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Trajectories of pain recovery during the first 8 weeks after shoulder arthroplasty: results from the shoulder diary study using latent growth curve modeling

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Background: Perioperative stress or discomfort in shoulder arthroplasty (SA) patients can be reduced using more individually tailored patient education and expectation management. Most published studies assess pain and function for the first time at 6 weeks or 3 months. Consequently, there is no thorough understanding of day-to-day recovery trajectories within the first postoperative weeks, hindering effective patient education and expectation management in the early postoperative phase. In this study, we explored the distinct pain recovery trajectories that emerge for SA patients during their first 8 postoperative weeks and examined how patients in the identified subgroups differ in terms of sociodemographic and psychological factors.

Methods: In our prospective multicenter cohort study, we included 230 SA patients who completed an 8-week postoperative diary containing daily Numeric Rating Scale of pain scores and medication use, weekly function scores, and twice-weekly quality of life scores.

The Medical Ethics Review Committee of Southwest Holland approved this study (study no. METC LDD, 17-117).

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In addition, patients completed preoperative questionnaires regarding pain, function, and demographic and psychological factors. We used Latent Growth Curve Modeling to classify groups of patients based on their early pain recovery trajectories; models included smooth functions based on natural cubic splines to represent the different trajectories of pain scores over time in the latent classes.

Results: Our final model contained 6 different classes whose trajectories differed during the first 2 weeks. The model contained random intercepts (ie, allowed for between-person variability around the initial pain score) and fixed slopes (ie, did not allow for between-person variability in subsequent change in pain scores over time) within each class. After the first 2 weeks, classes 1 through 4 (83.7%) were similarly stable with very low pain scores (the 'Faster group'). Classes 5 and 6 (16.3%) had a slower decline in pain scores (the 'Slower group'), but comparable scores to the Faster group at week 8. The Slower group also more frequently had American Society of Anesthesiologists score $\geq$3, was less often employed and had lower baseline Oxford Shoulder Score and EQ-5D visual analog scale scores. Both groups had similar recovery rates in Oxford Shoulder Score and EQ-5D visual analog scale scores, although the Slower group had lower scores than the Faster group.

Conclusion: In this study, we distinguished 6 early recovery trajectories after total shoulder arthroplasty. Our results enable clinicians to reassure their patients before surgery, as 5 of 6 patients likely have very low pain scores (Numeric Rating Scale $\leq$2) after only 2 weeks. Also, the sixth patient is at almost similar low pain scores at 8 weeks postsurgery.

Level of evidence: Level I; Prospective Cohort Design; Prognosis Study

Keywords: Shoulder arthroplasty; short-term pain recovery; longitudinal pain recovery trajectories; latent growth curve modeling; latent class growth analysis; growth mixture modeling

In most published studies focusing on postoperative pain and clinical outcomes in shoulder arthroplasty (SA), the first reported follow-up is generally set at 6 weeks or even 3 months after surgery.[8,9,21,44] Consequently, we still have no thorough understanding of early recovery trajectories within the first 8 weeks after surgery.

While we know from daily practice that recovery trajectories may strongly differ between patients in the first weeks after surgery, our knowledge of these specific trajectories and the risk factors for delayed recovery or increased pain scores is limited in the current literature. A deeper understanding of SA recovery trajectories and their predictors will enable more personalized preoperative education, expectation management, and postoperative support, potentially reducing anxious feelings or insecurity which may then reduce perioperative stress and discomfort. Such trajectories can be studied using Latent Growth Curve Modeling (LGCM), which can be used to discern previously unobserved subgroups of patients that have similar recovery patterns.

For longer-term recovery, multiple demographic and surgical factors have already been studied. Several studies have, for example, shown that male gender predicts better outcomes after SA,[15,26,31,46] as does osteoarthritis as indication for surgery compared to other indications.[5,27,43] Examples of predictors for worse outcomes were having a history of previous shoulder surgery[31,46] and a higher degree of preoperative opioid use.[5,14]

While demographic and surgical factors have been extensively studied in relation to longer-term recovery (eg, recovery measured at 1-year follow-up), the role of psychological factors in postoperative outcomes has been a relatively recent focus in joint replacement research.[13,28,49] Factors such as catastrophizing, optimism, expectations, and anxiety could significantly influence postoperative recovery trajectories and warrant further investigation.

The majority of these studies have been done in total knee and total hip arthroplasty. However, results from total knee arthroplasty and total hip arthroplasty studies cannot easily be extrapolated to SA as major differences exist in patient groups (with SA patients generally being older and more often having American Society of Anesthesiologists [ASA] class 3 or higher[11]), underlying pathology and postoperative rehabilitation protocols. Consequently, little is known about the relation between psychological factors and clinical outcomes after SA.

Therefore, the primary aim of this study is to assess how many and which different types of pain recovery patterns can be discerned during the first 8 weeks after SA. The secondary objective is exploratory in nature and is to investigate differences in baseline demographic characteristics, patient-reported outcome measures, and psychological factors between the different trajectories.

Materials and methods

Study population

This multicenter, prospective cohort study was assessed by our regional Medical Ethics Committee, who decided that the study did not fall under the scope of the Medical Research Involving Human Subjects Act because of the minimal patient burden (METC Leiden, Den Haag, Delft in the Netherlands; METC-no. 17-117). Patients were recruited between April 2018 and September 2021 from the orthopedic departments in 4 different hospitals in The Netherlands: Reinier de Graaf Hospital and Haga Hospital (merged in 2020 to become the Reinier Haga Orthopedic Center), Alrijne Hospital, and NorthWest Clinics. All patients placed on the waiting list for SA were screened consecutively and,

when meeting study criteria, contacted for participation. Inclusion criteria were age ≥18 years, scheduled to undergo primary or revision SA (hemiarthroplasty [HA], anatomic total shoulder arthroplasty [aTSA], or reverse total shoulder arthroplasty [rTSA]), good command of the Dutch language, and able and willing to participate. Exclusion criteria were cognitive impairment, arthroplasty for acute fractures, and difficulty with the Dutch language. All participating patients provided written informed consent prior to the study.

Data collection

As part of a larger study,[33] patients completed a set of questionnaires before surgery (6 weeks to 1 day preoperatively) and after surgery (at 6 months and 1 year). These questionnaires consisted of general demographic questions and questions regarding pain (Numeric Rating Scale [NRS] for pain [at rest and during activity]), function (Oxford Shoulder Score [OSS]),[1] quality of life (EQ-5D-5L),[39] and psychological factors (Hospital for Special Surgery Expectation questionnaire,[30] Sunnybrook expectation questionnaire,[41] Pain Catastrophizing Scale,[47] Life Optimism Test–Revised,[22,45] Fear of Pain Questionnaire–9 items,[32] and Central Sensitization Index[24]). In addition, the Tilburg Frailty Indicator[16] was used to assess frailty among the participants. For the Life Optimism Test–Revised, we specifically used the optimism subscale instead of the total score, as Ten Klooster et al[22] found that the Dutch version does not reflect a unidimensional construct and they thus advocate to use subscales.

The day after surgery, patients received a diary, which they were requested to fill in every day for 8 weeks. In this diary, NRS scores were prompted daily (both average NRS and worst NRS for each day), EQ-5D-5L scores twice per week, and OSS scores at the end of each week.

The current article focuses on the preoperative and diary data from the more extensive study. Results for data measured with the questionnaires at 6 months and 1 year will be described in future articles.

All study data were collected onto electronic case report forms in Castor electronic data capture.[6] Deviations of ±1 day were allowed between the actual day after surgery and the reported date in the diary. Data for days that deviated more than 1 day were entered into the electronic case report form as missing.

Surgical procedure, pain medication, and rehabilitation protocol

To ensure the generalizability of our results, we did not standardize the surgical procedure and rehabilitation protocol; each hospital could follow its own procedures and had its own postoperative rehabilitation protocol. Standard postoperative pain medication consisted of paracetamol combined with either Naproxen or Celecoxib, using Oxycodone (either instant or extended-release) as rescue medication.

In each hospital, patients were instructed to use a sling for 6 weeks. In the first 2 weeks, only passive exercises were allowed, after which exercises could gradually increase to active-assisted and, finally, active exercises.

Statistical analysis

Descriptive statistics were used to describe the characteristics of the entire sample, using number and frequency for categorical variables. For normally distributed continuous data, the mean and standard deviation, while for non-normally distributed data, the median, interquartile range, and range were used.

For the primary objective, we used LGCM to classify groups of patients based on their early pain recovery trajectories, using the NRS for average pain scores from the diaries. With LGCM, it is possible to detect latent (ie, previously unobserved) subgroups within the data: separate groups in which patients are similar with respect to the trajectory in health status over time. More specifically, LGCM can be used to group people together into separate classes by minimizing differences between individuals *within* each class and maximizing the differences between individuals *across* the classes.

To perform the LCGM analysis, we used R software[38] and RStudio,[36] with the hlme( ) function from the 'lcmm' package[37] and natural cubic splines to model the relationship between time and pain scores. In doing so, we allowed for nonlinear growth trajectories, that is, the trajectories were free to take on any shape or form. Since the computational burden of modeling each day of the 8 weeks was too high, we entered every other day of the first 2 and last 2 weeks and every third day of the remaining weeks into the models. For the splines, knots were placed on days 6, 14, 22, 28, 34, 43, and 49.

Three different types of models were specified: a Latent Class Growth Analysis (LCGA) (with fixed intercept and fixed slope) and 2 types of Growth Mixture Models (GMMs) (GMM-1, with random intercept and fixed slope and GMM-2, with random intercept and random slope). For more details, see the Supplementary Appendix S1.

After running all models, we used a combination of fit statistics (Akaike information criterion, Bayesian information criterion, and -log likelihood), visual inspection of the estimated mean trajectories with observed individual line plots, entropy, and clinical relevance of the models to choose our final model. R syntax for the LCGA and GMM models can be found in the Supplementary Appendix S1.

Since the literature has no concrete advice on sample size for LGCM, the sample size of 230 subjects was chosen arbitrarily and based on the feasibility of including the number of subjects.

For our secondary objective, we planned a priori to compare the different classes on baseline characteristics to investigate whether the trajectories in pain scores were associated with patient characteristics in an exploratory analysis. To compare these characteristics between the latent classes, nominal data were tested with chi-square tests or Fisher's exact tests, while normally distributed data were tested with independent samples *t*-tests (when comparing 2 groups) or analysis of variance (when comparing more than 2 groups). Non-normally distributed data were tested with Mann-Whitney *U* tests or Kruskal-Wallis tests.

In addition, we studied whether OSS and EQ-5D visual analog scale (VAS) scores during the 8 weeks differed between the groups by specifying linear mixed models to account for the repeated measurements within subjects, using the lmer( ) function from the 'lme4' package in R. For model specifications, see the Supplementary Appendix S1.

For medication use, we calculated the percentage of patients indicating they had used medication on the last day of each week.

This was calculated for the overall use of any type of medication and for paracetamol, nonsteroidal anti-inflammatory drugs (NSAIDs), and opioids separately. Statistically significant differences between the classes were tested with chi-square tests or Fisher's exact tests.

Not all diaries were complete: some participants had missing NRS data for several days (consecutively or nonconsecutively), for which we found no apparent reasons for missingness. Four participants started with the diary but found it too strenuous to complete every day and withdrew from the study. For each participant, all available NRS data were used in the LGCM analyses; missing data were not imputed. Given the exploratory nature of the secondary analysis, no correction for multiple testing was implemented.

Results

Patient characteristics

A total of 491 patients were found eligible during the recruitment period, of whom 230 gave informed consent. Two hundred twenty-two patients remained in the study until after the diary, and 205 patients completed the entire study period of 1 year. For details, see the study flowchart in Figure 1.

The majority of patients were female (69.6%), and the mean age was 69.9 (standard deviation: 8.5) years. The most frequent indication for surgery was osteoarthritis (60.4%). rTSA was the most commonly used type of implant (66.1%). In all instances, surgeons used the deltopectoral approach and general anesthesia combined with an interscalene nerve block.

Table I displays all baseline characteristics for the entire sample.

Latent growth curve modeling

The model that best fit our data was a GMM-1 model with 6 classes, due to the combination of good clinical interpretability, good fit statistics, and lower heterogeneity within classes than other models. As described in the methods section, patients were allocated to the class for which they had the highest posterior probability.

Figure 2 shows the estimated mean trajectories of the entire 6-class model, as well as the estimated mean trajectory and observed individual trajectories per class separately. Classes 2 and 4 start with relatively low pain scores and maintain low pain scores or decrease even further. Classes 1 and 5 start with moderate pain scores; pain scores decline very quickly in class 1 but much slower in class 5. Classes 3 and 6 start with the highest scores. Pain scores in class 3 decline faster and more dramatically than in class 5. For exact intercepts, standard errors, and class sizes, see Table II.

The Supplementary Appendix S1 contains graphical plots for all the models that were run (7 models each for the LCGA [Fig. A-1], GMM-1 [Fig. A-2], and GMM-2 models [Fig. A-3]), as well as their fit statistics, class size, and entropy (Fig. A4 and Table A-I).

Comparing groups

While from a statistical standpoint the 6-class model fit the observed data best, on visual inspection classes 1-4 evidently recover more quickly (NRS <3 within 2 weeks) than classes 5-6 (NRS <3 after 5 weeks). Hence, from a clinical standpoint, it is very interesting to compare these 2 groups: knowing how these patients differ from each other could help clinicians tailor their patient education and expectation management. We therefore made the post-hoc decision to compare classes 1-4 (collapsed into the 'Faster' group) to classes 5-6 (collapsed into the 'Slower' group) for our secondary objective instead of the 6 classes separately (Fig. 3).

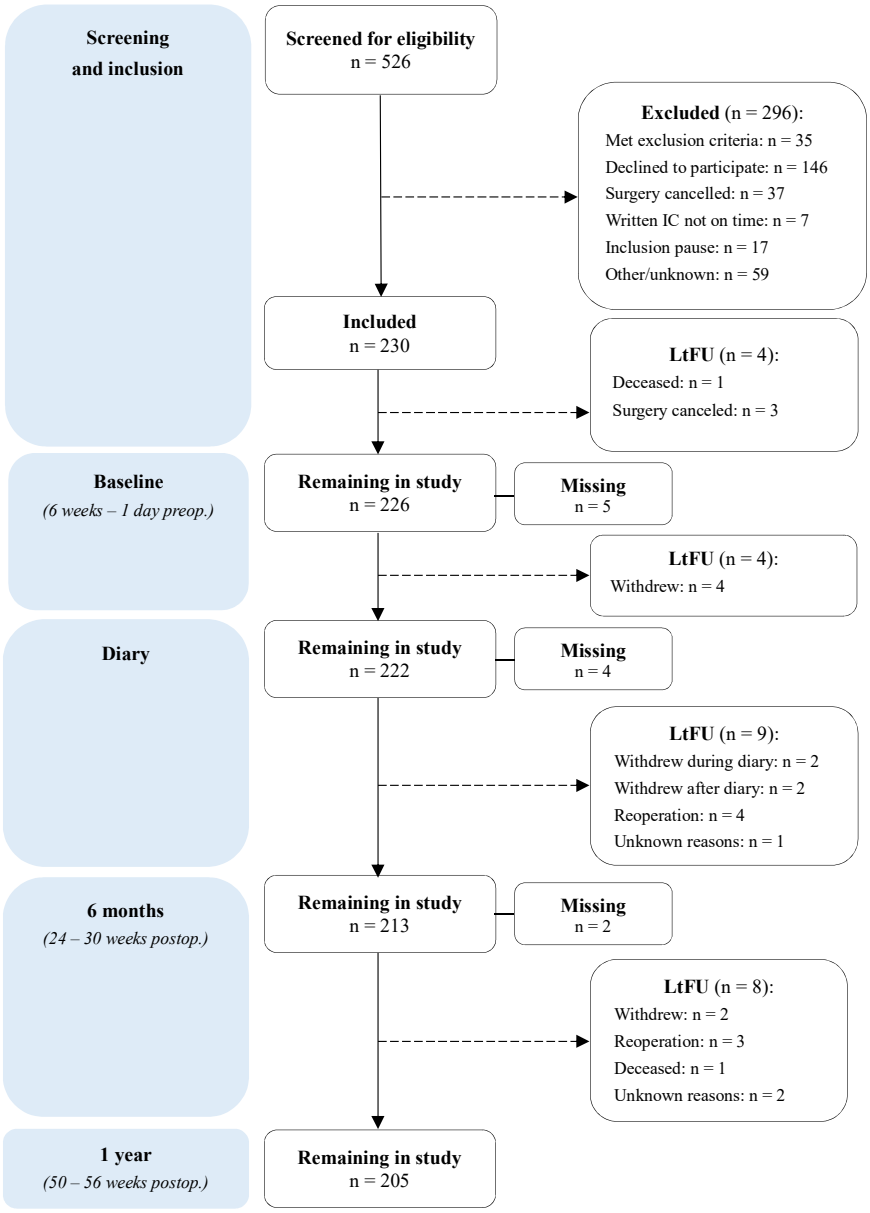
Compared to the Faster group, patients in the Slower group more often had ASA III scores (instead of ASA I or II, $P = .002$) and less often worked part-time or full-time ($P = .012$). They also had slightly lower baseline OSS scores ($P = .044$) and lower baseline EQ-5D VAS scores ($P = .024$), although the former did not exceed the smallest detectable change of 6.6 points.[29] For exact values of the univariable comparisons on all baseline variables, see Table III. Multivariable analyses were not feasible due to the limited number of patients in the Slower group. The a priori planned comparisons between all 6 classes can be found in Table A-II in the Supplementary Appendix S1.

Function and quality of life

The mean OSS and EQ-5D VAS scores for both groups during the 8 weeks are shown in Figure 4.

For the OSS, the final linear mixed model contained group membership (Slower group vs. Faster group) and time as fixed effects, a random intercept, and a random slope. Both groups progressed in OSS scores at a similar rate of 2.7 points per week. However, from the start, patients in the Slower group scored on average 6 points lower on the OSS than those in the Faster group. This was true for all time points since adding an interaction term ($P = .513$) between group and time did not significantly improve the model fit.

For the EQ-5D VAS, the final linear mixed model was similar to the OSS model: group membership and time were fixed effects, and a random intercept and slope were included, but no interaction term (P value for interaction term: $P = .120$). Both groups improved on the EQ-5D VAS with 0.29 points per day on average, with the Slower group scoring a little over 10 points lower than the Faster group. Table IV shows the relevant model parameters for both final models.



*: The transition from Reinier de Graaf Hospital and Haga Hospital into Reinier Haga Orthopedic Center (RHOC) resulted in an inclusion pause of approximately two months for these centers

Figure 1 Study flowchart.

Medication use

The Slower group consistently used more medication, including opioids, than the Faster group during the first 8 weeks. This difference was statistically significant at weeks 3 through 5 for any type of medication, weeks 3 through 8 for paracetamol, and weeks 3 and 4 for opioids. For exact percentages of patients using any type of medication and paracetamol, NSAIDs and opioids specifically, see Figure 5 in the main text and Table A-III in the Supplementary Appendix S1. Table A-IV also displays exact percentages of medication use during the first 6 days in detail.

Discussion

According to our study, patients who underwent SA can be grouped into 6 different classes based on their starting point and subsequent pain recovery trajectory during the first 8 weeks after surgery. These 6 classes can furthermore be categorized into 2 clinically relevant subgroups: approximately 84% of patients with a fast decline in pain scores during the first 2 weeks and a smaller group of approximately 16% of patients in whom pain scores decline more slowly. Compared with the Faster group, patients in the Slower group more often had ASA scores of 3, were less

Table I Descriptive statistics of preoperative patient characteristics and surgery characteristics of the entire sample

Variable	Entire sample (N = 230)
Demographic	
Age (mean [SD])	69.9 (8.5)
Sex (no. [%])	
Male	67 (29.1%)
Female	160 (69.6%)
ASA (no. [%])	
Class I	22 (9.6%)
Class II	138 (60.0%)
Class III or higher	65 (28.3%)
BMI (no. [%])	
Normal weight	61 (26.5%)
Overweight (BMI: 25-30)	94 (40.9%)
Obese (BMI $\geq$ 30)	70 (30.4%)
Duration of complaints in yr (median [IQR])	3.0 [1.5-6.0]
Indication (no. [%])	
OA	139 (60.4%)
mRCT/CTA	51 (22.2%)
Other	35 (15.2%)
Education (no. [%])	
Low	110 (51.2%)
Middle	63 (29.3%)
High	35 (16.3%)
Other	3 (1.3%)
Work status (paid/unpaid) (no. [%])	
No work/retired	167 (72.6%)
$<$12 h/week	6 (2.6%)
12-35 h/week	26 (11.3%)
$\geq$36 h/week	19 (8.3%)
Other	3 (1.3%)
Cultural background (no. [%])	
Dutch	212 (92.2%)
Surinamese	2 (0.9%)
Other	7 (3.0%)
Religion (no. [%])	
Christian	121 (56.3%)
Catholic	4 (1.9%)
Jewish	1 (0.5%)
Other	5 (2.3%)
Not religious	66 (30.7%)
I'd rather not say	7 (3.3%)
TFI (no. [%])	
Frail	148 (64.4%)
Not frail	64 (27.8%)
Surgical	
Primary/revision (no. [%])	
Primary	220 (95.7%)
Revision	5 (2.2%)
Type of prosthesis (no. [%])	
aTSA	64 (27.8%)
rTSA	152 (66.1%)
HA	7 (3.0%)
Dominant side (no. [%])	
Yes	100 (43.5%)
No	110 (47.8%)
Baseline PROMs	
Mean pain (mean [SD])	5.4 (2.1)
Worst pain (mean [SD])	6.7 (2.2%)
OSS (mean [SD])	20.2 (8.0)
EQ-5D item 'mobility' (no. [%])	
No problems in walking about	130 (56.5%)
Slight problems in walking about	34 (14.8%)
Moderate problems in walking about	36 (15.7%)
Severe problems in walking about	14 (6.1%)
Unable to walk about	1 (0.4%)
EQ-5D item 'self-care' (no. [%])	
No problems washing or dressing	52 (22.6%)
Slight problems washing or dressing	87 (37.8%)
Moderate problems washing or dressing	55 (23.9%)
Severe problems washing or dressing	18 (7.8%)
Unable to wash or dress	3 (1.3%)
EQ-5D item 'usual activities' (no. [%])	
No problems doing usual activities	17 (7.4%)
Slight problems doing usual activities	64 (27.8%)
Moderate problems doing usual activities	94 (40.9%)
Severe problems doing usual activities	34 (14.8%)
Unable to do usual activities	6 (2.6%)
EQ-5D item 'pain/discomfort' (no. [%])	
No pain or discomfort	3 (1.3%)
Slight pain or discomfort	36 (15.7%)
Moderate pain or discomfort	105 (46.7%)
Severe pain or discomfort	66 (28.7%)
Extreme pain or discomfort	5 (2.2%)
EQ-5D item 'anxiety/depression' (no. [%])	
Not anxious or depressed	136 (59.1%)
Slightly anxious or depressed	48 (20.9%)

(continued on next column)

(*continued on next page*)

Table I Descriptive statistics of preoperative patient characteristics and surgery characteristics of the entire sample (*continued*)

Variable	Entire sample (N = 230)
Moderately anxious or depressed	27 (11.7%)
Severely anxious or depressed	4 (1.7%)
Extremely anxious or depressed	-
EQ-5D VAS (median [IQR])	75.0 [64.0-82.0]
Baseline psychological factors	
PCS (median [IQR])	17.0 [9.0-26.0]
LOT-R optimism subscale (mean [SD])	8.1 (1.9)
FPQ-9 (median [IQR])	
Total	15.0 [12.0-18.0]
Fear of severe pain	7.0 [5.0-9.0]
Fear of minor pain	4.0 [3.0-5.0]
Fear of medical/dental pain	4.0 [3.0-5.0]
CSI (mean [SD])	30.5 (12.1)
HSS expectations (mean [SD])	5.7 (4.0)
Sunnybrook expectation 'Pain relief' (no. [%])	
N/A	4 (1.7%)
No	-
Yes, but just a little	1 (0.4%)
Yes, somewhat	47 (20.4%)
Yes, a lot	163 (70.9%)
Sunnybrook expectation 'Pain-free range of motion' (no. [%])	
N/A	3 (1.3%)
No	5 (2.2%)
Yes, but just a little	10 (4.4%)
Yes, somewhat	80 (34.8%)
Yes, a lot	117 (50.9%)
Sunnybrook expectation 'Ability to carry out normal activities of daily living' (no. [%])	
N/A	5 (2.2%)
No	4 (1.7%)
Yes, but just a little	15 (6.5%)
Yes, somewhat	78 (33.9%)
Yes, a lot	113 (49.1%)
Sunnybrook expectation 'Ability to care for others' (no. [%])	
N/A	59 (25.7%)
No	7 (3.0%)
Yes, but just a little	24 (10.4%)
Yes, somewhat	66 (28.7%)
Yes, a lot	59 (25.7%)
Sunnybrook expectation 'Participate in leisure, sports, or recreational activities like you did before' (no. [%])	
N/A	49 (21.3%)
No	11 (4.8%)
Yes, but not as much as before	105 (45.7%)
Yes, as much as before	49 (21.3%)
Sunnybrook expectation 'Shoulder back to the way it was before having problems' (no. [%])	
No	18 (7.8%)
No, but a little improved	3 (1.3%)
No, but somewhat improved	115 (50.0%)
Yes, completely	78 (33.9%)

(continued on next column)

Table I Descriptive statistics of preoperative patient characteristics and surgery characteristics of the entire sample (*continued*)

SD, standard deviation; *ASA*, American Society of Anesthesiologists; *BMI*, body mass index; *IQR*, interquartile range; *OA*, osteoarthritis; *mRCT*, massive rotator cuff tear; *CTA*, cuff tear arthropathy; *TFI*, Tilburg Frailty Indicator; *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *HA*, hemiarthroplasty; *PROMs*, patient-reported outcome measures; *OSS*, Oxford Shoulder Score; *VAS*, visual analog scale; *PCS*, Pain Catastrophizing Scale; *LOT-R*, Life Optimism Test–Revised; *FPQ-9*, Fear of Pain Questionnaire – 9 items; *CSI*, Central Sensitization Inventory; *HSS*, Hospital for Special Surgery; *N/A*, not applicable.

often part-time or full-time employed, and had lower baseline OSS and EQ-5D VAS scores. The pace of recovery in OSS and EQ-5D VAS were similar across the 2 groups, although the Slower group consistently had lower scores on these measures than the Faster group. This difference was statistically significant but not clinically relevant, as it did not pass the minimal clinically important difference of 6.9 that Liu et al[29] found in SA patients.

Our results enable clinicians to reassure their patients before surgery, as 5 of 6 patients likely have very low pain scores after only 2 weeks. Also, the sixth patient has almost similar low pain scores at 8 weeks postsurgery.

Comparison with previous literature

To the best of our knowledge, no other study has yet intensively studied the pain trajectories during the first few weeks after SA. However, we wish to highlight 2 recent studies that did model growth trajectories after SA.

Rubinstein et al[42] have used LCGA to investigate recovery trajectories after aTSA and rTSA using data from baseline and from 6 weeks, 6 months, 1 year, and 2 years postoperatively, a much longer timespan than our study and without intensive early postoperative data. They found 3 groups for the cohort as a whole (aTSA and rTSA combined): Resistant Responders, Steady Progressors, and

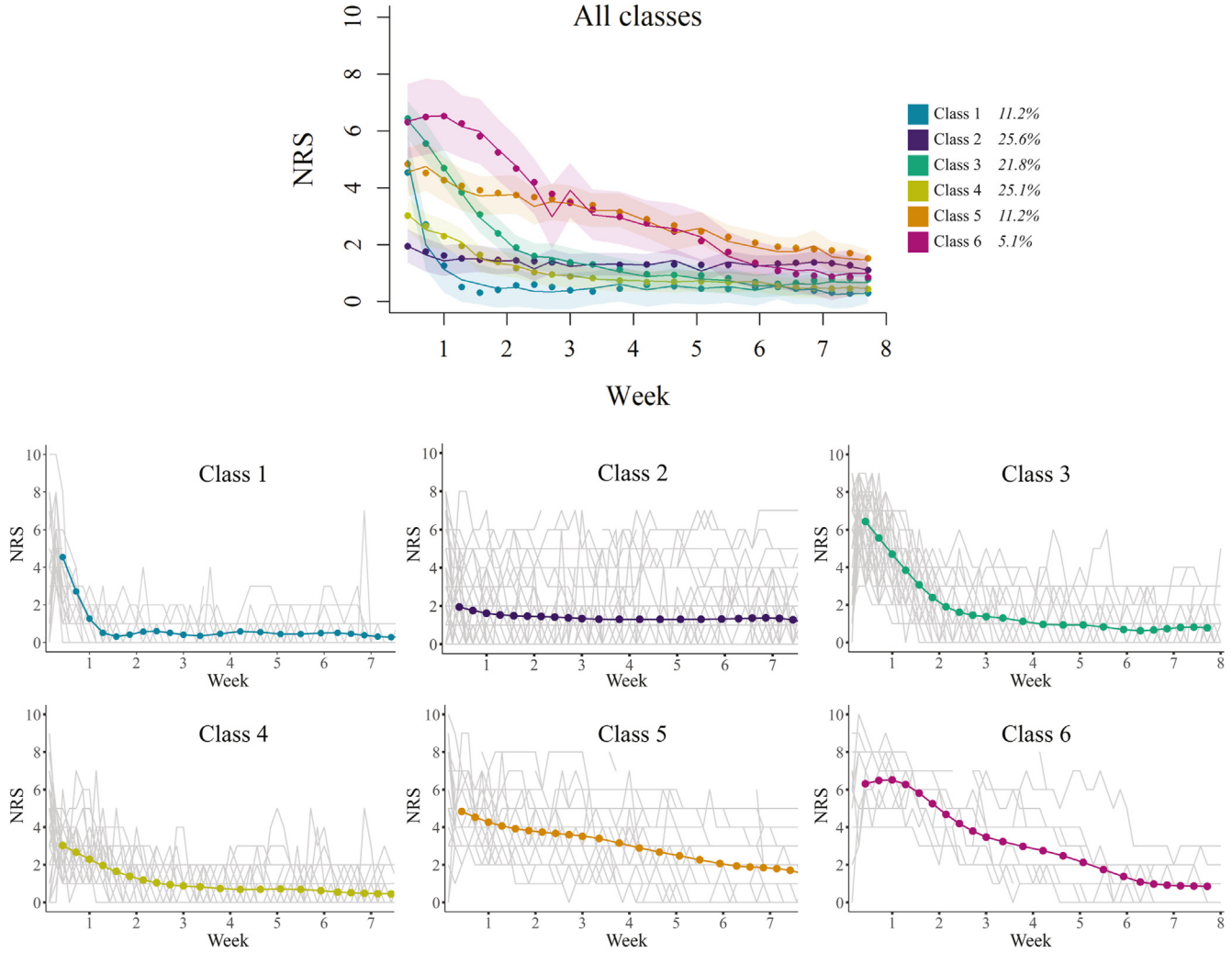


Figure 2 Mean predicted and observed individual trajectories per class of the GMM-1 6-class model. Shades around the mean predicted trajectories represent the 95% confidence interval. *GMM*, Growth Mixture Model; *NRS*, Numeric Rating Scale.

Table II Model parameters for the 6-class GMM-1 model

Class	Intercept	SE	Patients per class (%)
Class 1	4.5	0.19	24 (11.2)
Class 2	1.9	0.23	55 (25.6)
Class 3	6.4	0.20	47 (21.8)
Class 4	3.0	0.19	54 (25.1)
Class 5	4.8	0.38	24 (11.2)
Class 6	6.3	0.44	11 (5.1)

GMM, Growth Mixture Model; *SE*, standard error.

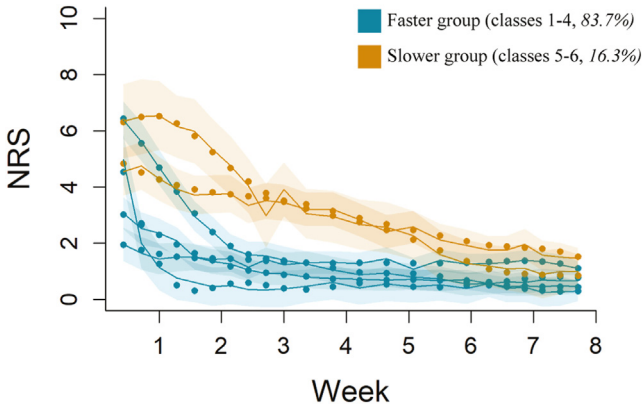


Figure 3 Faster group vs. Slower group. *NRS*, Numeric Rating Scale.

High Performers. They also analyzed aTSA and rTSA in separate analyses. In the separate aTSA and rTSA analyses, the Resistant Responders were replaced with Delayed Responders and Late Regressors, respectively.

Rubinstein et al[42] did not find clear answers on which patient characteristics impact class membership. They also stated that their findings suggest other unmeasured variables, among which psychological elements may be responsible for outcomes; in their study, they only investigated age, sex, body mass index, preoperative diagnosis, and type of arthroplasty.

Table III Preoperative patient characteristics and surgery characteristics of the Faster group vs. the Slower group

Variable	Faster group (N = 180)	Slower group (N = 35)	*P* value
Demographic			
Age (mean [SD] [95% CI])	69.9 (8.1) [68.7-71.1]	70.9 (9.0) [68.0-73.9]	.482
Sex (no. [%])			.52
Male	49 (27.2%)	12 (34.3%)	
Female	131 (72.8%)	23 (65.7%)	
ASA (no. [%])			.002
Class I	21 (11.7%)	1 (2.9%)	
Class II	117 (65.0%)	17 (48.6%)	
Class III or higher	42 (23.3%)	17 (48.6%)	
BMI (no. [%])			.792
Normal weight	50 (27.8%)	7 (20.0%)	
Overweight (BMI: 25-30)	72 (40.0%)	18 (51.4%)	
Obese (BMI $\geq$30)	58 (32.2%)	10 (28.6%)	
Duration of complaints in yr (median [IQR])	3.0 [1.5-6.0]	3.0 [1.25-6.5]	.932
Indication (no. [%])			.171
OA	117 (65.0%)	17 (48.6%)	
mRCT/CTA	38 (21.1%)	10 (28.5%)	
Other	25 (13.9%)	8 (22.9%)	
Education (no. [%])			.946
Low	92 (51.1%)	18 (51.4%)	
Middle	53 (29.4%)	10 (28.6%)	
High	30 (16.7%)	5 (14.3%)	
Other	3 (1.7%)	-	
Work (no. [%])			.012
No work	133 (73.9%)	26 (74.3%)	
$<$12 h per week	6 (3.3%)	-	
12-35 h per week	21 (11.7%)	2 (5.7%)	
$\geq$36 h per week	17 (9.4%)	2 (5.7%)	
Other	-	3 (8.6%)	
Cultural background (no. [%])			1.00
Dutch	171 (95.0%)	32 (91.4%)	
Surinamese	1 (0.6%)	-	
Other	5 (2.8%)	1 (2.9%)	
Religion (no. [%])			.702
Christian	102 (56.7%)	19 (54.3%)	
Catholic	2 (1.1%)	2 (5.7%)	
Jewish	1 (0.6%)	-	
Other	4 (2.2%)	1 (2.9%)	
Not religious	56 (31.1%)	10 (28.6%)	
I'd rather not say	7 (3.9%)	-	
TFI (no. [%])			.741
Frail	116 (64.4%)	23 (65.7%)	
Not frail	53 (29.4%)	9 (25.7%)	
Surgical			
Primary or revision (no. [%])			.592
Primary	176 (97.8%)	34 (97.1%)	
Revision	4 (2.2%)	1 (2.9%)	
Type of prosthesis (no. [%])			.517
aTSA	54 (30.0%)	8 (22.9%)	
rTSA	120 (66.7%)	27 (77.1%)	
HA	6 (3.3%)	-	
Dominant side (no. [%])			.110
Yes	89 (49.4%)	11 (31.4%)	
No	88 (48.9%)	22 (62.9%)	
Baseline PROMs			
Mean pain (mean [SD] [95% CI])	5.3 (2.1) [5.0-5.6]	5.7 (2.1) [5.0-6.4]	.272

(*continued on next page*)

Table III Preoperative patient characteristics and surgery characteristics of the Faster group vs. the Slower group (*continued*)

Variable	Faster group (N = 180)	Slower group (N = 35)	*P* value
Worst pain (mean [SD] [95% CI])	6.6 (2.2) [6.3-3.9]	7.1 (2.2) [6.4-7.8]	.234
OSS (mean [SD] [95% CI])	20.8 (7.7) [19.7-21.9]	17.7 (8.5) [14.9-20.6]	.044
EQ-5D item 'mobility' (no. [%])			.273
No problems in walking about	104 (57.8%)	20 (57.1%)	
Slight problems in walking about	30 (16.7%)	4 (11.4%)	
Moderate problems in walking about	28 (15.6%)	4 (11.4%)	
Severe problems in walking about	10 (5.6%)	3 (8.6%)	
Unable to walk about	-	1 (2.9%)	
EQ-5D item 'self-care' (no. [%])			.400
No problems washing or dressing	44 (24.4%)	5 (14.3%)	
Slight problems washing or dressing	68 (37.8%)	15 (42.9%)	
Moderate problems washing or dressing	45 (25.0%)	7 (20.0%)	
Severe problems washing or dressing	13 (7.2%)	4 (11.4%)	
Unable to wash or dress	2 (1.1%)	1 (2.9%)	
EQ-5D item 'usual activities' (no. [%])			.050
No problems doing usual activities	16 (8.9%)	1 (2.9%)	
Slight problems doing usual activities	48 (26.7%)	11 (31.4%)	
Moderate problems doing usual activities	81 (45.0%)	9 (25.7%)	
Severe problems doing usual activities	23 (12.8%)	10 (28.6%)	
Unable to do usual activities	4 (2.2%)	1 (2.9%)	
EQ-5D item 'pain/discomfort' (no. [%])			.183
No pain or discomfort	3 (1.7%)	-	
Slight pain or discomfort	30 (16.7%)	4 (11.4%)	
Moderate pain or discomfort	86 (47.8%)	14 (40.0%)	
Severe pain or discomfort	52 (28.9%)	12 (34.3%)	
Extreme pain or discomfort	1 (0.6%)	2 (5.7%)	
EQ-5D item 'anxiety/depression' (no. [%])			.154
Not anxious or depressed	116 (64.4%)	17 (48.6%)	
Slightly anxious or depressed	32 (17.8%)	12 (34.3%)	
Moderately anxious or depressed	21 (11.7%)	3 (8.6%)	
Severely anxious or depressed	3 (1.7%)	-	
Extremely anxious or depressed	-	-	
EQ-5D VAS (median [IQR])	75.0 [71.3-76.0]	65.0 [56.2-71.7]	.024
Baseline psychological factors			
PCS (median [IQR])	17.6 (10.8) [16.1-19.2]	21.2 (12.5) [17.0-25.3]	.099
LOT-R optimism subscale (mean [SD] [95% CI])	8.2 (1.94) [7.9-8.5]	7.9 (1.93) [7.2-8.5]	.430
FPQ-9 (median [IQR])			
Total	15.5 [12.0-19.0]	14.5 [12.0-16.3]	.223
Fear of severe pain	7.0 [5.0-9.0]	8.0 [5.0-8.0]	.828
Fear of minor pain	4.0 [3.0-5.0]	3.0 [3.0-4.0]	.004
Fear of medical/dental pain	4.0 [3.0-5.0]	4.0 [3.0-5.0]	.422
CSI (mean [SD] [95% CI])	29.9 (11.9) [28.2-31.7]	34.2 (13) [29.9-38.5]	.067
HSS (mean [SD] [95% CI])	5.8 (4.0) [5.2-6.4]	6.1 (4.0) [4.8-7.4]	.714
Sunnybrook expectation 'Pain relief' (no. [%])			.617
N/A	4 (2.2%)	-	
No	-	-	
Yes, but just a little	1 (0.6%)	-	
Yes, somewhat	35 (19.4%)	9 (25.7%)	
Yes, a lot	132 (73.3%)	23 (65.7%)	
Sunnybrook expectation 'Pain-free range of motion' (no. [%])			.657
N/A	3 (1.7%)	-	
No	5 (2.8%)	-	
Yes, but just a little	10 (5.6%)	-	
Yes, somewhat	59 (32.8%)	13 (37.1%)	
Yes, a lot	95 (52.8%)	19 (54.3%)	

(*continued on next page*)

Table III Preoperative patient characteristics and surgery characteristics of the Faster group vs. the Slower group (*continued*)

Variable	Faster group (N = 180)	Slower group (N = 35)	*P* value
Sunnybrook expectation 'ability to carry out normal activities of daily living' (no. [%])			.282
N/A	3 (1.7%)	1 (2.9%)	
No	2 (1.1%)	2 (5.7%)	
Yes, but just a little	13 (7.2%)	1 (2.9%)	
Yes, somewhat	62 (34.4%)	11 (31.4%)	
Yes, a lot	92 (51.1%)	17 (48.6%)	
Sunnybrook expectation 'Ability to care for others' (no. [%])			.966
N/A	49 (27.2%)	8 (22.9%)	
No	5 (2.8%)	1 (2.9%)	
Yes, but just a little	18 (10.0%)	4 (11.4%)	
Yes, somewhat	52 (28.9%)	9 (25.7%)	
Yes, a lot	48 (26.7%)	10 (28.6%)	
Sunnybrook expectation 'Participate in leisure, sports, or recreational activities like you did before' (no. [%])			.107
N/A	36 (20.0%)	10 (28.6%)	
No	10 (5.6%)	1 (2.9%)	
Yes, but not as much as before	88 (48.9%)	10 (28.6%)	
Yes, as much as before	37 (20.6%)	11 (31.4%)	
Sunnybrook expectation 'Shoulder back to the way it was before having problems' (no. [%])			.687
No	12 (6.7%)	4 (11.4%)	
No, but a little improved	3 (1.7%)	-	
No, but somewhat improved	93 (51.7%)	16 (45.7%)	
Yes, completely	63 (35.0%)	12 (34.3%)	

SD, standard deviation; *CI*, confidence interval; *ASA*, American Society of Anesthesiologists; *BMI*, body mass index; *IQR*, interquartile range; *OA*, osteoarthritis; *mRCT*, massive rotator cuff tear; *CTA*, cuff tear arthropathy; *TFI*, Tilburg Frailty Indicator; *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *HA*, hemiarthroplasty; *PROMs*, patient-reported outcome measures; *OSS*, Oxford Shoulder Score; *VAS*, visual analog scale; *PCS*, Pain Catastrophizing Scale; *LOT-R*, Life Optimism Test–Revised; *FPQ-9*, Fear of Pain Questionnaire – 9 items; *CSI*, Central Sensitization Inventory; *HSS*, Hospital for Special Surgery; *N/A*, not applicable.

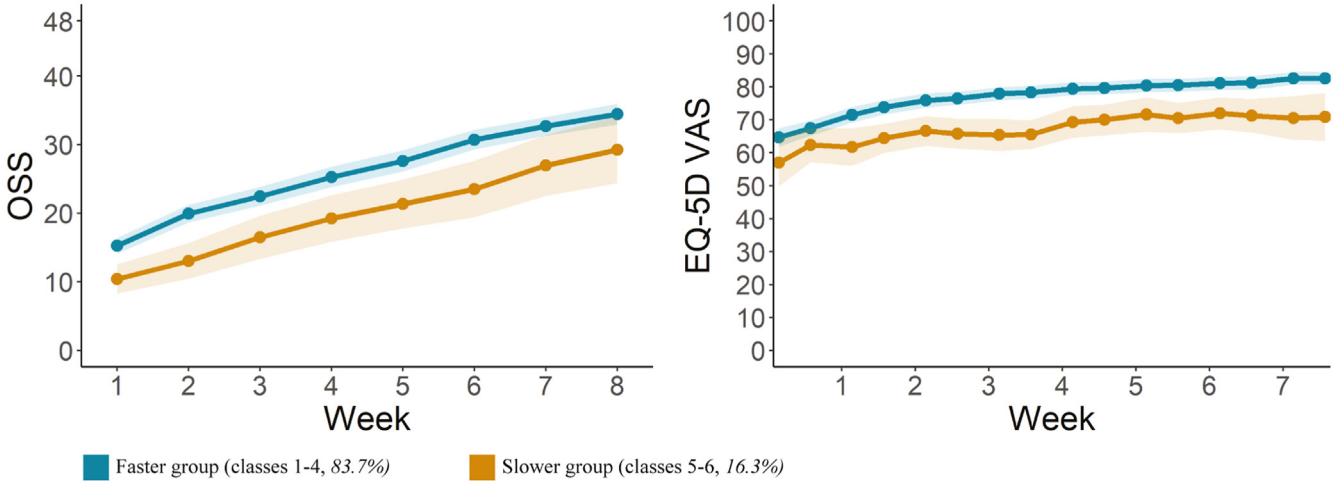


Figure 4 Longitudinal change in Oxford Shoulder Score (OSS) and EQ-5D visual analog scale for Faster group vs. Slower group.

In our study, however, we did not find clear indications for such an association despite measuring multiple psychological factors preoperatively: pain catastrophizing, fear of pain, optimism, expectations, and the Central Sensitization Inventory. None of these factors differed substantively between the Faster and Slower groups. Only the Fear of Pain Questionnaire–9 items subscale 'Fear of minor pain' had a statistically significant difference of 1

Table IV Model parameters for LMMs for OSS and EQ-5D VAS scores

LMM for OSS			
Fixed effects	Estimates	95% CI	*P* value
Intercept	14.05	12.79-15.30	<.001
Slower group membership	−5.93	−8.86 to −3.00	<.001
Time (week)	2.66	2.48-2.84	<.001
Random effects	Variance		
Subject	65.14		
Time	1.36		
Residual	13.56		
LMM for EQ-5D VAS			
Fixed effects	Estimates	95% CI	*P* value
Intercept	69.41	67.37-71.45	<.001
Slower group membership	−10.39	−14.87 to −5.92	<.001
Time (day)	0.29	0.25-0.32	<.001
Random effects	Variance		
Subject	190.20		
Time	5.96		
Residual	46.56		

LMM, linear mixed model; *OSS*, Oxford Shoulder Score; *VAS*, visual analog scale; *CI*, confidence interval.

point on the median score, but we strongly doubt this difference to be clinically relevant.

Another relevant study that is particularly interesting to highlight is the recent study by Broekman et al.[2] These authors also assessed postoperative trajectories after SA, but in a single-surgeon registry database study. They found that mental health was related to greater pain intensity at baseline but not to different rates of recovery. Their study differs from ours in some key aspects. Although we used LGCM to let previously undetected subgroups emerge from the data, they used growth models to study a priori selected subgroups stratified by quartiles of mental health measured with the mental component summary score of the Veterans RAND 12. Furthermore, alhough we allowed the trajectories to take any shape or form for each class, Broekman et al[2] fit quadratic growth models, thus imposing similar shapes onto the subgroups.

Finally, both Rubenstein et al[42] and Broekman et al[2] were limited to data that had already been collected at regular care intervals and were more interested in longer-term trajectories than in the first 8 weeks as we were in this study.

When comparing our study to the broader literature on outcomes after SA (not only studies that modeled growth trajectories), several previous studies did find possible associations between, for example, depression, anxiety, pain catastrophizing, or expectations and outcomes after SA specifically,[14,17,18,23,40,48] or after other types of joint arthroplasty.[4,18,35] Several mechanisms may be responsible for this discrepancy.

First, although we have a large sample size for such an intensive prospective longitudinal study in this patient category, our Slower group is still small in absolute terms (35 patients). We therefore may lack power to detect statistically significant differences.

Second, different methodological choices will yield different results. For example, when comparing subgroups of responders vs. nonresponders, different cut-off values can be chosen to define nonresponders. This will inevitably alter which patients are assigned to each subgroup, thereby affecting the resulting associations.

Finally, the choice of outcome measure and predictors may also affect the associations. For example, Swarup et al[48] found a positive association between higher preoperative expectations and improvement in the American Shoulder and Elbow Surgeons score, which measures both function and pain. Rauck et al[40] found better American Shoulder and Elbow Surgeons and VAS pain scores for patients with higher expectations for the surgery relieving night-time pain, but found no association between the overall number of 'very important' expectations and 2-year outcome or improvement scores. Hence, our choice for pain as our outcome measure and the mean number of 'very important' expectations as predictor (instead of the separate expectations) could explain why we could not corroborate their results.

Strengths and limitations

A prominent strength is that we succeeded in including 230 subjects in our prospective multicenter cohort study. Many previous studies on SA have resorted to retrospective designs to gather study samples of more than 100 subjects[7,12,15,17,19,23,34,43]; SAs only make up a small percentage of all arthroplasties. For example, a total of 3,581 SAs were performed in The Netherlands in 2021, only

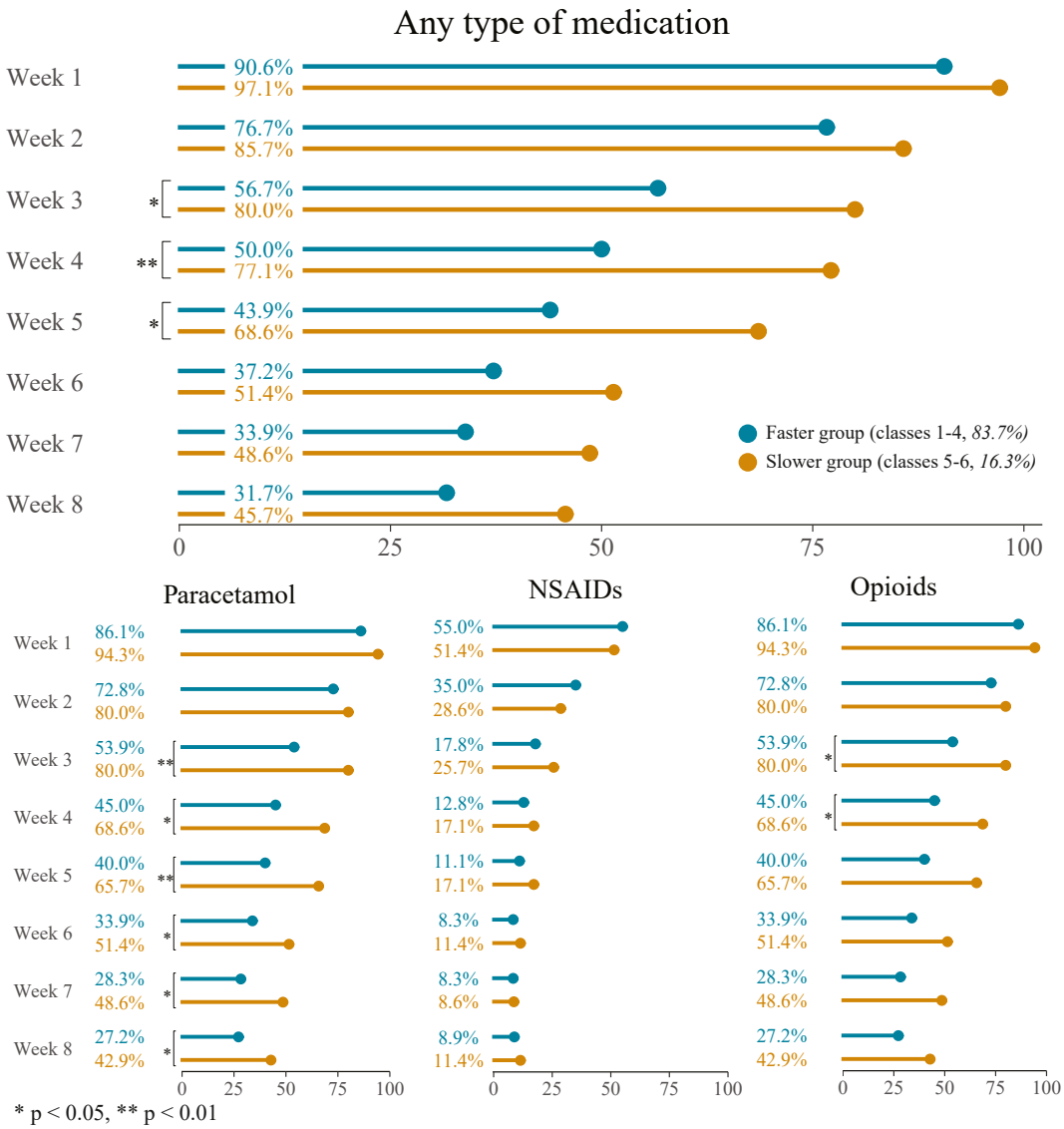


Figure 5 Medication use for Faster group vs. Slower group. *NSAIDs*, nonsteroidal anti-inflammatory drug.

4.7% of all registered arthroplasties.[25] By using a prospective design, we had control over which data to collect at which time points while simultaneously actively minimizing missing data.

This leads us to another strength of our study: the intensive longitudinal data we collected with the daily diaries. To our knowledge, no other study to date has collected daily data for 8 consecutive weeks starting the day after SA. This enabled us to shed light on a previously unanswered research question.

Finally, we were able to recruit a sample that is representative for the overall Dutch SA population regarding general demographics (ie, age, sex, body mass index).[25]

However, we need to address some limitations as well.

First, although we managed a very respectable sample size for a prospective study on SA patients, the Slower group still consisted of a small number of subjects. This precluded us from performing multivariable analyses and, thereby, from defining the independent predictive effect of preoperative patient characteristics on group membership. In addition, given the exploratory nature of the secondary analysis, we did not correct for multiple testing. Future studies may be needed to confirm or refute the findings of which factors are associated with Slower and Faster group membership.

Second, another possible limitation is that we included (both primary and revision) aTSA, rTSA, and HA patients and analyzed our sample as a whole. Stratifying the analysis according to implant type could have led to different results. For example, Jones et al[20] reported that rTSA patients required fewer opioids postoperatively than aTSA patients. However, when comparing the Faster and Slower groups, we found no statistically significant different proportions for implant type, although the Slower group did

contain slightly more rTSA patients. Since the Slower group also had higher proportions of patients using opioids, our results do not match those of Jones et al.[20] Our results do match with evidence for the HA patients: Craig et al[10] and Bryant et al[3] found in their systematic reviews slightly better pain and functional outcomes in favor of aTSA compared to HA, but these differences were not necessarily clinically relevant. Although the included number of HA patients was minimal (n = 6), they were all classified into the Faster group, indicating that they did not fare worse than aTSA patients in a clinically relevant manner. In addition, the percentages of primary and revision arthroplasty were similar between the Faster and Slower groups, suggesting that including both does not seem to influence our findings.

Third, the reader should bear in mind that we cannot state that altering the factors on which the Faster and Slower groups in our sample differed will also alter the probability of becoming part of the Slower group, as our analysis is only of an exploratory nature and univariable. Nevertheless, our results can still make a significant contribution, as clinicians can now offer more accurate expectation management by explaining which factors (ie, ASA scores of 3, not being employed and having lower baseline OSS and EQ-5D VAS scores) may predict a slower pain recovery in the early postoperative phase.

Finally, the postoperative pain and rehabilitation protocols were not standardized among the different participating centers. Different protocols could influence the patient's postoperative pain trajectory and, thereby, our models. On the other hand, not standardizing the protocols increases the generalizability of our results to the broader population of SA patients treated in different hospitals and clinics; differences in protocols for rehabilitation and pain management will always exist in the real world. For example, in the United States, first-line pain management after SA is often opioid medication, whereas in the Netherlands, paracetamol and NSAIDs are preferred. However, since a substantial proportion of our sample also used opioids as rescue medication in the first weeks postoperatively, we believe that our results are also generalizable to other countries such as the United States.

Conclusion

In this study, we distinguished 6 early recovery trajectories after SA. While recovery after SA clearly does not end at 8 weeks, this early recovery period is extremely impactful in patients' lives. Being able to better manage expectations and reassure patients is a major advantage during preoperative consultations. This study has taken an essential first step in elucidating how patients experience their pain in the first weeks postoperatively. Surgeons can now show the figures within this article and explain how many patients generally experience a fast recovery or a slower recovery in pain. It enables clinicians to reassure their patients prior to surgery that within 2 weeks after surgery, more than 80% of the patients have very low pain scores. For future studies, it would be relevant to know whether our results can be replicated in different samples and if, using our models, the patient-specific trajectory can be predicted based on daily pain data from the first 2 weeks. Also, we advise to explore if improved patient education focused on early recovery increases satisfaction in the first weeks after surgery, preferably with randomized controlled trials comparing patient education with and without detailed information regarding the first 8 weeks.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2025.06.016.

References

1. Berendes T, Pilot P, Willems J, Verburg H, te Slaa R. Validation of the Dutch version of the Oxford Shoulder Score. J Shoulder Elbow Surg 2010;19:829-36. https://doi.org/10.1016/j.jse.2010.01.017
2. Broekman MM, Brinkman N, Swanson D, Ring D, van den Bekerom M, Jawa A. Variations in 1-year trajectories of levels of pain and capability after shoulder arthroplasty are associated with baseline mental health. Clin Orthop Relat Res 2024;482:514-22. https://doi.org/10.1097/corr.0000000000002821
3. Bryant D, Litchfield R, Sandow M, Gartsman GM, Guyatt G, Kirkley A. A comparison of pain, strength, range of motion, and functional outcomes after hemiarthroplasty and total shoulder

arthroplasty in patients with osteoarthritis of the shoulder. A systematic review and meta-analysis. J Bone Joint Surg Am 2005;87:1947-56. https://doi.org/10.2106/jbjs.D.02854
4. Burns LC, Ritvo SE, Ferguson MK, Clarke H, Seltzer Z, Katz J. Pain catastrophizing as a risk factor for chronic pain after total knee arthroplasty: a systematic review. J Pain Res 2015;8:21-32. https://doi.org/10.2147/jpr.S64730
5. Carducci MP, Zimmer ZR, Jawa A. Predictors of unsatisfactory patient outcomes in primary reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2019;28:2113-20. https://doi.org/10.1016/j.jse.2019.04.009
6. Castor EDC. Castor electronic data capture. 2019. https://castoredc.com. Accessed November 18, 2024.
7. Chang NB, Bicknell R, Krupp R, Wiater JM, Levy J, Athwal GS. Sex-related differences in stemless total shoulder arthroplasty. JSES Int 2022;6:26-31. https://doi.org/10.1016/j.jseint.2021.09.008
8. Cho CH, Song KS, Hwang I, Coats-Thomas MS, Warner JJP. Changes in psychological status and health-related quality of life following total shoulder arthroplasty. J Bone Joint Surg Am 2017;99:1030-5. https://doi.org/10.2106/jbjs.16.00954
9. Claes A, De Mesel A, Struyf T, Verborgt O, Struyf F. Factors influencing outcome after shoulder arthroplasty (FINOSA study): protocol of a prospective longitudinal study with randomized group allocation. JMIR Res Protoc 2024;13:e56522. https://doi.org/10.2196/56522
10. Craig RS, Goodier H, Singh JA, Hopewell S, Rees JL. Shoulder replacement surgery for osteoarthritis and rotator cuff tear arthropathy. Cochrane Database Syst Rev 2020;4:Cd012879. https://doi.org/10.1002/14651858.CD012879.pub2
11. Dean MC, Cherian NJ, Eberlin CT, Rudisill SS, LaPorte ZL, Kucharik MP, et al. Total shoulder vs. hip and knee arthroplasty: an analysis of perioperative outcomes. Semin Arthroplasty 2023;33:627-36. https://doi.org/10.1053/j.sart.2023.06.011
12. Dekker TJ, Grantham WJ, Lacheta L, Goldenberg BT, Dey Hazra RO, Rakowski DR, et al. Glenoid retroversion does not impact clinical outcomes or implant survivorship after total shoulder arthroplasty with minimal, noncorrective reaming. JSES Int 2022;6:596-603. https://doi.org/10.1016/j.jseint.2022.02.011
13. Fernández-de-Las-Peñas C, Florencio LL, de-la-Llave-Rincón AI, Ortega-Santiago R, Cigarán-Méndez M, Fuensalida-Novo S, et al. Prognostic factors for postoperative chronic pain after knee or hip replacement in patients with knee or hip osteoarthritis: an umbrella review. J Clin Med 2023;12:6624. https://doi.org/10.3390/jcm12206624
14. Forlizzi JM, Puzzitiello RN, Hart PA, Churchill R, Jawa A, Kirsch JM. Predictors of poor and excellent outcomes after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2022;31:294-301. https://doi.org/10.1016/j.jse.2021.07.009
15. Friedman RJ, Cheung EV, Flurin PH, Wright T, Simovitch RW, Bolch C, et al. Are age and patient gender associated with different rates and magnitudes of clinical improvement after reverse shoulder arthroplasty? Clin Orthop Relat Res 2018;476:1264-73. https://doi.org/10.1007/s11999.0000000000000270
16. Gobbens RJ, van Assen MA, Luijkx KG, Wijnen-Sponselee MT, Schols JM. Determinants of frailty. J Am Med Dir Assoc 2010;11:356-64. https://doi.org/10.1016/j.jamda.2009.11.008
17. Green A, Neradilek MB, Thompson KM, Mayer A. Expectations affect outcome and satisfaction after anatomic total shoulder arthroplasty. Semin Arthroplasty 2020;30:297-307. https://doi.org/10.1053/j.sart.2020.09.005
18. Hardy A, Sandiford MH, Menigaux C, Bauer T, Klouche S, Hardy P. Pain catastrophizing and pre-operative psychological state are predictive of chronic pain after joint arthroplasty of the hip, knee or shoulder: results of a prospective, comparative study at one year follow-up. Int Orthop 2022;46:2461-9. https://doi.org/10.1007/s00264-022-05542-7
19. Huber J, Irlenbusch U, Kääb MJ, Reuther F, Kohut G, Judge A. Treatment effects of reverse total shoulder arthroplasty - a simple method to measure outcomes at 6, 12, 24 and 60 months for each patient. BMC Musculoskelet Disord 2020;21:397. https://doi.org/10.1186/s12891-020-03427-7
20. Jones CA, Chambers S, Renshaw AD, Throckmorton TW, Bernholt DL, Azar FM, et al. Patients undergoing reverse total shoulder arthroplasty have less pain and require fewer opioid pain medications compared to anatomic total shoulder arthroplasty in the early postoperative period: a retrospective review. J Shoulder Elbow Surg 2025;34:454-61. https://doi.org/10.1016/j.jse.2024.04.024
21. Kadum B, Inngul C, Ihrman R, Sjödén GO, Sayed-Noor AS. Higher preoperative sensitivity to pain and pain at rest are associated with worse functional outcome after stemless total shoulder arthroplasty: a prospective cohort study. Bone Joint J 2018;100-b:480-4. https://doi.org/10.1302/0301-620x.100b4.Bjj-2017-1000.R1
22. Klooster PT, Weekers A, Eggelmeijer F, Van Woerkom J, Drossaert C, Taal E, et al. Optimisme en/of pessimisme: factorstructuur van de Nederlandse Life Orientation Test-Revised. Psychol en Gezondheid 2010;38:89-100. https://doi.org/10.1007/BF03089356
23. Kohan EM, Aleem AW, Chamberlain AM, Keener JD. The influence of mental health on outcomes following total shoulder arthroplasty. Semin Arthroplasty 2020;30:18-27. https://doi.org/10.1053/j.sart.2020.04.001
24. Kregel J, Vuijk PJ, Descheemaeker F, Keizer D, van der Noord R, Nijs J, et al. The Dutch Central Sensitization Inventory (CSI): factor analysis, discriminative power, and test-retest reliability. Clin J Pain 2016;32:624-30. https://doi.org/10.1097/ajp.0000000000000306
25. Landelijke Registratie Orthopedische Interventies (LROI). Annual LROI report 2024. 2024. https://www.lroi.nl/jaarrapportage/shoulder/numbers/. Accessed May 15, 2025.
26. Lansdown DA, Ma GC, Aung MS, Gomez A, Zhang AL, Feeley BT, et al. Do patient outcomes and follow-up completion rates after shoulder arthroplasty differ based on insurance payor? J Shoulder Elbow Surg 2021;30:65-71. https://doi.org/10.1016/j.jse.2020.04.028
27. Lapner PL, Jiang L, Zhang T, Athwal GS. Rotator cuff fatty infiltration and atrophy are associated with functional outcomes in anatomic shoulder arthroplasty. Clin Orthop Relat Res 2015;473:674-82. https://doi.org/10.1007/s11999-014-3963-5
28. Lewis GN, Rice DA, McNair PJ, Kluger M. Predictors of persistent pain after total knee arthroplasty: a systematic review and meta-analysis. Br J Anaesth 2015;114:551-61. https://doi.org/10.1093/bja/aeu441
29. Liu P, Afzal I, Asopa V, Clement ND, Patel V. Changes and thresholds in the Oxford Shoulder Score following shoulder arthroplasty: minimal clinically important difference, minimal important and detectable changes, and patient-acceptable symptom state. Shoulder Elbow 2024;16:507-17. https://doi.org/10.1177/17585732231176642
30. Mancuso CA, Altchek DW, Craig EV, Jones EC, Robbins L, Warren RF, et al. Patients' expectations of shoulder surgery. J Shoulder Elbow Surg 2002;11:541-9. https://doi.org/10.1067/mse.2002.126764
31. Matsen FA 3rd, Iannotti JP, Churchill RS, De Wilde L, Edwards TB, Evans MC, et al. One and two-year clinical outcomes for a polyethylene glenoid with a fluted peg: one thousand two hundred seventy individual patients from eleven centers. Int Orthop 2019;43:367-78. https://doi.org/10.1007/s00264-018-4213-3
32. McNeil DW, Kennedy SG, Randall CL, Addicks SH, Wright CD, Hursey KG, et al. Fear of Pain Questionnaire-9: brief assessment of pain-related fear and anxiety. Eur J Pain 2018;22:39-48. https://doi.org/10.1002/ejp.1074
33. Overview of Medical Research in the Netherlands (OMON). Trial the shoulder diary. 2017, https://onderzoekmetmensen.nl/en/trial/25734. Accessed September 29, 2024
34. Pettit RJ, Saini SB, Puzzitiello RN, Hart PJ, Ross G, Kirsch JM, et al. Primary reverse total shoulder arthroplasty performed for glenohumeral arthritis: does glenoid morphology matter? J Shoulder Elbow Surg 2022;31:923-31. https://doi.org/10.1016/j.jse.2021.10.022
35. Pinto PR, McIntyre T, Araújo-Soares V, Costa P, Ferrero R, Almeida A. A comparison of predictors and intensity of acute post-surgical pain in patients undergoing total hip and knee arthroplasty. J Pain Res 2017;10:1087-98. https://doi.org/10.2147/jpr.S126467

36. Posit team. RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA. 2023. http://www.posit.co/. LROI, 2025. Annual report 202. Accessed November 18, 2024.
37. Proust-Lima C, Philipps V, Liquet B. Estimation of extended mixed models using latent classes and latent processes: the R package lcmm. J Stat Softw 2017;78:1-56. https://doi.org/10.18637/jss.v078.i02
38. R Development Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2024. http://www.R-project.org/. Accessed November 18, 2024.
39. Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group. Ann Med 2001;33:337-43.
40. Rauck RC, Swarup I, Chang B, Dines DM, Warren RF, Gulotta LV, et al. Effect of preoperative patient expectations on outcomes after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2018;27: e323-9. https://doi.org/10.1016/j.jse.2018.05.026
41. Razmjou H, Finkelstein JA, Yee A, Holtby R, Vidmar M, Ford M. Relationship between preoperative patient characteristics and expectations in candidates for total knee arthroplasty. Physiother Can 2009; 61:38-45. https://doi.org/10.3138/physio.61.1.38
42. Rubenstein WJ, Warwick HSL, Aung MS, Zhang AL, Feeley BT, Ma CB, et al. Defining recovery trajectories after shoulder arthroplasty: a latent class analysis of patient-reported outcomes. J Shoulder Elbow Surg 2021;30:2375-85. https://doi.org/10.1016/j.jse.2021.02.024
43. Saini SS, Pettit R, Puzzitiello RN, Hart P-A, Shah SS, Jawa A, et al. Clinical outcomes after reverse total shoulder arthroplasty in patients with primary glenohumeral osteoarthritis compared with rotator cuff tear arthropathy: does preoperative diagnosis make a difference? J Am Acad Orthop Surg 2022;30:e415-22. https://doi.org/10.5435/JAAOS-D-21-00797
44. Sayed-Noor AS, Pollock R, Elhassan BT, Kadum B. Fatty infiltration and muscle atrophy of the rotator cuff in stemless total shoulder arthroplasty: a prospective cohort study. J Shoulder Elbow Surg 2018; 27:976-82. https://doi.org/10.1016/j.jse.2017.12.021
45. Scheier MF, Carver CS, Bridges MW. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the Life Orientation Test. J Pers Soc Psychol 1994;67: 1063-78.
46. Shields EJW, Koueiter DM, Maerz T, Schwark A, Wiater JM. Previous rotator cuff repair is associated with inferior clinical outcomes after reverse total shoulder arthroplasty. Orthop J Sports Med 2017;5: 2325967117730311. https://doi.org/10.1177/2325967117730311
47. Sullivan MJ, Bishop SR, Pivik J. The pain catastrophizing scale: development and validation. Psychol Assess 1995;7:524.
48. Swarup I, Henn CM, Nguyen JT, Dines DM, Craig EV, Warren RF, et al. Effect of pre-operative expectations on the outcomes following total shoulder arthroplasty. Bone Joint J 2017;99-b:1190-6. https://doi.org/10.1302/0301-620x.99b9.Bjj-2016-1263.R1
49. Wood TJ, Gazendam AM, Kabali CB. Postoperative outcomes following total hip and knee arthroplasty in patients with pain catastrophizing, anxiety, or depression. J Arthroplasty 2021;36:1908-14. https://doi.org/10.1016/j.arth.2021.02.018