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Predictors of Patient-Reported Pain and Functional Outcomes Over 10 Years After Primary Total Knee Arthroplasty: A Prospective Cohort Study



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ABSTRACT

Background: This study aimed at identifying preoperative predictors of patient-reported outcomes after total knee arthroplasty (TKA) and at investigating their association with the outcomes over time.

Methods: We used data from 2080 patients from the Knee Arthroplasty Trial who received primary TKA in the United Kingdom between July 1999 and January 2003. The primary outcome measure was the Oxford knee score (OKS) collected annually over 10 years after TKA. Preoperative predictors included a range of patient characteristics and clinical conditions. Mixed-effects linear regression model analysis of repeated measurements was used to identify predictors of overall OKS, and pain and function subscale scores over 10 years, separately.

Results: Worse preoperative OKS, worse mental well-being, body mass index greater than 35 kg/m², living in the most deprived areas, higher American Society of Anesthesiologists grade, presence of comorbidities, and history of previous knee surgery were associated with worse overall OKS over 10 years after surgery. The same predictors were identified for pain and function subscale scores, and for both long-term (10 years) and short-to-medium-term outcomes (1 and 5 years). However, fitted models explained more variations in function and shorter-term outcomes than in pain and longer-term outcomes, respectively.

Conclusion: The same predictors were identified for pain and functional outcomes over both short-to-medium term and long term after TKA. Within the factors identified, functional and shorter-term outcomes were more predictable than pain and longer-term outcomes, respectively. Regardless of their preoperative characteristics, on average, patients achieved substantial improvement in pain over time, although improvement for function was less prominent.

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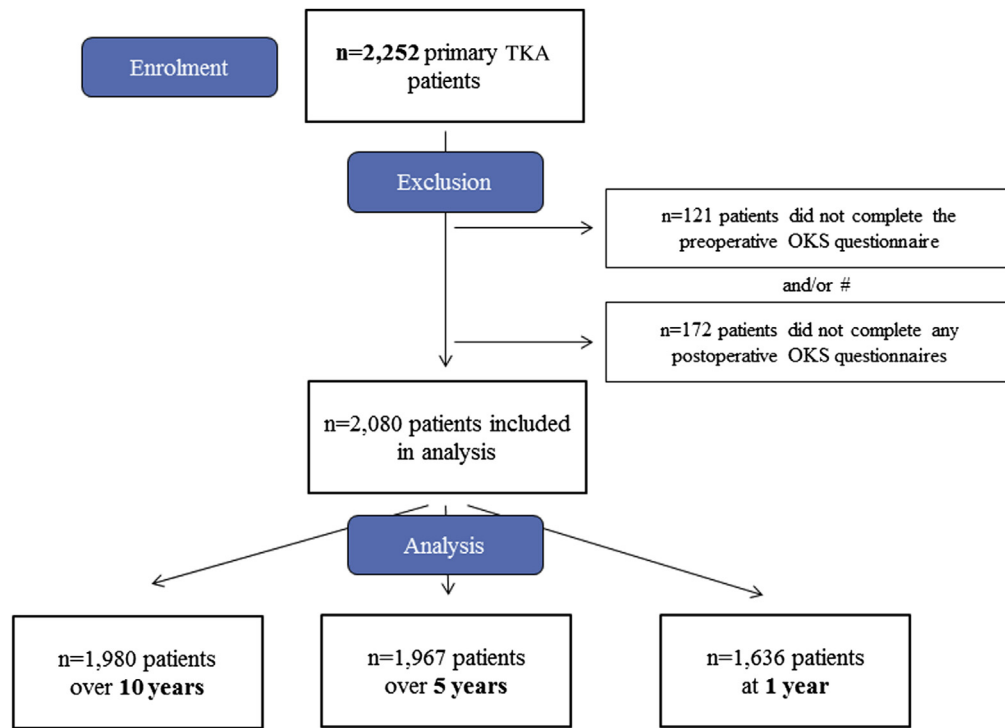
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21 patients did not complete neither the pre-operative OKS questionnaire nor any postoperative OKS questionnaires.

Fig. 1. A flow diagram of patients included and excluded for each analysis. TKA, total knee arthroplasty; OKS, Oxford knee score.

Total knee arthroplasty (TKA) is a commonly performed and effective surgical intervention to relieve pain and restore function in severely damaged knee joints. As the burden of knee arthritis keeps increasing, the number of TKAs performed is reported to be increasing every year [1]. However, variation in postoperative outcomes has been observed among patients, with up to 20% of patients dissatisfied with their outcomes [2]. It is important, therefore, for both clinicians and patients to understand the prognosis of surgery on an individual basis so as to decide whether to undergo TKA and whether it is necessary to enhance treatment protocols. In recent years, patient-reported outcome measures (PROMs) have been widely used to assess clinical outcomes from patients' perspective, which is believed to better reflect patients' health status and quality of life [3–5].

A range of potential predictors of PROMs after TKA have been identified within the literature, including preoperative level of pain and function [6–15], age [6–8,12,13,16–20], sex [6,8,9,13,16,19,21], body mass index (BMI) [13,15,18,20], comorbidities [6–9,12–15,20,22], preoperative mental health [9,10,12,18,20,22], and surgeon volume [22]. Most of these studies had a follow-up less than 5 years after TKA. Very few studies examined the effect of predictors over time [23]. Several studies suggested that predictors of pain were not necessarily the same as function [11,13,18,19,22,24,25]. It should be noted, however, that these studies distinguished pain and function based on the wording of questions without formal statistical validation.

Using data from the Knee Arthroplasty Trial (KAT) [26,27] which included patients receiving TKAs in the United Kingdom, this study aimed at the following: (1) identifying preoperative predictors of PROMs as measured by the Oxford knee score (OKS) over 10 years after primary TKA, with pain and function analyzed separately and (2) investigating their effect over short-to-medium-term outcomes.

Materials and Methods

The study used data from the KAT, a pragmatic, multicenter, randomized, controlled trial [26,27] (International Standard Randomized Trial No. ISRCTN45837371). From July 1999 to January 2003, a total of 2352 patients across 34 centers in the United Kingdom were randomly allocated to primary knee arthroplasty with metal-backed tibial component or not; patellar resurfacing or not; mobile bearing or not; or, TKA or unicompartmental arthroplasty.

Outcome Variables

The primary outcome measure was the OKS [28] completed by patients at baseline (preoperative), at 1 year after operation, and annually thereafter by postal questionnaire. The OKS is a validated questionnaire specifically developed to assess patient's pain and function status after knee arthroplasty. It comprises 12 questions, each with 5 responses on a Likert scale. Each question is scored from 0 (most severe pain or most limited function) to 4 (no pain or no function limitation). An overall OKS is created by summing the scores for each question, ranging from 0 (the worst outcome) to 48 (the best outcome) [29]. OKS pain and function subscale scores were calculated according to Harris et al [30]: the function subscale score was obtained by summing the scores for OKS questions 2, 3, 7, 11, and 12 (ranging from 0 to 20) and the pain subscale score by summing scores for the other 7 questions (ranging from 0 to 28). Higher subscale scores indicate better function or less pain. Patients were censored for follow-up if they died or received revision surgery within 10 years after the primary TKA.

Table 1
Multivariable Analysis of Overall OKS at 1 Year, and over 5 and 10 Years After TKA.

Variables	At 1 y (n = 1636)		Over 5 y (n = 1967)		Over 10 y (n = 1980)	
	Multivariable ^a Coefficient (95% CI)		Multivariable ^a Coefficient (95% CI)		Multivariable ^a Coefficient (95% CI)	
	R ² = 18.76%		R ² = 15.62%		R ² = 14.51%	
Patient characteristics						
Sex						
Female	0		0		0	
Male	0.44 (−1.05, 1.92)		0.33 (−0.96, 1.61)		0.31 (−0.96, 1.58)	
Age at operation (y)						
<60	−0.86 (−3.18, 1.46)		−2.09 (−3.89, −0.30) [*]		−1.96 (−3.73, −0.20) [*]	
60–70	0		0		0	
70–80	0.74 (−0.59, 2.08)		0.07 (−1.11, 1.25)		−0.28 (−1.45, 0.88)	
80+	−2.75 (−4.98, −0.51) [*]		−2.92 (−4.73, −1.10) ^{**}		−3.23 (−5.03, −1.42) ^{***}	
Sex#age at operation^b						
Male#age < 60	−4.29 (−7.80, −0.78) [*]		−1.90 (−4.63, 0.83)		−1.94 (−4.64, 0.76)	
Male#age 60–70	−0.53 (−2.48, 1.41)		−0.10 (−1.83, 1.62)		−0.15 (−1.86, 1.55)	
Male#age 80+	2.74 (−0.36, 5.84) [†]		3.57 (0.90, 6.23) ^{**}		3.42 (0.76, 6.08) [*]	
Marital status						
Married	0		0		0	
Living alone	−0.48 (−1.48, 0.52)		−0.65 (−1.52, 0.21) [†]		−0.72 (−1.59, 0.15) [†]	
BMI (kg/m²)						
<25	0		0		0	
25–30	−0.33 (−1.55, 0.90)		−0.36 (−1.45, 0.73)		−0.36 (−1.40, 0.69)	
30–35	−1.84 (−3.23, −0.46) ^{**}		−0.95 (−2.11, 0.21) [†]		−0.92 (−2.06, 0.21) [†]	
>35	−1.97 (−3.62, −0.32) [*]		−1.67 (−3.07, −0.27) [*]		−1.79 (−3.12, −0.46) ^{**}	
IMD 2004 quintiles						
1st (most deprived)	0		0		0	
2nd	1.22 (−0.82, 3.25)		0.39 (−0.53, 1.32)		0.39 (−0.28, 1.05)	
3rd	2.38 (0.47, 4.29) [*]		1.08 (0.19, 1.98) [*]		0.82 (0.21, 1.43) ^{**}	
4th	2.70 (0.86, 4.53) ^{**}		1.07 (0.17, 1.97) [*]		0.96 (0.35, 1.58) ^{**}	
5th (most affluent)	1.97 (0.04, 3.91) [*]		1.08 (0.15, 2.02) [*]		0.94 (0.26, 1.61) ^{**}	
Preoperative patient-reported health status						
Preop overall OKS	0.35 (0.29, 0.42) ^{***}		0.39 (0.34, 0.45) ^{***}		0.41 (0.35, 0.46) ^{***}	
Preop SF-12 MCS						
<50	0		0		0	
50+	1.65 (−0.70, 2.61) ^{**}		1.77 (0.96, 2.57) ^{***}		1.61 (0.81, 2.40) ^{***}	
Preoperative clinical conditions						
ASA grade						
Fit and healthy	0		0		0	
Asymptomatic	−1.04 (−2.25, 0.17) [†]		−0.81 (−1.83, 0.21) [†]		−0.66 (−1.60, 0.28)	
Symptomatic	−2.69 (−4.25, −1.13) ^{**}		−2.19 (−3.43, −0.95) ^{**}		−1.91 (−3.07, −0.75) ^{**}	
Previous knee surgery						
No	0		0		0	
Yes	−1.78 (−2.72, −0.84) ^{***}		−1.24 (−2.07, −0.42) ^{**}		−1.17 (−1.98, −0.36) ^{**}	
Comorbidities						
No	0		0		0	
Yes	−3.00 (−4.35, −1.65) ^{***}		−2.37 (−3.50, −1.24) ^{***}		−2.24 (−3.36, −1.12) ^{***}	
Year of follow-up						
			−0.16 (−0.25, −0.06) ^{**}		−0.33 (−0.38, −0.27) ^{***}	

Coefficient: the regression coefficient represents the difference in outcome compared with the reference group. A positive value indicates that the group has better post-operative pain/function.

OKS, Oxford knee score; TKA, total knee arthroplasty; CI, confidence interval; IMD, Index of Multiple Deprivation; BMI, body mass index; SF-12 MCS, 12-item Short-Form Health Survey Mental Component Summary; ASA, American Society of Anesthesiologists.

***<.001; **<.01; *<.05; †<.20.

^a In the multivariable models, all variables are mutually adjusted and an interaction term between age and sex was included.

^b Interaction between sex and age at operation.

Predictor Variables

Patient characteristics including age at operation (<60, 60–70, 70–80, or 80+ years), sex, marital status (married or living alone), and BMI (<25, 25–30, 30–35, or >35 kg/m²) were collected by local research nurses using patient entry questionnaires and routine medical database [27]. The Index of Multiple Deprivation 2004 was used as a measure of social deprivation [31]. Residential postcodes of patients at randomization were linked to the Lower Layer Super Output Areas. A higher score indicates higher rate of deprivation in that area. The Index of Multiple Deprivation 2004 was analyzed using quintiles in this study.

Preoperative mental well-being was assessed using the 12-Item Short Form Health Survey Mental Component Summary (SF-12 MCS)

[32], with higher scores indicating better mental well-being. In the analysis, SF-12 MCS score was categorized into 2 groups: <50 and 50+. This was based on the sample distribution in this study (the mean of preoperative SF-12 MCS was 49.9) and also on previous studies [33].

Preoperative clinical conditions included diagnosis of arthritis (osteoarthritis or rheumatoid arthritis), joints affected (one knee, both knees, or general), presence of comorbidities, history of previous surgery, and the American Society of Anesthesiologists (ASA) grade. ASA grading system is a standard assessment of the patient's general physical health before surgery [34]. In the KAT study, the range of ASA grade is from 1 (fit and healthy) to 4 (symptomatic with severe restriction on daily activities). Grades 3 and 4 were collapsed into 1 group to ensure a sufficient number of patients.

Table 2
Multivariable Analysis of OKS Pain Subscale Score at 1 Year, and Over 5 and 10 Years After TKA.

Variables	At 1 y (n = 1636)	Over 5 y (n = 1967)	Over 10 y (n = 1980)
	Multivariable Coefficient (95% CI) ^a	Multivariable Coefficient (95% CI) ^a	Multivariable Coefficient (95% CI) ^a
	R ² = 14.85%	R ² = 10.89%	R ² = 10.10%
Patient characteristics			
Sex			
Female	0	0	0
Male	-0.29 (-1.23, 0.65)	-0.23 (-1.03, 0.57)	-0.22 (-1.01, 0.56)
Age at operation (y)			
<60	-0.78 (-2.29, 0.73)	-1.53 (-2.65, -0.40)**	-1.52 (-2.63, -0.42)**
60-70	0	0	0
70-80	0.54 (-0.31, 1.39)	0.27 (-0.47, 1.01)	0.11 (-0.62, 0.83)
80+	-1.50 (-2.94, -0.07)*	-1.61 (-2.75, -0.48)**	-1.74 (-2.86, -0.61)**
Sex#age at operation^b			
Male#age <60	-2.38 (-4.67, -0.09)*	-1.06 (-2.77, 0.64)	-1.10 (-2.78, 0.58)
Male#age 60-70	-0.21 (-1.45, 1.03)	-0.11 (-1.19, 0.96)	-0.22 (-1.28, 0.84)
Male#age 80+	1.92 (-0.04, 3.88) [†]	2.44 (0.77, 4.11)**	2.30 (0.64, 3.96)**
Marital status			
Married	0	0	0
Living alone	-0.38 (-1.01, 0.25)	-0.43 (-0.97, 0.11) [†]	-0.46 (-1.00, 0.07) [†]
BMI (kg/m²)			
<25	0	0	0
25-30	-0.33 (-1.10, 0.44)	-0.28 (-0.96, 0.40)	-0.27 (-0.92, 0.39)
30-35	-1.28 (-2.17, -0.39)**	-0.63 (-1.35, 0.09) [†]	-0.60 (-1.29, 0.08) [†]
>35	-1.25 (-2.31, -0.19)*	-1.00 (-1.86, -0.14)*	-1.11 (-1.93, -0.28)**
IMD 2004 quintiles			
1st (most deprived)	0	0	0
2nd	0.75 (-0.54, 2.04)	0.26 (-0.35, 0.86)	0.25 (-0.20, 0.70)
3rd	1.49 (0.30, 2.69)*	0.74 (0.14, 1.35)*	0.55 (0.13, 0.97)*
4th	1.60 (0.43, 2.77)**	0.71 (0.11, 1.31)*	0.63 (0.21, 1.05)**
5th (most affluent)	1.18 (-0.06, 2.42) [†]	0.72 (0.11, 1.34)*	0.62 (0.17, 1.06)**
Preoperative patient-reported health status			
Preop OKS pain score	0.29 (0.22, 0.36)***	0.30 (0.24, 0.35)***	0.31 (0.26, 0.37)***
Preop SF-12 MCS			
<50	0	0	0
50+	1.11 (0.51, 1.72)***	1.26 (0.76, 1.76)***	1.16 (0.68, 1.65)***
Preoperative clinical conditions			
ASA grade			
Fit and healthy	0	0	0
Asymptomatic	-0.56 (-1.33, 0.21) [†]	-0.41 (-1.05, 0.23)	-0.35 (-0.94, 0.25)
Symptomatic	-1.60 (-2.60, -0.60)**	-1.33 (-2.11, -0.55)**	-1.17 (-1.90, -0.44)**
Previous knee surgery			
No	0	0	0
Yes	-1.20 (-1.79, -0.59)***	-0.81 (-1.33, -0.30)**	-0.75 (-1.25, -0.25)**
Comorbidities			
No	0	0	0
Yes	-1.73 (-2.61, -0.85)***	-1.34 (-2.04, -0.63)***	-1.29 (-1.99, -0.60)***
Year of follow-up		-0.04 (-0.10, 0.03)	-0.15 (-0.19, -0.12)***

Coefficient: the regression coefficient represents the difference in outcome compared with the reference group. A positive value indicates that the group has better post-operative pain/function.

OKS, Oxford knee score; TKA, total knee arthroplasty; CI, confidence interval; IMD, Index of Multiple Deprivation; BMI, body mass index; SF-12 MCS, 12-item Short-Form Health Survey Mental Component Summary; ASA, American Society of Anesthesiologists.

***<.001; **<.01; *<.05; [†]<.20.

^a In the multivariable models, all variables are mutually adjusted and an interaction term between age and sex was included.

^b Interaction between sex and age at operation.

Statistical Methods

STATA 13.0 (Statacorp, College Station, TX) was used for all statistical analyses. Complete case analysis can be biased [35]. Moreover, missing data in several variables often lead to a substantial loss of observations, reducing the power and precision of estimates. Multiple imputation has been proposed to overcome this problem [36]. In this study, multiple imputation by chained equations procedures in STATA were used [37]. We included all predictor variables as described above and the outcome variable in each imputation process. For each analysis (at 1 year, over 5 years, and over 10 years), a total of 200 imputed datasets were created separately. The statistically significant level was set at .05.

Predictors of Overall OKS, and Pain and Function Subscale Scores Over Time

To identify predictors of continuous outcomes over 10 years, multilevel, mixed-effects linear regression with an unstructured variance-covariance matrix was conducted to take into account of clustering on the same patient. For each predictor variable as described previously, a univariable model adjusting for preoperative OKS was performed. Variables with $P < .20$ in the univariable models were included in the multivariable model. Age at operation, sex, preoperative OKS, and year of follow-up were included as a priori predictors. Fractional polynomial regression modelling was used to explore evidence of nonlinear relationships for continuous variables. An interaction term was fitted between the predictor

Table 3
Multivariable Analysis of OKS Function Subscale Score at 1 Year, and Over 5 and 10 Years After TKA.

Variables	At 1 y (n = 1636)	Over 5 y (n = 1967)	Over 10 y (n = 1980)
	Multivariable Coefficient (95% CI) ^a	Multivariable Coefficient (95% CI) ^a	Multivariable Coefficient (95% CI) ^a
	R ² = 23.76%	R ² = 22.30%	R ² = 20.72%
Patient characteristics			
Sex			
Female	0	0	0
Male	0.66 (0.04, 1.28)*	0.49 (−0.05, 1.03) [†]	0.49 (−0.05, 1.02) [†]
Age at operation (y)			
<60	−0.13 (−1.07, 0.80)	−0.65 (−1.40, 0.09) [†]	−0.53 (−1.26, 0.21)
60–70	0	0	0
70–80	0.24 (−0.33, 0.81)	−0.16 (−0.66, 0.33)	−0.35 (−0.84, 0.13)
80+	−1.20 (−2.13, −0.27)*	−1.24 (−2.00, −0.49)**	−1.42 (−2.18, −0.67)***
Sex#age at operation^b			
Male#age <60	−1.84 (−3.24, −0.44)*	−0.74 (−1.88, 0.39)	−0.76 (−1.89, 0.36)
Male#age 60–70	−0.29 (−1.11, 0.52)	0.07 (−0.64, 0.79)	0.11 (−0.60, 0.82)
Male#age 80+	0.91 (−0.42, 2.24)	1.22 (0.11, 2.33)*	1.20 (0.09, 2.30)*
Marital status			
Married	0	0	0
Living alone	−0.11 (−0.53, 0.31)	−0.23 (−0.59, 0.14)	−0.26 (−0.63, 0.10)
BMI (kg/m²)			
<25	0	0	0
25–30	0.02 (−0.51, 0.55)	−0.08 (−0.54, 0.38)	−0.09 (−0.54, 0.36)
30–35	−0.55 (−1.14, 0.04) [†]	−0.32 (−0.82, 0.17)	−0.34 (−0.84, 0.16)
>35	−0.75 (−1.44, −0.06)*	−0.73 (−1.32, 0.14)*	−0.75 (−1.33, −0.17)*
IMD 2004 quintiles			
1st (most deprived)	0	0	0
2nd	0.50 (−0.34, 1.33)	0.16 (−0.22, 0.54)	0.15 (−0.13, 0.44)
3rd	0.92 (0.12, 1.72)*	0.40 (0.04, 0.77)*	0.31 (0.05, 0.57)*
4th	1.13 (0.37, 1.89)**	0.42 (0.04, 0.79)*	0.38 (0.12, 0.64)**
5th (most affluent)	0.84 (0.05, 1.62)*	0.42 (0.04, 0.80)*	0.36 (0.08, 0.64)*
Preoperative patient-reported health status			
Preop OKS function score	0.40 (0.34, 0.47)***	0.46 (0.41, 0.51)***	0.47 (0.42, 0.52)***
Preop SF-12 MCS			
<50	0	0	0
50+	0.57 (0.17, 0.97)**	0.59 (0.25, 0.93)**	0.54 (0.20, 0.88)**
Preoperative clinical conditions			
ASA grade			
Fit and healthy	0	0	0
Asymptomatic	−0.46 (−0.97, 0.05) [†]	−0.39 (−0.82, 0.03) [†]	−0.32 (−0.72, 0.08) [†]
Symptomatic	−1.05 (−1.70, −0.40)**	−0.87 (−1.39, −0.35)**	−0.77 (−1.27, −0.28)**
Previous knee surgery			
No	0	0	0
Yes	−0.58 (−0.97, −0.19)**	−0.43 (−0.77, −0.08)*	−0.42 (−0.76, −0.08)*
Comorbidities			
No	0	0	0
Yes	−1.24 (−1.77, −0.70)***	−1.03 (−1.50, −0.57)***	−0.96 (−1.43, −0.50)***
Year of follow-up		−0.11 (−0.15, −0.07)***	−0.17 (−0.20, −0.15)***

Coefficient: the regression coefficient represents the difference in outcome compared with the reference group. A positive value indicates that the group has better post-operative pain/function.

OKS, Oxford knee score; TKA, total knee arthroplasty; CI, confidence interval; IMD, Index of Multiple Deprivation; BMI, body mass index; SF-12 MCS, 12-item Short-Form Health Survey Mental Component Summary; ASA, American Society of Anesthesiologists.

***<.001; **<.01; *<.05; [†]<.20.

^a In the multivariable models, all variables are mutually adjusted and an interaction term between age and sex was included.

^b Interaction between sex and age at operation.

variable and year of follow-up to see whether the effect of predictors depended on time. The same process was repeated for overall OKS, and pain and function subscale scores, respectively. To better understand the effect of predictor variables over medium-term and short-term outcomes, we repeated the above process for OKS outcomes over 5 years and at 1 year after TKA.

Changes in Overall OKS, and Pain and Function Subscale Scores over 10-Year Time, Stratified by Identified Predictors

For analyses over 10 years, after the final model was built, the outcome was expanded to include both baseline OKS (year 0) and follow-up OKS (year 1 through to year 10) and an interaction term was fitted between predictors that have been identified as statistically significant and year of follow-up. Average marginal effects were obtained to show the adjusted mean OKS over time across

categories of important predictors. The same process was repeated for overall OKS, and OKS pain and function subscale scores, respectively.

Results

Description of the Study Sample

One hundred patients were excluded from this study because they received unicompartmental knee arthroplasty, withdrew from the trial before surgery, or died before the first follow-up of the trial. Of the remaining 2252 patients receiving TKA, 75.8% of patients completed the OKS at 1 year and 41.6% responded at 10 years after TKA (254 [11.3%] patients died within 10 years and 101 [4.5%] patients received revision surgery during follow-up). Patients were

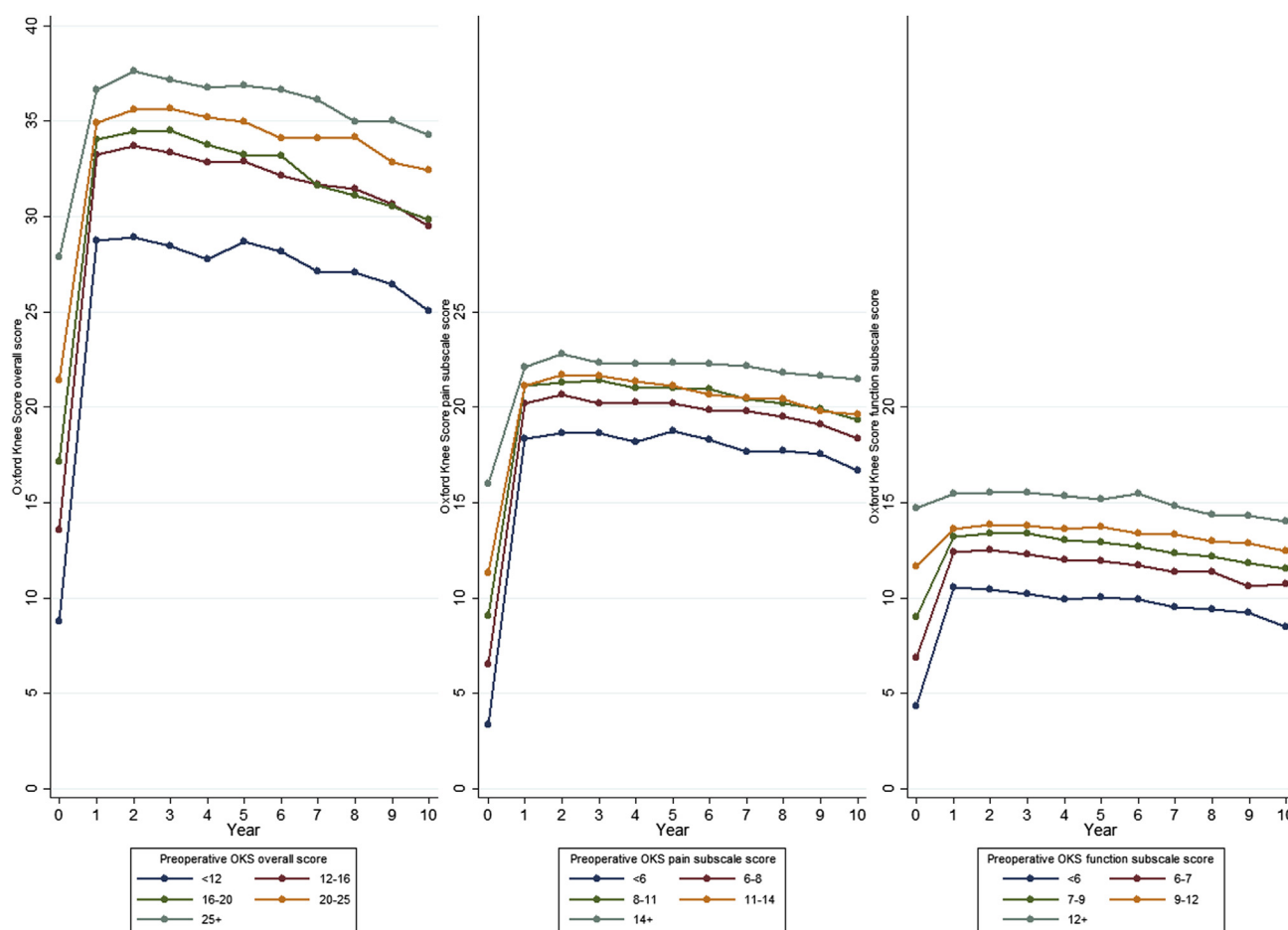


Fig. 2. Distribution of absolute differences in overall OKS, and pain and function subscale scores between baseline and 10-year follow-up after primary TKA.

included for analysis if they completed the preoperative and at least 1 postoperative OKS questionnaire during follow-up, which included 1980 (87.9%) for analyses over 10 years, 1967 (87.3%) over 5 years, and 1636 (72.6%) at 1 year (Fig. 1). A comparison of the patients who were included and excluded from analysis over 10 years is described in Supplementary Table 1. Patients included tended to be younger, had better preoperative OKS, had better mental well-being, and had lower ASA grading system. They were also more likely to have a history of previous knee surgery or present with comorbidities.

The mean preoperative overall OKS was 18.2 ± 7.5 (mean \pm standard deviation), with a pain subscale score of 9.5 ± 4.6 and function subscale score of 8.5 ± 3.5 . Histograms of the absolute difference between year 10 and preoperative OKS (Supplementary Fig. 1) suggested that whereas a small number of patients received no improvement or got worse at 10 years after TKA, the majority achieved improvement in overall OKS, as well as pain and function subscale scores.

Predictors of OKS Over Time After TKA

A number of variables were identified as statistically significant predictors of postoperative OKS over 10 years after TKA (Tables 1–3, last column). Better baseline scores were associated with better postoperative scores over 10 years, while worse mental well-being (SF-12 MCS < 50), BMI > 35 kg/m², living in more deprived areas, higher ASA grade, presence of comorbidities, and history of previous knee surgery were associated with worse outcomes.

A statistically significant interaction was found between age at the time of operation and sex (Supplementary Fig. 2). For women, patients aged younger than 60 or older than 80 at the time of operation presented worse outcomes over 10 years, while for men, only those younger than 60 showed statistically significantly worse outcomes. For patients younger than 60, women had better outcome while for those older than 80, men did better. There was also strong evidence that all OKS decreased over time, with an average annual decrease of 0.3 points for overall scores, and 0.2 points for both pain and function subscale scores. Predictors and their direction of effect were the same for both pain and functional outcomes, whereas difference was observed in the R² statistic. The final model of overall OKS explained 14.5% of variability in outcome, whereas the model for function explained 20.7% and pain only 10.1%. No significant interaction was found between predictors and year of follow-up. For outcomes over 5 years and at 1 year, the same predictors were identified but the fitted models explained slightly more of the variability in each outcome measure (Tables 1–3, first column for outcomes at 1 year and second column for outcomes over 5 years).

Changes in OKS Over Time, Stratified by Important Predictors

Figures 2–4 describe the change in outcomes over time stratified by predictors identified. The graphs highlighted again that the effect of predictors on pain and functional outcomes remained almost unchanged over time. They also demonstrated that despite the small size of difference in the attained postoperative outcomes

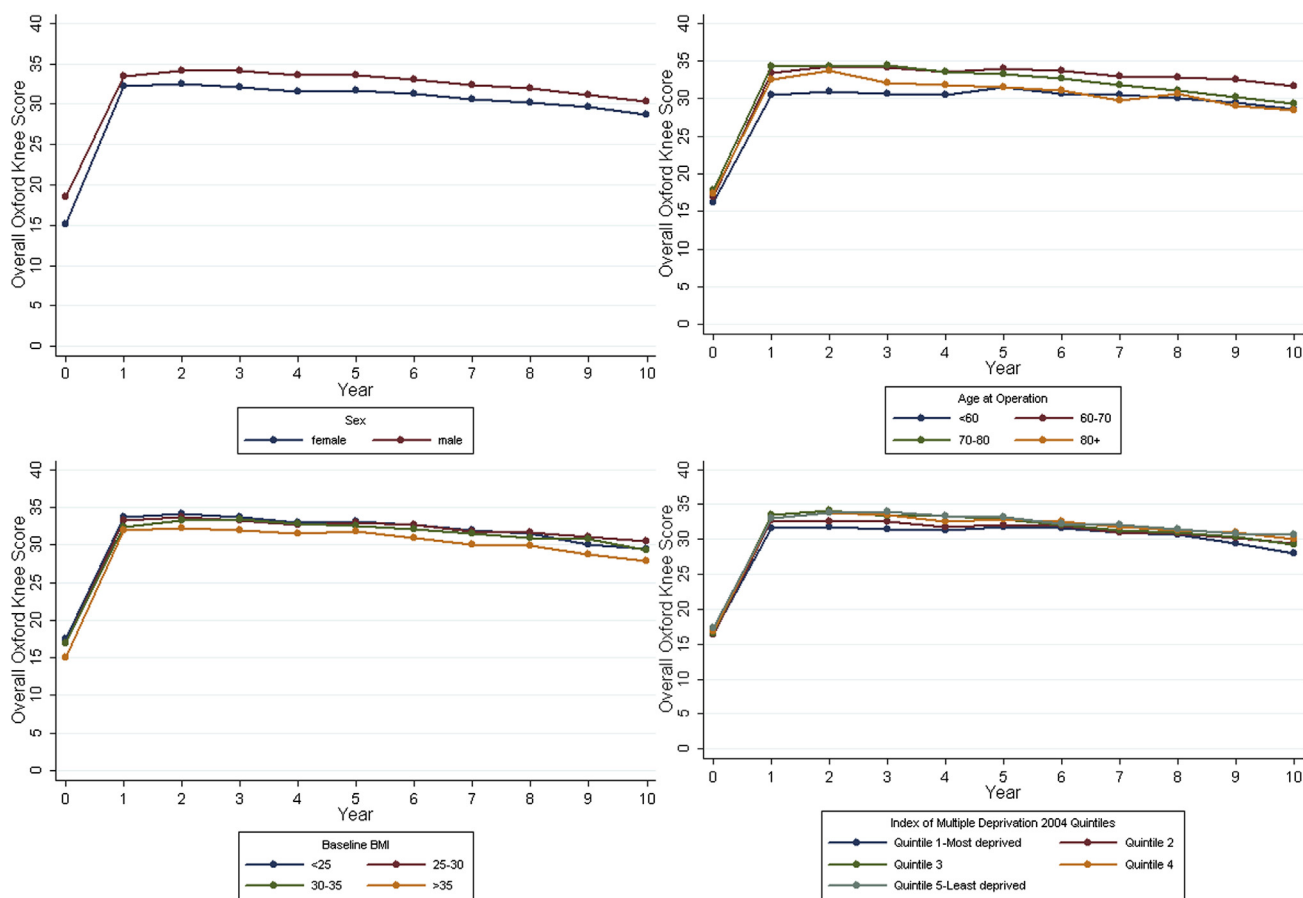


Fig. 3. Change in overall OKS over 10 years after primary TKA, stratified by preoperative patient characteristics and controlled for variables retained into the final regression model. The best possible score for overall OKS, and pain and function subscale scores is 48, 28, and 20, respectively. BMI, body mass index.

among patients with different preoperative characteristics, on average, these patients achieved substantial improvement in pain from preoperative level regardless of which group they belong to. For functional outcomes, on average, the improvement was less prominent especially for patients whose preoperative function score was among the highest quintile.

Discussion

Main Findings

Using a large prospective cohort of patients receiving primary TKA in the United Kingdom, we identified a number of statistically significant predictors of patient-reported pain and functional outcomes as measured by the OKS over 10 years after operation. Worse preoperative OKS, worse mental well-being (SF-12 MCS < 50), BMI > 35 kg/m², living in the most deprived areas, higher ASA grade, presence of comorbidities, and history of previous knee surgery were associated with worse postoperative outcome. A statistically significant interaction was found between sex and age at the time of operation. Predictors and their direction of effect were the same for both pain and functional outcomes, and for both short-term and medium-term results. Within the predictors identified, functional outcome was more predictable than pain, and shorter-term outcomes more predictable than longer-term outcomes. There was a slight yet statistically significant decrease in postoperative OKS over time.

What Is Already Known?

In line with previous studies, we found that worse baseline scores, living in the most deprived areas, history of previous knee surgery, presence of comorbidities, and worse mental well-being were associated with worse short-term and long-term OKS. The association between age and postoperative PROMs is inconclusive in the literature, with some indicating no relationship [7], while others showing that older age is related to poorer outcomes [11–13,19,38]. Most previous studies analyzed age by fitting a linear relationship with the outcome. In this study, a nonlinear relationship was evident and the effect varied by sex. For patients younger than 60, women had better outcome while for those older than 80, men did better. Possible explanation might be that daily activities are more physically demanding for younger male patients, while older female patients might have more disabling conditions or experience more pain.

Several studies suggested that predictors of pain were not necessarily the same as function [11,13,18,19,22,24,25]. One of them used OKS as the outcome measure [11]. In that study, the authors extracted pain and function subscale scores based on face validity (ie, the wording of questions) and looked at outcomes 6 months after TKA. In this study, we extracted subscale scores according to Harris et al [30] who distinguished pain and function scores using formal factor analysis. Different from what they have found, the same predictors were identified for both pain and function outcomes in this study.

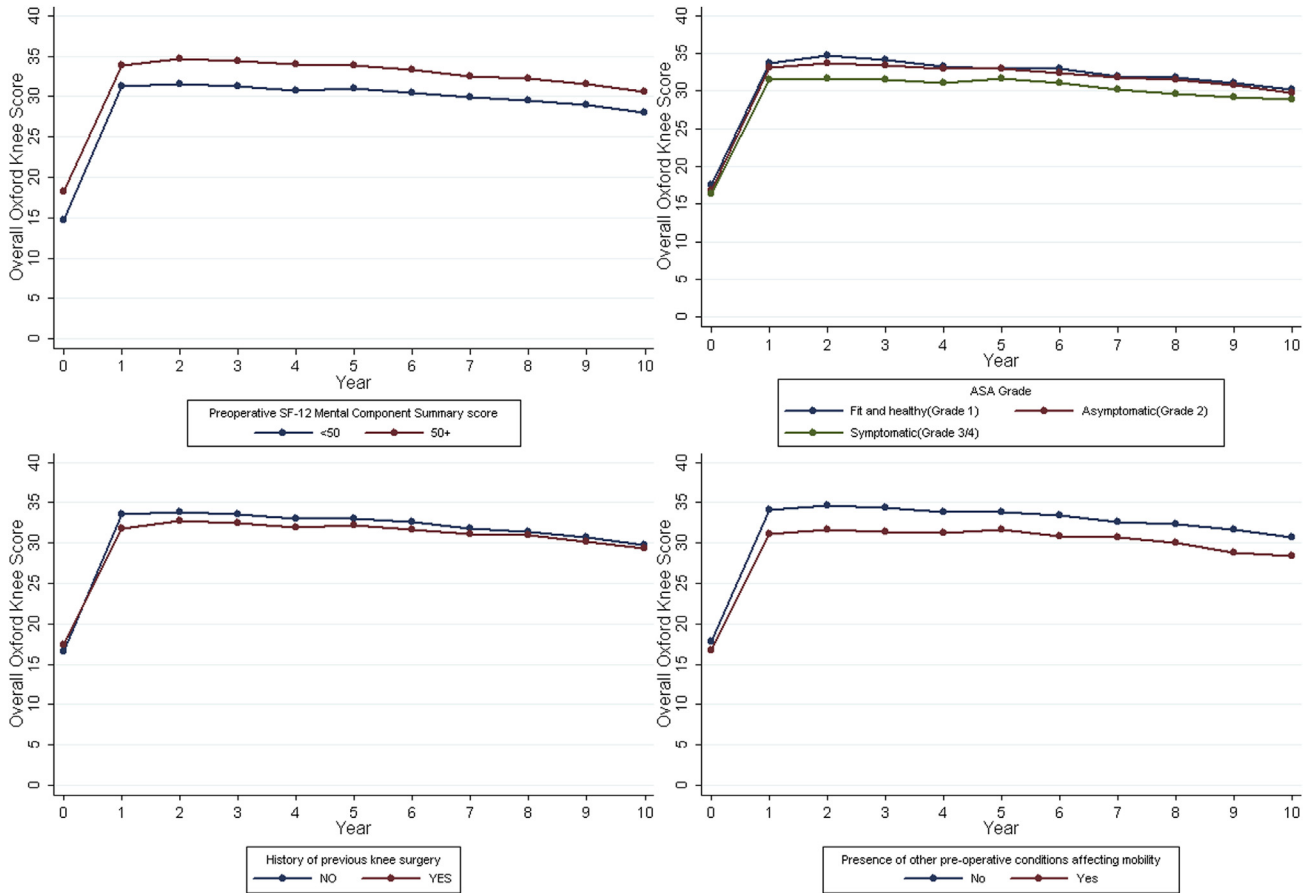


Fig. 4. Change in overall OKS over 10 years after primary TKA, stratified by preoperative health status and controlled for variables retained into the final regression model. The best possible score for overall OKS, and pain and function subscale score is 48, 28, and 20, respectively. ASA, American Society of Anesthesiologists.

Fitted models explained more variability in functional outcome than in pain over 10 years (20.7% vs 10.1%). It is possible that unmeasured predictors might explain a greater proportion of pain variability such as expectations of surgery. Some suggested that greater expectation of surgical outcome independently predicted greater pain relief but not for function [39]. Several studies also demonstrated that pain catastrophizing scale, the extent of a patient's negative or exaggerated orientation to pain, was a strong predictor of pain outcome after TKA [24,40]. It is also possible that the way information is measured on predictors is not detailed enough to capture the variability in their relation to pain. Previous studies suggested some patients might experience chronic pain after TKA despite the lack of noxious stimuli, which might be due to a dysfunction of pain modulation in the central nervous system, known as central sensitization [41]. The proportion of outcome variability explained by fitted models also decreased over time, which might be due to that some other unknown or unmeasured factors start to play an increasing role in the variability of outcomes.

Although our results showed statistically significant difference in attained postoperative OKS relating to preoperative patient and clinical characteristics, the size of effect for all identified variables is small. Moreover, regardless of their preoperative characteristics, on average, patients still achieved substantial improvement in pain and benefited from surgery over a long term. Improvement in function was less prominent, especially for patients with the highest quintile of preoperative function subscale scores. This

might be explained by a ceiling effect or that TKA is less effective in restoring function compared to relieving pain.

What This Study Adds?

Within this study, we have identified a number of preoperative predictors of attained postoperative PROMs over a long term after TKA. Predictors were the same for both pain and functional outcomes, and for both short-to-medium-term and long-term results. Within the variables collected, functional outcome was more predictable than pain and shorter-term outcomes more predictable than longer-term outcomes. Changes in outcomes over time revealed that regardless of their preoperative characteristics, on average, patients benefited from TKA and improved substantially in pain over 10 years, although the improvement was less prominent in functional outcomes.

Strengths and Limitations

The strengths of this project include the following. (1) Relatively large cohort; a total of 1980 patients were included in the multi-variable analysis over 10 years. (2) Long-term follow-up; repeated measurements of OKS were examined over 10 years after TKA. (3) The inclusion of a wide range of predictor variables; this made it possible to identify predictor variables more comprehensively and to minimize residual confounding. (4) Pain and functional outcomes analyzed separately; this is important to inform patients of their specific outcomes that can be expected.

Limitations include that other potential predictor variables suggested by previous studies, for example, patient expectations [39] and surgeon volume [22], were not measured in this project. The medical conditions of the involved knee joint were not examined either. Response bias is also possible as those included for analysis tended to be younger and healthier. Patients who were recruited in the KAT study might also have different characteristics from those declining to participate or not eligible and thus limit the generalizability of this study. However, the sample of patients included for analysis (mean age of 70 years with 56.4% females) is similar to all patients treated by the National Health Service (NHS) in 2005–2006 (mean age of 70 years with 57.7% females) [42], suggesting that our sample is fairly representative of the general population in the United Kingdom.

Conclusion

The same predictors were identified for pain and functional outcomes over both short-to-medium-term and long-term after primary TKA. Functional outcome and shorter-term outcomes were more predictable than pain and longer-term outcomes, respectively. Regardless of their preoperative characteristics, on average, patients still benefited from surgery and improved substantially in pain, although the improvement in function was less prominent.

Acknowledgment

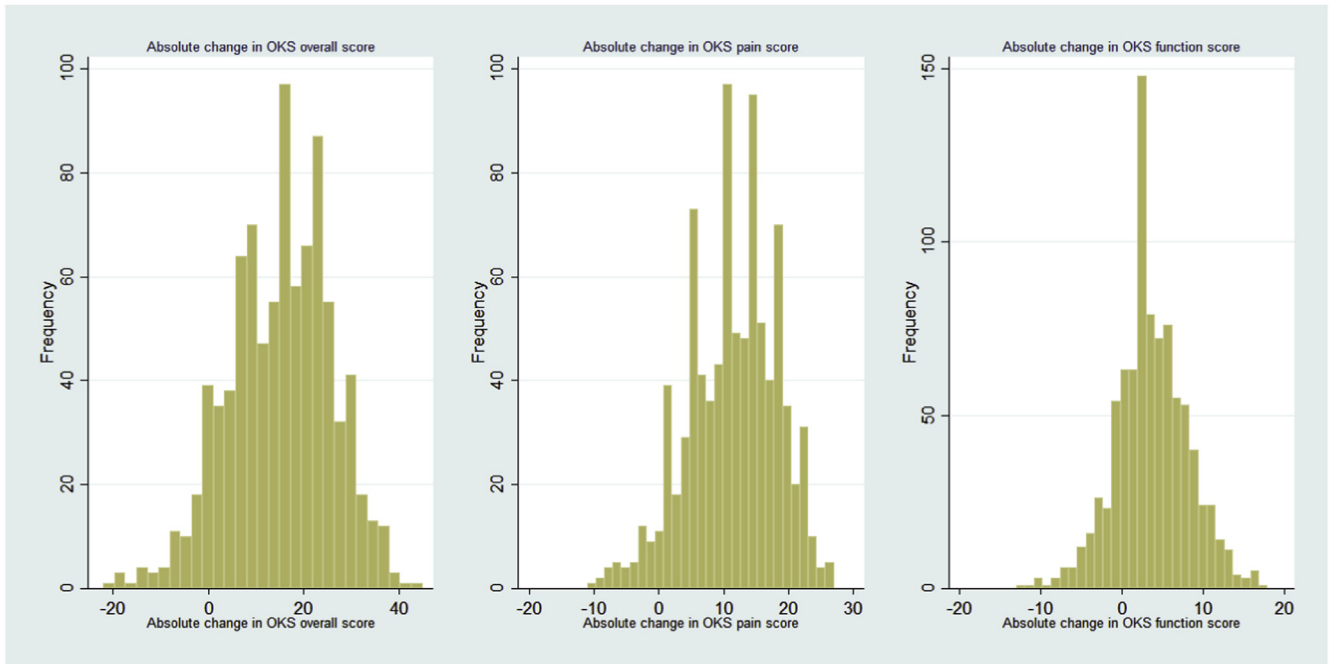
We would like to acknowledge all the patients and professionals who participated in data collection within the KAT study.

Appendix A. Supplementary Data

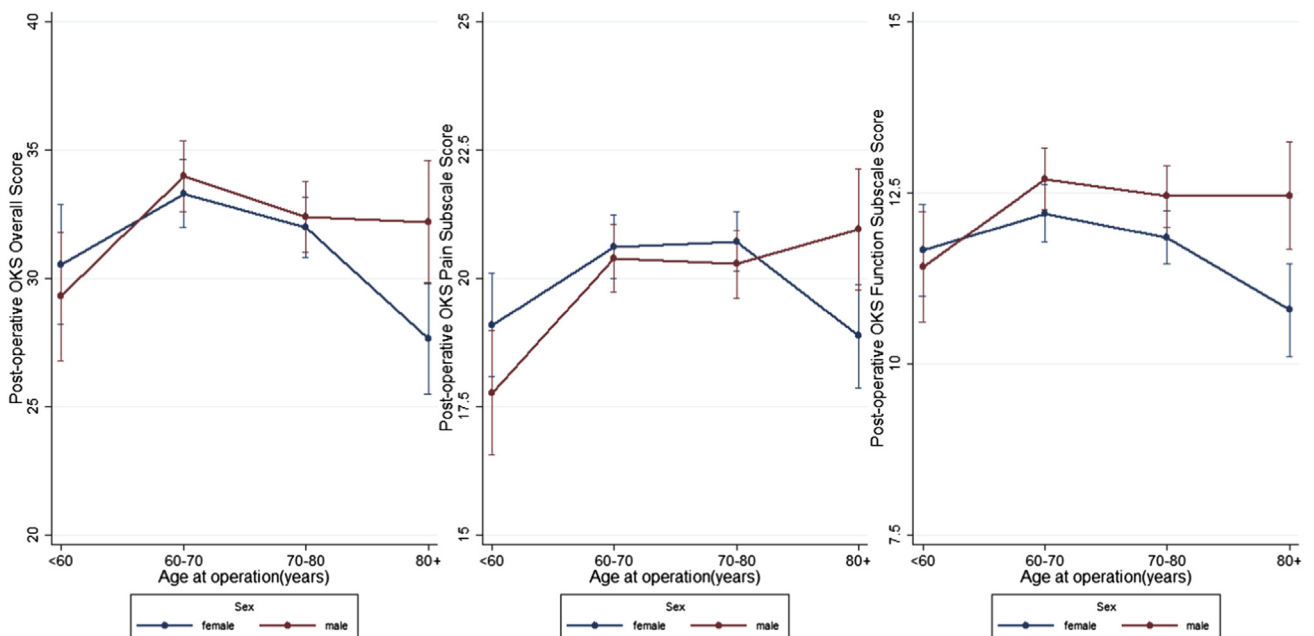
Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.arth.2016.06.009>.

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Supplementary Fig. 1. Distribution of absolute differences in overall Oxford knee score (OKS), and pain and function subscale scores between baseline and 10-year follow-up after primary total knee arthroplasty.



Supplementary Fig. 2. Marginal effect (95% confidence interval) of age-groups on postoperative OKS divided by sex and controlling for preoperative variables retained into the final regression model.

Supplementary Table 1

Descriptive Statistics and Comparison of Those Who Were Included, and Not, Into the Analysis.

Variables	Missing	Overall (N = 2252)	Inclusion Into Analysis		P Value
			Included (n = 1980)	Excluded (n = 272)	
Preop overall OKS (mean, SD)	121 (5.4%)	18.0 (7.5)	18.2 (7.5)	15.2 (7.3)	<.001
Postop overall OKS (median, IQR)					
1 y	544 (24.2%)	36 (28, 42)	36 (28, 42)	34 (25, 42)	.35
2 y	683 (30.3%)	38 (28, 43)	38 (28, 43)	38 (28, 42)	.78
3 y	603 (26.8%)	37 (28, 43)	37 (28, 43)	38 (30, 44)	.48
4 y	608 (27.0%)	37 (27, 43)	36 (27, 43)	39 (29, 44)	.23
5 y	690 (30.6%)	37 (28, 43)	37 (28, 43)	39 (28, 44)	.30
6 y	838 (37.2%)	37 (28, 43)	37 (28, 43)	39 (31, 43)	.34
7 y	912 (40.5%)	37 (27, 43)	37 (27, 43)	37 (30, 42)	.77
8 y	989 (43.9%)	36 (27, 43)	36 (27, 43)	37 (28, 41)	.78
9 y	1105 (49.1%)	36 (27, 43)	36 (27, 43)	36 (29, 42)	.53
10 y	1316 (58.4%)	36 (26, 43)	36 (26, 43)	35 (27, 42)	.68
Patient characteristics					
Sex, n (%)	0				
Female		1271 (56.4%)	1116 (56.4%)	155 (57.0%)	.85
Male		981 (43.6%)	864 (43.6%)	117 (43.0%)	
Marital status, n (%)	38 (1.7%)				
Married		1458 (65.8%)	1305 (66.3%)	153 (62.5%)	.23
Alone		756 (34.2%)	664 (33.7%)	92 (38.5%)	
Age, y (mean, SD)	0	71 (8)	70 (8)	72 (9)	.004
BMI, kg/m ²	106 (4.7%)				.98
<25		366 (17.1%)	327 (17.1%)	39 (17.0%)	
25-30		878 (40.9%)	781 (40.8%)	97 (42.2%)	
30-35		597 (27.8%)	534 (27.9%)	63 (27.4%)	
>35		305 (14.2%)	274 (14.3%)	31 (13.5%)	
IMD 2004 quintiles	819 (36.4%)				.53 ^a
1st (most deprived)		210 (14.6%)	179 (14.4%)	31 (16.6%)	
2nd		255 (17.8%)	227 (18.2%)	28 (15.0%)	
3rd		343 (23.9%)	304 (24.4%)	39 (20.9%)	
4th		349 (24.4%)	299 (24.0%)	50 (26.7%)	
5th (most affluent)		276 (19.3%)	237 (19.0%)	39 (20.9%)	
Preoperative mental well-being					
Preop SF-12 MCS	148 (6.6%)				.01
		1024 (48.7%)	916 (47.8%)	108 (57.5%)	
		1080 (51.3%)	1000 (52.2%)	80 (42.5%)	
Preoperative clinical conditions					
Diagnosis, n (%)	42 (1.9%)				
OA		2102 (95.1%)	1871 (95.2%)	231 (94.7%)	.74
RA		108 (4.9%)	95 (4.8%)	13 (5.3%)	
Joint affected, n (%)	42 (1.9%)				
One knee		569 (25.8%)	515 (26.2%)	54 (22.1%)	.18
Both knees		874 (39.5%)	765 (38.9%)	109 (44.7%)	
General		767 (34.7%)	686 (34.9%)	81 (33.2%)	
ASA grade, n (%)	111 (4.9%)				
Grade 1		366 (17.1%)	332 (17.5%)	34 (14.1%)	.002
Grade 2		1320 (61.7%)	1185 (62.4%)	135 (56.0%)	
Grade 3-4		455 (21.3%)	383 (20.2%)	72 (39.9%)	
Previous knee surgery, n (%)	42 (1.9%)				
No		1420 (64.3%)	1246 (63.4%)	174 (71.3%)	.02
Yes		790 (36.7%)	720 (36.6%)	70 (28.7%)	
Previous contralateral TKA, n (%)	42 (1.9%)				
No		1916 (86.7%)	1705 (86.7%)	211 (86.5%)	.91
Yes		294 (13.3%)	261 (13.3%)	33 (13.5%)	
Comorbidities, n (%)	49 (1.9%)				
No		1882 (85.4%)	1688 (86.0%)	194 (81.2%)	.05
Yes		321 (14.6%)	276 (14.0%)	45 (18.8%)	

The *t* tests were used for continuous variables and χ^2 tests for categorical variables.

OKS, Oxford knee score; SD, standard deviation; BMI, body mass index; Preop, preoperative; Postop, postoperative; SF-12 MCS, 12-item Short-Form Health Survey Mental Component Summary; IMD, Index of Multiple Deprivation; IQR, interquartile range; OA, osteoarthritis; RA, rheumatoid arthritis; ASA, American Society of Anesthesiologists; TKA, total knee arthroplasty.

^a *t* test based on log transformation of IMD 2004.