated.

Comorbidity
Preoperatively, comorbidities in the previous year were assessed according to the Dutch Central Bureau of Statistics (CBS) (21). These comorbidities were classified into two domains: musculoskeletal comorbidities (elbow, wrist or hand pain; back pain; other rheumatic diseases) and non-musculoskeletal comorbidities (chronic lung-; cardiac- or coronary diseases; arteriosclerosis; hypertension; stroke; bowel disorder; diabetes mellitus; migraine; psoriasis; eczema; cancer or a history of cancer; incontinence of urine; hearing or vision impairments; dizziness in combination with falling). Both domains were dichotomized (yes/no).

Mental Health
Preoperative mental health was assessed with the Mental Component Score (MCS) of the Short Form-12 Health Survey questionnaire (SF-12). The MCS ranges from 0 to 100, with 100 representing the best outcome (22).

Postoperative complications
At six months, postoperative complications were assessed by asking patients to report reoperations at the same joint, readmissions in relation to the joint arthroplasty surgery or visits to the first aid due to severe pain of the operated joint.

Statistical analyses
All analyses were done separately for THA and TKA and for pain and function outcomes. First, the prevalence of the four clinical recovery trajectories were assessed. Median pain/function outcomes and interquartile ranges of the clinical recovery trajectories were determined at six months and at one-year.

Secondly, descriptive statistics were calculated as means (SD) or medians (range) (depending on their distribution). Independent t-test (continuous data) and chi-square tests (categorical data) were used to compare demographic variables between (1) included and lost to follow-up patients and (2) patients with initial favourable and initial unfavourable

pain/function outcomes. Third, univariate and multivariate logistic regression analyses were done with favourable/unfavourable one-year pain as dependent variable (favourable outcome = 0, unfavourable outcomes = 1) and the initial clinical recovery of pain and/or preoperative pain as continuous independent variable(s). Similar analyses were done for function. Fourth, Receiver Operating Curves (ROC) were calculated to assess the performance of the prediction based on solely initial clinical recovery or preoperative predictors versus predictions based on initial clinical recovery combined with preoperative predictors. Outcomes were expressed as Area Under the Curve (AUC). Based on the multivariate prediction models, different scenarios for unfavourable long-term pain or function outcome were sketched in patients with unfavourable initial pain or function outcome by filling in the prediction models with different values. Risks were calculated as follows: Linear predictor (LP) = $\alpha + \beta 1X1 + \beta 2X2$. The risk= $\exp(LP)/1+\exp(LP)$.

Two sensitivity analyses were performed. First, the logistic regression models were repeated with the cut off of 70 as described by the FORCE-TJR. Secondly, univariate (including initial clinical recovery) and multivariate (including both initial clinical recovery and preoperative scores) linear regression analyses were done with the continuous one year pain/function outcome. All analyses were performed using IBM SPSS statistical package (version 23.0, SPSS, Chicago, Illinois).

Results

Study population

For both THA and TKA patients, the study group was older, had a lower BMI, better mental health and better preoperative function and QoL, as well as a better six-month QoL outcome as compared to the lost to follow-up **(**FU**)** group ($p<0.05$; supplementary table 1). Besides, the study group had reported less musculoskeletal comorbidities solely for THA and better six-month postoperative pain and function solely for TKA patients ($p<0.05$; supplementary table 1).

Table 1. Characteristics, preoperative score and initial clinical recovery of HOOS/KOOS scores of patients with favourable and unfavourable pain or function outcomes

	Initial favourable **pain** outcomes	Initial unfavourable **pain** outcomes	P-value	Initial favourable **function** outcome	Initial unfavourable **function** outcome	p-value
Total Hip	N=731	N=229		N=755	N=206	
Female; n (%)	440 (60%)	164 (72%)	0.002*	454 (60%)	151 (73%)	0.001*
Age; mean (SD)	68.2 (9.5)	68.0 (10.1)	0.816	68.1 (9.3)	68.4 (10.8)	0.709
BMI; mean (SD)	26.9 (4.3)	27.6 (4.3)	0.044*	26.8 (4.1)	28.1 (4.7)	0.000*
Comorbidity						
Musculoskeletal	254 (53%)	103 (71%)	0.000*	258 (52%)	100 (76%)	0.000*
Non-musculoskeletal	413 (68%)	145 (75%)	0.070	429 (68%)	131 (80%)	0.002*
Postoperative self-reported complications	65 (9%)	53 (23%)	0.000*	64 (9%)	54 (26%)	0.000*
SF12 MCS; mean (SD)	55.5 (9.2)	53.2 (10.1)	0.001*	55.5 (9.1)	53.1 (10.4)	0.002*
Preoperative HOOS; mean (SD)						
Function	42.4 (19.8)	34.1 (18.5)	0.000*	43.0 (19.4)	30.7 (18.2)	0.000*
Pain	40.1 (18.7)	31.8 (17.5)	0.000*	40.2 (18.6)	30.3 (17.3)	0.000*
QoL	29.8 (17.1)	24.4 (15.7)	0.000*	29.9 (17.0)	23.5 (15.5)	0.000*
6-month postoperative HOOS; mean (SD)						
Function	88.8 (10.8)	59.9 (17.6)	0.000*	89.6 (8.4)	53.6 (13.8)	0.000*
Pain	94.3 (6.4)	58.9 (14.4)	0.000*	92.3 (9.8)	62.2 (19.4)	0.000*
QoL	80.8 (17.1)	47.5 (17.1)	0.000*	79.8 (17.5)	47.2 (18.7)	0.000*
Initial clinical recovery HOOS; mean (SD)						
Function	46.6 (19.9)	26.5 (22.0)	0.000*	46.7 (19.9)	23.0 (20.5)	0.000*
Pain	54.3 (19.0)	27.3 (20.7)	0.000*	52.0 (19.9)	31.8 (24.7)	0.000*
QoL	51.1 (22.5)	23.3 (21.1)	0.000*	50.0 (22.8)	23.8 (22.3)	0.000*

Total Knee	N=646	N=233		N=682	N=200	
Female; n (%)	425 (66%)	172 (74%)	0.024*	453 (66%)	145 (73%)	0.106
Age; mean (SD)	68.2 (8.5)	66.2 (8.7)	0.002*	67.9 (8.4)	67.3 (9.1)	0.378
BMI; mean (SD)	29.0 (4.6)	29.5 (4.5)	0.128	28.9 (4.5)	29.8 (4.8)	0.013*
Comorbidity						
Musculoskeletal	196 (48%)	90 (65%)	0.001*	209 (49%)	78 (63%)	0.007*
Non-musculoskeletal	404 (75%)	138 (75%)	0.990	421 (74%)	121 (80%)	0.129
Postoperative self-reported complications	51 (8%)	77 (33%)	0.000*	60 (9%)	67 (34%)	0.000*
SF12 MCS; mean (SD)	56.1 (9.1)	54.2 (9.8)	0.010*	56.3 (9.0)	53.2 (10.0)	0.000*
Preoperative KOOS; mean (SD)						
Function	47.5 (18.0)	40.4 (17.3)	0.000*	47.8 (17.8)	38.1 (16.9)	0.000*
Pain	41.2 (18.3)	33.6 (16.2)	0.000*	40.6 (18.2)	34.3 (16.8)	0.000*
QoL	28.1 (15.9)	23.9 (13.8)	0.000*	28.2 (15.6)	23.1 (14.1)	0.000*
6-month postoperative KOOS; mean (SD)						
Function	88.2 (10.8)	59.5 (17.9)	0.000*	88.7 (8.7)	52.4 (13.7)	0.000*
Pain	91.3 (8.4)	54.1 (14.1)	0.000*	88.7 (11.9)	56.6 (19.2)	0.000*
QoL	70.4 (18.4)	41.7 (16.1)	0.000*	69.5 (18.2)	39.5 (16.7)	0.000*
Initial clinical recovery KOOS; mean (SD)						
Function	40.4 (18.2)	19.0 (21.0)	0.000*	40.7 (17.8)	14.3 (18.9)	0.000*
Pain	50.1 (19.6)	20.8 (20.0)	0.000*	47.9 (20.7)	22.6 (22.4)	0.000*
QoL	42.3 (22.4)	17.6 (17.8)	0.000*	41.3 (21.9)	16.4 (19.5)	0.000*

Baseline = 6 months after surgery
Favourable outcome = 1-year pain/function score above the 20th percentile; unfavourable outcome = 1-year pain/function score below the 20th percentile.
BMI = Body Mass Index
SF12 MCS = Short-Form 12 Mental Component Score
HOOS = Hip disability and Osteoarthritis Outcome Score
KOOS = Knee injury and Osteoarthritis Outcome Score
QoL = Quality of Life
* Significance level $p<0.05$

Initial clinical outcomes and trajectories

In THA, patients with an initial unfavourable outcome were more often female, had a higher BMI, more musculoskeletal comorbidities, more often self-reported postoperative complications, worse mental health as well as worse preoperative pain, function and QoL and initial clinical recovery scores compared to patients with initial favourable outcome ($p<0.05$) (Table 1). In TKA patients similar results were found (Table 1).

The recovery trajectories showed that most THA and TKA patients, approximately 70-74%, had favourable initial and one-year outcomes. (Table 2).

Table 2. The prevalence of different trajectories of clinical recovery of pain and function after THA or TKA

		1. Favourable initial – favourable one-year outcome	2. Favourable initial – unfavourable one-year outcome	3.Unfavourable initial – favourable one-year outcome	4. Unfavourable initial – unfavourable one-year outcome
THA N=972	**Pain** N=938	655 (70%)	61 (6%)	93 (10%)	129 (14%)
	Function N=943	694 (74%)	53 (6%)	65 (7%)	131 (14%)
TKA N=892	**Pain** N=860	598 (70%)	34 (4%)	104 (12%)	124 (14%)
	Function N=870	623 (72%)	49 (6%)	78 (9%)	120 (14%)

Initial outcome = outcome six months after surgery
THA/TKA = Total Hip Arthroplasty/Total Knee Arthroplasty

Moreover, approximately 7-12% of THA and TKA patients had an initial unfavourable pain/function outcome, yet a favourable one-year outcome (trajectory 3), whereas 14% of the THA and TKA patients remained an unfavourable outcome (trajectory 4) (Table 2). From these numbers can be derived that 42% of THA and 46% of TKA patients with initial unfavourable pain outcome eventually reached a favourable one-year outcome. For function, this were 33% THA and 39% TKA patients. The different pain and function trajectories are depicted in Figure 2a-d.

Figure 2a. Self-reported pain trajectory from preoperative to one-year follow-up in THA patients

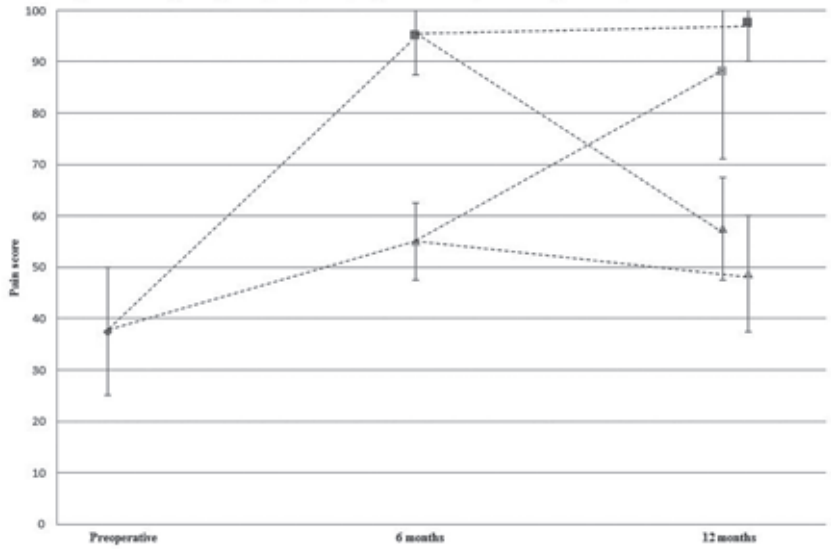

Figure is based on the median and interquartile range
■ = Favourable outcome (subscale score >75.0)
▲ = Unfavourable outcome (subscale score ≤75.0)

Figure 2b. Self-reported function trajectory from preoperative to one-year follow-up in THA patients

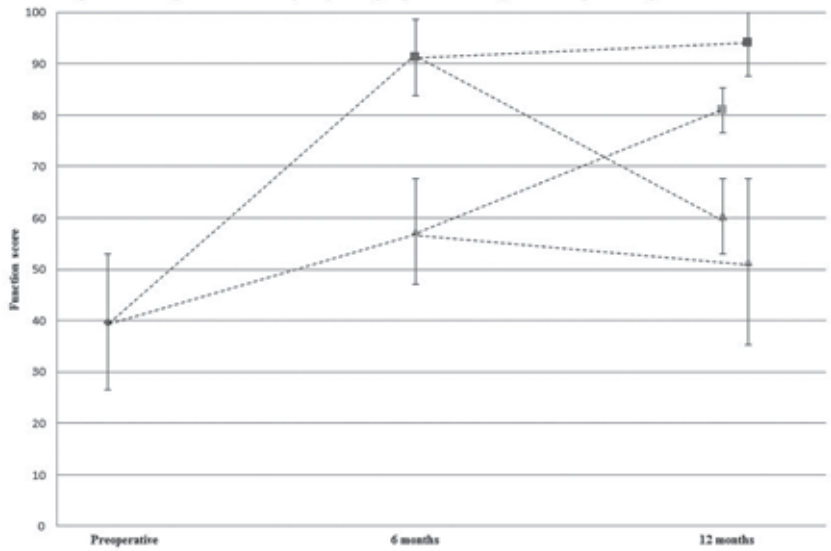

Figure is based on the median and interquartile range
■ = Favourable outcome (subscale score >70.3)
▲ = Unfavourable outcome (subscale score ≤70.3)

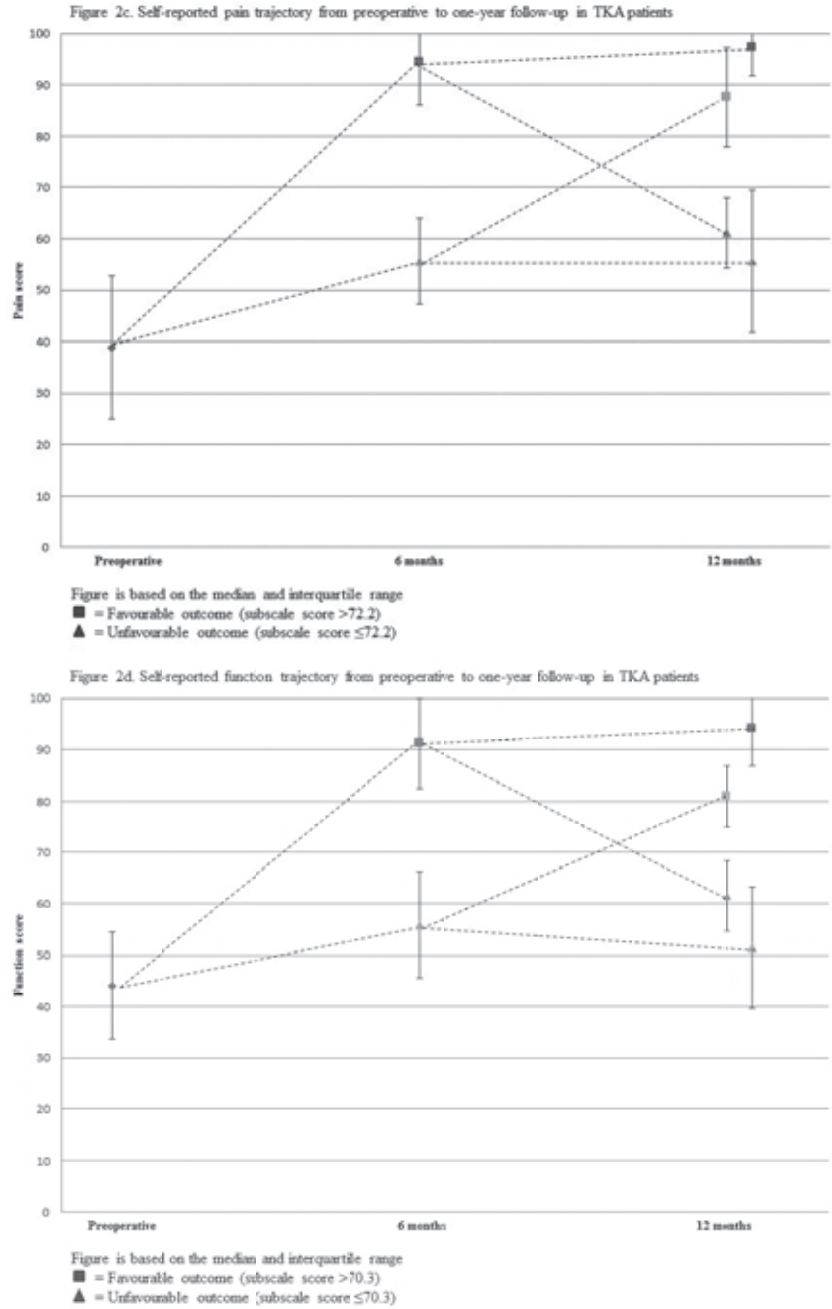

Figure 2. Self-reported pain/function trajectories from preoperative scores to one-year follow-up in patients undergoing Total Hip or Knee Arthroplasty (THA/TKA).'

Prediction of one-year pain

In both THA and TKA patients, higher initial clinical recovery and higher preoperative pain scores (e.g. less pain) were associated with a lower risk on an unfavourable one-year pain outcome (Table 3). A more accurate prediction of one-year outcome was determined based on the initial clinical recovery as compared to preoperative scores (AUC 0.69 versus 0.64 for THA and AUC 0.75 versus 0.63 for TKA), whereas the best prediction was based on the model including both variables (AUC 0.86 for THA and AUC 0.89 for TKA) (Table 3).

Table 3. Prediction of one-year unfavourable pain and function outcome

	Unfavourable one-year **pain or function** outcome					
Pain	**THA** N=938			**TKA** N=860		
	OR	95% CI	AUC	OR	95% CI	AUC
Model 1 Initial clinical recovery	0.97	0.96-0.98	0.69	0.96	0.95-0.97	0.75
Model 2 Preoperative pain#	0.97	0.96-0.98	0.64	0.97	0.96-0.98	0.63
Model 3 Initial clinical recovery	0.92	0.91-0.94	0.86	0.92	0.91-0.93	0.89
Preoperative pain#	0.91	0.90-0.93		0.90	0.88-0.92	
Function	**THA** N=943			**TKA** N=870		
Model 1 Initial clinical recovery	0.97	0.96-0.98	0.70	0.96	0.95-0.97	0.72
Model 2 Preoperative function#	0.96	0.95-0.97	0.69	0.96	0.95-0.97	0.67
Model 3 Initial clinical recovery	0.90	0.89-0.92	0.91	0.92	0.90-0.93	0.89
Preoperative function#	0.89	0.87-0.90		0.90	0.88-0.92	

#High pain scores indicate less pain
Unfavourable outcome = one-year pain/function score below the 20th percentile.
AUC = Area Under the Curve
Model 1 = Univariate analysis including initial clinical recovery
Model 2 = Univariate analysis including preoperative pain
Model 3 = Multivariate analysis including initial clinical recovery and preoperative scores
THA = Total Hip Arthroplasty
TKA = Total Knee Arthroplasty

To illustrate the importance of the initial clinical recovery and preoperative scores on the odds for the one-year outcome, different scenarios are described based on the 25th and 50th percentile of the initial clinical recovery and preoperative scores (Table 4). The odds for a THA patient with a poor profile (e.g. poor initial clinical recovery and high preoperative pain) on a unfavourable outcome was 1.5 as compared to 0.1 for a THA

patient with a favourable profile (e.g. better initial clinical recovery and low preoperative pain). The risk on an unfavourable outcome for patients with a poor vs. favourable profile was 0.60 vs. 0.12, respectively. For TKA patients similar results were found with odds of 1.7 and 0.1 and risks of 0.63 and 0.09, respectively (Table 4).

Prediction of one-year function

With respect to function similar results were found in univariable and multivariable regression analyses (Table 3). Moreover, the one-year outcome was better predicted by both the initial clinical recovery and preoperative score, than on solely the initial clinical recovery or preoperative score. Furthermore, the importance of the initial clinical recovery and preoperative scores on the odds for one-year outcomes was described (Table 4). The risk on a one-year unfavourable outcome was 0.75 for a THA patient with a poor function profile and 0.09 for a THA patient with a favourable profile. For TKA patients, these risks were 0.59 and 0.12, respectively (Table 4).

Table 4. Different scenarios of the odds for unfavourable one-year pain or function outcome *in patients with unfavourable initial pain or function outcomes*

	Initial clinical recovery		Preoperative score		Odds for unfavourable one-year outcome		Risk on unfavourable one-year outcome	
Pain	**THA**	**TKA**	**THA**	**TKA**	**THA**	**TKA**	**THA**	**TKA**
Scenario 1	35	28	25	25	1.5	1.7	0.60	0.63
Scenario 2	50	44	25	25	0.5	0.4	0.31	0.30
Scenario 3	35	28	38	39	0.4	0.4	0.31	0.28
Scenario 4	50	44	38	39	0.1	0.1	0.12	0.09
Function								
Scenario 1	27	22	26	34	3.0	1.4	0.75	0.59
Scenario 2	43	35	26	34	0.6	0.4	0.36	0.31
Scenario 3	27	22	40	45	0.5	0.4	0.35	0.30
Scenario 4	43	35	40	45	0.1	0.1	0.09	0.12

Pain and function outcomes are based on the Hip Disability and Knee Injury and Osteoarthritis Outcome Scores (HOOS/KOOS) (range 0-100)
Scenarios are based on the 25th and 50th percentile of the initial clinical recovery and preoperative score.
Scenario 1 = low initial clinical recovery and preoperative score
Scenario 2 = good initial clinical recovery and low preoperative score
Scenario 3 = low initial clinical recovery and good preoperative score and
Scenario 4 = good initial clinical recovery and preoperative score
THA = Total Hip Arthroplasty
TKA = Total Knee Arthroplasty

Sensitivity analyses

The first sensitivity analysis showed comparable cut-offs, odds ratios and AUC outcomes to our initial analysis (supplementary table 2). In addition, the second sensitivity analyses showed comparable univariate and multivariate associations as compared to outcomes of the logistic regression analysis ($p<0.05$; supplementary table 3.

Discussion

This study evaluated outcomes after THA and TKA and showed that patients at risk for unfavourable outcome could be identified at six months postoperatively, which may provide opportunities for early interventions to improve long term outcome. First, we showed that of the patients with an unfavourable initial clinical recovery, 33-46% reported favourable outcomes at one-year. For both THA and TKA, patients at risk for unfavourable one-year outcome could be identified six months postoperatively by the initial clinical recovery of pain/function and the preoperative values. Patients with more preoperative pain and little initial clinical recovery have an increased likelihood of pain one-year after surgery. This also applies to function.

Previous studies suggested that patients could expect solely small clinical gains beyond three months (7-10), whereas we showed improvements between 20-35 points on the HOOS/KOOS subscale score beyond six months for a substantial amount of patients. A possible explanation for these differences is our focus on the clinical recovery in subgroups instead of the total group. Hence, we also did not find substantial recovery after six months when we averaged the recovery of the overall group (data not shown). This can be explained by the fact that patients with unfavourable initial outcomes that do further improve after six months represent a relatively small group of patients (here approximately 10%). The size of this group and the magnitude of their recovery beyond the initial six postoperative months are not sufficient to cause an improvement on group level. Nevertheless, this relatively small group of patients signifies yearly thousands of THA/TKA patients in the Western world (23, 24).

Besides, a recent study showed that three satisfaction trajectories could be distinguished in TKA patients: 'early', 'persistent', and 'late' dissatisfaction (25). This emphasises that recovery time differs between patients and that, when assessing recovery, an individual approach is needed.

Furthermore, the current study showed that, for both pain and function, recovery as well as preoperative scores predicted one-year outcomes. Our findings that more preoperative pain and worse preoperative function were related to lower outcomes, were in accordance with previous literature (26-29). Nevertheless, earlier studies concluded that, even though there was an association, the explained variance of solely preoperative pain and function on postoperative outcomes was not sufficient to adjust the decision making for THA or TKA (28), which was confirmed by our results (i.e. the AUC for solely preoperative pain or function was approximately 60-69). Moreover, we investigated if, in addition to the preoperative variables, the initial postoperative clinical recovery could be a predictor for one-year outcomes after THA or TKA as two other studies illustrated that initial postoperative outcomes could predict one-year outcomes (30, 31). In other medical specialties it is more common to use early treatment results as determinants for one-year outcomes, for example to evaluate psychiatric interventions (11, 12, 32). It is hypothesized that due to the impact of the intervention (e.g. THA/TKA), preoperative variables are no longer representative after surgery and are therefore less suitable to predict one-year outcomes (30, 31). Furthermore, early postoperative identification of patients at risk for one-year unfavourable outcomes provides the opportunity for early interventions (30, 31). By targeting these patients shortly after surgery, early postoperative interventions could result in shortened time to response, reduced distress for the patients and maximized cost-effectiveness (11). These interventions should include intensive rehabilitation programmes or postoperative non-surgical management strategies, aimed at their coping with persisting pain and functional disability (11). Besides, early postoperative identification of patients at risk for unfavourable long-term outcome could help orthopaedic surgeons to identify which patients should be invited at the outpatient

clinic. Currently, orthopaedic surgeons invite all patients to the outpatient clinic for routine follow-up visits. These visits add substantial costs to the health care system and are time consuming for both patient and physician, whereas in only very few cases patient management is altered (33, 34). Our results emphasize that PROs, specifically the initial clinical recovery and preoperative scores, should be used for clinical decision-making and patient-centred care and not solely to measure and compare group-averages in the context of registries.

Several strengths and limitations of the present study should be acknowledged. Strengths of our study were that we used a large, unselected cohort of patients representing a common patient population in clinical care. Furthermore, our outcome measures are included in the international standard set of outcome measures for patients with hip or knee OA defined by the International Consortium for Health Outcomes Measurement (ICHOM)(35) and included in United States and European registries (23). As all patients included in these registries already complete the questionnaires, orthopaedic surgeons could implement our findings in clinical practice. Besides, we added two sensitivity analyses. Both showed comparable outcomes to our initial analysis (supplementary table 2 and 3). Our study also had some limitations. First, we used absolute cut off points to determine favourable and unfavourable outcome instead of change-scores such as the Minimal Clinical Important Difference (MCID) as the use of the MCID is accompanied by many pitfalls (36). Patients with good preoperative pain- and function are less likely to achieve the MCID. Moreover, patients with extremely low preoperative scores that do improve the MCID-threshold are considered to have favourable outcomes, whereas their absolute outcomes remain very low indicating severe complaints. Secondly, 24% of THA and 27% of TKA patients were lost to follow-up, which could have led to selection bias. Comparisons between included and lost to follow-up patients showed that lost to included patients reported fewer complaints compared to lost to follow-up patients (supplementary table 1). This reduces the generalizability of our results and could have influenced our results by over- or underestimating the amount of non-responding patients. Third, in line with the first postoperative data-measurement of TKA patients

in the Dutch Arthroplasty Register, we measured the initial outcome six months after surgery. By then, a substantial part of the recovery already occurred. Whether targeted rehabilitation strategies at six months are capable of improving long-term outcome should be investigated in future studies. Lastly, patients at risk for unfavourable outcome could potentially be identified even sooner after surgery. The optimal time point to early postoperatively identify patients at risk for unfavourable outcome should be investigated in future studies.

In conclusion, most patients showed favourable initial postoperative pain and function outcomes after THA and TKA, and of the patients with unfavourable initial clinical recovery, one-third still improved up to one-year postoperatively. Patients at risk for unfavourable pain or function outcomes at one-year could be identified at six months after surgery by initial clinical recovery and their preoperative pain or function scores. The latter provides opportunities for timely postoperative interventions to optimize pain and function outcome.

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Supplementary table 1. Patient characteristics, preoperative score, six month outcome and initial clinical recovery of HOOS/KOOS scores of included patients and patients lost to follow-up

	Included	Lost to follow-up	P-value
Total Hip	(n=973)	(n=302)	
Female; n (%)	597 (63%)	188 (64%)	0.652
Age; mean (SD)	68.2 (9.6)	66.4 (10.9)	0.005*
BMI; mean (SD)	27.1 (4.3)	27.7 (5.1)	0.047*
Comorbidity			
Musculoskeletal	364 (57%)	137 (67%)	0.010*
Non-musculoskeletal	565 (70%)	172 (73%)	0.395
Postoperative complications	119 (12%)	16 (13%)	0.757
Mental health; mean (SD)	55.0 (9.4)	53.5 (11.0)	0.030*
Preoperative score; mean (SD)			
Function	40.4 (19.9)	37.3 (19.5)	0.021*
Pain	38.1 (18.8)	36.3 (19.4)	0.165
QoL	28.5 (16.9)	25.9 (16.8)	0.020*
Six-month outcome; mean (SD)	(n=962)	(n=118)	
Function	81.9 (17.8)	79.1 (20.5)	0.123
Pain	85.9 (17.6)	86.1 (18.2)	0.883
QoL	73.0 (22.2)	68.5 (22.1)	0.041*
Initial clinical recovery; mean (SD)	(n=962)	(n=118)	
Function	41.8 (22.2)	43.3 (23.0)	0.517
Pain	47.8 (22.6)	51.3 (23.5)	0.142
QoL	44.6 (25.1)	43.1 (26.2)	0.547
Total Knee	(n=892)	(n=328)	
Female; n (%)	592 (67%)	212 (65%)	0.504
Age; mean (SD)	67.8 (8.6)	66.1 (10.1)	0.005*
BMI; mean (SD)	29.1 (4.6)	29.8 (4.8)	0.013*
Comorbidity			
Musculoskeletal	287 (52%)	105 (51%)	0.850
Non-musculoskeletal	544 (75%)	194 (77%)	0.578
Postoperative complication	129 (15%)	20 (14%)	0.908
Mental health; mean (SD)	55.7 (9.3)	54.1 (10.3)	0.016*
Preoperative score; mean (SD)			
Function	45.5 (18.1)	41.6 (19.6)	0.002*
Pain	39.1 (18.1)	35.9 (18.5)	0.008*
QoL	27.1 (15.5)	23.7 (16.7)	0.002*
Six-month outcome; mean (SD)	(n=879)	(n=141)	
Function	80.4 (18.3)	73.9 (21.6)	0.000*
Pain	81.4 (19.4)	74.3 (23.0)	0.000*
QoL	62.7 (21.8)	57.8 (22.6)	0.014*
Initial clinical recovery; mean (SD)	(n=879)	(n=141)	
Function	34.5 (21.2)	31.5 (23.8)	0.133
Pain	42.1 (23.6)	38.1 (25.0)	0.079
QoL	35.7 (23.9)	34.6 (25.4)	0.619

Initial clinical recovery = clinical recovery at six months
HOOS/KOOS = Hip Disability or Knee Injury and Outcomes of Osteoarthritis Score
BMI = Body Mass Index
QoL = Quality of Life
* Significance level p<0.05

Supplementary table 2. Prediction of one-year unfavourable pain and function outcome based on a cut-off point according to the Function and Outcomes Research for Comparative Effectiveness in Total Joint Replacement (FORCE-TJR).

	Unfavourable one-year **pain or function** outcome					
Pain	**THA** N=938			**TKA** N=860		
	OR	95% CI	AUC	OR	95% CI	AUC
Model 1 Initial clinical recovery	0.97	0.96-0.98	0.70	0.96	0.95-0.97	0.76
Model 2 Preoperative pain#	0.96	0.95-0.97	0.69	0.97	0.96-0.98	0.63
Model 3 Initial clinical recovery	0.92	0.91-0.93	0.90	0.92	0.91-0.93	0.90
Preoperative pain#	0.90	0.88-0.91		0.90	0.88-0.92	
Function	**THA** N=943			**TKA** N=870		
Model 1 Initial clinical recovery	0.97	0.96-0.98	0.70	0.96	0.95-0.97	0.72
Model 2 Preoperative function#	0.96	0.95-0.97	0.69	0.96	0.95-0.97	0.67
Model 3 Initial clinical recovery	0.90	0.89-0.92	0.91	0.92	0.90-0.93	0.89
Preoperative function#	0.89	0.87-0.90		0.90	0.88-0.92	

#High pain scores indicate less pain
Unfavourable outcome = one-year pain/function score below the 20th percentile
AUC = Area Under the Curve
Model 1 = Univariate analysis including initial clinical recovery
Model 2 = Univariate analysis including preoperative pain
Model 3 = Multivariate analysis including initial clinical recovery and preoperative scores
THA = Total Hip Arthroplasty
TKA = Total Knee Arthroplasty

Supplementary table 3. Associations with one-year pain or function continuous outcome

	One-year unfavourable **pain or function** outcomes in all patients	
	B	95% CI
Pain; THA	N=955	
Model 1 Initial clinical recovery	0.26	0.21 – 0.31*
Model 2 Initial clinical recovery	0.67	0.62 – 0.72*
Preoperative pain#	0.75	0.69 – 0.81*
Pain; TKA	N=874	
Model 1 Initial clinical recovery	0.32	0.27 – 0.37*
Model 2 Initial clinical recovery	0.67	0.62 – 0.71*
Preoperative pain#	0.74	0.68 – 0.80*
Function; THA	N=951	
Model 1 Initial clinical recovery	0.28	0.22 – 0.33*
Model 2 Initial clinical recovery	0.78	0.73 – 0.83*
Preoperative function	0.86	0.80 – 0.91*
Function; TKA	N=880	
Model 1 Initial clinical recovery	0.32	0.27 – 0.38*
Model 2 Initial clinical recovery	0.72	0.68 – 0.77*
Preoperative function	0.82	0.77 – 0.88*

#High pain scores indicate less pain
Model 1 = Univariate analysis including initial clinical recovery
Model 2 = Multivariate analysis including initial clinical recovery and preoperative score
THA = Total Hip Arthroplasty
TKA = Total Knee Arthroplasty
ADL = Activity Daily Living
HOOS = Hip Disability and Outcomes of Osteoarthritis Score
KOOS = Knee injury and Outcomes of Osteoarthritis Score
* Statistical significance P<0.05