Comparison of KOOS scores of middle-aged patients undergoing total knee arthroplasty to the general Dutch population using KOOS percentile curves: the LOAS study

Loef, M.; Gademan, M.G.J.; Latijnhouwers, D.A.J.M.; Kroon, H.M.; Kaptijn, H.H.; Marijnissen, W.J.C.M.; ... ; LOAS Study Grp

The Journal of Arthroplasty 36 (2021) 2779–2787

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Primary Knee

Comparison of KOOS Scores of Middle-Aged Patients Undergoing Total Knee Arthroplasty to the General Dutch Population Using KOOS Percentile Curves: The LOAS Study

Marieke Loef, MD [a, *], Maaike G.J. Gademan, PhD [b, c], Daisy A.J.M. Latijnhouwers, MSc [b], Herman M. Kroon, MD, PhD [d], Herman H. Kaptijn, MD [e], Willem J.C.M. Marijnissen, MD, PhD [f], Rob G.H.H. Nelissen, MD, PhD [b], Thea P.M. Vliet Vlieland, MD, PhD [b], Margreet Kloppenburg, MD, PhD [a, c], for the LOAS Study Group

[a] Department of Rheumatology, Leiden University Medical Center, Leiden, the Netherlands
[b] Department of Orthopedics, Leiden University Medical Center, Leiden, the Netherlands
[c] Department of Clinical Epidemiology, Leiden University Medical Center, Leiden, the Netherlands
[d] Department of Radiology, Leiden University Medical Center, Leiden, the Netherlands
[e] Department of Orthopedics, LangeLand Hospital, Zoetermeer, the Netherlands
[f] Department of Orthopedics, Albert Schweitzer Hospital, Dordrecht, the Netherlands

ARTICLE INFO

Article history:
Received 17 December 2020
Received in revised form
16 March 2021
Accepted 23 March 2021
Available online 30 March 2021

Keywords:
patient-reported outcome measures
osteoarthritis
knee
arthroplasty
KOOS

ABSTRACT

Background: We aimed to investigate the application of the Knee Injury and Osteoarthritis Outcome Score (KOOS) percentile curves, using preoperative and postoperative data of patients with knee osteoarthritis undergoing total knee arthroplasty (TKA).

Methods: We used Longitudinal Leiden Orthopedics Outcomes of Osteo-Arthritis study data of patients between 45 and 65 years and undergoing primary TKA. KOOS scores (0-100) were obtained preoperatively and 6, 12, and 24 months after TKA. Preoperative knee radiographs were assessed according to Kellgren-Lawrence (KL) in a subset (37%) of patients. Comorbidities were self-reported using a standardized questionnaire. The median (interquartile range) population-level KOOS scores were plotted on previously developed population-based KOOS percentile curves. In addition, we assessed the application of the curves on patient level and investigated differences in scores between patients with preoperative KL scores $\leq$2 and $\geq$3 and presence (vs absence) of comorbidities.

Results: The study population consisted of 853 patients (62% women, mean age 59 years, body mass index 30 kg/m^2) with knee osteoarthritis undergoing primary TKA. Preoperatively, median KOOS scores of all subscales were at or below the 2.5th percentile. Scores increased to approximately the 25th percentile 12 months postoperatively. Greater improvements were observed in pain and less improvements in sport and recreational function and quality of life. Patients with higher preoperative KL scores and without comorbidities showed greater improvements.

Conclusion: The KOOS percentile curves provided visual insights in knee complaints of patients relative to the general population. Furthermore, the KOOS percentile curves give insight in how preoperative patient characteristics are correlated with postoperative results.

Funding: The LOAS study is supported by the Dutch Arthritis Society (LLP13). This funding source had no role in the design of this study and had no role during its execution, analyses, interpretation of the data, or decision to submit results.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2021.03.050.

* Address correspondence to: Marieke Loef, MD, Department of Rheumatology, C1-R, Leiden University Medical Center, PO Box 9600, 2300, RC, Leiden, the Netherlands.

https://doi.org/10.1016/j.arth.2021.03.050

Patient-reported outcome measures (PROMs) have been vastly incorporated in clinical research and are nowadays increasingly used in daily clinical practice [1]. PROMs enable capturing the patients' health status in a standardized way and support a more comprehensive understanding of outcomes and effectiveness. There are various ways in which PROMs can be used. Individual, patient-level PROM data can be routinely used to aid shared decision-making and patient-centered care by facilitating patient-clinician and multidisciplinary communication [2,3]. In addition, PROMs can be used for monitoring of disease progression and treatment effects. On population level, PROMs can be used to identify patient groups that benefit most from treatment, assess treatment (cost-)effectiveness, or compare performance of health organizations [4–6]. However, the interpretation of PROMs can be difficult if benchmarks are lacking and if there is uncertainty about which level of change in score is clinically meaningful.

Knee complaints, such as pain and functional disability, are estimated to occur in 32.1 per 1000 persons per year in the Dutch population. Knee osteoarthritis (OA) is one of the most important causes of knee complaints [7]. Because of the absence of disease-modifying drugs for OA, knee OA is treated symptomatically until progression to end-stage disease warrants a total knee arthroplasty (TKA). In the Netherlands, the annual number of TKAs has tripled in the last decade to over 25 thousand TKAs in 2018 [8]. The Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire is a condition-specific PROM developed to investigate the patients' burden due to knee complaints [9]. The KOOS consists of five subscales, measuring different knee-specific domains: symptoms, pain, activities of daily living (ADL) function, sport and recreational function, and quality of life (QOL). The items of these domains are transformed to subscale scores ranging from 0 to 100. By itself, these scores can be difficult to interpret, as suboptimal scores may be unrelated to musculoskeletal pathology [10–12]. Therefore, we have previously developed KOOS percentile curves in a middle-aged population-based cohort of Dutch men and women [13], to provide a benchmark for comparison of patient scores with the general population. Alternative ways to show PROMs data can optimize the interpretation of PROMs both by clinicians and patients, to support patient-clinical communication and making well-informed shared treatment decisions.

The aim of the present study was to investigate the application of the KOOS percentile curves to compare the preoperative and postoperative KOOS scores of patients with knee OA undergoing primary TKA, with the distribution of KOOS scores in the Dutch general population. Furthermore, we compared KOOS scores between specific patient groups with gain insight in possible differences in treatment benefit.

Materials and Methods

Study Population

The Longitudinal Leiden Orthopedics Outcomes of Osteo-Arthritis (LOAS) study (Trial ID NTR3348) started in June 2012 and is an ongoing, observational, multicenter, longitudinal cohort study designed to determine long-term outcomes of TKA and total hip arthroplasty. Patient recruitment has been described previously [14]. Briefly, patients were eligible if they had a diagnosis of OA, an age of 18 years or older, were listed for total hip arthroplasty or TKA, and were fluent in the Dutch language. Patients were recruited consecutively from eight hospitals in the Netherlands: Leiden University Medical Center (LUMC), Alrijne Hospital Leiderdorp, Alrijne Hospital Leiden, Groene Hart Hospital Gouda, LangeLand Hospital Zoetermeer, Reinier de Graaf Groep Delft, Albert Schweitzer Hospital Dordrecht, Waterland Hospital Purmerend [15]. Informed consent was obtained in accordance with the declaration of Helsinki. The Medical Ethical Committee of the LUMC approved the design of the study. The current analyses are comprised patients who have been included from June 2012 to June 2017, who were between 45 and 65 years of age and undergoing primary TKA. Supplementary Figure S1 presents a flowchart of included and excluded patient numbers.

Demographic Data and Comorbidities

Patient characteristics including age, sex, bodyweight (kg), and height (m) were collected by questionnaire and verified with data from the Landelijke Registratie Orthopedische Implantaten. Weight and height were used to calculate body mass index (BMI) (kg/m^2). A comorbidity questionnaire provided by the Dutch Central Bureau of Statistics was used to determine the presence of comorbidities in the past year [16].

Patient-Reported Outcomes

Patients completed the KOOS [9,17] preoperatively and at 6, 12, and 24 months after surgery. Patient numbers at each time point are presented in supplementary table S2. The KOOS is a knee-specific instrument consisting of five subscales: pain (nine items), symptoms (seven items), ADL function (17 items), sport and recreation function (five items) and knee-related quality of life (QOL) (four items). Items were scored considering the previous week from 0 (no problems) to 4 (extreme problems), on a 5-point Likert scale. Subscale scores were calculated as per the KOOS user's guide [18] as the sum of the items included, and subsequently transformed to a 0-100 scale, with zero representing extreme knee problems and 100 representing no knee problems.

Patient treatment satisfaction was assessed at 6 and 12 months postoperatively using the Friends and Family Test phrasing [19], asking patients if they would recommend the surgery to friends or family members if they would have the same complaints.

The Short Form Health Survey was used to measure patients' health-related QOL. This questionnaire consists of 12 questions covering 8 different dimensions (general health, physical functioning, role physical, role emotional, bodily pain, vitality, social functioning, and mental health). We calculated summary scores for the physical component (PCS) and mental component (MCS). The MCS and PCS scores range from 0 (worst QOL) to 100 (best QOL) [20]. Average scores of the United States population were used to derive norm-based scores with a mean of 50 and a standard deviation of 10.

Radiographic Knee Osteoarthritis Severity

Weight-bearing anteroposterior knee radiographs of the affected knee were obtained in all patients before surgery as part of routine care. The radiographs were retrieved from five of the local hospitals LUMC, Alrijne Hospital Leiderdorp, Alrijne Hospital Leiden, Groene Hart Hospital Gouda, LangeLand Hospital Zoetermeer, Albert Schweitzer Hospital Dordrecht) and therefore available in a subset (37%) of patients. The radiographs were centrally scored by an experienced musculoskeletal radiologist. The Kellgren and Lawrence (KL) grading system was used to assess radiographic OA severity on a 0-4 scale (grade 0: no OA; grade 1: doubtful OA; grade 2: minimal OA; grade 3: moderate OA; and grade 4: severe OA) [21]. Ten percent of radiographs was scored twice for assessment of an intraobserver reliability, which was 98% (97%-99%) [14]. A comparison of baseline characteristics between patients with and without radiographs showed no differences (supplementary table S1).

Table 1
Baseline Patient Characteristics of the LOAS Study, Stratified by Sex.

	Overall n = 853	Men n = 321 (36%)	Women n = 532 (64%)
Patient characteristics			
Age, y	59.1 (4.7)	59.6 (4.4)	58.8 (4.9)
BMI, kg/m^2	30.4 (5.0)	29.8 (4.4)	30.8 (5.3)
Any comorbidities, n (%)	636 (75)	230 (72)	406 (76)
Kellgren and Lawrence score[a]			
0, n (%)	13 (4)	3 (3)	10 (5)
1, n (%)	18 (6)	5 (5)	13 (6)
2, n (%)	52 (17)	16 (15)	36 (17)
3, n (%)	163 (52)	59 (55)	104 (50)
4, n (%)	68 (22)	24 (22)	44 (21)
SF-12			
MCS	54.1 (10.2)	54.4 (10.2)	53.9 (10.2)
PCS	31.1 (8.7)	33.2 (8.7)	29.7 (8.5)

Numbers represent mean (SD) unless otherwise specified. KOOS subscale scores are transformed to a 0-100 scale, with zero representing extreme knee problems and 100 representing no knee problems.

[a] Knee radiographs were scored in a random subset of n = 314 (37%) patients. SF-12 scores were missing in 101 patients. Abbreviations: ADL, activities daily living; BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Score; n, number; SD, standard deviation.

Reference Population

The reference population consisted of middle-aged individuals included in the population-based Netherlands Epidemiology of Obesity (NEO) study. The NEO study is a prospective cohort study that included Dutch men and women between 45 and 65 years of age living in the greater are of Leiden (the Netherlands) between 2008 and 2012. Detailed study design and data collection have been described elsewhere [22]. Briefly, individuals with a self-reported BMI $\geq$ 27 kg/m^2 were eligible to participate resulting in an oversampling of overweight or obese individuals. In addition, all inhabitants aged between 45 and 65 years from one municipality (Leiderdorp) were invited to participate irrespective of their BMI, allowing for a reference BMI distribution comparable with the general Dutch population [23]. To correctly represent associations in the general population, adjustments were made for the oversampling of individuals with BMI $\geq$27 kg/m^2 [24]. This was performed by weighting individuals toward the BMI distribution of participants from the Leiderdorp municipality (n = 1671), whose BMI distribution was similar to the BMI distribution in the general Dutch population [23]. Consequently, results apply to a population-based study without oversampling of participants with BMI $\geq$27 kg/m^2. The Medical Ethical Committee of the LUMC approved the design of the study and all participants gave written informed consent.

Population-Based Outcomes

Participant characteristics and KOOS scores were collected cross sectionally at baseline. The NEO study reference population consisted of 6643 participants. Mean age of the population was 56

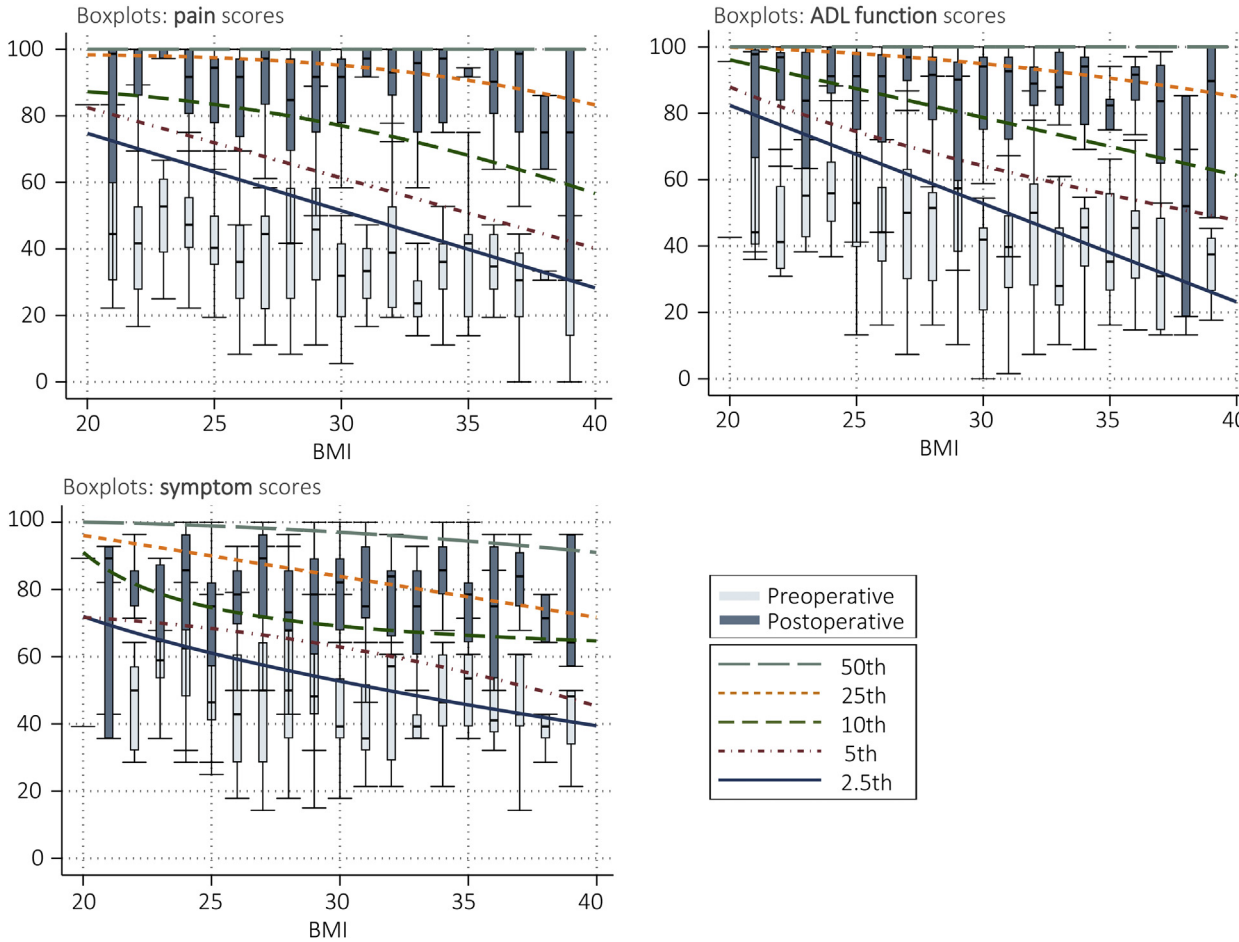

Fig. 1. Comparison of the preoperative and 12 months postoperative KOOS pain, symptom, and ADL scores in men undergoing primary total knee arthroplasty, with KOOS scores in the general population. The KOOS scores (Y-axis) are given over BMI (X-axis). The preoperative KOOS scores are represented by the light gray boxplots, and the postoperative scores are given in dark gray boxplots. The boxplots represent the median (horizontal line) and interquartile range. The KOOS score distribution of the general population is depicted with the colored percentile lines.

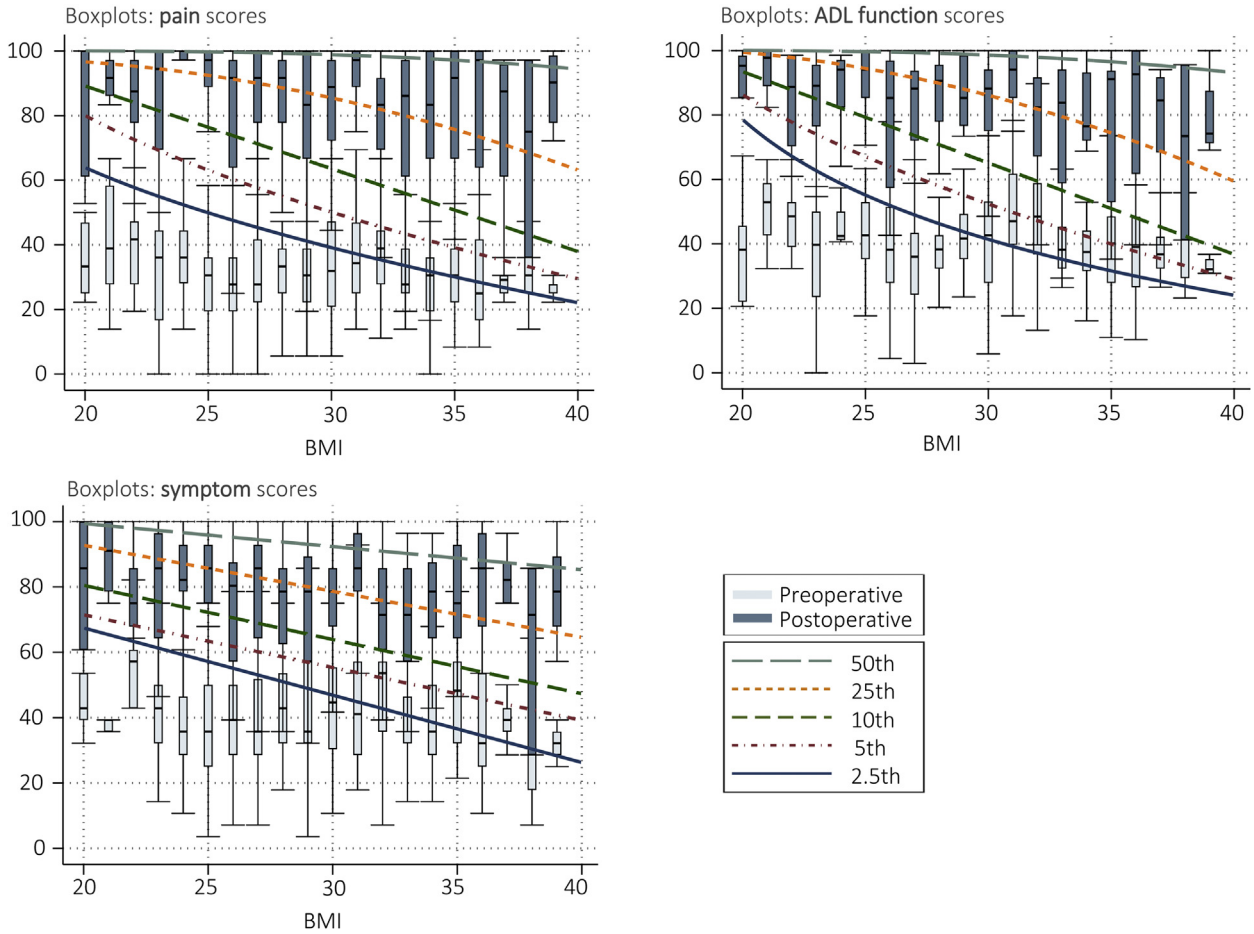

Fig. 2. Comparison of the preoperative and 12 months postoperative KOOS pain, symptom, and ADL scores in women undergoing primary total knee arthroplasty, with KOOS scores in the general population. The KOOS scores (Y-axis) are given over BMI (X-axis). The preoperative KOOS scores are represented by the light gray boxplots, and the postoperative scores are given in dark gray boxplots. The boxplots represent the median (horizontal line) and interquartile range. The KOOS score distribution of the general population is depicted with the colored percentile lines.

years, with a mean BMI of 26 kg/m^2, and 56% were women. Clinical knee OA was defined using the American College of Rheumatology classification criteria, and 15% of the population was classified with clinical knee OA. KOOS scores were handled in accordance with the KOOS user's manual similar to the LOAS study. Most of this middle-aged general population showed a lack of pain and other knee-related problems, with KOOS subscale scores (median; IQR) of: pain (100; 94-100), symptoms (96; 86-100), ADL function (100; 96-100), sport and recreation function (100; 80-100), and QOL (100; 75-100). Among investigated patient characteristics, we showed that sex and BMI were most strongly associated with KOOS scores. Hence, sex- and BMI-specific percentile curves were developed using quantile regression with fractional polynomials [13]. The curves can be interpreted as follows: the 50th percentile is equal to the median. A score at the 25th percentile means that 25% of the scores in the (reference) population are at or below this score and 75% of the population has a higher score. A similar interpretation applies to the other percentiles.

Statistical Analysis

Patient characteristics, radiographic knee OA severity, and presence of comorbidities were analyzed using descriptive statistics. In previous analyses by our group, KOOS scores were influenced by sex and BMI, therefore reference curves have been developed stratified for these variables. Therefore, we provided the LOAS patient characteristics stratified by sex. We plotted the preoperative and postoperative KOOS scores of patients with knee OA included in the LOAS cohort on the KOOS percentile curves for comparison of patient scores with the Dutch general population, as well as to visualize the score trajectories after TKA. We assessed the application of the reference curves on both patient level and population level. To get more insight in the differences of TKA treatment effect, KOOS scores of patients with preoperatively low ($\leq$2) and high ($\geq$3) KL scores were compared, as well as KOOS scores of patient with at least one comorbidity of any kind and without comorbidities. Stata V16.0 (StataCorp LP, College Station, TX, USA) was used for all analyses.

Data Availability

The data underlying this article were provided by the LOAS study group by permission. The data will be shared on reasonable request to the corresponding author, with permission of the LOAS study group.

Results

Patient Characteristics

The study population consisted of 853 patients, with a mean age of 59.1 years, a mean BMI of 30 kg/m^2, and predominantly women

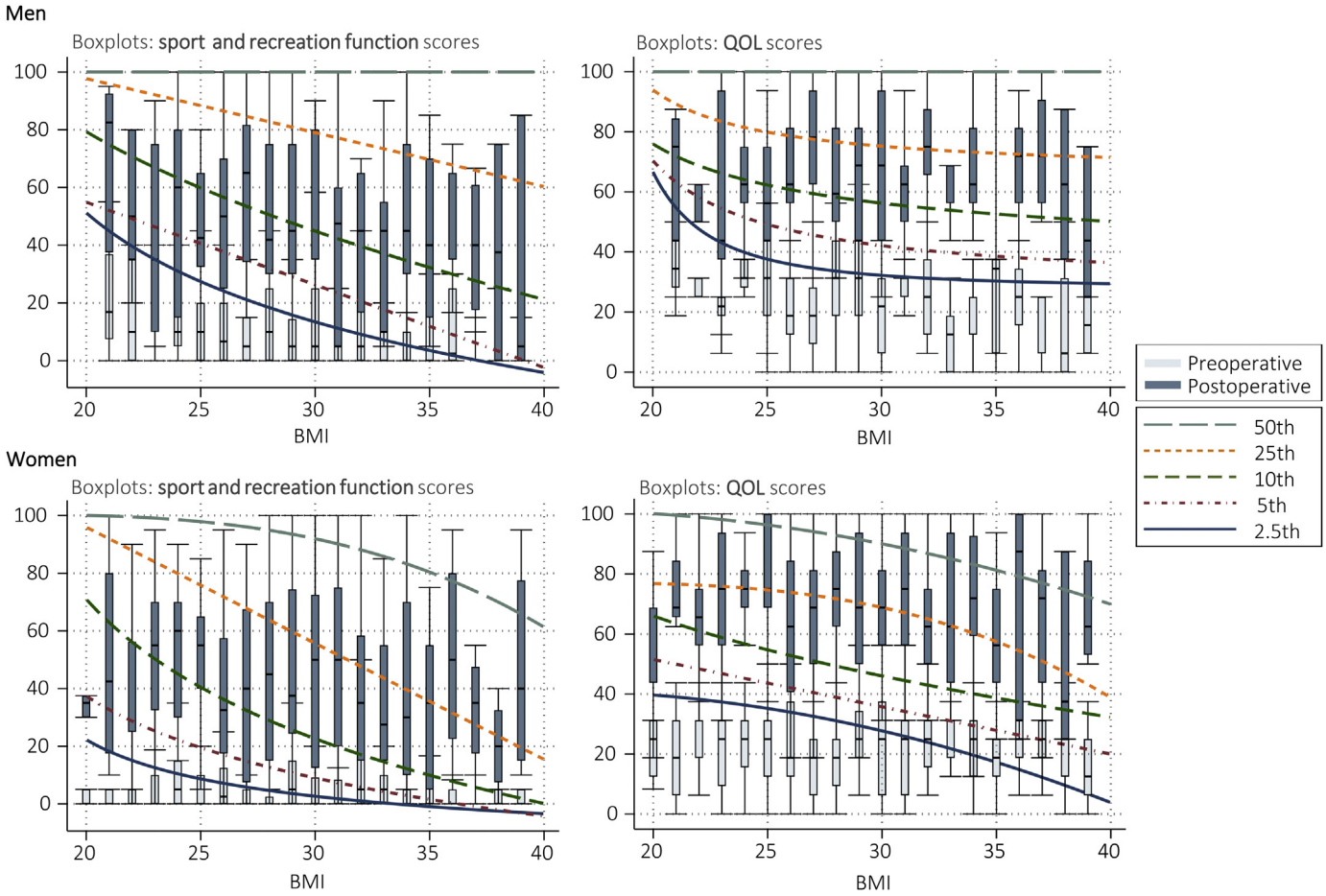

Fig. 3. Comparison of the preoperative and 12 months postoperative KOOS sport and recreation, and QOL subscale scores in patients undergoing primary total knee arthroplasty, with KOOS scores in the general population. The KOOS scores (Y-axis) are given over BMI (X-axis). The preoperative KOOS scores are represented by the light gray boxplots, and the postoperative scores are given in dark gray boxplots. The boxplots represent the median (horizontal line) and interquartile range. The KOOS score distribution of the general population is depicted with the colored percentile lines.

(62%). Overall, 75% of the LOAS population had one or more comorbidities; patients reported more often nonmusculoskeletal (68%) than musculoskeletal (23%) comorbidities. Mean MCS and PCS scores were 54 and 31, respectively. While 74% of the population had moderate to severe radiographic OA, a subset had no (4%), doubtful (6%) or minimal (17%) radiographic OA (Table 1).

Treatment Satisfaction

At 12 months postoperatively, 92% of patients (90% of men and 92% of women) replied that they would recommend the surgery to friends or family if they would have the same complaints, reflecting treatment satisfaction in the great majority of patients.

Knee-Specific Outcomes up to 2 Years After Total Knee Arthroplasty

Preoperatively, KOOS scores were very poor across all subscales and were lower in women than men. All subscale scores increased to a great extent 6 months after surgery and showed further improvement between 6 and 12 months. Twelve months after surgery, KOOS scores stabilized. With exception of sport and recreational function, which remained lower in women, postoperative KOOS subscale scores were similar between men and women (supplementary table S2).

Using the KOOS percentile curves for population-level comparison of patients' KOOS scores with the general population

For comparison of population-level patient KOOS scores with the Dutch general population, the median (interquartile range) preoperative and 12 month postoperative KOOS scores of all five subscales were plotted on the KOOS percentile curves (Figs. 1-3). By example, pain scores of all postoperative timepoints are shown in supplementary Figure S2. All subscale scores showed notable interpatient variability, as can be seen from the wide range of the boxplots and accompanying error bars. Visual comparison of the graphs in Figures 1 and 2 showed that before TKA, median KOOS pain scores were worse in women compared to men. In comparison to the general population, preoperative median KOOS pain scores were below the 2.5th percentile (solid blue line) in both men and women. At 12 months postoperatively, median pain scores were around the 25th percentile (dotted yellow line) in men and between the 25th and 50th percentile (striped navy line) in women. Preoperatively, median scores of the other subscales varied from below the 2.5th percentile, to around the 5th percentile (dotted maroon line) in patients with a higher BMI. Median symptom and ADL function scores increased to around the 25th percentile postoperatively in both men (Fig. 1) and women (Fig. 2). Similarly, postoperative QOL scores were around the 25th percentile in men (Fig. 3). In women, somewhat higher postoperative scores were observed, approaching the 50th percentile

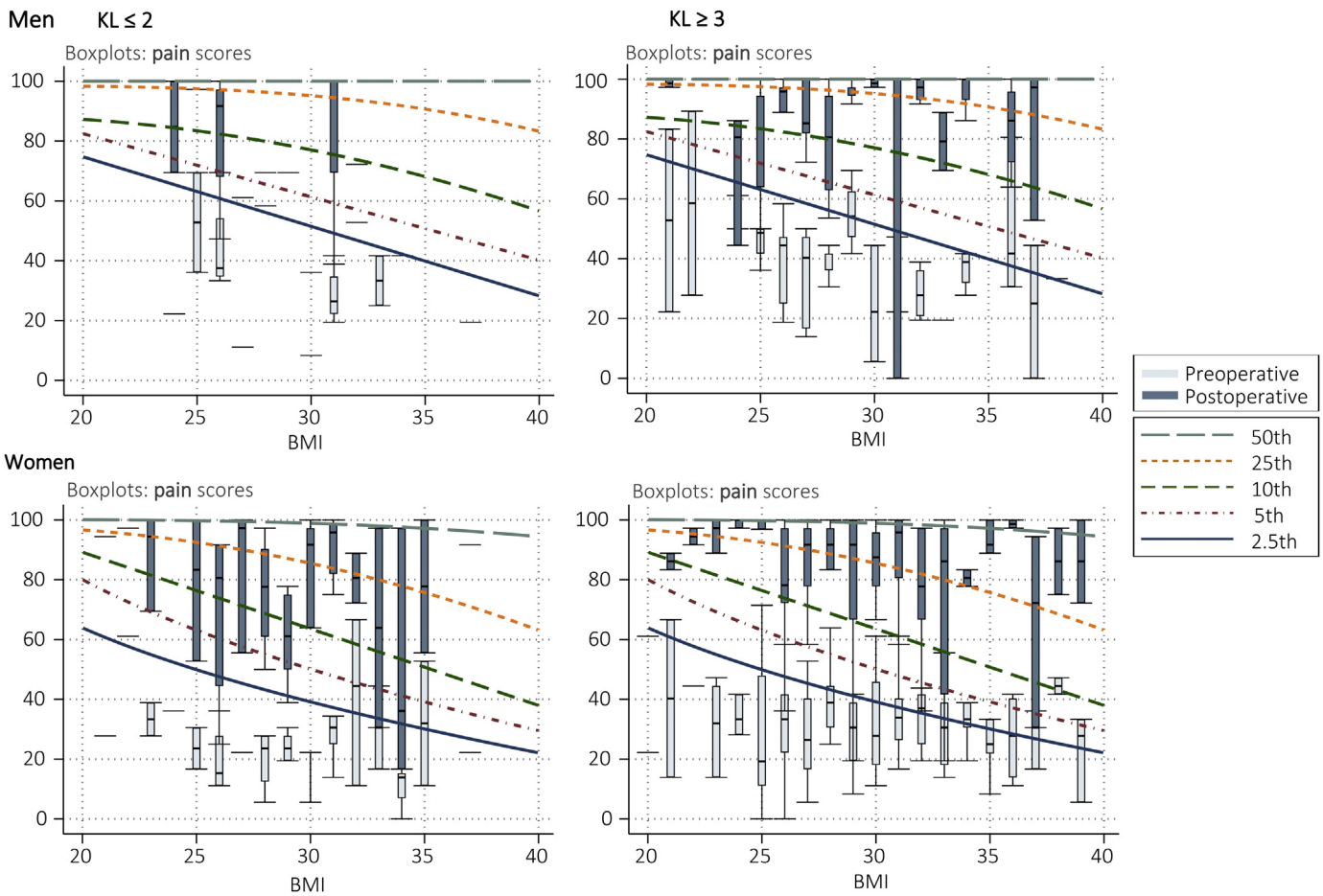

Fig. 4. Comparison of the preoperative and 12 months postoperative KOOS pain scores in patients with low- vs high-preoperative radiographic OA severity. Preoperative and 12 months postoperative KOOS pain scores were stratified by Kellgren-Lawrence (KL) scores, comparing patients with a preoperative KL score ≤2 with patients with a preoperative KL score ≥3. The KOOS scores (Y-axis) are given over BMI (X-axis). The preoperative KOOS scores are represented by the light gray boxplots, and the postoperative scores are given in dark gray boxplots. The boxplots represent the median (horizontal line) and interquartile range. The KOOS score distribution of the general population is depicted with the colored percentile lines.

in women with a higher BMI. A flooring effect was observed preoperatively in the sport and recreational function scores (Fig. 3). Postoperatively, sport and recreation scores increased; however, they remained around the 10th percentile (striped green line) of the general population.

Applying the KOOS percentile curves for follow-up of patient-level KOOS scores after TKA

To show the use of the KOOS percentile curves on a patient level, for illustrative purposes five randomly selected men and women with knee OA were selected, and the preoperative and postoperative KOOS pain scores were plotted alongside the distribution in the general population (supplementary Fig. S3). A clear interpatient variability in preoperative pain status, as well as at postoperative time points was observed. Despite that all depicted patients start with a preoperative KOOS pain score at or below the 2.5th percentile of the general population, some improve to (almost) the 50th percentile already at 6 months postoperatively, while others improve more gradually or to a lesser extent.

Comparison of KOOS Score Trajectories Between Specific Patient Groups

KOOS pain scores from patients with preoperative KL scores below or equal to 2 points were compared with scores from patients with preoperative KL scores of 3 points or higher (Fig. 4). In men, patient numbers were too low to give conclusive results. In women, median preoperative pain scores did not differ with respect to KL score. Postoperatively, pain scores improved to a greater extent in women with preoperative moderate to severe radiographic OA compared with women with preoperative no to mild radiographic OA.

Figure 5 shows the KOOS pain scores of patients included in the LOAS study without any comorbidity and with at least one comorbidity. Preoperatively, across both sexes, median pain scores were below the 2.5th percentile, with no differences between study group patients with and without comorbidities. At 12 months postoperatively, in both groups of LOAS patients, median pain scores were about the 25th percentile in men. In women, median pain scores were at or just below the 50th percentile in patients without comorbidities, while median pain scores were about the 25th percentile in women who had at least one comorbidity.

Discussion

The increasing routine use of PROMs to evaluate conservative as well as surgical interventions necessitates the development of methodology to optimize the interpretation and evaluation of PROMS across several follow-up moments. Therefore, we aimed to compare the KOOS scores of a large prospective cohort of TKA patients with the KOOS scores of the general population, to show the

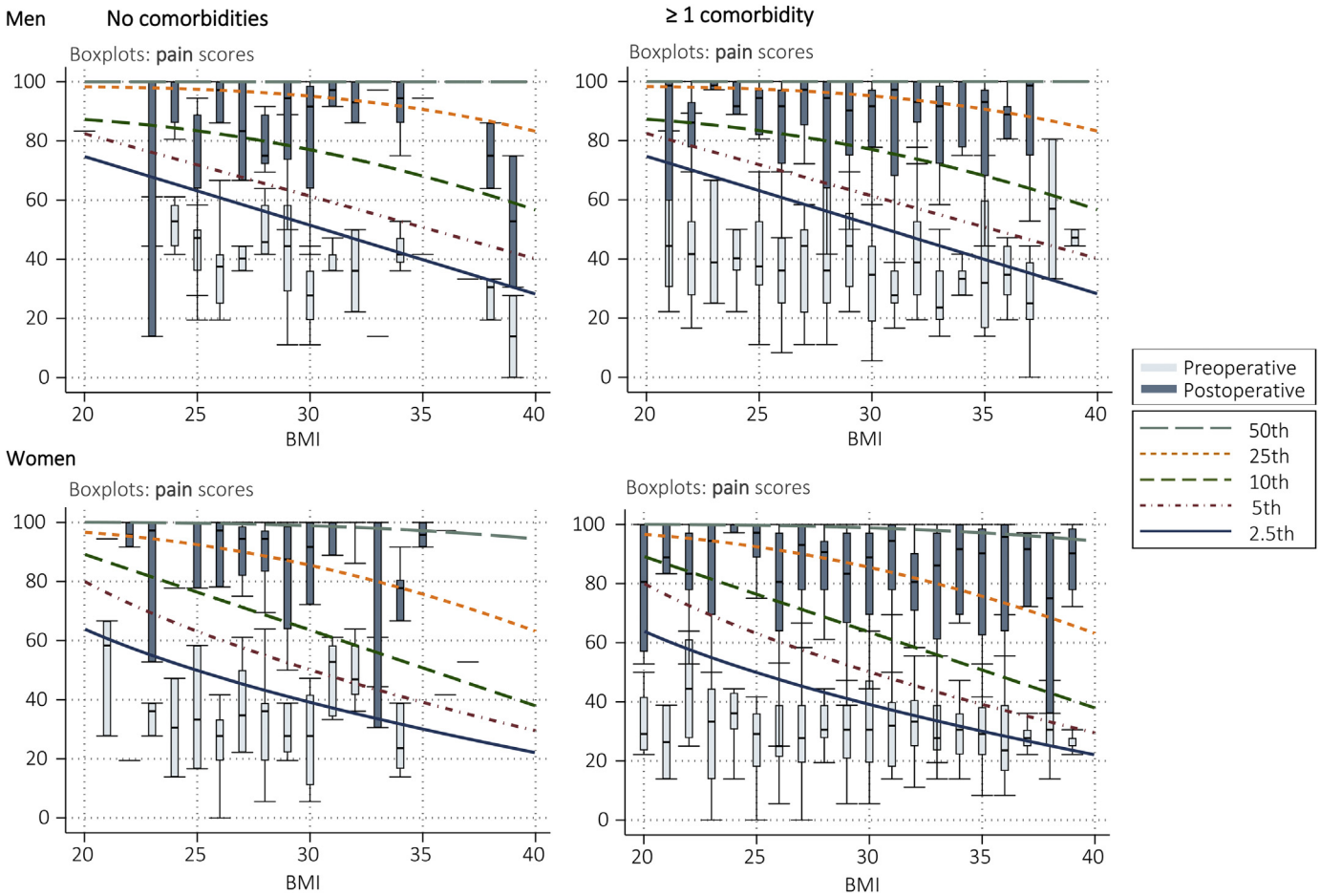

Fig. 5. Comparison of the preoperative and 12 months postoperative KOOS pain scores in patients with no comorbidities vs patients with at least one comorbidity. The KOOS scores (Y-axis) are given over BMI (X-axis). The preoperative KOOS scores are represented by the light gray boxplots, and the postoperative scores are given in dark gray boxplots. The boxplots represent the median (horizontal line) and interquartile range. The KOOS score distribution of the general population is depicted with the colored percentile lines.

use of the previously developed population-based percentile curves of the KOOS questionnaire [13] as method to aid the interpretation of the KOOS subscale scores. Applying preoperative and up to two years postoperative KOOS scores of patients with knee OA undergoing TKA to the general population-based percentile curves, allowed to visualize the preoperative and postoperative knee-specific health status of these patients relative to the general population. Furthermore, we have shown that the KOOS percentile curves can give insight in the correlation of specific preoperative patient characteristics with postoperative results. We observed that absence of moderate to severe preoperative radiographic OA, as well as the presence of comorbidities, was associated with less improvement after surgery.

Implementing alternative ways to show PROMs data can support patient-clinician communication about the patients' symptoms and QOL. Moreover, it may aid managing patients' expectations, making treatment decisions, and improve patient autonomy [3]. In the Netherlands, the number of TKAs has strongly risen in the last decade. The annual number of TKAs has more than tripled, with a little over 7 thousand TKAs in 2007 to more than 25 thousand TKAs in 2018 [8]. A systematic review has reported that 10%-34% of patients are not satisfied after knee replacement surgery [25]. In our patient population, at one year postoperatively, only 8% of patients responded that they would not recommend the surgery to friends or family if they would have the same complaints, which can be interpreted as dissatisfaction with the treatment result. Data on potential underlying factors related to this specific query were not collected in the present study, which prohibited in-depth insight in explanations for (dis)satisfaction after surgery. In addition, we showed that although most patients show great improvements far beyond the minimal important change [26] in all KOOS subscales after surgery, in most patients' KOOS scores do not normalize to the median score of the general population. We observed worse preoperative KOOS scores than previous studies investigating KOOS scores in TKA populations [27,28]. For example, Lyman et al. observed in a TKA population with a mean age of 74 years mean preoperative KOOS pain and ADL function scores of 51 and 55, respectively (vs 34 and 44 in our population). One year postoperative, KOOS scores were more similar [27]. Vestergaard et al. observed better preoperative KOOS pain and sport and recreation scores compared with ours. Scores on the other KOOS subscales were similar to the scores we observed [28]. The observed differences may be explained by differences in lifestyle and physical activities associated with age because our population was notably younger than the populations included in previous studies. Our results give insight in the expected postoperative improvements in knee pain, symptoms, and function. Therefore, they are important to communicate with patients, as part of the shared decision-making process during the preoperative consultation, to manage their expectations, as this may reduce treatment dissatisfaction [29].

Visualizing differences in treatment benefit in different patient groups may help making a well-informed patient-centered (conservative or surgical) treatment decision. In line with others investigating patients undergoing TKA [30,31], we observed a high frequency of comorbidities in our study population. Similarly, we observed less improvement postoperatively in patients having at least one comorbidity compared with patients without comorbidities. Furthermore, we observed greater improvements in patients with preoperatively more severe radiographic OA compared with patient with no to minimal radiographic OA, which is in line with previous findings in the LOAS study [32,33], and with others [34,35]. However, not all previous studies are in agreement [36,37], which could be explained by the inclusion of a limited patient number [36], including only patients with mild radiographic OA in contrast to also including patients with no radiographic OA [36,37], as well as other differences in patient characteristics such as higher age.

Our study has notable strengths. The LOAS study has a multicenter design allowing the inclusion of a diverse patient population from both academic and nonacademic hospitals with a low threshold for inclusion, reflecting a real-life care situation and improves the generalizability of the study results. However, as only Dutch hospitals were included, extrapolating our data to other countries, with likely differences in health care access or insurance, should be performed cautiously. In addition, the prospective longitudinal design resulted in a structured data collection at standardized time points. Furthermore, the present analyses show a variety of applications for the KOOS percentile curves, which are easy to implement in research and clinical care.

However, our study is also limited in several ways. The age range of the population in which the percentile curves were developed was restricted to persons between 45 and 65 years of age. This makes the percentile curves less ideal for the use of end-stage OA or TKA data, as a considerable number of these patients will be older than 65 years. Restriction of the LOAS population to the required age range resulted in a loss of data from almost two thirds of LOAS patients. However, the age range between 45 and 65 years is well suited for other patient populations, for example, to track conservative treatment response in patients with an earlier stage of OA. In addition, the percentile curves may be extrapolated to a broader age range. However, no data are available on accuracy and reliability of extrapolation at this moment. Another limitation is the healthy attendant bias that is inherent to the population-based design in which the percentile curves were developed. This form of selection bias may lead to overly optimistic results. To which extent this might play a role depends on the patient group under investigation, as the patient group may also be subject to a degree of selection. In addition, we observed that a minority of operated patients had no to minimal preoperative radiographic OA. Many factors influence the decision to perform TKA, which may go beyond OA-related health status [38]. Unfortunately, we did not obtain data on which factors drove the orthopedic surgeon's decision to perform TKA. Furthermore, we did not have data within 3 months after surgery, which could have given information on performance in the time window shortly after surgery when no improvement or even worsening of complaints could be anticipated. In addition, we did not obtain lateral knee X-rays, which might have resulted in underreporting of predominantly patellofemoral knee OA. However, we used one of the most commonly reported radiographic OA scoring methods, the KL grading, which does not include lateral view X-rays. Therefore, current results are well comparable with previous OA literature. Finally, in our subgroup analyses, the patient numbers were rather small, especially for men, which hampered conclusiveness. However, despite the smaller patient number, our results were in line with previous findings [32].

In conclusion, our study showed that the previously developed KOOS percentile curves can be used in research and clinical care to examine the preoperative and postoperative knee-related health status of patients with knee OA undergoing TKA. The percentile curves may aid patient-clinician communication, improve management of treatment expectations, and support shared decision-making.

Acknowledgments

The authors thank the LOAS study group comprised by P.J. Damen (Waterland Hospital), B.L. Kaptein (LUMC), H.M.J. van der Linden-van der Zwaag (LUMC), R. Onstenk (Groene Hart Hospital), S.B.W. Vehmeijer (Reinier de Graaf Hospital, Delft), and S.H.M. Verdegaal (Alrijne Hospital) for their contribution in the acquisition/structuring of clinical data. The authors express their gratitude to all patients and colleagues from the participating hospitals for their willingness to participate in this project. The LOAS study is supported by the Dutch Arthritis Society (LLP13). This funding source had no role in the design of this study and had no role during its execution, analyses, interpretation of the data, or decision to submit results.

References

[1] Rolfson O, Wissig S, van Maasakkers L, Stowell C, Ackerman I, Ayers D, et al. Defining an international standard set of outcome measures for patients with hip or knee osteoarthritis: consensus of the international consortium for health outcomes measurement hip and knee osteoarthritis working group. Arthritis Care Res 2016;68:1631–9. https://doi.org/10.1002/acr.22868.

[2] Santana M-J, Feeny D. Framework to assess the effects of using patient-reported outcome measures in chronic care management. Qual Life Res 2014;23:1505–13. https://doi.org/10.1007/s11136-013-0596-1.

[3] Yang LY, Manhas DS, Howard AF, Olson RA. Patient-reported outcome use in oncology: a systematic review of the impact on patient-clinician communication. Support Care Cancer 2018;26:41–60. https://doi.org/10.1007/s00520-017-3865-7.

[4] Appleby J, Poteliakhoff E, Shah K, Devlin N. Using patient-reported outcome measures to estimate cost-effectiveness of hip replacements in English hospitals. J R Soc Med 2013;106:323–31. https://doi.org/10.1177/0141076813489678.

[5] Devlin NJ, Appleby J. Getting the most out of PROMs: putting health outcomes at the heart of NHS decision-making. London: King's Fund; 2010.

[6] Smith PC, Street AD. On the uses of routine patient-reported health outcome data. Health Econ 2013;22:119–31. https://doi.org/10.1002/hec.2793.

[7] Nielen M, Boersma-van Dam M, Schermer T. Incidentie en prevalentie van gezondheidsproblemen in de Nederlandse huisartsenpraktijk in 2017. Uit: NIVEL Zorgregistraties eerste lijn. Feb 2019 n.d. https://www.nivel.nl/nl/zorgregistraties-eerste-lijn/incidenties-en-prevalenties [accessed 31.03.20].

[8] LROI- Registered procedures 2007-2018 n.d.. https://www.lroi-rapportage.nl/knee-numbers-registered-procedures-2007-2018 [accessed 31.03.20].

[9] Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee injury and osteoarthritis outcome score (KOOS)–development of a self-administered outcome measure. J Orthop Sports Phys Ther 1998;28:88–96. https://doi.org/10.2519/jospt.1998.28.2.88.

[10] Bremner-Smith AT, Ewings P, Weale AE. Knee scores in a "normal" elderly population. Knee 2004;11:279–82. https://doi.org/10.1016/j.knee.2003.06.001.

[11] Demirdjian AM, Petrie SG, Guanche CA, Thomas KA. The outcomes of two knee scoring questionnaires in a normal population. Am J Sports Med 1998;26:46–51. https://doi.org/10.1177/03635465980260012401.

[12] Jinks C, Jordan K, Croft P. Measuring the population impact of knee pain and disability with the Western Ontario and McMaster universities osteoarthritis index (WOMAC). Pain 2002;100:55–64.

[13] Loef M, Kroon FPB, Böhringer S, Roos EM, Rosendaal FR, Kloppenburg M. Percentile curves for the knee injury and osteoarthritis outcome score in the middle-aged Dutch population. Osteoarthritis Cartilage 2020. https://doi.org/10.1016/j.joca.2020.03.014.

[14] Leichtenberg CS, Meesters JJL, Kroon HM, Verdegaal SHM, Tilbury C, Dekker J, et al. No associations between self-reported knee joint instability and radiographic features in knee osteoarthritis patients prior to Total Knee Arthroplasty: a cross-sectional analysis of the Longitudinal Leiden Orthopaedics Outcomes of Osteo-Arthritis study (LOAS) data. Knee 2017;24:816–23. https://doi.org/10.1016/j.knee.2017.04.001.

[15] Tilbury C, Leichtenberg CS, Kaptein BL, Koster LA, Verdegaal SHM, Onstenk R, et al. Feasibility of collecting multiple patient-reported outcome measures

alongside the Dutch arthroplasty register. J Patient Exp 2019. https://doi.org/10.1177/2374373519853166. 2374373519853166.
[16] Centraal Bureau voor de Statistiek (CBS). Zelfgerapporteerde medische consumptie, gezondheid en leefstijl. 2020.
[17] de Groot IB, Favejee MM, Reijman M, Verhaar JAN, Terwee CB. The Dutch version of the knee injury and osteoarthritis outcome score: a validation study. Health Qual Life Outcomes 2008;6:16. https://doi.org/10.1186/1477-7525-6-16.
[18] The 2012 User's Guide to Knee injury and Osteoarthritis Outcome Score KOOS. WwwKoosNu. 2012.
[19] Wilberforce M, Poll S, Langham H, Worden A, Challis D. Measuring the patient experience in community mental health services for older people: a study of the Net Promoter Score using the Friends and Family Test in England. Int J Geriatr Psychiatry 2019;34:31–7. https://doi.org/10.1002/gps.4978.
[20] Gandhi SK, Salmon JW, Zhao SZ, Lambert BL, Gore PR, Conrad K. Psychometric evaluation of the 12-item short-form health survey (SF-12) in osteoarthritis and rheumatoid arthritis clinical trials. Clin Ther 2001;23:1080–98. https://doi.org/10.1016/s0149-2918(01)80093-x.
[21] Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16:494–502. https://doi.org/10.1136/ard.16.4.494.
[22] de Mutsert R, den Heijer M, Rabelink TJ, Smit JWA, Romijn JA, Jukema JW, et al. The Netherlands Epidemiology of Obesity (NEO) study: study design and data collection. Eur J Epidemiol 2013;28:513–23.
[23] Ministerie van VWS. 2013.
[24] Lumley T. http://www.jstatsoft.org/v09/i08/paper; 2004.
[25] Beswick AD, Wylde V, Gooberman-Hill R, Blom A, Dieppe P. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients. BMJ Open 2012;2:e000435. https://doi.org/10.1136/bmjopen-2011-000435.
[26] Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. Health Qual Life Outcomes 2003;1:64. https://doi.org/10.1186/1477-7525-1-64.
[27] Lyman S, Lee Y-Y, McLawhorn AS, Islam W, MacLean CH. What are the minimal and substantial improvements in the HOOS and KOOS and JR versions after total joint replacement? Clin Orthop Relat Res 2018;476:2432–41. https://doi.org/10.1097/CORR.0000000000000456.
[28] Vestergaard V, Colon Iban YE, Kappel A, Melnic CM, Bedair H, Huddleston JI, et al. Do knee osteoarthritis patterns affect patient-reported outcomes in total knee arthroplasty? Results from an international multicenter prospective study with 3-year follow-up. J Arthroplasty 2021;36:507–13. https://doi.org/10.1016/j.arth.2020.08.033.
[29] Scott CEH, Howie CR, MacDonald D, Biant LC. Predicting dissatisfaction following total knee replacement: a prospective study of 1217 patients. J Bone Joint Surg Br 2010;92:1253–8. https://doi.org/10.1302/0301-620X.92B9.24394.
[30] Peter WF, Dekker J, Tilbury C, Tordoir RL, Verdegaal SHM, Onstenk R, et al. The association between comorbidities and pain, physical function and quality of life following hip and knee arthroplasty. Rheumatol Int 2015;35:1233–41. https://doi.org/10.1007/s00296-015-3211-7.
[31] Hawker GA, Badley EM, Borkhoff CM, Croxford R, Davis AM, Dunn S, et al. Which patients are most likely to benefit from total joint arthroplasty? Arthritis Rheum 2013;65:1243–52. https://doi.org/10.1002/art.37901.
[32] van de Water RB, Leichtenberg CS, Nelissen RGHH, Kroon HM, Kaptijn HH, Onstenk R, et al. Preoperative radiographic osteoarthritis severity modifies the effect of preoperative pain on pain/function after total knee arthroplasty: results at 1 and 2 Years postoperatively. J Bone Joint Surg Am 2019;101:879–87. https://doi.org/10.2106/JBJS.18.00642.
[33] Keurentjes JC, Fiocco M, So-Osman C, Onstenk R, Koopman-Van Gemert AWMM, Pöll RG, et al. Patients with severe radiographic osteoarthritis have a better prognosis in physical functioning after hip and knee replacement: a cohort-study. PLoS One 2013;8:e59500. https://doi.org/10.1371/journal.pone.0059500.
[34] Kahn TL, Soheili A, Schwarzkopf R. Outcomes of total knee arthroplasty in relation to preoperative patient-reported and radiographic measures: data from the osteoarthritis initiative. Geriatr Orthop Surg Rehabil 2013;4:117–26. https://doi.org/10.1177/2151458514520634.
[35] Valdes AM, Doherty SA, Zhang W, Muir KR, Maciewicz RA, Doherty M. Inverse relationship between preoperative radiographic severity and postoperative pain in patients with osteoarthritis who have undergone total joint arthroplasty. Semin Arthritis Rheum 2012;41:568–75. https://doi.org/10.1016/j.semarthrit.2011.07.002.
[36] Perry KI, Strasser NL, Harmsen WS, Pagnano MW, Trousdale RT. Minimal preoperative degenerative arthritis may not predict poor TKA outcome. Orthopedics 2015;38:e681–684. https://doi.org/10.3928/01477447-20150804-54.
[37] Meding JB, Ritter MA, Faris PM, Keating EM, Harris W. Does the preoperative radiographic degree of osteoarthritis correlate to results in primary total knee arthroplasty? J Arthroplasty 2001;16:13–6. https://doi.org/10.1054/arth.2001.16501.
[38] Gossec L, Paternotte S, Maillefert JF, Combescure C, Conaghan PG, Davis AM, et al. The role of pain and functional impairment in the decision to recommend total joint replacement in hip and knee osteoarthritis: an international cross-sectional study of 1909 patients. Report of the OARSI-OMERACT Task Force on total joint replacement. Osteoarthritis Cartilage 2011;19:147–54. https://doi.org/10.1016/j.joca.2010.10.025.

Appendix

Table S1
Comparison of Baseline Characteristics of Patients With and Without Kellgren-Lawrence Scores.

	All	KL Available 314 (37%)	KL Missing 539 (63%)
Patient characteristics			
Age, y	59.1 (4.7)	59.1 (4.7)	59.1 (4.7)
Sex, % women	532 (64)	207 (66)	325 (60)
BMI, kg/m^2	30.4 (5.0)	30.5 (5.3)	30.3 (4.8)
Any comorbidities, n (%)	636 (75)	235 (75)	401 (74)
Musculoskeletal, n (%)	117 (23)	73 (23)	121 (22)
Nonmusculoskeletal, n (%)	338 (68)	219 (70)	357 (66)
KOOS subscales			
Pain	34 (17)	32 (17)	36 (17)
Symptoms	44 (17)	43 (18)	45 (17)
ADL function	42 (18)	40 (17)	43 (18)
Sport and recreation function	8 (12)	7 (12)	8 (12)
Quality of life	23 (15)	24 (14)	23 (15)

Numbers represent mean (SD) unless otherwise specified. KOOS subscale scores are transformed to a 0-100 scale, with zero representing extreme knee problems and 100 representing no knee problems.
ADL, activities daily living; BMI, body mass index; IQR, interquartile range; KOOS, Knee Injury and Osteoarthritis Outcome Score; n, number; SD, standard deviation.

Table S2
Preoperative and Postoperative KOOS Scores.

KOOS subscales	All Mean (SD)	N	Men Mean (SD)	Women Mean (SD)	*P*-Value[a]
Preoperative					
Pain	34 (17)	706	38 (18)	32 (16)	-
Symptoms	44 (17)	705	48 (18)	42 (17)	-
ADL function	42 (18)	706	45 (20)	40 (16)	-
Sport and recreation function	8 (12)	763	11 (14)	6 (11)	-
Quality of life	23 (15)	722	26 (16)	22 (14)	-
6 mo postoperative					
Pain	77 (21)	588	79 (21)	76 (21)	<.0001
Symptoms	69 (18)	590	66 (18)	69 (18)	<.0001
ADL function	78 (20)	588	80 (19)	77 (20)	<.0001
Sport and recreation function	36 (26)	628	41 (26)	33 (26)	<.0001
Quality of life	59 (21)	591	58 (21)	59 (22)	<.0001
12 mo postoperative					
Pain	84 (20)	586	85 (19)	83 (21)	<.0001
Symptoms	76 (18)	585	75 (19)	76 (18)	<.0001
ADL function	82 (20)	588	84 (20)	82 (19)	<.0001
Sport and recreation function	44 (29)	602	48 (30)	42 (29)	<.0001
Quality of life	67 (23)	588	65 (23)	68 (23)	<.0001
24 mo postoperative					
Pain	83 (20)	415	85 (19)	82 (21)	.50
Symptoms	77 (17)	399	76 (17)	78 (17)	.002
ADL function	82 (20)	416	83 (19)	82 (20)	.64
Sport and recreation function	43 (28)	416	50 (28)	39 (28)	.79
Quality of life	66 (23)	414	64 (24)	66 (23)	.57

ADL, activities daily living; KOOS, Knee Injury and Osteoarthritis Outcome Score; SD, standard deviation.
[a] Unstratified comparison of KOOS subscale scores of consecutive time points using 2-sided paired t-tests (6 mo vs preoperative, 12 mo vs 6 mo, and 24 mo vs 12 mo).

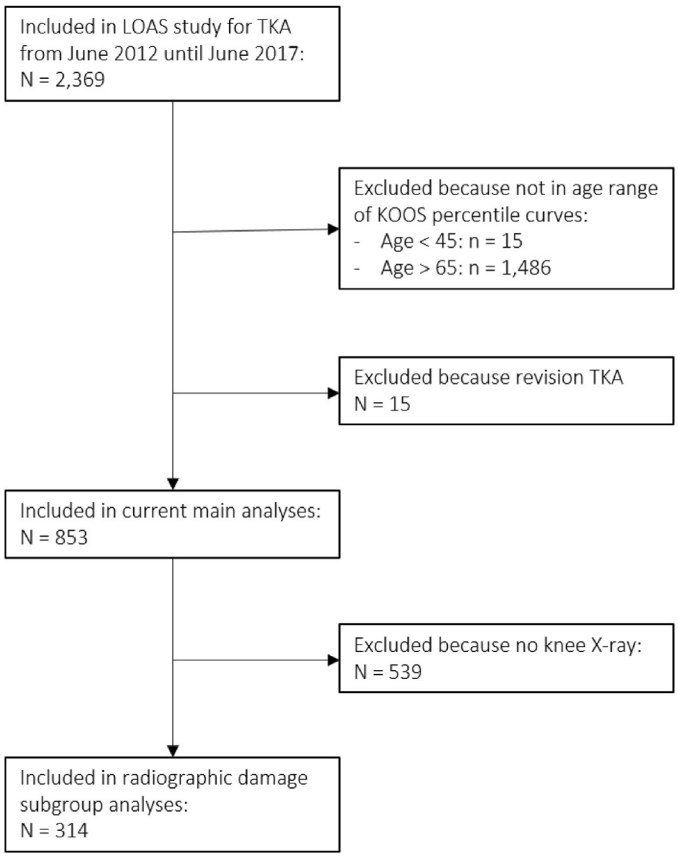

Figure S1. Flowchart of included LOAS participants for current analyses.

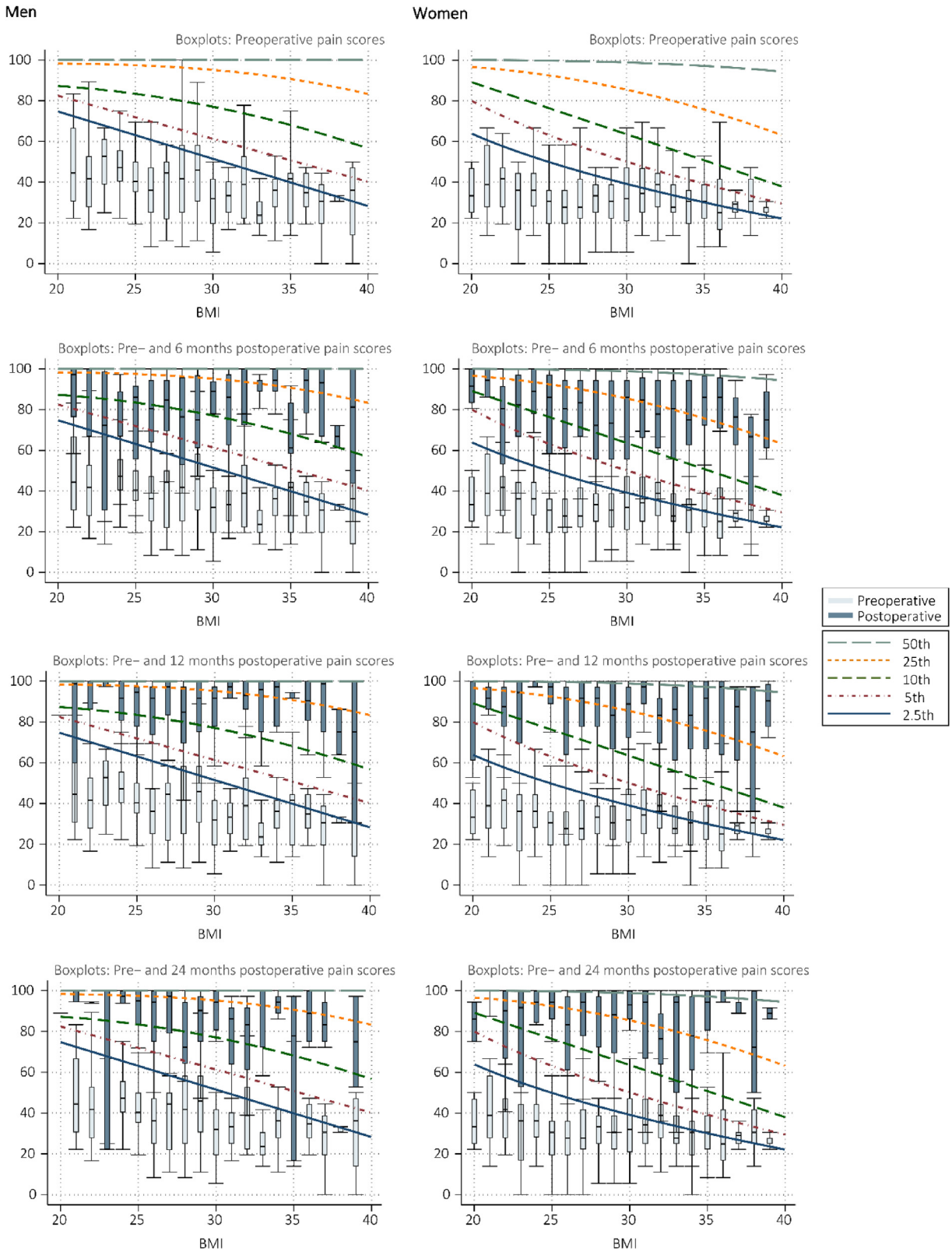

Figure S2. Preoperative and 6, 12, and 24 months postoperative KOOS pain subscale scores plotted on the KOOS percentile curves. Preoperative (light gray) and postoperative scores (dark gray) of men (left) and women (right) with knee OA undergoing total knee replacement, in comparison with the KOOS pain score distribution in the general population (colored lines). For clarification purposes, the top row shows only preoperative scores.

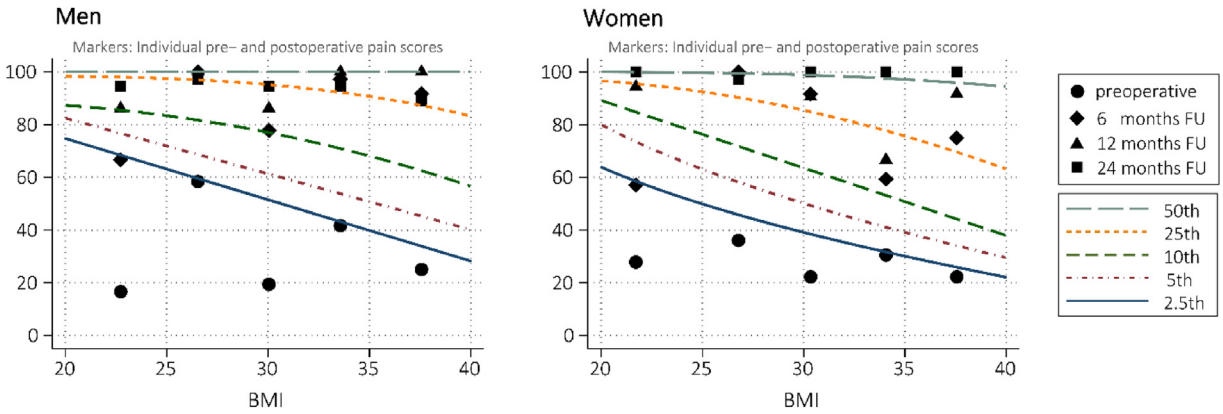

Figure S3. Preoperative, 6, 12, and 24 months postoperative KOOS pain subscale scores at patient-level. For illustrative purposes, the figures depict scores at all available time point of follow-up of five randomly selected men and women from the LOAS cohort, in comparison with the KOOS score distribution of the general population (colored lines).