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Which patients improve most after total hip arthroplasty? Influence of patient characteristics on patient-reported outcome measures of 22,357 total hip arthroplasties in the Dutch Arthroplasty Register

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Abstract

Background: Patient-reported outcome measures (PROMs) after total hip arthroplasty (THA), can be influenced by patient characteristics (case-mix factors). We used the Dutch Arthroplasty Register (LROI) to determine the effect of case-mix on improvement of PROMs after primary THA.

Methods: We included all primary THAs ($n = 22,357$) performed in the Netherlands between 2014 and 2018. The Hip disability and Osteoarthritis Outcome Score Physical function short form (HOOS-PS), Oxford Hip Score (OHS), EQ-5D index score and thermometer, and Numeric Rating Scales (NRS) measuring pain during activities and at rest, were recorded. The difference between preoperative and 3- and 12-month postoperative scores was calculated (delta-PROM) and used as primary outcome variable. Multivariable linear regression was used to examine the association between patient characteristics (age, sex, ASA score, body mass index (BMI), Charnley class, smoking, and previous operations to the affected hip) and PROMs. Cohens' d was used to measure effect size.

Results: Postoperative improvement (delta-PROM) on HOOS-PS, OHS, EQ-5D, and pain relief were significantly higher in patients < 60 years, in patients with female gender, a high ASA score (III–IV), a BMI > 30 kg/m², and patients without a previous operation to the hip. Cohen's d indicated clinically small differences (0.2).

Conclusions: Patients benefiting most in terms of postoperative improvement of self-reported physical functioning, pain relief and quality of life after primary THA were young, female, with a high ASA or BMI score, and without previous operations to the hip.

Keywords

Case-mix, hip replacement, patient characteristics, patient-reported outcome measures, PROMs, total hip arthroplasty

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Background

In the Dutch healthcare system, the need for transparency by reporting outcomes is increasing. Publication of outcome measures is compulsory, driven by the increasing influence of health insurance companies and market mechanisms.¹ The intended benefits are to drive quality improvement, demonstrate transparency, facilitate patient choice, and allow identification of poor performance.²

Patient-reported outcome measures (PROMs) registered in national arthroplasty registers are increasingly

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used to evaluate provider and device performance in orthopaedic care. However, one of the primary criticisms is the lack of well-developed risk adjustment models that adjust for factors unrelated to the provider or device that are known to influence outcomes, generally known as patient characteristics or case-mix factors.³ Case-mix is the term used in surgical practice to describe variation in the population, relating to factors such as age, gender, American Society of Anesthesiologists (ASA) physical status, diagnosis, smoking and body mass index (BMI).⁴

PROMs can be affected by patient characteristics (case-mix factors). It is important to have an accurate, comprehensive, and standardised method to identify differences in case mix, enabling fair adjustment in order to compare outcomes across providers and hospitals. This also benefits the integrity of public reporting of provider performance. Moreover, appropriate case-mix adjustment will decrease incentives that might otherwise encourage hospitals to minimise treatment of patients with comorbid conditions which might increase the risk for complications.³

The influence of case-mix factors on PROMs after THA in the Netherlands is not well investigated. Therefore, our aim is to determine the effect of patient characteristics (case mix: e.g. age, gender, BMI, ASA score, and Charnley class, previous operations on the affected joint, and smoking status) on improvement of PROMs (measured as delta-PROM) after primary THA in the Netherlands. The future goal is to enable risk-adjustment models for outcome of THA that account for case-mix variation in the Netherlands.

Methods

Dutch Arthroplasty Registry

A retrospective observational study was performed using data of the Dutch Arthroplasty Register (LROI). The LROI is a prospective database containing data derived from all hospitals performing hip replacement surgery in the Netherlands. The completeness is >95% for primary THA.⁵ The LROI contains demographic information, surgical variables, prosthesis characteristics, survival of the prosthesis and PROMs. Hip specific and general health-related PROMs have been collected since 2014. The vital status and, if applicable, date of death are obtained via access to the national insurance database on healthcare in the Netherlands.⁶ PROM data is not available for patients registered before 2014. Baseline characteristics were collected from the LROI and categorised similar to previous studies using LROI-data.^{5,7,8}

Patient-reported outcome measures

In order to determine the influence of case-mix factors on PROMs, our cohort was compiled from all primary THAs ($n=22,357$) performed in the Netherlands, for the diagnosis

osteoarthritis, in the period 2014 until 2018. Health-related quality of life (HRQoL), pain and functional outcomes, were assessed using a set of PROMs as recommended by the Dutch Orthopedic Association.⁹ This consists of the EuroQoL 5-Dimensions (EQ-5D-3L) questionnaire with EQ-5D index score and thermometer to measure health perception and HRQoL, a Numeric Rating Scale (NRS) measuring pain during activity and rest, Oxford Hip Score (OHS), and the short version of the Hip disability and Osteoarthritis Outcome Score (HOOS-PS) to assess physical functioning and disability.

The EQ-5D-3L questionnaire asks patients to value their general health status in multiple dimensions. The index score ranges from -0.329 (poor health) to 1.0 (perfect health). The EQ-5D thermometer is a one question PROM which scores current health status on a scale ranging from 0 (worst imaginable health) to 100 (best imaginable health). Physical functioning was assessed using the HOOS-PS, a validated, joint-specific measure to assess activity during daily living, recreational activities and sports. This PROM ranges from 0 to 100 with zero representing no effort and 100 the most possible effort. HRQoL and disability in patients with osteoarthritis of the hip was measured using the OHS (range 12–60). Higher scores on the OHS indicate less disability. Lastly, a Numeric Rating Scale (NRS) was used to measure pain during activity and rest on a 11-point Likert scale with higher scores indicating more severe pain. The PROMs were filled in preoperatively, at, 3 months and 1 year postoperatively.¹⁰ The preoperative PROMs were collected during consultation at the outpatient clinic. Postoperative PROM data were registered during follow-up visits by pen and paper or using a web-based tool after invitation by email.^{4,10} To measure changes, the differences between preoperative and postoperative scores were calculated and described as delta-PROM. This method was previously applied in a national cohort study comparing improvement of PROMs after primary THA for different surgical approaches.¹⁰

Statistics

Baseline characteristics of all included patients were provided. Testing for differences in postoperative improvements in PROMs (delta-PROM) was performed in a multivariable linear regression analysis. We entered the following confounders into the analysis: age, gender, ASA score, smoking status, BMI, Charnley class, previous operation on the affected hip, fixation technique, femoral-head diameter, surgical approach, and period of surgery. Previous operations were defined as a prior operation on the affected hip (e.g. osteosynthesis, arthroscopy). Categorical variables were made binary to simplify interpretation: age <60 versus ≥60 years, ASA I-II versus ASA III-IV, Charnley A, B1, or B2 versus C, and BMI <30 kg/m² versus BMI ≥30 kg/m². Also, surgical hospital volume

Table 1. Descriptives for patients who received a primary THA in the period 2014–2018 with completed pre- and postoperative PROMs.

	THAs with 3 and 12 months follow-up (n = 22,357)*	
Age (years)		
<60	3,349	15.0
60–74	12,760	57.1
≥75	6243	27.9
Gender		
Male	8072	36.1
Female	14,276	63.9
ASA score		
I	4482	20.1
II	14,468	64.7
III–IV	3398	15.2
Smoking		
Yes	2075	9.5
No	19,792	90.5
Previous operation		
Yes	393	1.8
No	21,838	98.2
Charnley class		
A	9975	44.8
B1	6995	31.4
B2	4707	21.2
C	569	2.6
BMI (kg/m ²)		
≤18.5	114	0.5
>18.5–25	7259	32.6
>25–30	9693	43.5
>30–40	4994	22.4
>40	224	1.0
Hospital volume		
0–500 THAs	796	3.6
500–1000 THAs	8428	37.7
1000–1250 THA	6263	28.0
>1250 THAs	6870	30.7
Approach		
Anterior	6968	31.2
Posterolateral	12,253	54.8
Straight lateral	1848	8.3
Anterolateral	1098	4.9
Fixation		
Cemented	4771	21.4
Cementless	15,917	71.5
Hybrid: stem cemented	858	3.9
Reversed hybrid: cup cemented	718	3.2
Articulation		
Metal-on-PE	5537	24.8
Ceramic-on-PE	12,980	58.1
Ceramic-on-ceramic	1492	6.7
Oxidized zirconium-on-PE	1141	5.1
Femoral head size (mm)		
22–28	3566	16.6

(Continued)

Table 1. (Continued)

	THAs with 3 and 12 months follow-up (n = 22,357)*	
32	12,919	60.2
36	4932	23.0
≤38	43	0.2

BMI, body mass index; THA, total hip arthroplasty; PE, polyethylene.
Note: *numbers do not add up to total due to unknown or missing values.

can be expected to influence delta-PROM.¹¹ Hospital volume was divided into institutions in which 0–1000 procedures versus institutions in which >1000 procedures were performed during our research period.

The outcome was presented as adjusted mean difference (AMD) with associated 95% confidence interval (CI). Post-hoc analysis to adjust for multiple comparisons was done using Bonferroni. Cohen's d was used as a standard measure of effect size. The effect size was calculated by dividing the difference between two means by the standard deviation of the data (small effect: 0.2–0.5; medium: 0.5–0.8; large: 0.8–1.3; very large: >1.3).^{12,13} All analyses were performed using SPSS version 23.0.

Ethics

The study was approved by the board and scientific advisory committee of the LROI and the Medical Ethics Committee of University Medical Centre Groningen (no. 154 METc2017/388).

Results

In total, 22,357 THAs were included in this study (Table 1). The majority of patients were aged between 60 and 74 years, female, ASA II, non-smoking, and had Charnley score A or B1.

Physical functioning

The unadjusted delta-PROM data demonstrated higher postoperative scores (more improvement) on the HOOS-PS for young (<60 years) patients (respectively 32 after 3 months and 37 after 1 year), female patients (31 and 35), those with a high ASA-score (III–IV) (32 and 35), those without a previous operation to the affected hip joint (30 and 35), patients with a low Charnley class (30 and 35 for Charnley A, B1 and B2), or patients with a BMI ≥30 kg/m² (31 and 35) (Figure 1). Adjusted analyses showed similar results for all examined case-mix factors, except the Charnley score which was no longer statistically significant. Furthermore, high BMI and ASA-score were only associated with more improvement in physical functioning at 3 months postoperatively. All effect sizes were <0.2.

Figure 1. HOOS-PS for patients with a THA who completed the preoperative and 3- and 12-month postoperative questionnaires ($n = 22,357$).

Lower scores indicate higher physical function.

Table 2(A). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **gender** ($n = 22,357$).

	Female ($n = 14,276$)			Male ($n = 8072$)		
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	-0.03 (-0.04 to -0.02)	0.000	0.11	-0.03 (-0.04 to -0.02)	0.000	0.11
Δ EQ-5D thermometer	-0.72 (-1.38 to -0.07)	0.02	0.03	-0.78 (-1.61 to 0.05)	0.07	0.03
Δ NRS (active)	-0.06 (-0.14 to 0.02)	0.21	0.01	-0.20 (-0.29 to -0.10)	0.000	0.07
Δ NRS (in rest)	-0.28 (-0.36 to -0.20)	0.000	0.10	-0.38 (-0.48 to -0.29)	0.000	0.14
Δ HOOS-PS	-1.40 (-1.98 to -0.81)	0.000	0.08	-1.71 (-2.41 to -1.00)	0.000	0.08
Δ Oxford Hip Score	-0.83 (-1.17 to -0.49)	0.000	0.09	-1.32 (-1.66 to -0.98)	0.000	0.14

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, ASA score, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, smoking status, hospital volume, fixation technique, articulation and femoral head size.

Health-related quality of life and disability

Postoperative improvement after 3 and 12 months on the OHS was higher in female patients (17 and 19), young patients (17 and 20), a high ASA (18 and 20) or high BMI score (17 and 20), patients without a previous operation to the hip (16 and 19), and a high Charnley class (C) (17 and 19) (Figure 2, appendix). The adjusted analyses demonstrated that higher pain reduction at rest was associated with gender (female), age (<60 years), ASA (III–IV), and BMI ($\geq 30 \text{ kg/m}^2$), and hospital volume (low volume <1000) (Table 2(A–E) and appendix Table 2(F–H)). The Cohen's d effect sizes were <0.2.

Patient perception of health

Unadjusted postoperative improvement on the EQ5D index score, respectively 3 and 12 months postoperatively, was higher for female patients (0.27 and 0.30), young patients (<60 years) (0.29 and 0.33), and patients with high ASA-score (III–IV) (0.30 and 0.32) and high BMI ($\geq 30 \text{ kg/m}^2$) (0.28 and 0.31) (Figure 5, appendix). In the adjusted analyses

these improvements remained significant, with an effect size <0.2. In addition, patients who smoked showed a larger improvement in HrQoL after 1 year compared to patients without a smoking habit in the adjusted analysis. Furthermore, young patients (<60 years), patients with a BMI above 30 kg/m^2 (only at 3 months), patients who smoked (only at 3 months) and patients with a Charnley score A, B1 or B2 (only at 1 year) had a larger improvement in health perception (Figure 6, appendix and Table 2(A–E) and appendix Table 2(F–H)). Except for age, these differences had an effect size <0.2.

Pain during activity and rest

Larger improvement in pain reduction during activities was associated with female gender, young age (only after 1 year), a high ASA score or BMI (only at 3 months), no previous operation (only at 3 months), and smoking habit (only at 3 months) (Appendix Figure 3). All effect sizes were <0.2. Postoperative pain reduction at rest was best accomplished in patients aged <60 years (0.48; 95% CI, 0.39 to -0.57, Cohen's d: 0.21 after

Table 2(B). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **age** ($n = 22,357$).

Age ≥ 60 years ($n = 19,003$; 85.0%)	Age < 60 years ($n = 3349$; 15.0%)					
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	0.04 (0.03–0.05)	0.000	0.14	0.05 (0.04–0.06)	0.000	0.17
Δ EQ-5D thermometer	2.70 (1.96–3.45)	0.000	0.15	4.18 (3.24–5.13)	0.000	0.20
Δ NRS (active)	–0.06 (–0.030 to 0.15)	0.19	0.05	0.14 (0.03–0.24)	0.01	0.04
Δ NRS (in rest)	0.48 (0.39 to –0.57)	0.000	0.21	0.52 (0.41–0.62)	0.000	0.18
Δ HOOS-PS	–0.89 (0.24 to –1.55)	0.01	0.08	2.80 (2.00–3.60)	0.000	0.14
Δ Oxford Hip Score	0.65 (0.26–1.04)	0.001	0.06	1.27 (0.88–1.66)	0.000	0.13

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: gender, ASA score, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, smoking status, hospital volume, fixation technique, articulation and femoral head size.

Table 2(C). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **ASA score** ($n = 22,357$).

ASA III–IV ($n = 3,398$; 15.2%)	ASA I–II ($n = 18,950$; 84.8%)					
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	–0.04 (–0.05 to –0.03)	0.000	0.17	–0.04 (–0.05 to –0.03)	0.000	0.14
Δ EQ-5D thermometer	–0.04 (–0.75 to 0.68)	0.92	0.03	0.25 (–0.69 to 1.18)	0.61	0.04
Δ NRS (active)	–0.15 (–0.24 to –0.07)	0.000	0.06	–0.08 (–0.18 to 0.03)	0.14	0.04
Δ NRS (in rest)	–0.05 (–0.13 to –0.04)	0.28	0.01	–0.03 (–0.14 to 0.08)	0.56	0.01
Δ HOOS-PS	–1.63 (–2.29 to –0.98)	0.000	0.10	–0.74 (–1.57 to 0.09)	0.08	0.02
Δ Oxford Hip Score	–1.36 (–1.74 to –0.97)	0.000	0.15	–0.99 (–1.38 to –0.61)	0.000	0.10

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, gender, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, smoking status, hospital volume, fixation technique, articulation and femoral head size.

3 months and 0.52 (0.41–0.62), Cohen's d: 0.18) (Appendix Figure 4) (Table 2A–E and Appendix Table 2F–H).

Discussion

In this arthroplasty register study, we identified the effect of patient characteristics (case-mix factors) on postoperative improvement of PROMs 3 months and 1 year after THA in the Netherlands. Gender, age, ASA score, BMI, and surgical history of the affected joint were significantly associated with postoperative improvement of self-reported physical functioning, pain relief and health-related quality of life after primary THA. However, absolute differences were small.

SooHoo et al.³ advocated that adequate risk-adjustment is required in order to enable fair comparisons after total

joint arthroplasty. The California Joint Replacement Registry was used to report on predictors of adverse outcome after joint replacement surgery using complication rate. Age and ASA score were the strongest predictors of complication rates. It was stated that adequate risk adjustment plays an important role in objective comparison of providers, institutions, and implant devices using more traditional parameters to estimate the success rate of surgery based on complication rate.³

There is increased interest in using PROMs, registered in national arthroplasty registries, to evaluate outcome after primary THA. In this study the influence of case-mix on postoperative improvement of physical function, pain and HRQoL after THA was determined. Improvement of physical outcome score after THA was strongly associated with surgical history of the hip joint: patients with no previous

Table 2(D). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **BMI** ($n = 22,357$).

BMI ≥ 30 kg/m² ($n = 5218$; 23.4%)	BMI < 30 kg/m² ($n = 17,066$; 76.6%)					
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	-0.02 (-0.03 to -0.01)	0.000	0.10	-0.02 (-0.03 to -0.01)	0.000	0.10
Δ EQ-5D thermometer	-0.71 (-1.32 to -0.10)	0.02	0.02	-0.15 (-0.94 to 0.63)	0.70	0.01
Δ NRS (active)	-0.143 (-0.22 to -0.07)	0.000	0.08	-0.08 (-0.17 to 0.02)	0.10	0.03
Δ NRS (in rest)	-0.26 (-0.34 to -0.19)	0.000	0.10	-0.14 (-0.23 to -0.05)	0.003	0.07
Δ HOOS-PS	-1.02 (-1.58 to -0.47)	0.000	0.06	-0.38 (-1.05 to -0.30)	0.28	0.03
Δ Oxford Hip Score	-1.00 (-1.32 to -0.68)	0.000	0.13	-0.73 (-1.01 to -0.41)	0.000	0.10

BMI, body mass index; EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, sex, ASA score, previous operations, fixation, articulation, femoral head size, Charnley class, smoking status, hospital volume, fixation technique, articulation and femoral head size.

Table 2(E). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **previous operation** ($n = 22,357$).

No previous operation ($n = 21,838$; 98.2%)	Previous operation ($n = 393$; 1.8%)					
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	0.01 (-0.03 to 0.04)	1.00	0.00	0.01 (-0.02 to 0.05)	1.00	0.04
Δ EQ-5D thermometer	-0.01 (-2.46 to 2.44)	1.00	0.10	2.70 (-0.34 to 5.73)	0.10	0.10
Δ NRS (active)	-0.32 (-0.61 to -0.02)	0.03	0.11	-0.52 (-0.87 to -0.18)	0.001	0.18
Δ NRS (in rest)	-0.05 (-0.35 to 0.24)	1.00	0.00	-0.13 (-0.48 to 0.23)	1.00	0.04
Δ HOOS-PS	-3.12 (-5.32 to -0.92)	0.002	0.12	-0.79 (-3.42 to 1.84)	1.00	0.04
Δ Oxford Hip Score	-0.32 (-1.58 to 0.94)	1.00	0.03	-0.52 (-1.77 to 0.73)	0.95	0.06

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, sex, ASA score, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, hospital volume, fixation technique, articulation and femoral head size.

operation on the hip reported greater improvement in physical functioning as measured by the HOOS-PS.

Patients with an ASA-score III or IV had a larger improvement of physical functioning after primary THA. Based on the lower preoperative scores for these patients, this might be an effect of more advanced disease. A higher risk profile might make surgeons more reluctant to operate, causing a longer waiting period preoperatively. In addition, patients with a BMI above 30 demonstrated higher postoperative improvement on HrQoL and physical functioning. Obesity in combination with advanced osteoarthritis of the hip might result in a lower level of physical performance before joint replacement surgery. Severe obesity is widely associated with reduced cardiopulmonary capacity, metabolic abnormalities and decreased haemostasis, which may

predispose patients to morbidity and mortality after surgery.¹⁴ These factors might lead to a higher threshold for orthopaedic surgeon to progress to surgery.

Furthermore, young age was associated with a higher postoperative improvements in health perception and physical functioning. Osteoarthritis of the hip is not limited to people of advanced age, as it also affects patients participating in the labor market. Such patients aged < 60 years might be unable to fulfil their work responsibilities, especially in physically demanding jobs. Return to work after the procedure might result in a larger improvement of patient perceived outcome measures.

Another factor which resulted in more improvement in perceived health postoperatively was low hospital volume. Little is known about the effect of hospital volume on PROMs after THA. Laucis et al.¹⁵ found that higher hospital

volume resulted in lower surgical complication rates using the National Inpatient Sample (NIS) in the United States. However, the authors used different cut off points to indicate low (0–99 annually), intermediate (100–399) and high volume (≥ 400) hospitals. Based on the distribution of our data, only 3.6% of THAs were performed in low-volume hospitals, based on the above cut-offs. According to international standards, the majority of joint prostheses in the Netherlands is implanted in high-volume hospitals.

Although statically significant differences in PROM-improvement were found among patients with differences in case-mix characteristics, absolute differences between the groups were small. An effect size (Cohens' d) can be calculated. This method was previously used in studies from the Norwegian and Dutch Arthroplasty Register.^{10,13} An effect size of 0.2, implicates a small effect.¹² In our study, the largest effect size found measured 0.21, indicating a small effect.

Limitations and possibilities

Arthroplasty registries are designed to identify and monitor differences in comparative outcomes, like revision rate or PROMs. This is done by the collection of observational data reflecting clinical practice for the entire population without exclusions. Causality cannot be distracted from observational registry data and there might be (unmeasured) factors influencing the outcome of interest. Therefore, our finding that specific patient groups improve more on PROMs after THA does not imply that these patient groups should receive THA. Many more factors, like grade of osteoarthritis, health status, and shared decision making are of vital importance in deciding whether a patient should undergo THA.

In addition, we do not know the number of orthopaedic surgeons performing THAs per hospital. However, we do know the number of THAs per hospital.

Conclusion

In conclusion, young age, female gender, a high ASA- or BMI-score, and no previous operations on the hip are independently associated with higher postoperative improvement of self-reported physical functioning, pain relief and quality of life (PROMS) after primary THA.

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Appendices

Figure 2. Oxford Hip Score (OHS) for patients **with a THA** who completed the preoperative and 3- and 12-month postoperative questionnaires ($n = 22,357$). Lower scores indicate higher physical function.

Figure 3. NRS (active) for patients **with a THA** who completed the preoperative and 3- and 12-month postoperative questionnaires ($n = 22,357$).

Figure 4. NRS (in rest) for patients **with a THA** who completed the preoperative and 3- and 12-month postoperative questionnaires ($n = 22,357$).

Figure 5. EQ-5D index score for patients **with a THA** who completed the preoperative and 3- and 12-month postoperative questionnaires (n = 22,357).

Figure 6. EQ-5D thermometer score for patients **with a THA** who completed the preoperative and 3- and 12-month postoperative questionnaires (n = 22,357).

Table 2(F). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **Charnley** (n = 22,357).

	Charnley C (n = 569; 2.6%)			Charnley A, B1 or B2 (n = 21,677; 97.4%)		
	Adjusted mean difference (CI) ^a	p-value	Cohen's d	Adjusted mean difference (CI) ^a	p-value	Cohen's d
	3 Months			12 Months		
Δ EQ-5D index score	-0.02 (-0.05 to 0.00)	0.08	0.07	-0.01 (-0.03 to 0.02)	0.70	0.03
Δ EQ-5D thermometer	0.48 (-1.12 to 2.08)	0.56	0.05	2.27 (0.19 to 4.35)	0.03	0.11
Δ NRS (active)	-0.08 (-0.27 to 0.11)	0.41	0.01	0.07 (-0.17 to 0.30)	0.58	0.02
Δ NRS (in rest)	-0.27 (-0.46 to -0.07)	0.01	0.08	-0.17 (-0.41 to 0.07)	0.16	0.08
Δ HOOS-PS	-0.22 (-1.69 to 1.25)	0.77	0.02	1.33 (-0.51 to 3.18)	0.16	0.05
Δ Oxford Hip Score	-0.62 (-1.45 to 0.21)	0.14	0.07	-0.34 (-1.16 to 0.49)	0.43	0.04

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, sex, ASA score, previous operations, fixation, articulation, femoral head size, body mass index, smoking status, hospital volume, fixation technique, articulation and femoral head size.

Table 2(G). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **smoking status** ($n = 22,357$).

	Non-smoking ($n = 19,792$; 90.5%)			Smoking ($n = 2075$; 9.5%)		
	Adjusted mean difference (CI) ^a			Adjusted mean difference (CI) ^a		
	3 Months			12 Months		
Δ EQ-5D index score	0.02 (0.00–0.03)	0.07	0.03	0.02 (0.01–0.04)	0.002	0.07
Δ EQ-5D thermometer	1.35 (0.28–2.42)	0.01	0.04	0.50 (–0.87 to 1.86)	1.00	0.02
Δ NRS (active)	–0.15 (–0.28 to –0.02)	0.02	0.04	–0.10 (–0.26 to 0.05)	0.35	0.03
Δ NRS (in rest)	0.04 (–0.08 to –0.17)	1.00	0.02	0.07 (–0.09 to 0.22)	0.96	0.02
Δ HOOS-PS	0.47 (–0.50 to –1.43)	0.74	0.02	0.65 (–0.53 to 1.82)	0.56	0.03
Δ Oxford Hip Score	–0.07 (–0.63 to 0.50)	1.00	0.01	0.35 (–0.21 to 0.91)	0.41	0.04

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, sex, ASA-score, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, hospital volume, fixation technique, articulation and femoral head size.

Table 2(H). PROMs for patients who underwent THA: adjusted mean differences and confidence interval (CI) in PROMs according to **hospital volume** ($n = 22,357$).

	≥1000 THAs ($n = 13,133$; 58.7%)			Hospital volume 0–1000 THAs ($n = 9224$; 41.3%)		
	Adjusted mean difference (CI) ^a			Adjusted mean difference (CI) ^a		
	3 Months			12 Months		
Δ EQ-5D index score	–0.01 (–0.02 to 0.00)	0.05	0.04	–0.004 (–0.01 to 0.004)	0.34	0.00
Δ EQ-5D thermometer	–0.06 (–0.59 to –0.47)	0.82	0.01	–0.02 (–0.71 to 0.67)	0.95	0.00
Δ NRS (active)	–0.003 (–0.07 to 0.06)	0.92	0.05	0.06 (–0.02 to 0.14)	0.15	0.01
Δ NRS (in rest)	–0.07 (–0.13 to –0.001)	0.05	0.03	0.01 (–0.08 to 0.09)	0.90	0.00
Δ HOOS-PS	–0.10 (–0.58 to 0.38)	0.69	0.04	–0.08 (–0.68 to 0.52)	0.78	0.01
Δ Oxford Hip Score	0.30 (0.01–0.58)	0.04	0.02	0.61 (0.33 to –0.90)	0.000	0.04

EQ-5D, EuroQoL 5-Dimension questionnaire; NRS, Numeric Rating Scales; HOOS-PS, Hip disability and Osteoarthritis Outcome Score Physical function short form.

^aAdjusted for covariates: age, sex, ASA-score, previous operations, fixation, articulation, femoral head size, body mass index, Charnley class, smoking status, fixation technique, articulation and femoral head size.