Fast Starters, Slow Starters, and Late Dippers

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Results from a Dutch Nationwide Database

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Investigation performed at Reinier de Graaf Hospital, Delft, the Netherlands

Background: The purpose of this study was to explore whether subgroups of patients with different functional recovery trajectories after total hip arthroplasty can be discerned, as well as their predictors, using data from the Dutch Arthroplasty Register (Landelijke Registratie Orthopedische Implantaten [LROI]).

Methods: We retrospectively reviewed prospectively collected Oxford Hip Scores (OHS) up to 1 year postoperatively for patients who had undergone a primary total hip arthroplasty. Latent class growth modeling was used to classify subgroups of patients according to the trajectory of functional recovery represented by the patients' OHS. We used multivariable multinomial logistic regression analysis to explore factors associated with class membership.

Results: A total of 6,030 patients were analyzed. Latent class growth modeling identified fast starters (fast initial improvement, high 12-month scores; 87.7%), slow starters (no initial change and subsequent improvement; 4.6%), and late dippers (initial improvement and subsequent deterioration; 7.7%). Factors associated with slow starters were female sex (odds ratio [OR], 1.63 [95% confidence interval (CI), 1.14 to 2.33]) and smoking (OR, 1.95 [95% CI, 1.26 to 3.03]); an anterior approach (OR, 0.47 [95% CI, 0.29 to 0.78]) had a protective effect against a less favorable response. Factors associated with late dippers were age of >75 years (OR, 1.62 [95% CI, 1.22 to 2.15]), smoking (OR, 1.68 [95% CI, 1.17 to 2.42]), American Society of Anesthesiologists (ASA) grade of III or IV (OR, 1.41 [95% CI, 1.05 to 1.91]), obesity (OR, 1.96 [95% CI, 1.43 to 2.69]), poorer EuroQol-5 Dimensions (EQ-5D) Self-Care (OR, 1.41 [95% CI, 1.09 to 1.82] for "some problems" and OR, 2.90 [95% CI, 1.39 to 6.03] for "unable"), poorer EQ-5D Anxiety/Depression (OR, 1.31 [95% CI, 1.00 to 1.71] for "moderately" and OR, 1.86 [95% CI, 1.06 to 3.24] for "extremely"), poorer EQ-5D visual analog scale (OR, 0.91 [95% CI, 0.86 to 0.97] per 10 points), direct lateral approach (OR, 2.18 [95% CI, 1.58 to 3.02]), and hybrid fixation with a cemented acetabular implant (OR, 1.79 [95% CI, 1.00 to 3.21]).

Conclusions: We discerned fast starters, slow starters, and late dippers after total hip arthroplasty. Female sex, older age, obesity, higher ASA grades, and worse EQ-5D scores were associated with a less favorable response to total hip arthroplasty, as well as hybrid fixation (cemented acetabular implant) and direct lateral approach. Anterior approach had a protective effect against a less favorable response. However, all subgroups experienced functional improvement following total hip arthroplasty.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Although the majority of patients with end-stage hip osteoarthritis respond well to total hip arthroplasty, a reported 7% to 23% of patients do not respond as favorably, indicating that some degree of heterogeneity in recovery after total hip arthroplasty exists[1-4]. To further improve the outcomes of total hip arthroplasty, it is important to better understand the differences between patients in how they respond to total hip arthroplasty.

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TABLE I Descriptive Statistics of Preoperative Patient Characteristics and Surgery Characteristics of the Entire Sample and of the 3 Separate Classes

Variable	Entire Sample (N = 6,030)	Slow Starters (N = 277)	Late Dippers (N = 463)	Fast Starters (N = 5,290)
Age* *(yr)*	68.64 ± 8.99 (68.42 to 68.87)	68.19 ± 9.25 (67.10 to 69.29)	70.44 ± 9.47 (69.57 to 71.30)	68.51 ± 8.92 (68.27 to 68.75)
Age†				
≤75 years	4,644 (77%)	207 (75%)	316 (68%)	4,121 (78%)
>75 years	1,384 (23%)	70 (25%)	147 (31%)	1,167 (22%)
Sex†				
Male	2,175 (36%)	78 (28%)	135 (29%)	1,962 (37%)
Female	3,849 (64%)	199 (72%)	328 (71%)	3,322 (63%)
Smoking†				
No	5,045 (84%)	221 (80%)	371 (80%)	4,453 (84%)
Yes	544 (9%)	37 (13%)	54 (12%)	453 (9%)
ASA grade†				
I or II	5,163 (86%)	226 (82%)	350 (76%)	4,587 (87%)
III or IV	859 (14%)	50 (18%)	113 (24%)	696 (13%)
BMI†				
Normal weight (<25 kg/m^2)	1,998 (33%)	78 (28%)	119 (26%)	1,801 (34%)
Overweight (25 to <30 kg/m^2)	2,573 (43%)	109 (40%)	172 (38%)	2,292 (44%)
Obese (≥30 kg/m^2)	1,405 (23%)	88 (32%)	165 (36%)	1,152 (22%)
Previous surgery†				
No	5,909 (98%)	272 (99%)	451 (97%)	5,186 (98%)
Yes	103 (2%)	4 (1%)	12 (3%)	87 (2%)
Charnley class†				
A	2,784 (46%)	112 (41%)	198 (44%)	2,474 (47%)
B1	1,760 (29%)	86 (31%)	137 (30%)	1,537 (30%)
B2	1,255 (21%)	68 (25%)	100 (22%)	1,087 (21%)
C	162 (3%)	8 (3%)	20 (4%)	134 (3%)
Pain at rest*	4.97 ± 2.52 (4.91 to 5.03)	5.39 ± 2.40 (5.10 to 5.67)	5.87 ± 2.31 (5.66 to 6.08)	4.87 ± 2.53 (4.80 to 4.94)
Pain during activity*	7.04 ± 2.07 (6.99 to 7.09)	7.35 ± 1.97 (7.11 to 7.59)	7.67 ± 1.79 (7.50 to 7.83)	6.97 ± 2.08 (6.91 to 7.03)
EQ-5D Mobility†				
No problems	316 (5%)	9 (3%)	23 (5%)	284 (5%)
Some problems in walking about	5,666 (94%)	263 (95%)	432 (94%)	4,971 (94%)
Confined to bed	39 (1%)	4 (1%)	6 (1%)	29 (1%)
EQ-5D Self-Care†				
No problems	3,630 (60%)	149 (54%)	204 (44%)	3,277 (62%)
Some problems washing or dressing	2,322 (39%)	122 (44%)	239 (52%)	1,961 (37%)
Unable to wash or dress	65 (1%)	5 (2%)	18 (4%)	42 (1%)
EQ-5D Usual Activities†				
No problems	805 (13%)	24 (9%)	29 (6%)	752 (14%)
Some problems performing usual activities	4,671 (78%)	217 (78%)	346 (75%)	4,108 (78%)
Unable to perform usual activities	547 (9%)	36 (13%)	87 (19%)	424 (8%)
EQ-5D Pain/Discomfort†				
No pain or discomfort	314 (5%)	10 (4%)	9 (2%)	295 (6%)
Moderate pain or discomfort	4,184 (70%)	173 (63%)	259 (56%)	3,752 (71%)
Extreme pain or discomfort	1,520 (25%)	92 (34%)	191 (42%)	1,237 (23%)
EQ-5D Anxiety/Depression†				
Not anxious or depressed	4,470 (74%)	190 (69%)	278 (60%)	4,002 (76%)
Moderately anxious or depressed	1,382 (23%)	69 (25%)	153 (33%)	1,160 (22%)
Extremely anxious or depressed	160 (3%)	17 (6%)	31 (7%)	112 (2%)
EQ-5D VAS*	66.95 ± 19.65 (66.45 to 67.45)	63.85 ± 21.04 (61.33 to 66.38)	59.5 ± 21.08 (57.55 to 61.44)	67.77 ± 19.29 (67.24 to 68.29)
Approach†				
Posterolateral	3,819 (63%)	191 (69%)	294 (64%)	3,334 (63%)
Anterior	1,368 (23%)	38 (14%)	63 (14%)	1,267 (24%)
Anterolateral	214 (4%)	8 (3%)	19 (4%)	187 (4%)
Direct lateral	626 (10%)	39 (14%)	86 (19%)	501 (10%)

continued

TABLE I (*continued*)

Variable	Entire Sample (N = 6,030)	Slow Starters (N = 277)	Late Dippers (N = 463)	Fast Starters (N = 5,290)
Other	1 (0%)	0 (0%)	1 (0%)	0 (0%)
Fixation†				
Cemented	1,233 (21%)	61 (22%)	139 (30%)	1,033 (20%)
Hybrid, cemented acetabular implant	169 (3%)	6 (2%)	26 (6%)	137 (3%)
Hybrid, cemented femoral implant	273 (5%)	19 (7%)	25 (5%)	229 (4%)
Uncemented	4,347 (72%)	191 (69%)	273 (59%)	3,883 (74%)
Articulation†				
Ceramic-on-polyethylene	3,549 (59%)	194 (70%)	259 (57%)	3,096 (59%)
Metal-on-polyethylene	1,839 (31%)	60 (22%)	163 (36%)	1,616 (31%)
Ceramic-on-ceramic	157 (3%)	10 (4%)	8 (2%)	139 (3%)
Oxidized zirconium-on-polyethylene	413 (7%)	12 (4%)	28 (6%)	373 (7%)
Other	6 (<0.01%)	0 (0%)	0 (0%)	6 (<0.01%)
Femoral-head diameter†				
22 to 28 mm	1,362 (23%)	61 (22%)	144 (31%)	1,157 (22%)
32 mm	3,429 (57%)	159 (58%)	234 (51%)	3,036 (58%)
≥36 mm	1,223 (20%)	56 (20%)	85 (18%)	1,082 (21%)

*The values are given as the mean and the standard deviation, with the 95% confidence interval (CI) in parentheses. †The values are given as the number of patients, with the percentage (number of patients divided by the column total) in parentheses. Due to missing values, some categories do not equal the total number of patients for each column.

Several previous studies have examined recovery after total hip arthroplasty in terms of reported pain and functioning and found, on average, a clinically meaningful, nonlinear improvement in which most of the improvement occurred in the first 3 months[1-5]. These studies did not investigate the degree of variation between patients in recovery. However, several studies have shown associations between preoperative and perioperative factors, such as body mass index (BMI) or surgical approach, and postoperative outcomes[6-8], suggesting that variation in recovery trajectories may exist.

A suitable method to investigate heterogeneity in change patterns is latent class growth modeling[9-11]. This is an extension

TABLE II Fit Statistics for the GMMs and LCGA

Model	Log Likelihood	Bayesian Information Criterion	Akaike Information Criterion	Adjusted Bayesian Information Criterion	P Value, Bootstrapped Likelihood Ratio Test	Entropy	No. of Free Parameters
GMM							
1 class	−60,290.731	120,659.803	120,599.462	120,631.203	—	—	9
2 classes	−58,998.010	118,109.178	118,022.019	118,067.867	<0.001	0.945	13
3 classes	−58,463.891	117,075.758	116,961.781	117,021.737	<0.001	0.928	17
4 classes	−58,047.954*	116,278.703	116,137.908	116,211.970	<0.001	0.913	21
5 classes	−57,775.794*	115,769.200	115,601.587	115,689.757	<0.001	0.911	25
6 classes	−57,589.403*	115,431.236	115,236.806	115,339.082	<0.001	0.906	29
LCGA							
1 class	−61,941.774	123,935.774	123,895.547	123,916.708	—	—	6
2 classes	−59,796.150	119,679.346	119,647.569	119,612.301	<0.001	0.919	10
3 classes	−59,013.834	118,149.532	118,055.669	118,105.044	<0.001	0.897	14
4 classes	−58,600.489*	117,357.660	117,236.979	117,300.461	<0.001	0.885	18
5 classes	−58,206.217*	116,603.933	116,456.434	116,534.023	<0.001	0.898	22
6 classes	−57,949.465*	116,125.247	115,950.930	116,042.626	<0.001	0.893	26

*Although the best log likelihood value was replicated in these classes, solutions from subsequent log likelihood values revealed different parameter estimates and/or class sizes, or produced errors. Therefore, the results of these models may not be trustworthy[31].

TABLE III Model Parameters for the GMMs and LCGA

Model and Class	Factor Loading, 3-Month OHS	Intercept*	Slope*	Patients per Class†
GMM 1 class				
Class 1	0.856	23.84 ± 0.109	18.52 ± 0.121	6,030 (100%)
GMM 2 classes				
Class 1	−3.38	25.82 ± 0.471	−0.143 ± 0.178	460 (7.6%)
Class 2	0.851	24.17 ± 0.114	19.59 ± 0.122	5,570 (92.4%)
GMM 3 classes				
Class 1	2.164	19.72 ± 0.518	5.16 ± 0.484	463 (7.7%)
Class 2	0.868	24.37 ± 0.119	19.71 ± 0.126	5,290 (87.7%)
Class 3	−0.018	23.72 ± 0.755	15.86 ± 0.986	277 (4.6%)
GMM 4 classes				
Class 1	−0.088	23.00 ± 0.888	18.22 ± 1.135	176 (2.9%)
Class 2	3.287	16.84 ± 0.851	3.13 ± 0.346	232 (3.8%)
Class 3	1.095	21.65 ± 0.334	12.35 ± 0.444	865 (14.3%)
Class 4	0.847	24.66 ± 0.126	20.42 ± 0.134	4,757 (78.9%)
GMM 5 classes				
Class 1	−1.516	18.65 ± 0.816	−3.59 ± 0.399	102 (1.7%)
Class 2	0.983	21.99 ± 0.295	14.57 ± 0.381	1,028 (17%)
Class 3	−0.108	23.07 ± 0.877	19.00 ± 1.070	152 (2.5%)
Class 4	1.938	21.14 ± 0.992	5.88 ± 1.161	325 (5.4%)
Class 5	0.838	24.84 ± 0.132	20.69 ± 0.134	4,423 (73.3%)
GMM 6 classes				
Class 1	1.863	20.43 ± 0.630	6.84 ± 0.850	189 (3.1%)
Class 2	1.052	22.40 ± 0.311	14.96 ± 0.436	314 (5.2%)
Class 3	−0.106	24.18 ± 1.006	20.17 ± 1.117	945 (15.7%)
Class 4	−1.552	18.78 ± 0.906	−3.48 ± 0.390	4,351 (72.2%)
Class 5	0.319	20.42 ± 0.847	13.65 ± 1.049	124 (2.1%)
Class 6	0.837	24.87 ± 0.136	20.74 ± 0.135	107 (1.8%)
LCGA 1 class				
Class 1	0.856	23.84 ± 0.109	18.52 ± 0.121	6,030 (100%)
LCGA 2 classes				
Class 1	0.875	18.75 ± 0.342	10.53 ± 0.514	765 (12.7%)
Class 2	0.855	24.60 ± 0.120	19.70 ± 0.125	5,265 (87.3%)
LCGA 3 classes				
Class 1	2.371	16.47 ± 0.574	3.84 ± 0.870	238 (3.9%)
Class 2	0.846	25.00 ± 0.132	20.25 ± 0.131	4,666 (77.4%)
Class 3	0.831	20.79 ± 0.271	14.74 ± 0.392	1,126 (18.7%)
LCGA 4 classes				
Class 1	0.822	21.72 ± 0.247	17.16 ± 0.368	1,383 (22.9%)
Class 2	8.871	15.91 ± 0.734	0.97 ± 0.957	146 (2.4%)
Class 3	1.153	19.69 ± 0.456	9.86 ± 0.606	458 (7.6%)
Class 4	0.836	25.34 ± 0.146	20.63 ± 0.141	4,043 (67%)
LCGA 5 classes				
Class 1	−0.157	20.60 ± 0.989	22.17 ± 1.469	86 (1.4%)
Class 2	0.844	25.39 ± 0.149	20.59 ± 0.140	4,015 (66.6%)
Class 3	0.884	21.79 ± 0.254	16.95 ± 0.410	1,336 (22.2%)
Class 4	9.165	15.82 ± 0.770	0.91 ± 1.045	140 (2.3%)
Class 5	1.154	19.56 ± 0.495	9.84 ± 0.707	453 (7.5%)

continued

TABLE III (*continued*)

Model and Class	Factor Loading, 3-Month OHS	Intercept*	Slope*	Patients per Class†
LCGA 6 classes				
Class 1	−4.779	15.70 ± 0.846	−1.48 ± 1.455	91 (1.5%)
Class 2	0.859	22.16 ± 0.252	18.40 ± 0.559	1,393 (23.1%)
Class 3	−0.175	20.19 ± 1.151	24.16 ± 1.841	62 (1%)
Class 4	0.966	21.21 ± 0.592	12.69 ± 0.626	604 (10%)
Class 5	1.467	17.99 ± 0.656	7.58 ± 1.068	261 (4.3%)
Class 6	0.840	25.64 ± 0.170	20.75 ± 0.146	3,619 (60%)

*The values are given as the mean and the standard error. †The values are given as the number of patients, with the percentage in parentheses.

to latent growth curve modeling, or its often used mathematical equivalence, the mixed or multilevel model[12]. A mixed model applied to longitudinal data allows for estimating the degree of heterogeneity between patients in recovery trajectories by estimating the random slope variance (see the study by Laird and Ware[13] for an explanation of random slope models). Porsius et al.[14] used latent class growth modeling to analyze subgroups of patients according to their hip function trajectory during the first 6 weeks after total hip arthroplasty. To our knowledge, only 1 other study used such a model to examine change in patient-reported outcomes after total hip arthroplasty, but the authors did not report on their random effects and used a small sample of only 80 patients[15]. The advantage of latent class growth modeling is that heterogeneity can be addressed by modeling different recovery patterns for different subgroups of patients[9,16,17]. For example, previous successful applications have illustrated the wide variety in patients' responses to total knee arthroplasty[18] or cardiac rehabilitation[19].

To properly study heterogeneity in recovery after total hip arthroplasty, it is important to study a large, nationally representative sample of patients. In the present study, we applied latent class growth modeling to outcomes as gathered by the Dutch Arthroplasty Register (Landelijke Registratie Orthopedische Implantaten [LROI])[20]. We aimed to characterize subgroups of patients according to their hip function and pain trajectory, as measured with the Oxford Hip Score (OHS), and to determine associations with preoperative and perioperative characteristics.

Materials and Methods

Data Source

The data for this study were extracted from the LROI. This Dutch national, web-based longitudinal database contains data on primary and revision arthroplasties and on patient-reported outcome measures; the database began in 2007 and started recording patient-reported outcome measures in 2014. Large-scale registration of patient-reported outcome measures from patients who underwent total hip arthroplasty started in 2015. In 2016, data on surgical procedures (e.g., patient characteristics and surgical variables) were provided by up to 100 hospitals and clinics, with a completeness of registration of 99% of the total number of performed arthroplasties. Data on patient-reported outcome measures were provided by up to 80 centers[20].

Data Collection

We obtained prospectively collected data from the LROI, from patients who had undergone a primary total hip arthroplasty between January 1, 2014, and December 31, 2016, and who had a primary diagnosis of osteoarthritis. For the purpose of the present study, we selected all patients who completed the OHS preoperatively (a maximum of 182 days preoperatively), at 3 months postoperatively (63 to 110 days postoperatively), and at 12 months postoperatively (323 to 407 days postoperatively). Obtained data comprised patient characteristics (age, sex, smoking, American Society of Anesthesiologists [ASA] grades and Charnley class, BMI, and previous surgical procedures on the involved hip), surgery details (approach, fixation, articulation, and femoral-head diameter), revision status, and patient-reported outcome measures (Numeric Rating Scale for pain, OHS, Hip disability and Osteoarthritis Outcome Score Physical Function Shortform (HOOS-PS)[21], and EuroQol-5 Dimensions (EQ-5D)[22].

Outcome

The outcome of interest consisted of the reported severity of problems with the involved hip as measured with the commonly used OHS (range, 0 to 48 points)[23]. The OHS is calculated by summing the answers of 12 questions related to pain and functional problems with regard to the involved hip. Higher scores indicate better functioning and less pain[24]. Anchor-based methods have revealed that a change score of approximately 11 points on the OHS indicates a meaningful improvement at the group level[25].

Predictors

Predictors of interest that were extracted from the database included preoperative patient characteristics (age [dichotomized to ≤75 years and >75 years], sex, smoking, ASA grade, Charnley class, BMI, previous surgical procedure on the involved hip, and all preoperative EQ-5D items and EQ-5D visual analog scale [VAS] scores as predictors (except for EQ-5D Mobility because the OHS itself already contains items

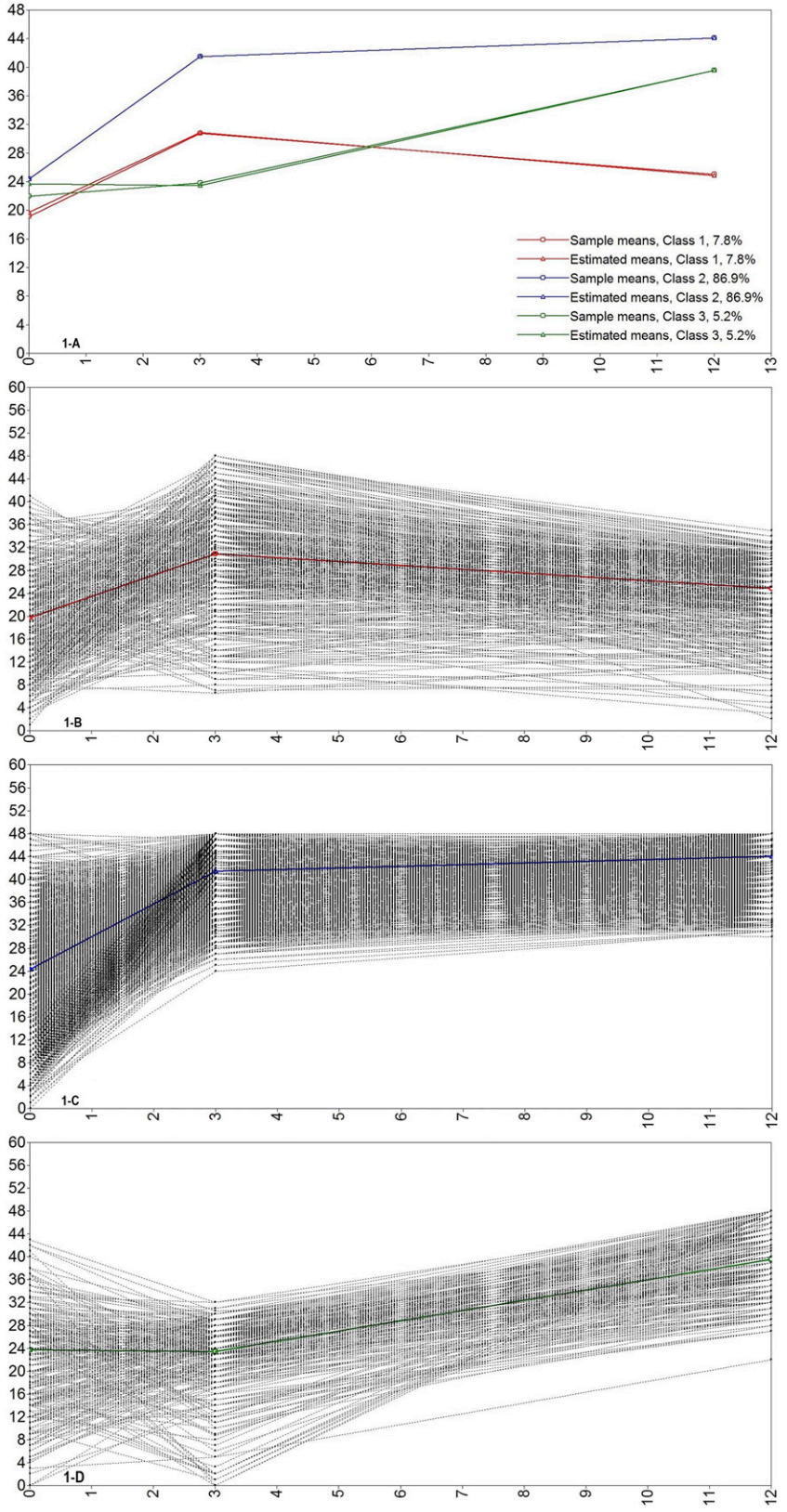

Fig. 1

Figs. 1-A through 1-D Plots of the 3-class GMM: the estimated means and sample means (**Fig. 1-A**) and the estimated means and observed individual values for class 1 (late dippers) (**Fig. 1-B**), class 2 (fast starters) (**Fig. 1-C**), and class 3 (slow starters) (**Fig. 1-D**).

TABLE IV Univariable Multinomial Logistic Regression Analysis with Class Membership as the Dependent Variable*

	Slow Starters vs. Fast Starters		Late Dippers vs. Fast Starters	
	OR†	P Value	OR†	P Value
Age >75 years vs. ≤75 years	1.21 (0.88 to 1.68)	0.247	1.72 (1.37 to 2.16)	<0.001
Female vs. male	1.61 (1.17 to 2.22)	0.004	1.49 (1.18 to 1.87)	0.001
Smoking vs. no smoking	1.76 (1.17 to 2.66)	0.007	1.48 (1.06 to 2.05)	0.020
ASA grade III or IV vs. I or II	1.52 (1.05 to 2.19)	0.026	2.27 (1.78 to 2.90)	<0.001
BMI				
Normal weight (<25 kg/m^2) (reference)	1.0	—	1.0	—
Overweight (BMI 25 to <30 kg/m^2)	1.11 (0.78 to 1.59)	0.551	1.15 (0.88 to 1.51)	0.307
Obese (BMI ≥30 kg/m^2)	1.90 (1.31 to 2.74)	0.001	2.33 (1.77 to 3.07)	<0.001
Had previous surgery	0.84 (0.24 to 2.89)	0.779	1.65 (0.86 to 3.18)	0.133
Charnley class				
A (reference)	1.0	—	1.0	—
B1	1.28 (0.91 to 1.80)	0.154	1.12 (0.88 to 1.45)	0.360
B2	1.46 (1.01 to 2.09)	0.042	1.16 (0.88 to 1.53)	0.286
C	1.36 (0.57 to 3.25)	0.492	1.97 (1.16 to 3.33)	0.012
EQ-5D Self-Care				
No problems (reference)	1.0	—	1.0	—
Some problems washing or dressing	1.42 (1.06 to 1.89)	0.018	2.10 (1.69 to 2.61)	<0.001
Unable to wash or dress	2.88 (0.96 to 8.62)	0.059	8.08 (4.37 to 14.95)	<0.001
EQ-5D Usual Activities				
No problems (reference)	1.0	—	1.0	—
Some problems with performing usual activities	1.80 (1.05 to 3.08)	0.031	2.44 (1.53 to 3.90)	<0.001
Unable to perform usual activities	3.04 (1.60 to 5.78)	0.001	6.40 (3.82 to 10.71)	<0.001
EQ-5D Pain/Discomfort				
No pain or discomfort (reference)	1.0	—	1.0	—
Moderate pain or discomfort	1.42 (0.64 to 3.16)	0.385	2.64 (1.10 to 6.32)	0.030
Extreme pain or discomfort	2.43 (1.08 to 5.48)	0.033	6.35 (2.64 to 15.29)	<0.001
EQ-5D Anxiety/Depression				
Not anxious or depressed (reference)	1.0	—	1.0	—
Moderately anxious or depressed	1.28 (0.92 to 1.78)	0.149	2.02 (1.61 to 2.54)	<0.001
Extremely anxious or depressed	3.66 (2.01 to 6.65)	<0.001	4.50 (2.88 to 7.06)	<0.001
EQ-5D VAS (per 10 points)	0.90 (0.83 to 0.97)	0.003	0.81 (0.78 to 0.84)	<0.001
Approach				
Posterolateral (reference)	1.0	—	1.0	—
Anterior	0.46 (0.30 to 0.73)	0.001	0.53 (0.38 to 0.73)	<0.001
Anterolateral	0.70 (0.29 to 1.70)	0.433	1.17 (0.69 to 1.99)	0.560
Direct lateral	1.40 (0.93 to 2.11)	0.110	2.06 (1.56 to 2.72)	<0.001
Other‡	—	—	—	—
Fixation				
Cemented (reference)	1.0	—	1.0	—
Hybrid, cemented acetabular implant	0.68 (0.23 to 2.02)	0.486	1.44 (0.89 to 2.34)	0.138
Hybrid, cemented femoral implant	1.49 (0.81 to 2.73)	0.201	0.80 (0.49 to 1.30)	0.363
Uncemented	0.82 (0.58 to 1.17)	0.274	0.49 (0.39 to 0.62)	<0.001
Femoral-head diameter				
32 mm (reference)	1.0	—	1.0	—
22 to 28 mm	0.99 (0.69 to 1.42)	0.965	1.69 (1.33 to 2.15)	<0.001
≥36 mm	0.99 (0.68 to 1.42)	0.939	1.02 (0.77 to 1.36)	0.884

*The fast starters class was used as the reference class. †The values are given as the OR, with the 95% CI in parentheses. ‡No reliable OR could be determined.

TABLE V Multivariable Multinomial Logistic Regression Analysis with Class Membership as the Dependent Variable*

	Slow Starters vs. Fast Starters		Late Dippers vs. Fast Starters	
	OR†	P Value	OR†	P Value
Age >75 years vs. ≤75 years	1.22 (0.83 to 1.79)	0.310	1.62 (1.22 to 2.15)	0.001
Female vs. male	1.63 (1.14 to 2.33)	0.007	1.22 (0.94 to 1.59)	0.132
Smoking vs. no smoking	1.95 (1.26 to 3.03)	0.003	1.68 (1.17 to 2.42)	0.005
ASA grade III or IV vs. I or II	1.20 (0.78 to 1.87)	0.405	1.41 (1.05 to 1.91)	0.023
BMI				
Normal weight (<25 kg/m^2) (reference)	1.0	—	1.0	—
Overweight (BMI 25 to <30 kg/m^2)	1.19 (0.82 to 1.74)	0.360	1.17 (0.86 to 1.58)	0.320
Obese (BMI ≥30 kg/m^2)	1.54 (1.02 to 2.33)	0.041	1.96 (1.43 to 2.69)	<0.001
Had previous surgery	0.82 (0.19 to 3.51)	0.788	1.13 (0.51 to 2.51)	0.764
Charnley class				
A (reference)	1.0	—	1.0	—
B1	1.41 (0.97 to 2.04)	0.070	1.14 (0.86 to 1.52)	0.353
B2	1.46 (0.98 to 2.19)	0.066	1.26 (0.93 to 1.71)	0.130
C	1.39 (0.57 to 3.36)	0.467	1.57 (0.82 to 3.00)	0.171
EQ-5D Self-Care				
No problems (reference)	1.0	—	1.0	—
Some problems washing or dressing	0.98 (0.70 to 1.37)	0.887	1.41 (1.09 to 1.82)	0.008
Unable to wash or dress	1.40 (0.42 to 4.70)	0.590	2.90 (1.39 to 6.03)	0.004
EQ-5D Usual Activities				
No problems (reference)	1.0	—	1.0	—
Some problems with performing usual activities	1.50 (0.81 to 2.77)	0.201	1.36 (0.81 to 2.27)	0.242
Unable to perform usual activities	1.89 (0.86 to 4.13)	0.112	1.53 (0.83 to 2.83)	0.175
EQ-5D Pain/Discomfort				
No pain or discomfort (reference)	1.0	—	1.0	—
Moderate pain or discomfort	1.23 (0.50 to 3.04)	0.660	1.79 (0.71 to 4.48)	0.215
Extreme pain or discomfort	1.65 (0.64 to 4.26)	0.305	2.47 (0.96 to 6.33)	0.060
EQ-5D Anxiety/Depression				
Not anxious or depressed (reference)	1.0	—	1.0	—
Moderately anxious or depressed	0.93 (0.63 to 1.36)	0.699	1.31 (1.00 to 1.71)	0.048
Extremely anxious or depressed	1.84 (0.92 to 3.71)	0.086	1.86 (1.06 to 3.24)	0.030
EQ-5D VAS (per 10 points)	0.96 (0.89 to 1.04)	0.366	0.91 (0.86 to 0.97)	0.003
Approach				
Posterolateral (reference)	1.0	—	1.0	—
Anterior	0.47 (0.29 to 0.78)	0.003	0.71 (0.50 to 1.01)	0.057
Anterolateral	0.64 (0.25 to 1.60)	0.335	1.13 (0.63 to 2.02)	0.689
Direct lateral	1.39 (0.86 to 2.24)	0.176	2.18 (1.58 to 3.02)	<0.001
Other†	—	—	—	—
Fixation				
Cemented (reference)	1.0	—	1.0	—
Hybrid, cemented acetabular implant	0.75 (0.21 to 2.70)	0.665	1.79 (1.00 to 3.21)	0.049
Hybrid, cemented femoral implant	1.97 (0.97 to 4.01)	0.060	1.54 (0.91 to 2.63)	0.110
Uncemented	1.19 (0.77 to 1.82)	0.435	0.89 (0.67 to 1.19)	0.431
Femoral-head diameter				
32 mm (reference)	1.0	—	1.0	—

continued

TABLE V (*continued*)

	Slow Starters vs. Fast Starters		Late Dippers vs. Fast Starters	
	OR†	P Value	OR†	P Value
22 to 28 mm	0.95 (0.62 to 1.45)	0.814	1.29 (0.98 to 1.71)	0.066
≥36 mm	1.16 (0.77 to 1.76)	0.479	1.00 (0.72 to 1.40)	0.998

*The fast starters class was used as the reference class. †The values are given as the OR, with the 95% CI in parentheses. ‡No reliable OR could be determined.

with regard to walking), as well as surgery-specific factors (approach, fixation, and femoral-head diameter).

Statistical Analyses

We used SPSS Statistics version 21.0 (IBM) for data cleaning and providing descriptive values of our overall sample. To investigate whether different subgroups could be distinguished in our sample based on the trajectories of the OHS, we used Mplus Version 8.1 (Muthén & Muthén[26]) to perform 1-class to 6-class latent class growth modeling analyses in the form of a latent class growth analysis (LCGA) and a growth mixture model (GMM) in addition to a conventional growth model. See Appendix 1 for a description of the differences between a conventional growth model and the LCGA and GMM and for a detailed description of our model specification and selection.

As previous research has demonstrated a nonlinear growth pattern after total hip arthroplasty[1-5], we specified a latent basis model for the growth pattern in all models[9,17]. The first measurement (preoperative) was fixed to 0, the last measurement (12 months postoperatively) was fixed to 1, and the second measurement (3 months postoperatively) was estimated freely. As such, the estimated mean slopes in our models represent the amount of change between the first and last measurements, and the estimated factor loading of the second measurement represents how much of that change occurred at 3 months. All models were unconditional models, meaning that the latent class probabilities were independent from other variables.

Subsequently, we used the r3step procedure in Mplus to perform both univariable and multivariable multinomial logistic regression analyses in which we compared the smaller subgroups of patients with the largest subgroup of patients.

Results

Patient Characteristics

A total of 6,030 (8.12%) of the 74,284 patients who had undergone a total hip arthroplasty in the study period had OHS data at all time points and were therefore included in the analysis; 48,926 patients (65.86%) had no OHS at any time point, 7,336 patients (9.88%) only had preoperative scores, and 11,992 patients (16.14%) were missing 1 of the 3 OHS.

Patients who had no missing OHS (and were thus included in our analysis) were slightly younger, slightly more often male, and slightly more often nonsmokers and had somewhat better weight, Charnley class, and ASA grade compared with patients who were missing 1 or more OHS (see also Appendix 2, Table 1). These differences are similar to those found by the LROI, which compared patients who completed preoperative and 3-month patient-reported outcome measures in 2016 with the entire total hip arthroplasty population of 2016[27].

Table I displays the patient characteristics of the entire sample, as well as the characteristics of each class in our final model.

Selection of the Final Model

The model fit statistics are summarized in Table II, as well as the model parameters (i.e., factor loading, intercept, slope, and class size) shown in Table III.

We chose the 3-class GMM as our final model (Fig. 1); we based this on the combination of the distinct trajectories, entropy, class sizes, and the fact that, although fit statistics continued to decrease up to the 6-class model, this decrease started to flatten out from the 3-class model. See Appendix 3 for figures showing the latent class growth analyses (Appendix 3, Figs. 2-A through 2-F) and GMMs with 1 to 6 classes (Appendix 3, Figs. 3-A through 3-F); the conventional growth model is identical to the 1-class GMM.

A detailed explanation of the selection process of the final model and detailed model results that show that our final model demonstrated good classification accuracy are given in Appendix 2.

Trajectory Patterns

Figure 1 shows the estimated trajectory for the entire group in combination with the observed individual trajectories of each class.

The largest class consisted of 5,290 patients and was portrayed by a steep improvement in the OHS during the first 3 months, after which the OHS leveled out. We labeled this class as fast starters. At 3 months, the fast starters reached 86.8% of the total amount of change at 1 year postoperatively.

The class labeled as late dippers (463 patients) demonstrated an initial, more modest improvement in the OHS and subsequently a decline toward the 1-year mark, although there was still improvement at 1 year postoperatively compared with preoperatively. At 3 months postoperatively, the late dippers reached 216.4% of their overall change between the preoperative and 1-year postoperative OHS.

The smallest class, consisting of 277 patients and labeled as slow starters, was characterized by virtually no change at the

3-month mark (−1.8% of their overall change), followed by an improvement in OHS at 1 year postoperatively.

Tables II and III show the exact values of the initial status and the overall change for each class.

Differences Between Classes in Patient Characteristics

For all analyses, the fast starters class was chosen as the reference category. The results of the multinomial logistic regression analyses are shown in Table IV for the univariable analysis and in Table V for the multivariable analysis.

In the univariable analysis, the following variables were significant ($p < 0.05$) for membership in the class of slow starters: female sex; smoking; ASA grades of III or IV; obesity (BMI ≥30 kg/m^2); Charnley class B2; problems in the EQ-5D Self-Care, Usual Activities, Pain/Discomfort, and Anxiety/Depression; poorer EQ-5D VAS (per 10 points); and an anterior approach, which had a protective effect against class membership.

The variables that were significant for membership in the class of late dippers were age of >75 years; female sex; smoking; ASA grades of III or IV; obesity (BMI ≥30 kg/m^2); Charnley class C; problems in EQ-5D Self-Care, Usual Activities, Pain/Discomfort, and Anxiety/Depression; poorer EQ-5D VAS (per 10 points); direct lateral approach; anterior approach, which had a protective effect against class membership; not uncemented fixation; and femoral-head diameter of 22 to 28 mm.

In the multivariable analysis, the following variables remained significant ($p < 0.05$) for membership in the class of slow starters: female sex, smoking, obesity (BMI ≥30 kg/m^2), and an anterior approach, which had a protective effect against class membership.

The variables that remained significant ($p < 0.05$) for membership in the class of late dippers were age of >75 years, smoking, ASA grades of III or IV, obesity (BMI ≥30 kg/m^2), problems in EQ-5D Self-Care and Anxiety/Depression, poorer EQ-5D VAS (per 10 points), direct lateral approach, and hybrid fixation (cemented acetabular implant).

Discussion

We found 3 subgroups with different functional recovery trajectories in our large sample of 6,030 patients who had undergone total hip arthroplasty: fast starters, slow starters, and late dippers. Based on our results using the OHS as an outcome measure for patients who underwent total hip arthroplasty, fast starters had the most favorable trajectory and late dippers had the least favorable response trajectory.

In addition, we found in a multivariable analysis that female sex, age of >75 years, obesity, ASA grade of III or IV, lower preoperative perceived health, direct lateral approach, and hybrid fixation (cemented acetabular implant) were associated with not being classified as a fast starter.

Our study corroborated other studies that found an association of certain variables with an unfavorable response. Systematic reviews by Buirs et al.[6], Hofstede et al.[7], and Lungu et al.[8] found that functional outcomes were associated with, among other variables, higher BMI, more comorbidities, and poorer general mental health. Accordingly, in our study, patients with obesity, higher ASA grades, lower EQ-5D VAS scores, and higher scores on EQ-5D Self-Care and Anxiety/Depression were more likely to be classified into the late dippers subgroup.

Interestingly, problems with Self-Care, Anxiety/Depression, and overall quality of life were not just markers for general health in our sample, but appear to have had an independent effect on the outcomes after total hip arthroplasty; even after correcting for age, smoking, ASA grade, and BMI, these items still increased the odds of becoming late dippers.

The subgroups and trajectories that we found in our study differ from those in the study by Lenguerrand et al.[15]. This may be due to the different statistical approach: Lenguerrand et al.[15] predefined 2 subgroups (i.e., high or low preoperative scores) and used a random effects model to estimate 1 trajectory per subgroup. In contrast, we did not predefine subgroups but used latent class growth modeling to explore if and how many different subgroups could be distinguished and, although we hypothesized that trajectories of the subgroups could differ qualitatively, we did not impose specific shapes of trajectories. This gave us the advantage of letting previously unknown subgroups emerge from the data.

We find it interesting that no subgroup marking "no improvement" or "decline" in outcomes emerged. Visual inspections of the plots suggest that these trajectories are very uncommon in our large sample and are therefore incorporated in the smaller, more heterogeneous, subgroups, instead of forming a separate subgroup; even in the 6-class models, no such trajectory emerged.

Unfortunately, we could not define any factors that clearly distinguished between late dippers and slow starters. We find it likely that the difference between late dippers and slow starters is determined by other patient-related factors that were not measured in the LROI.

For example, psychological factors such as preoperative expectations might influence how patients perceive pain and functional outcomes[28,29]. Expectations and other psychological factors such as pain catastrophizing[30] and illness perceptions were not measured in the LROI; therefore, we could not investigate their role in the subgroups that we found.

Moreover, the subjective nature of our outcome scores may have been amplified in the trajectories. For example, late dippers may have been quite pleased at the 3-month mark with the progress so far in relation to their starting point and thus offered an optimistic valuation of the OHS. Subsequently, this elation may have worn off after time (while perhaps the progress stagnated), allowing for a more realistic (or even pessimistic) valuation of the OHS at 12 months.

The greatest strength of this study is the uniquely large sample size combined with the analysis of recovery trajectories, therefore adding to the current literature a more detailed understanding of the degree of variation between patients in recovery after total hip arthroplasty.

There were also some important potential drawbacks associated with our study. One limitation was that the database did not contain more detailed patient-related information (e.g., coping style), probably one of the reasons that we could not differentiate between late dippers and slow starters. Furthermore, although the 3 observations of the OHS are sufficient to employ a latent basis

model, it is possible that the true underlying trajectories could have been described more accurately with more observations.

Another drawback was that we analyzed data from patients who had complete OHS data for all time points; because large-scale registration of patient-reported outcome measures started in 2015, not all hospitals registered patient-reported outcome measures for the patients in this study. In addition, the methods of collecting patient-reported outcome measures differ between hospitals; this may also have affected the completeness of the patient-reported outcome measures. Consequently, our results represented the outcomes of 8% of all primary total hip arthroplasties performed during our study period and no findings were available for patients who underwent revision within the first postoperative year or who had missing OHS data. However, although we found slight differences between patients who were included in our analysis and those who were excluded, comparable with the differences found by the LROI[27], the extent to which these small differences affected the generalizability of our results to the entire Dutch total hip arthroplasty population was uncertain. Moreover, the heterogeneity in collecting patient-reported outcome measures was also present in the LROI investigation of differences between patients.

In conclusion, we discerned fast starters, slow starters, and late dippers after total hip arthroplasty. Female sex, smoking, older age, obesity, higher ASA grades, and poorer EQ-5D scores were associated with a less favorable response to total hip arthroplasty, as well as hybrid fixation (cemented acetabular implant) and direct lateral approach. Anterior approach had a protective effect against a less favorable response. Ultimately, all subgroups experienced functional improvement following total hip arthroplasty. Our findings may enable surgeons to more accurately estimate which patients are at risk of a less favorable recovery. In turn, this will improve the capability of surgeons to provide tailored expectation management to patients undergoing total hip arthroplasty.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/F582). ■

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