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Variability in recovery following microdiscectomy and postoperative physiotherapy for lumbar radiculopathy: A latent class trajectory analysis☆

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ABSTRACT

Objectives: The clinical course of lumbar radiculopathy following microdiscectomy and post-operative physiotherapy varies substantially. No prior studies assessed this variability by deriving outcome trajectories. The primary aims of this study were to evaluate the variability in long-term recovery after lumbar microdiscectomy followed by post-operative physiotherapy and to identify outcome trajectories. The secondary aim was to assess whether demographic, clinical characteristics and patient-reported outcome measures routinely collected at baseline could predict poor outcome trajectories.

Methods: We conducted a prospective cohort study with a 24-month follow-up. We included 479 patients with clinical signs and symptoms of lumbar radiculopathy confirmed by Magnetic Resonance Imaging findings, who underwent microdiscectomy and post-operative physiotherapy. Outcomes were leg pain and back pain measured with Visual Analogue Scales, and disability measured with the Roland-Morris Disability Questionnaire. Descriptive statistics were performed to present the average and the individual clinical course. A latent class trajectory analysis was conducted to identify leg pain, back pain, and disability outcome trajectories. The best number of clusters was determined using the Bayesian Information Criterion, Akaike's information criteria, entropy, and overall interpretability. Prediction models for poor outcome trajectories were assessed using multivariable logistic regression analyses.

Results: Several outcome trajectories were identified. Most patients were assigned to the 'large improvement' trajectory (leg pain: 79.3%; back pain: 70.2%; disability: 59.5% of patients). Smaller proportions of patients were assigned to the 'moderate improvement' trajectory (leg pain: 7.9%; back pain: 10.6%; disability: 20.7% of patients), the 'minimal improvement' trajectory (leg pain: 4.9%, back pain: 6.7%, disability: 16.3% of patients) and the 'relapse' trajectory (leg pain: 7.9%; back pain: 12.5%; disability: 3.5%). Approximately one-third of patients

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(32.6%) belonged to one or more than one poor outcome trajectory. Patients with previous treatment (prior back surgery, injection therapy, and medication use) and those who had higher baseline pain and disability scores were more likely to belong to the poor outcome trajectories in comparison to the large improvement trajectories in back pain, leg pain and disability, and the moderate improvement trajectory in disability. The explained variance (Nagelkerke R2) of the prediction models ranged from 0.06 to 0.13 and the discriminative ability (Area Under the Curve) from 0.66 to 0.73.

Conclusion: The clinical course of lumbar radiculopathy varied following microdiscectomy and post-operative physiotherapy, and several outcome trajectories could be identified. Although most patients were allocated to favorable trajectories, one in three patients was assigned to one or more poor outcome trajectories following microdiscectomy and post-operative physiotherapy for lumbar radiculopathy. Routinely gathered data were unable to predict the poor outcome trajectories accurately. Prior to surgery, clinicians should discuss the high variability and the distinctive subgroups that are present in the clinical course with their patients.

1. Introduction

Lumbar microdiscectomy is a common intervention for lumbar radiculopathy when conservative treatment fails [17,32,36]. Lumbar microdiscectomy often results in an immediate clinically relevant improvement in leg pain and disability with accompanying improvements in back pain [18,27]. However, serious complications and the need for additional treatment, such as reoperation (7.3%), nerve root blocks (6.7%), or opioid use (15.6%) occur in the first year after surgery, reflecting undesirable outcomes [29]. Furthermore, most patients still experience mild to moderate pain and disability up to 7 years after surgery [18,27].

Knowledge of the clinical course is important because this information can help clinicians to better inform patients about the expected outcomes and identify patients at risk for a poor outcome [6,27]. The course of pain and disability is often expressed as the general group mean or variance-weighted mean [27]. However, the general group means masks important heterogeneity, and many patients may not fit the average trajectory profiles [2,21].

An alternative way of understanding how patients recover after lumbar microdiscectomy is to assess the variability in their course by classifying them into clinically meaningful outcome trajectories [7,21,34]. Identifying variables that predict these trajectories enable clinicians to predict patients at risk for poor outcome trajectories [7,21,34]. In patients with lumbar spinal stenosis, three outcome trajectories have been identified for pain and disability following surgery: leg pain (excellent outcome: 14.4%, good outcome: 49.5%, poor outcome: 36.1% of patients), and disability (excellent outcome: 30.8%, fair outcome: 40.1%, poor outcome: 29.1% of patients) [12]. Several factors, such as higher preoperative disability, longer surgery waiting time, pain duration longer than two years, and financial compensation predicted poor overall outcome trajectories for surgery for spinal stenosis [13]. In spinal deformity surgery, four distinctive outcome trajectories with different patient characteristics and levels of patient satisfaction were identified (most improved: 45.3%, mildly improved: 40.2%, remained the same: 13.0%, and a worsened-condition: 1.4% of patients) [41].

To the best of our knowledge, no prior studies identified the variability in the clinical course by deriving outcome trajectories for lumbar radiculopathy following microdiscectomy and post-operative physiotherapy. This information can further increase our understanding of how subgroups of patients with lumbar radiculopathy recover after microdiscectomy and may help clinicians in determining perioperative rehabilitation strategies. The primary aims of this study were to evaluate the variability in long-term recovery after lumbar microdiscectomy followed by post-operative physiotherapy and to identify outcome trajectories. The secondary aim was to assess whether demographic, clinical characteristics, and patient-reported outcome measures at routinely collected baseline could predict poor outcome trajectories.

2. Material and methods

2.1. Design

We conducted a prospective cohort study with 24 months of follow-up. The methods and results were reported in accordance with recommendations made in the GRoLTS-Checklist, a guideline for reporting latent class trajectory studies [35] (Appendix A). The Medical Ethics Review Board of the Elisabeth Hospital in Tilburg, The Netherlands, approved the study (METC-T2012).

2.2. Patients

Patients were recruited in a multidisciplinary musculoskeletal health clinic in the Netherlands. Those who had clinical signs and symptoms of lumbosacral nerve root compression, confirmed by Magnetic Resonance Imaging (MRI) findings of a disc herniation at the corresponding level, and who underwent microdiscectomy and postoperative physiotherapy, were eligible for participation. Patients had to be at least 18 years of age, and proficient in Dutch to complete the questionnaires.

A lumbar microdiscectomy was performed via a posterior approach by a neurosurgeon (13 years of experience) or an orthopaedic surgeon (35 years of experience). The aim of the intervention is to relieve pressure on the lumbar nerve root by removing part of the disc and the ligament flavum. The day after surgery, all patients received a physiotherapy session which included information about recovery, guidelines for home, and some basic exercises. At discharge, patients were referred to a primary care physiotherapist with a treatment plan including goals to improve knowledge and understanding about rehabilitation, muscle strength, muscle endurance, mobility and resume daily activities, work, and sports. The content of the program, number of sessions, and treatment duration were tailored to the individual goals and needs of the patients.

2.3. Data collection

At baseline, demographic information and clinical characteristics were gathered by the neurosurgeon or orthopaedic surgeon, and PROMs for leg pain, back pain, and disability were completed by the patients. Baseline characteristics were contained in five domains: (1). Sociodemographic data: age, sex, and comorbidity. (2). Presurgical treatment data: prior back surgery, physiotherapy preoperative, injection therapy preoperative, and pain medication preoperative. (3). Symptoms: preoperative back and leg pain intensity (Visual Analogue Scale (VAS): 0–100 mm), leg pain more intense than back pain (VAS), baseline disability (Roland-Morris Disability Questionnaire (RMDQ): 0–24 points). (4). Neurological examination: Straight Leg Raise test (SLR), reflexes, sensitivity, and muscle strength. (5). Medical imaging: level of disc herniation, comorbidity seen on MRI, such as spinal stenosis, spinal cyst, facet arthrosis, and hypoplastic disc.

The data gathered were based on routinely gathered data that are commonly collected in clinical care. The outcome measures to

determine success were collected 3, 12, and 24 months postoperatively using OnlinePROMS, an internet-based platform designed to collect questionnaire data (Interactive Studios, Rosmalen, The Netherlands). Patients who preferred paper-based forms received the questionnaires via mail. Reminders were sent to non-responders 7 and 14 days after the scheduled follow-up time-point. Patients who did not or only partly completed the questionnaires were approached once by telephone and encouraged to complete the questionnaires.

2.4. Outcome measures

Outcome measures included leg pain, back pain intensity (VAS), and disability (RMDQ). The VAS ranged from 0 to 100, where a higher score indicates a higher intensity of pain [37]. The RMDQ contains 24 yes/no items. The RMDQ-24 score is calculated by adding the number of "yes" items. The scale ranges from 0 (no disability) to 24 (maximum disability) [25]. The RMDQ and VAS are considered valid and reliable instruments with a high test-retest reliability and are commonly used in lumbar spinal surgery [25,33,42].

2.5. Statistical analysis

Descriptive statistics were performed to present the average and the individual clinical course of lumbar radiculopathy following microdiscectomy and post-operative physiotherapy. Latent class trajectory analysis was employed for the identification of homogeneous clusters [7,24,34]. Separate group-based trajectory models were created to identify outcome trajectories for each outcome variable (leg pain, back pain, and disability) with different time points (3, 12, and 24 months). Missing value analyses were performed by using Little's MCAR-test. Group--based trajectory models handle missing data with maximum likelihood estimation, resulting in asymptotically unbiased parameter estimates when data were missing (completely) at random [21]. For the determination of the optimal number of latent classes, we used Akaike's information criteria (AIC), the Bayesian Information Criterion (BIC), and the adjusted Bayesian Information criteria (aBIC) [7]. Lower information criteria indicate a better fit [7]. A decrease of at least 10 points for the BIC indicates sufficient improvement. Furthermore, a Bootstrap Likelihood Ratio Test (lower p-values indicate better model fit) was used to assess the goodness of fit of the models [11]. Furthermore, we looked at the posterior probabilities for individuals in the sample, and the entropy. For Entropy, the values closer to 1 were considered favourable. The best-fitting model was selected based on a combination of statistical and clinical judgment. Patients were then assigned to the outcome trajectories based on their most likely trajectory membership. Descriptive statistics were performed to present the patient demographics, clinical characteristics, and PROMs for each outcome trajectory for pain and disability.

Baseline variables were obtained in the following five domains: sociodemographic factors, previous medical history, symptoms, neurological examination, and radiological findings. These variables were selected as predictors based on previous systematic reviews which revealed at least moderate evidence for a univariable association with the outcomes of lumbar microdiscectomy [5,9,28,40]. Additionally, predictor variables deemed relevant by a clinical expert panel (n = 4) consisting of a neurosurgeon, two orthopaedic surgeons, and a physiotherapist was considered. Appendix B summarises all potential predictor variables selected for the different trajectories. The number of selected variables per outcome varied depending on the number of (non)recovered patients using the rule of thumb of ten patients per predictor variable [6].

The relationship between predictor variables and the outcome trajectories was evaluated using multivariable logistic regression analyses with a backward Wald selection procedure (final model, $P < 0.157$) [20,31]. All assumptions (linearity between independent continuous variables, log odds, and multicollinearity) were checked before model building. The quality of the multivariable model was determined with Hosmer–Lemeshow goodness-of-fit statistic and the explained variance with Nagelkerke R2 [14]. The discriminative ability of the models was assessed using the area under the receiver-operating characteristic

Table 1
Baseline characteristics of the patients (n = 479).

Sociodemographic	
Age (mean (SD)) in years	44 (10.9)
Sex (male)	286 (59.7%)
Comorbidity (yes)[a]	89 (18.6%)
History	
Prior back surgery (yes)	73 (15.2%)
Previous physiotherapy (yes)	303 (63.3%)
Previous injection therapy (yes)	166 (34.7%)
Preoperative medication use (yes)	110 (23.0%)
Symptoms	
Pain intensity back (VAS)[b] (median (IQR))	50.0 (20.0–73.6)
Pain intensity leg (VAS)[b] (median (IQR))	75.0 (58.8–85.9)
Level of disability (RMDQ)[c] (median (IQR))	17.0 (14.0–20.0)
Neurological	
Straight leg raise test (positive)	313 (63.3%)
Reflex (absent)	119 (24.8%)
Strength (absent)	10.8 (22.5%)
Sensibility (absent)	159 (33.2%)
Radiological	
Level of disc herniation	
• L2-L3	2 (0.4%)
• L3-L4	21 (4.4%)
• L4-L5	171 (35.7%)
• L5-S1	258 (53.9%)
• More than one level n (%)	23 (4.8%)
Structural changes seen on MRI at the affected level of disc-herniation[d]	150 (31.3%)

[a] : Comorbidity, such as diabetes, cardiovascular disease, chronic obstructive pulmonary disease, hyperthyroidism. [b]: VAS = Visual Analogue Score (0–100 mm) [c]: RMDQ = Roland-Morris Disability Questionnaire (0–24 points) [d]: Structural changes on MRI on the affected level of disc herniation, spinal stenosis, spinal cyst, facet arthrosis, hypoplastic disc, or a combination.

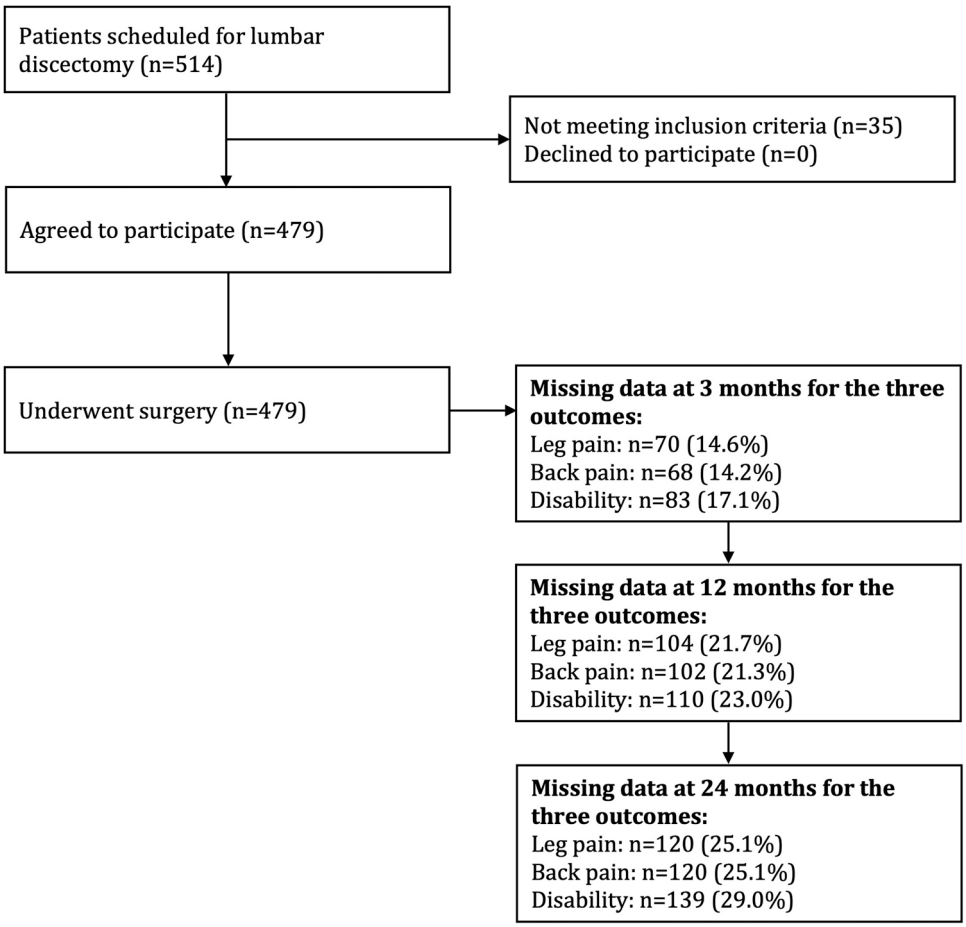

Fig. 1. Patient flow diagram.

curve. An area under the curve (AUC) of ≥ 0.5 and < 0.7 indicates poor discrimination, ≥ 0.7 and < 0.8 is acceptable discrimination, ≥ 0.8 and < 0.9 is excellent discrimination, and ≥ 0.9 indicates outstanding discrimination [14]. To correct for overfitting, the internal validity of the models was assessed through bootstrapping techniques with 500 repetitions. A Venn diagram was created to present the relationships between the distribution of patients with poor outcome in the different outcome trajectories. The latent class trajectory analysis was conducted in Mplus version 8.0; the bootstrapping was performed in R 4.0.5 and the other analyses in SPSS version 28.0 (Inc., Chicago, IL).

3. Results

3.1. Study population

Of the 532 consecutive patients scheduled for lumbar microdiscectomy, 479 patients were included in this study (mean (SD) age: 44.0 (10.9) years; 40.2% female, Table 1). Seventy-three of the patients had prior back surgery, 303 prior physiotherapy, and 110 used medications preoperatively. Most patients had surgery on one level (n = 452). L4-L5 and L5-S1 were the most frequently treated levels. The average leg pain intensity score was 75.0 (IQR 58.8–85.9), the back pain intensity score was 50.0 (IQR 20.0–73.6) and the disability score was 17.0 (IQR 14.0–20.0).

Fig. 1 shows the patient flow diagram and the loss to follow-up rates for all the outcomes. The maximum percentage lost to follow-up was 17.1% at 3 months, 23.0% at 12 months, and 29.0% at 24 months. There were no significant differences at baseline between the full cases and those who were lost to follow-up at the three follow-up time points, except for previous injection therapy on the three outcomes and previous physiotherapy on the outcome disability. The missing value analysis showed missings (completely) at random.

3.2. Population averaged and individual clinical course

The average leg pain intensity decreased from a median score of 75.0 (IQR 58.8–85.9) at baseline to 7.0 (IQR 1.0–26.0) at 3 months, 6.0 (IQR 0.5–27.0) at 12 months and 5.0 (IQR 1.0–30.0) at 24 months (Fig. 2A). The individual course for leg pain for each participant is presented in Fig. 2B.

The average back pain intensity decreased from a median of 50.0 (IQR 20.0–73.6) at baseline to 12.0 (IQR 4.7–30.0) at 3 months, 11.0 (IQR 2.4–38.8) at 12 months, and 11.8 (IQR 2.4–40.0) at 24 months (Fig. 2C). The individual course for back pain intensity for each participant is presented in Fig. 2D.

The average disability score decreased from a median score of 17.0 (IQR 14.0–20.0) at baseline to 6.0 (IQR 3.0–10.0) at 3 months, 4.0 (IQR 1.0–10.0) at 12 months and 4.0 (IQR 0.0–9.0) at 24 months (Fig. 2E). The individual course for disability for each participant is presented in Fig. 2F.

3.3. Latent class model accuracy and fit parameters

Latent class trajectory analysis was conducted for models comprising 1–5 trajectories (Table 2). Based on statistical and clinical judgment, the 4-class model provided the best fit and was selected. Detailed information regarding model fit and additional results according to the GRoLTS-Checklist are presented on Open Science Framework. (https://osf.io/ew6nh/?view_only=a78c160939a841079f6e1eb16ee42c31).

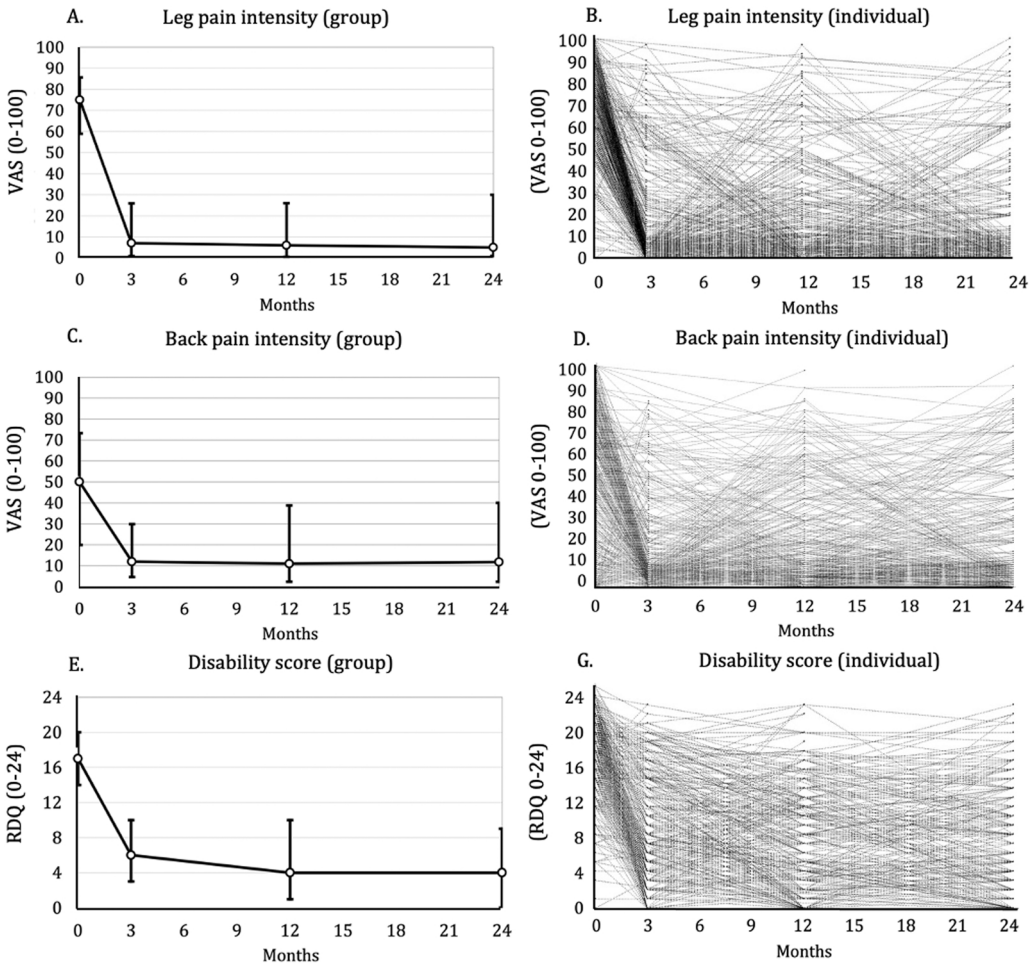

Fig. 2. Average group and individual clinical course for leg pain, back pain, and disability (n = 479). VAS = Visual Analogue Score, RMDQ = Roland-Morris Disability Questionnaire. Group data are expressed by median (IQR). Individual clinical course: each line represents one patient.

Table 2
Latent class model accuracy and fit parameters.

	# Trajectories	Loglikelihood	AIC	BIC	Adjusted BIC	BLRT	Entropy	Sample size per trajectory
Leg pain	1-class model	-7.437.718	14.891.436	14.924.809	14.899.418	p<0.001	1.000	479
	2-class model	-7.229.018	14.484.036	14.538.268	14.497.008	p<0.001	0.930	417/62
	3-class model	-7.135.154	14.306.307	14.381.398	14.324.268	p<0.001	0.892	392/54/33
	4-class model	-7.056.076	14.158.153	14.254.102	14.181.102	p<0.001	0.895	380/38/23/38
	5-class model	-7.002.799	14.061.597	14.178.405	14.089.536	p<0.001	0.910	358/45/27/34/15
Back pain	1-class model	-7657.550	15.331.100	15.364.473	15.339.082	p<0.001	1.000	479
	2-class model	-7461.673	14.949.345	15.003.577	14.962.317	p<0.001	0.845	384/95
	3-class model	-7362.520	14.761.039	14.836.130	14.779.000	p<0.001	0.873	364/62/53
	4-class model	-7289.379	14.624.759	14.720.708	14.647.708	p<0.001	0.883	336/60/51/32
	5-class model	-7254.329	14.564.657	14.681.465	14.592.596	p<0.001	0.874	312/53/63/25/29
Disability	1-class model	-4.696.080	9.408.159	9.441.533	9.416.142	p<0.001	1.000	479
	2-class model	-4.486.868	8.999.735	9.053.967	9.012.707	p<0.001	0.779	327/152
	3-class model	-4.439.830	8.915.660	8.990.750	8.933.620	p<0.001	0.764	289/121/69
	4-class model	-4.411.955	8.869.910	8.965.859	8.892.860	p<0.001	0.778	285/17/78/99
	5-class model	-4.389.758	8.835.517	8.952.324	8.863.455	p<0.001	0.745	254/96/34/18/77

AIC = Akaike's Information Criteria, BIC = Bayesian information criterion, aBIC= adjusted Bayesian Information Criteria. BLRT = Bootstrap Likelihood Ratio Test. The grey shading indicates the best fit model

Table 3
Descriptive clinical outcomes stratified by the outcome trajectories.

	Preoperative	3 months	12 months	24 months
Leg pain outcome trajectories (VAS 0–100)				
1. Large improvement (n = 380, 79.3%)	73.0 (55.5–85.0)	5.0 (1.0–14.4)	4.0 (0.0–15.0)	2.7 (0.0–16.5)
2. Moderate improvement (n = 38, 7.9%)	80.5 (60.0–90.0)	50.0 (40.0–59.8)	20.0 (6.3–48.3)	20.0 (5.9–30.0)
3. Minimal change (n = 23, 4.9%)	85.0 (68.0–90.0)	73.5 (55.9–81.8)	58.1 (33.3–70.0)	69.1 (58.8–79.3)
4. Relapse (n = 38, 7.9%)	77.5 (62.2–81.8)	6.0 (0.9–28.9)	37.6 (1.0–62.4)	60.0 (49.6–70.7)
Back pain outcome trajectories (VAS 0–100)				
1. Large improvement (n = 336, 70.2%)	45.5 (17.4–70.0)	7.0 (2.4–15.0)	7.0 (1.0–20.0)	9.0 (1.2–21.0)
2. Moderate improvement (n = 51, 10.6%)	61.0 (39.0–80.0)	40.0 (32.0–48.2)	27.7 (10.0–50.0)	20.0 (7.3–30.0)
3. Minimal change (n = 32, 6.7%)	62.0 (50.0–75.0)	64.0 (58.8–78.2)	60.0 (40.0–71.0)	50.0 (43.0–62.3)
4. Relapse (n = 60, 12.5%)	70.0 (49.3–79.9)	20.0 (13.0–27.0)	50.0 (20.0–70.2)	64.0 (50.0–75.0)
Disability outcome trajectories (RMDQ 0–24)				
1. Large improvement (n = 285, 59.5%)	17.0 (13.0–20.0)	4.0 (2.0–6.0)	1.0 (0.0–3.0)	1.0 (0.0–3.0)
2. Moderate improvement (n = 99, 20.7%)	17.0 (15.0–20.0)	9.0 (6.0–13.0)	9.5 (8.0–11.0)	7.0 (5.0–9.0)
3. Minimal change (n = 78, 16.3%)	19.0 (17.0–20.0)	14.0 (10.0–16.0)	15.0 (13.0–17.0)	14.0 (13.0–16.0)
4. Relapse (n = 17, 3.5%)	17.5 (15.3–20.8)	4.0 (3.0–8.0)	3.0 (1.5–4.3)	12.0 (11.0–15.0)

N = number of patients, median (IQR). VAS = Visual Analogue Score (0–100 mm), RMDQ = Roland-Morris Disability Questionnaire (0–24 points).

3.4. Outcome trajectories for leg pain

The descriptive clinical course stratified by outcome trajectories for the outcome of leg pain is presented in Table 3 and Fig. 3A. The demographics and clinical characteristics at baseline stratified by outcome trajectories are presented in Appendix C. Previous injection therapy differs between the outcome trajectories (large improved trajectory vs. moderate improved trajectory ($p < 0.001$), large improved trajectory vs. minimal change trajectory ($p < 0.001$), moderate improved vs. minimal change trajectory ($p < 0.001$)). In the four-class model for leg pain, the following trajectories were observed: Trajectory 1: large improvement trajectory (79.3% of patients) consisted of patients who experienced nearly no pain at 3, 12, and 24 months. Trajectory 2: moderate improvement (7.9% of patients) consisted of patients who experienced improvement but experienced mild leg pain that persisted over the course of the 24-month follow-up. Trajectory 3: minimal change trajectory (4.9% of patients) consisted of patients who had little benefit from surgery with persistently high scores of leg pain at 3, 12, and 24 months. Trajectory 4: relapse trajectory (7.9% of patients) consisted of patients who improved rapidly at 3 months but had relapsed with increasing leg pain at 12 and 24 months.

3.5. Outcome trajectories for back pain

The descriptive clinical course stratified by outcome trajectories for the outcome of back pain is presented in Table 3 and Fig. 3B. The demographics and clinical characteristics at baseline stratified by outcome trajectories are presented in Appendix D. Prior back surgery and previous injection therapy differed between the outcome trajectories (prior back surgery: large improved trajectory vs. moderate improved trajectory ($p < 0.001$), previous injection therapy: large improved trajectory vs. moderate improved ($p < 0.001$)). In the four-class model for back pain, the following trajectories were observed: Trajectory 1: large improvement trajectory (70.2% of patients) consisted of patients with low pain scores at 3, 12, and 24 months. Trajectory 2: moderate improvement trajectory (10.6% of patients) consisted of patients who experienced improvement but maintained persistent mild back pain at follow-up. Trajectory 3: minimal change trajectory (6.7% of patients) consisted of patients who had little benefit from surgery with persistent high back pain scores at 3, 12, and 24 months. Trajectory 4: relapse trajectory (12.5% of patients) consisted of patients who improved rapidly by 3 months but relapsed with increased back pain scores at 12 and 24 months.

3.6. Outcome trajectories for disability

The descriptive clinical course stratified by outcome trajectories for the outcome disability is presented in Table 3 and Fig. 3C. The demographics, clinical characteristics, and PROMs at baseline stratified by outcome trajectories are presented in Appendix E. Prior back surgery differed between the outcome trajectories (large improved trajectory vs. moderate improved trajectory ($p < 0.001$)).

In the four-class model for disability, the following trajectories were observed: Trajectory 1: large improvement trajectory (59.5% of the patients) consisted of patients characterised by a fast decrease of disability at 3 months and a further slow decrease at 12 and 24 months. Trajectory 2: moderate improvement trajectory (20.7% of patients) consisted of patients who experienced an improvement in disability but continued to have mild disability over the course of the follow-up. Trajectory 3: minimal change trajectory (16.3% of patients) consisted of patients who reported only minor changes in their disability scores at 3, 12, and 24 months. Trajectory 4: relapse trajectory (3.5% of patients) consisted of patients who had improved rapidly by 3 and 12 months but had relapsed with increased disability scores at 24 months.

3.7. Distribution of patients in poor outcome trajectories

One-hundred and fifty-six patients (32.6%) belonged to one or more than one poor outcome trajectory (i.e., minimal change and relapse trajectories) for the different outcome measures (leg pain, back pain, and disability) (Fig. 4). Ninety-two patients (19.2%) had one poor outcome, thirty-six patients (7.5%) had two poor outcomes and twenty-eight patients (5.8%) had three poor outcomes.

3.8. Prediction models for poor outcome trajectories

Due to the relatively low number of patients with a poor outcome, the minimal change trajectory and relapse trajectory were combined, and were classified as poor recovery for all outcome measurements. The prediction model for a poor outcome (n = 61) versus a large improvement (n = 380) on leg pain contained the following variables: female, previous injection therapy, and a higher leg pain intensity score (Table 4). After internal validation, the explained variance (R2) was 0.06 and the AUC was 0.66. No variables remained in the model for a poor outcome (n = 61) versus a moderate outcome on leg pain (n = 38).

The prediction model for a poor outcome (n = 92) versus a large improvement in back pain (n = 336) contained the variables: prior back surgery, previous injection therapy, and a higher leg pain intensity score (Table 4). The explained variance was 0.121 and the AUC was 0.71. No variables remained in the model for a poor outcome (n = 92) versus a moderate outcome on back pain (n = 51).

The prediction model for a poor outcome on disability (n = 95) versus a large improvement on disability (n = 285) contained the variables: prior back surgery, a negative straight leg raise test, preoperative

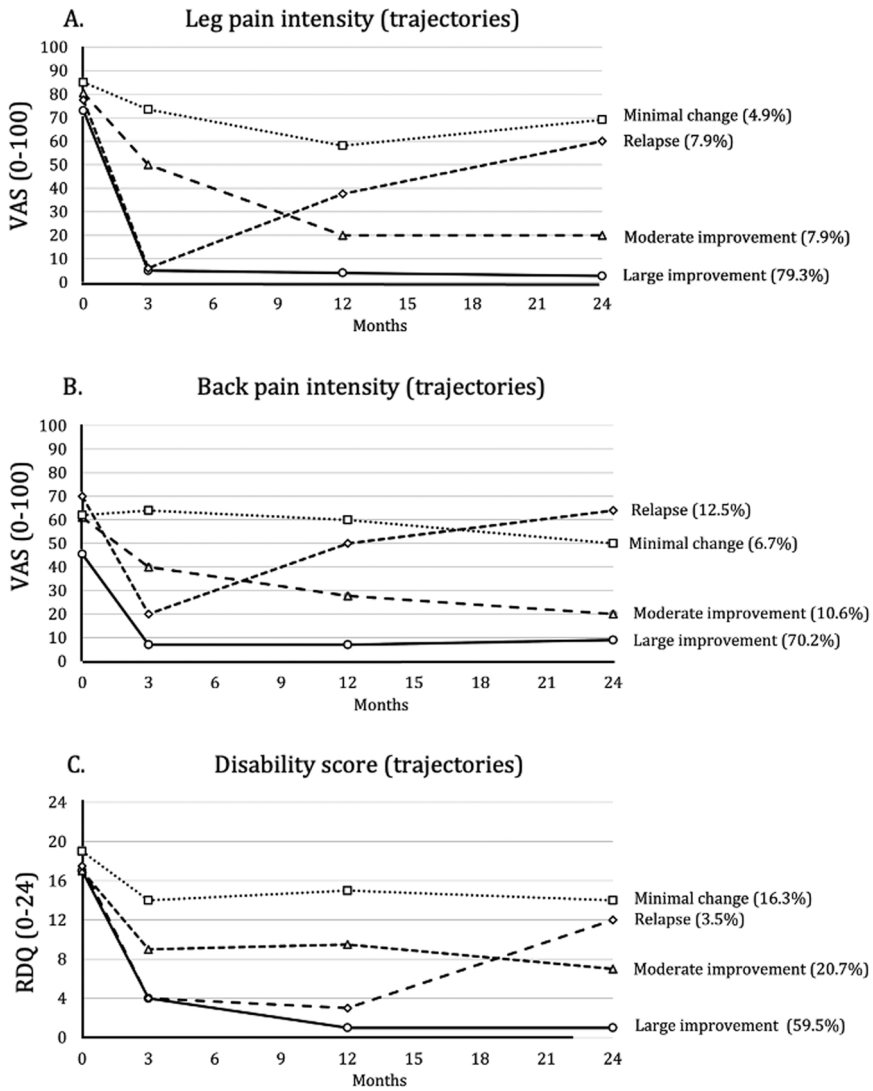

Fig. 3. Outcome trajectories for leg pain, back pain, and disability. VAS = Visual Analogue Score, RMDQ = Roland-Morris Disability Questionnaire. Trajectories expressed by medians.

medication use, a higher leg pain intensity score, and a higher level of disability (Table 4). The explained variance was 0.13 and the AUC was 0.73. The prediction model for a poor outcome (n = 95) versus a moderate outcome on disability (n = 99) contained the following variables: previous injection therapy, previous medication use, and higher levels of disability. The explained variance was 0.04 and the AUC was 0.70 (Table 5).

4. Discussion

Prospective cohort studies have shown that most patients experience a clinically relevant improvement in pain and disability after lumbar radiculopathy following microdiscectomy, supporting the role of surgery and suggesting a favorable average course [27]. However, many patients do not fit the average trajectory profile and for some, the outcomes result in serious complications and/or long-term, persistent problems [18,27,29]. Therefore, this study aimed to explore the variability in recovery after lumbar microdiscectomy and post-operative physiotherapy by deriving and predicting outcome trajectories.

This is the first study showing high interindividual variability after lumbar microdiscectomy followed by physiotherapy. We identified distinct outcome trajectories, reflecting a 'large improvement', 'moderate improvement', 'minimal change', and 'relapse' trajectory for each outcome measure (leg pain, back pain, and disability). Thirty-two percent of the patients were assigned to one or more poor outcome trajectories. Patients with previous treatment (prior back surgery, injection therapy, and medication use) and those who had higher baseline pain and disability scores were more likely to belong to the poor outcome trajectories in comparison to the large improvement trajectories in back pain, leg pain, and disability and compared to the moderate improvement trajectory for disability.

The average pain and disability trajectories identified in our study were similar to the average clinical course of pain and disability experienced by patients undergoing lumbar microdiscectomy presented in systematic reviews [18,27]. However, our results provide insight into the high interindividual variability that reflects the clinical course. Furthermore, our outcome trajectories demonstrated that about 30% were classified as a member of at least one outcome trajectory that experienced no change or relapse in pain and disability scores after surgery. This is in line with recent studies in which 29–42% of the patients were classified as belonging to a poorly recovered outcome trajectory after lumbar spinal stenosis surgery and 14.4% as belonging to poor outcome trajectories in patients after spinal deformity surgery [12, 41].

Higher baseline scores of leg pain and back pain predicted the poor outcome trajectories of leg pain and back pain, and higher baseline

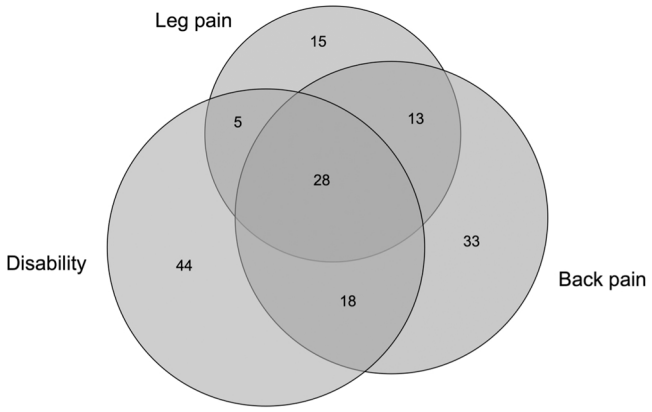

Fig. 4. Distribution of patients belonging to one or more than one poor outcome trajectory (i.e., minimal change and relapse trajectories) for the outcomes of leg pain, back pain, and disability. The numbers represent the number of patients with poor outcomes. A total of 156 patients belonged to one or more poor outcome trajectories, 44 patients had a poor outcome on disability only, 33 on back pain only, and 15 on leg pain only. Eighteen patients belonged to poor outcome trajectories for back pain and disability, 13 for back pain and leg pain, and 5 for leg pain and disability. Twenty-eight patients belonged to poor outcome trajectories for all outcomes (back pain, leg pain, and disability).

disability scores predicted poor outcome trajectories of disability in comparison with the large improved trajectories for leg pain, back pain, and disability and the moderate improved trajectory in disability. Higher baseline pain and disability scores have previously been associated with poor outcomes after lumbar microdiscectomy [9,40] and are widely accepted prognostic variables for musculoskeletal pain [4,19].

Interestingly, patients who had a history of injection therapy, medication use, and prior back surgery were more likely to belong to the poor outcome trajectories in comparison to patients who belong to the large improvement trajectories in pain and the moderate improvement trajectory in disability. When managing lumbar radiculopathy, clinical guidelines recommend a stepped care approach that begins with pain medication, and physiotherapy, followed by epidural injections as the initial steps for treatment, reserving surgery for those who do not respond to these modalities [17,32,36]. However, it remains challenging to clinicians how long conservative care should be prolonged and when surgical intervention is indicated [30]. Furthermore, prior back surgery was an important predictor for the poor outcome trajectories of pain and disability in comparison with the large improved trajectory. Previous research shows there is a high risk of reoperations (0.6–24%) for patients who underwent lumbar discectomy and more than half of these patients undergo reoperation within the first two years [1,15,16,29]. Consequently, worse outcomes are reported for patients requiring multiple lumbar spine operations [16,23]. Therefore, our findings can help clinicians and their patients to set appropriate expectations before surgery when patients have a history of back surgery.

Our results show that some patients were classified to more than one poor outcome trajectory for a specific outcome (i.e., leg pain, back pain, or disability), but others had only one poor outcome trajectory in combination with good trajectories for other outcomes. Therefore, clinicians and patients should set appropriate expectations for surgery by illustrating the postoperative outcome trajectories that fit the patient's specific goals and expectations.

Table 5
Prediction model for poor outcome trajectories versus a moderate improvement.

Disability			
Variables			
- Previous injection therapy (yes)	2.12 (1.03–4.34)	0.75	0.05
- Previous medication use (yes)	1.85 (0.83–4.11)	0.61	0.12
- Level of disability (RMDQ)	1.15 (1.03–1.28)	0.14	0.06
Performance measures	**Initial†**	**Bootstrap§**	
- Nagelkerke R^2	0.12	0.04	
- AUC (95%CI)	0.68 (0.59–0.77)	0.69 (0.61–0.78)	

RMDQ: Roland-Morris Disability Questionnaire; 95%CI: 95% Confidence Interval; AUC: Area Under the Curve; IQR: Interquartile range; OR: odds ratio; R2: Nagelkerke R-squared; † acquired from the full cases datasets; § performance measure acquired from bootstrapping procedure

Table 4
Prediction models for poor outcome trajectories versus a large improvement.

	OR (95%CI)	Beta†	P-value
Leg pain			
Variables			
- Sex (female)	2.34 (1.23–4.46)	0.85	0.01
- Previous injection therapy (yes)	2.30 (1.22–4.30)	0.83	0.01
- Pain intensity leg (VAS)	1.02 (1.00–1.04)	0.02	0.07
Performance measures	**Initial†**	**Bootstrap§**	
- Nagelkerke R^2	0.10	0.06	
- AUC (95%CI)	0.66 (0.59–0.74)	0.66 (0.60–0.74)	
Back pain			
Variables			
- Prior back surgery (yes)	2.54 (1.30–5.26)	0.93	0.01
- Previous injection therapy (yes)	2.23 (1.27–3.93)	0.80	0.01
- Pain intensity back (VAS)	1.02 (1.01–1.03)	0.02	< 0.001
Performance measures	**Initial†**	**Bootstrap§**	
- Nagelkerke R^2	0.14	0.12	
- AUC (95%CI)	0.70 (0.64–0.76)	0.71 (0.65–0.77)	
Disability			
Variables			
- Prior back surgery (yes)	4.30 (1.85–10.0)	1.46	<0.001
- Straight leg raise test (positive)	0.58 (0.29–1.15)	-0.54	0.12
- Preoperative medication use (yes)	1.91 (0.98–3.73)	0.01	0.06
- Pain intensity leg (VAS)	1.01 (0.10–1.03)	0.12	0.14
- Level of disability (RDQ)	1.13 (1.03–1.23)	0.65	0.01
Performance measures	**Initial†**	**Bootstrap§**	
- Nagelkerke R^2	0.18	0.13	
- AUC (95%CI)	0.72 (0.65–0.79)	0.73 (0.66–0.80)	

95%CI: 95% Confidence Interval; AUC: Area Under the Curve; IQR: Interquartile range; OR: odds ratio; R2: Nagelkerke R-squared; † acquired from the full cases datasets; § performance measure acquired from bootstrapping procedure

It is important to note that all patients received post-operative physiotherapy at the hospital and in primary care with the goal to resume daily activities, work, and sports. Although a treatment protocol was provided, treatment was tailored to the individual goals and needs of the patient and, therefore may have varied. However, this reflects best clinical practice and increases the generalizability of the finding. Previous research showed little consistency between exercise protocols and the most effective rehabilitation approach is still unknown. [22,39]. Optimal rehabilitation strategies, especially for those who belong to a poor outcome trajectory are important, as this may also help shift patients to a more beneficial trajectory. Therefore, identifying the most important preoperative predictors of poor outcome trajectories, and the effect of postoperative care on pain and disability trajectories are important priorities for future research.

The number of retained classes in a latent class trajectory analysis also deserves attention. Patients were assigned to the outcome trajectories based on statistical and clinical judgment. Although the 5-class model performed slightly better than the 4-class model, based on overall model interpretability and the only small differences in performance, we preferred the 4-class model. For transparency and replicability of the selection procedure, we have reported detailed information regarding the performance of all models via Open Science Framework. (https://osf.io/ew6nh/?view_only=a78c160939a841079f6e1eb16ee42c31).

This study has several limitations. The derivation and internal validation of the prognostic models revealed that the explained variance scored poorly, and the discriminative ability was poor to acceptable. This is in line with previous research on prediction models for lumbar microdiscectomy [8,10,26,38]. The role of potentially important biomedical factors (e.g., degeneration, type of disc herniation) and psychosocial factors (e.g., distress, depression, or fear-avoidance) should be further explored [3,5,9,10,40].

Furthermore, no factors remained in the model for the poor outcome trajectories in comparison with the moderate improvement trajectory for the outcomes of leg and back pain. Therefore, baseline characteristics cannot differentiate patients with poor outcome trajectories compared to patients who experienced a moderate improvement in back and leg pain.

In conclusion, our results confirmed the high variability in the clinical course for people with lumbar radiculopathy undergoing microdiscectomy and post-operative physiotherapy. Furthermore, our study revealed four distinctive subgroups of how these people recover. These different trajectories should be considered when clinicians inform patients about the outcome of microdiscectomy and post-operative physiotherapy for lumbar radiculopathy.

CRediT authorship contribution statement

Conception and design of study: R.W. Ostelo, G.G.M Scholten-Peeters; Acquisition of data: S.J. Willems, S. Rooker; Analysis and/or interpretation of data: S.J. Willems, M.W. Coppieters, S. Rooker, R.W. Ostelo, T. Hoekstra, G.G.M Scholten-Peeters, Drafting the manuscript: S. J. Willems, G.G.M Scholten-Peeters; Revising the manuscript critically for important intellectual content: M.W. Coppieters, S.Rooker, R.W. Ostelo, T. Hoekstra, G.G.M Scholten-Peeters, Approval of the version of the manuscript to be published (the names of all authors must be listed): S.J. Willems, M.W. Coppieters, S. Rooker, R.W. Ostelo, T. Hoekstra, G.G. M Scholten- Peeters.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.clineuro.2022.107551.

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