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Original article

Depression affects the recovery trajectories of patients with distal radius fractures: A latent growth curve analysis.

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ABSTRACT

Background: Distal radius fractures (DRFs) are common and can lead to substantial pain and disability. Most people recover in six months, but some experience persistent pain and disability for one year or longer after injury. Therefore, it is important to understand the factors that can help predict poor recovery.
Objective: To identify recovery trajectories in DRF patients and to determine the factors that can help predict poor recovery.
Methods: Recovery was assessed in 318 patients using the Patient-Rated Wrist Evaluation scale at baseline, three, six, and 12 months. Demographic information was collected in addition to the Self-Administered Comorbidity Questionnaire, from which data regarding depression were extracted. Latent growth curve analysis (LGCA) was used to identify the recovery trajectories. Comparisons of proportion between the emergent classes were then conducted using chi-square and Kruskal-Wallis tests.
Results: The LGCA revealed three distinct trajectories (rapid-recovery: (69%), slow-recovery: (23%), and non-recovery: (8%) as the best fit to the data. The proportion of people with depression was significantly greater in the non-recovery class (24%) compared to the slow (16%, $p = 0.04$) and rapid-recovery (8%, $p = 0.03$) classes. Additionally, the proportion of females were significantly lower in the non-recovery (64%, $p = 0.03$) compared to the slow (85%, $p = 0.03$) and the rapid-recovery classes (81%, $p = 0.048$).
Conclusion: Recovery from DRF was best described using three different trajectories. Greater self-reported depression and a lower proportion of females in the non-recovery class were distinguishing factors between the classes. Patients who appear to be in slow-recovery or non-recovery classes may be followed more closely.

1. Introduction

Distal radius fractures (DRFs) are common injuries among all age groups, can lead to severe pain and disability (MacDermid et al., 2003; Porrino et al., 2014), and impose a considerable economic burden on society (Shauver et al., 2011). MacDermid and colleagues describe recovery following DRFs as occurring in two phases; reparative, which is the soft tissue and bone healing phase, and rehabilitative, during which the slower, more sustained improvements occur (MacDermid et al., 2003). Most recovery happens in the first six months following the injury, however, a subset develop chronic pain and disability when measured at least one year later (MacDermid et al., 2001, 2003; Lalone et al., 2014; Dewan et al., 2017).

Previous studies that have used the Patient-Rated Wrist Evaluation (PRWE) scale as an outcome measure to address predictors of functional outcomes following DRFs have evaluated the role of anatomic indicators (e.g., dorsal angulation and < 15° radial inclination) (Lalone et al., 2014, 2016; Cibulka et al., 2009; Grewal and MacDermid, 2007), patient characteristics (e.g., age and gender) (Bobos et al., 2017), bone health (Dewan et al., 2018), associated soft-tissue injury (Kasapinova and Kamiloski, 2015, 2017), injury compensation (MacDermid et al., 2002), patient-centered care (Constand et al., 2014), occupation (MacDermid et al., 2007), and social support (Symonette et al., 2013). All of these factors have been shown to have some influence on PRWE outcomes after DRF, but they have provided limited information on mechanisms to explain the variance in functional recovery among people. A common characteristic of these prior studies is the modeling of outcomes at a single time point (e.g., six or 12 months) rather than

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exploring longitudinal trajectories.

Psychological factors have also been considered as predictors of recovery following DRF. In a cross-sectional study of people with various wrist conditions including DRF, kinesiophobia and catastrophic thinking were found to be significant predictors of outcome [measured with Disabilities of the Arm, Shoulder, and Hand (DASH)] (Das De et al., 2013). Depression is known to affect outcomes of many health conditions (Lichtman et al., 2008; Morris et al., 1992; Atay et al., 2016), and has been investigated as a predictor in DRF (Das De et al., 2013; Yeoh et al., 2016; Ring et al., 2006). In two cross-sectional studies the associations were shown using Pearson's correlation, where higher depression scores were associated with greater levels of disability (Das De et al., 2013; Ring et al., 2006). Yeoh and colleagues used multivariate regression to examine the effect of depression [measured with Centre of Epidemiologic Studies Depression (CES-D)] on one-year post-DRF outcomes (using DASH scores) in a sample of older (> 55 years) adults (Yeoh et al., 2016). After removing the effects of age, gender, treatment, comorbidities, and the occurrence of complications, they found that depression was the strongest predictor of DASH scores, where for every one point change in CES-D score, a proportional 2.9 point difference was observed in DASH scores (Yeoh et al., 2016). Still needed, are studies that define and predict the recovery trajectories rather than just predicting functional scores at a single time point.

There has yet to be a rigorous exploration of recovery trajectories in this population, and how baseline characteristics may predict those trajectories. This type of exploration has been conducted in other musculoskeletal trauma populations including traumatic neck (Sterling et al., 2010) and low back pain (Downie et al., 2016) and has led to the creation of clinical prognostic tools (Ritchie et al., 2013).

The first objective of this study was to identify the recovery trajectories in a large existing database of people following DRF using latent growth curve analysis (LGCA). The second objective was to compare proportions of potential predictor variables, including the presence of depression, age, sex, education level, smoking history, and work status across the emergent trajectories. The results may help clinicians identify those patients who are less likely to recover quickly.

2. Methods

2.1. Study design and participants

This was an exploratory study conducted using an existing database previously collected from consecutive patients of the Roth McFarlane Hand and Upper Limb Center in London, Ontario, Canada. The results of this study were reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Elm et al., 2007). All participants in the database were diagnosed with DRF by a specialized hand surgeon. Other inclusion criteria were: the ability to speak and understand English, 18 years of age or older, and no other chronic or systemic disorders that would affect the participants' level of pain and disability. We only included participants that had baseline data and were followed for six to 12 months post-injury. All data in the database were collected after obtaining informed consent from the participants. As a secondary analysis, the primary researcher received only de-identified data. The process for data collection and storage was approved by the Western University Research Ethics Board.

2.2. Primary outcome measure

The level of pain and disability experienced by patients at four time points (baseline, three, six, and 12 months) post-injury were measured using the PRWE. The PRWE is a 15-item region-specific patient-reported outcome measure that provides two subscales: pain and disability about the wrist and forearm (MacDermid, 1996). The maximum possible score on this scale is 100, with a higher number indicating higher pain or functional limitation. A recent systematic review of measurement properties of PRWE supported this tool's reliability and validity in this patient population (Mehta et al., 2015a).

2.3. Participants' demographics and characteristics

Participants' baseline characteristics and demographic information such as age, sex, education level, smoking status, and work status were collected through a standardized form during the initial visit that occurred within two to seven days from injury (baseline). Participants also completed a Self-Administered Comorbidity Questionnaire (SCQ) upon entry into the study. In this questionnaire, participants were asked to indicate whether they have any number of health conditions by answering yes or no. For the purposes of this study, the single item pertaining to depression was extracted and used as a binary potential predictor variable in our models.

2.4. Analytical approach

Participants' demographic data were calculated as means and standard deviations (SDs) or frequencies and percentages as appropriate. To compare the proportion of females and males, and to compare the age of females and males in the entire sample we used the *t*-test and chi-square test, respectively. A preliminary analysis was conducted using Repeated measures one-way Analysis of Variance (RM ANOVA) to assess whether participants' PRWE scores differed significantly from one time point to the next. Time was the repeated variable and the PRWE scores were the dependent variables. Significant main effects were explored using Bonferroni's post-hoc test. LGCA was conducted in Mplus (version 6.12) (Muthén and Muthén, 2012) using Maximum likelihood-based Growth Mixture Modeling (GMM) with the quadratic term variance constrained at zero, to identify the classes of recovery trajectories based on PRWE scores at the four time points. This is a data-driven technique that is robust to missing values and for which hypotheses are emergent rather than set *a priori*. To determine the best number of classes that adequately described the data with the smallest number of distinct trajectories, we used the Bayesian Information Criterion (BIC) (Schwarz, 1978) and Akaike Information Criterion (AIC) (A, 1998), entropy values (Celeux and Soromenho, 1996), and the Vuong Lo-Mendell-Rubin (VLMR) likelihood ratio test (Aitkin and Rubin, 1985). While there are no set thresholds for what is considered acceptable, smaller BIC and AIC levels and higher entropy indicate a better fit of the data to the model. The VLMR likelihood ratio test offers a statistical comparison of the fit of the data (residuals) of the *k* number of latent classes to a model with *k*-1 latent classes. An inferential statistic associated with the *p*-value is calculated and, if significant, the model with the *k*-1 number of latent classes is rejected (Geiser, 2012). This continues until the fit no longer improves in a meaningful way, at which point the last model to offer significant improvement that also made theoretical sense and had no class with less than 5% of the sample was accepted (Patrick et al., 2009). All participants were then coded according to their most likely class for comparison of baseline characteristics across groups. Proportions of those endorsing depression (yes/no), sex (male/female), education level (no post-secondary education/completed post-secondary education), smoking status (non-smoker/smoker), and work status (unable to work due to other reasons/unable to work due to injury/working part- or full-time), we used the chi-square test. To determine class differences with respect to age, we used the Kruskal-Wallis test, since the assumptions of Analysis of Variance were not met.

In this study, we employed the complete case approach in dealing with missing data for depression, PRWE (at baseline and three months), age, and sex variables. The complete case approach is the simplest, most expedient way of handling missing data in which data from participants that have missing values for variables of interest are excluded from the statistical analysis (Mukaka et al., 2016). To handle the missing data for PRWE scores at six and 12 months we used the full maximum-likelihood

Table 1
Baseline characteristics and demographic information as well as Patient-Rated Wrist Evaluation scores of all time points of all participants.

	Mean (SD)	Valid Percent
Age	59.6 (11.9)	–
Sex (% female)	–	80.5%
Smoking	–	
Non-smoker		88%
Smoker		12%
Education	–	
Didn't complete post-secondary education		80%
Completed post-secondary education		20%
Work status	–	
Unable to work (due to various reasons)		54%
Unable to work (due to this injury)		19%
Part-time or full-time work		27%
Depression (% yes)	–	11.3%
Baseline Patient-Rated Wrist Evaluation	66.5 (21.2)	–
Month 3 Patient-Rated Wrist Evaluation	31.8 (21.6)	–
Month 6 Patient-Rated Wrist Evaluation	19.8 (18.2)	–
Year 1 Patient-Rated Wrist Evaluation	13.5 (17.1)	–

estimation, which is a method of directly fitting the model to raw data without imputation. This is an accepted technique given that previous research has shown minimal change occurs between six and 12 months (MacDermid et al., 2001). All between-class comparisons were conducted using the Statistical Package for the Social Sciences (version 25.0) program (SPSS, Inc, Chicago, Illinois) accepting an alpha error rate (*p*-value) of 0.05 to indicate statistical significance.

3. Results

In total, 318 participants with complete PRWE data for at least six months post-injury, depression, age, and sex were included in this study. Baseline characteristics and demographic information, as well as the PRWE scores (at all time points) of all participants without data imputation, are summarized in Table 1. The age range of participants was 20–87, a significant majority of participants were females (81%), and females were significantly older than males (mean age of 60.6 versus 55.4, $p < 0.01$). The mean PRWE score was 66.5/100 (SD = 21.2) at baseline and overall mean scores improved significantly at each follow-up time point (F = 859.7, $p < 0.001$, Fig. 1). The majority of participants were non-smokers (88%), did not have post-secondary education (80%), and were not working due to various other reasons (e.g., other medical reasons, retired, student) (54%). Fig. 1 is a plot of PRWE scores of all participants at all time points (i.e., baseline, 3-month, 6-month, and 1-year). Visual inspection indicated that recovery was not linear and so LGCA was conducted including a quadratic term to conform to the nature of the data. Table 2 presents the fit indicators for one, two, three, and four-class solutions. The three-class solution was accepted as the optimal model for describing the data based on BIC, AIC, entropy, and VLMR likelihood ratio test. Classification accuracy of the three-class model was high (all > 85%) with no class having fewer than 5% of the overall sample. A sensitivity analysis (not shown) compared fit indicators of the quadratic model against a similar three-class linear model that further supported better fit when the quadratic term was included. Fig. 2 shows the recovery trajectories of the three classes. Class one (69% of the sample) started with a relatively lower score but recovered rapidly to report mild to no pain and disability at three months and was labeled a 'rapid recovery' class. Class two (23% of the sample) started with higher levels of pain and disability and a moderate and steady level of recovery with a mild residual disability at six months, labeled a 'slow recovery' class. Class three (8% of the sample) started with the highest level of pain and disability scores at baseline, showed little recovery, and continued to report high pain and disability at six months and one year, and was labeled a 'non-recovery' class.

Table 2
Latent growth curve analysis model fit statistics for classification of recovery rates following distal radius fracture.

Classes	AIC	BIC	Entropy	VLMR Log (p)
1	10044.36	10081.98	–	–
2	9899.03	9951.7	0.94	−5012.18 (0.004)
3	9846.06	9913.78	0.86	−4935.52 (0.03)
4	9825.40	9908.17	0.87	−4905.03 (0.86)

AIC, akaike information criterion; BIC, Bayesian information criterion; VLMR, Vuong Lo-Mendell-Rubin; p, probability value.

Table 3 presents the characteristics of the independent patient variables across the three classes. When compared with the non-recovery class (64%), both the slow-recovery (85%, $x^2 = 5.02$, $p = 0.03$) and the rapid-recovery class (81%, $x^2 = 3.89$, $p < 0.05$) had a significantly higher percentage of females. Proportions of people with likely depression were higher in the non-recovery class (24%)

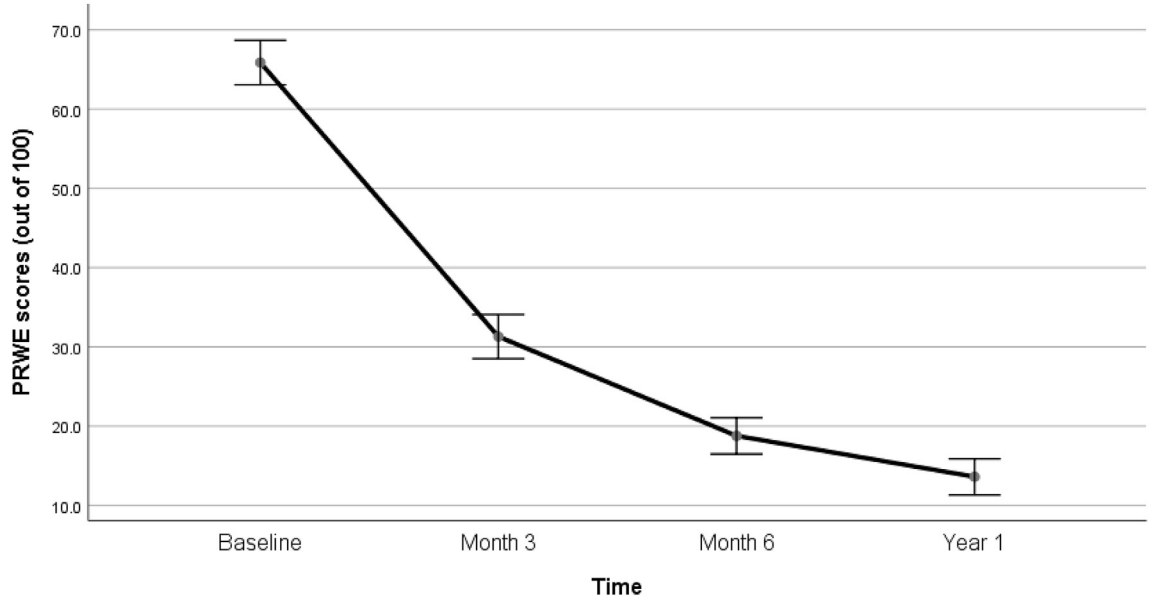

Fig. 1. Patient Rated Wrist Evaluation (PRWE) scores at four time points of baseline, month three, month six, and year 1.

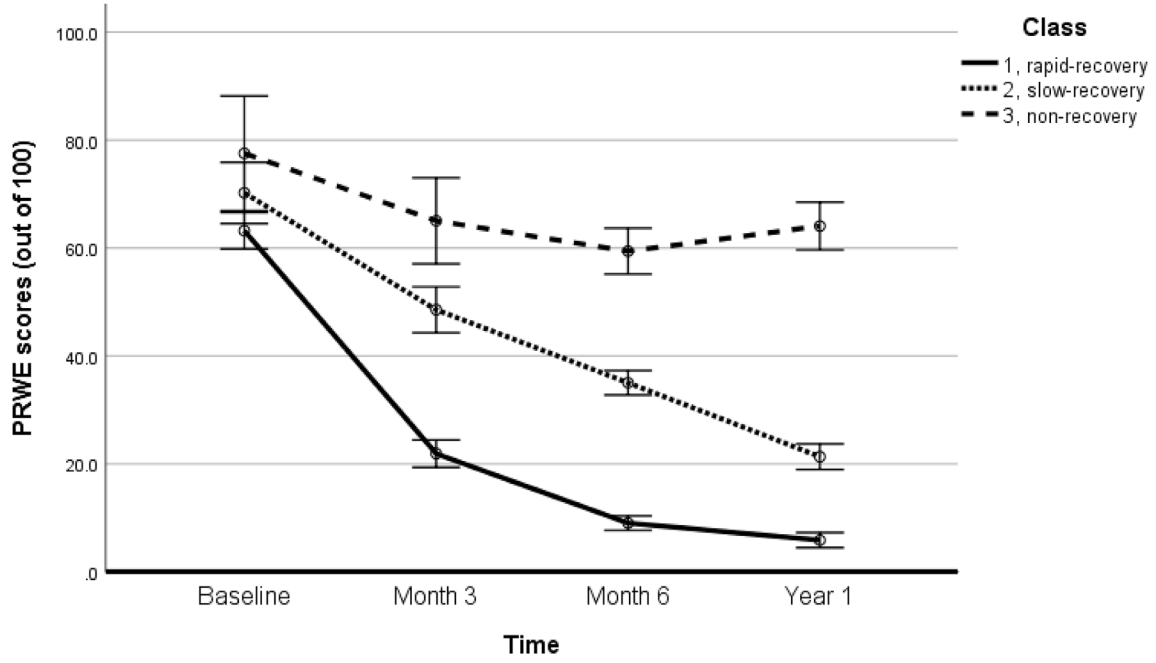

Fig. 2. The three classes of recovery trajectory following a distal radius fracture. Class one is defined as rapid-recovery, class two is slow-recovery, and class three is non-recovery. Error bars are 95% confidence intervals.

compared to both the rapid-recovery (8%, $x^2 = 6.36$, $p = 0.01$) and slow-recovery (16%, $x^2 = 4.07$, $p = 0.04$) classes. None of the other patient characteristics were present in significantly greater proportion between classes.

Table 3 also shows other potential differences in participant variables between classes that did not reach statistical significance but may be worthy of further exploration. These include: the rapid-recovery class had the lowest baseline PRWE score and proportion of smokers, and the highest proportion of people that had finished post-secondary education and were working at baseline. The non-recovery class had the highest proportion of smokers, people that were unable to work due to the injury, and people with no post-secondary education, in addition to the highest baseline PRWE scores.

4. Discussion

In this study, we took a unique approach to answer the question of how patient factors affect health outcomes by categorizing patients with DRFs based on their recovery trajectories over a course of one year post-injury using LGCA. Patients who appear to be in slow-recovery or non-recovery classes may require additional assessments, closer monitoring, supervised therapy, or other interventions to improve outcomes.

The majority of people in this study belonged to the rapid-recover class which is consistent with previous research showing that following DRF most people recover within six months (MacDermid et al., 2003). Additionally, earlier studies have shown that patients that take no or minimal time off work after DRFs have lower baseline PRWE scores and improve at each re-evaluation point (MacDermid et al., 2007), which is also in line with the trajectory of the rapid recovery class in our sample. While low rates of depression and a high proportion of females were the only significant predictors of rapid recovery, this class may be further described by a cluster of factors including lower baseline PRWE scores, early return to work, highest rates of non-smokers and people with post-

Table 3
Baseline characteristics and Patient Rated Wrist Evaluation (PRWE) scores of all timepoints of participants based on class membership.

	Class one (rapid- recovery, 69%)	Class two (slow-recovery, 23%)	Class three (non- recovery, 8%)
Mean age (SD)	60 (12.2)	60 (10.6)	55 (12.8)
Sex (% female)	**81%**	**84%**	**65%***
Smoking			
Non-smoker	89%	84%	80%
Current smoker	11%	16%	20%
Education (%)			
Didn't complete post-secondary education	80%	77%	84%
Completed post-secondary education	20%	23%	16%
Work status			
Unable to work (due to various reasons)	54%	55%	52%
Unable to work (due to this injury)	18%	20%	28%
Part-time or full-time work	28%	25%	20%
Depression (% yes)	**8%**	**16%**	**24%***
Baseline_PRWE (SD)	63.2 (21.2)	72.6 (19.4)	77.3 (19)
Month 3 PRWE (SD)	22.5 (16.4)	47.8 (14.5)	66.6 (16.7)
Month 6_PRWE (SD)	9.5 (7.0)	35.0 (9.8)	60.0 (12.0)
Year 1_PRWE (SD)	6.1 (6.6)	22.0 (12.1)	63.4 (13.3)

*: Proportions are significantly different between the non-recovery class compared to the other two classes. Proportions between the rapid and slow-recovery classes were not significantly different.

secondary education. This is consistent with a previous study that found people with the highest level of education and lowest rates of smoking had the best outcome one year following DRFs (Grewal et al., 2007). An outcome model proposed for DRF suggests that when minimal physical and psychological impairments are present, minimal supervision (e.g., home exercise programs) might suffice for rehabilitation (Mehta et al., 2010).

A small number of people experience chronic pain and disability post-DRF (MacDermid et al., 2003; Swart et al., 2012) which can negatively affect daily activities and cause increased dependence (Vergara et al., 2016). In this study, the non-recovery class was described by the lowest proportion of females, the highest proportion of people endorsing co-morbid depression, and other trends towards having the highest baseline PRWE scores, being current smokers, not working due to this injury, and having no post-secondary education. A prior study that did not control for depression showed that when the PRWE pain subscale was greater than 35/50 at baseline, the risk of chronic pain at one year was 8.4 times higher (Mehta et al., 2015b). Golkari and colleagues also found that depression was associated with higher baseline pain or being off work longer following DRF (Golkari et al., 2015). In addition, Yeoh and colleagues found that people with baseline depression had significantly poorer one-year recovery than nondepressed patients (Yeoh et al., 2016). This association was also reported in a previous study that used the PRWE to assess pain and compared patient characteristics and comorbidities of people with DRFs and found that certain disorders including depression were significantly higher in people that got worse one year post fracture (Lalone et al., 2017). Another study reported that depression was strongly associated with pain intensity and disability in patients recovering from one or more fractures (Vranceanu et al., 2014). Collectively, these and the current study suggest that there is a negative link between depression and recovery from DRF.

Pain is measured routinely, making it a convenient predictor for clinicians. However, it is arguably a coarse measure that provides little guidance for clinical decisions, in that it is hard to know how a clinician should modify their intervention in patients with a pain score of 40/50 rather than 30/50. As we used the consolidated PRWE score that included both pain and functional interference in a single number, we had the opportunity to explore other potential mechanisms for predicting recovery. In this study the single depression item from the SCQ was used, being a similarly low burden but a coarse measure that offered different insights into the potential mechanisms for predicting recovery. There are several such other tools that exist, such as the single 'downhearted and blue' question on the 36-item Short Form Health Survey (question #9) that is nearly identical to the question from SCQ, and has shown to be a powerful detector for depression (Berwick et al., 1991). While screening for depressive symptoms may not be part of a routine clinical evaluation, the results of the current and prior studies indicate that it may be of value and can be done with relatively low burden. The underlying mechanism of how depression can affect recovery following DRF is potentially complex. Depression could affect recovery directly or affect the way that it is self-assessed. Depression might affect recovery through health behaviors such as sleep, exercise, and nutrition. Other potential contributing factors are patients' adherence to rehabilitation programs during the recovery process (Lenze et al., 2004), which could be associated with reluctance and psychomotor retardation (Atay et al., 2016). It has also been suggested that depression can weaken the immune system which might contribute to an extended recovery period (Phillips et al., 2013). Furthermore, according to the cognitive-bias model of depression, people with depressive symptoms have a negative perspective about themselves, (Beck, 1967), therefore, it is also possible that our participants with depression had a negative outlook about their recovery and their self-reports were negatively biased despite no actual difference in outcomes to nondepressed counterparts.

Another finding of this study is that the proportion of females was the lowest in the non-recovery class. Studies that have compared DRF outcomes with respect to sex, report conflicting results (Dewan et al., 2017; MacDermid et al., 2002; Grewal et al., 2007; Mehta et al., 2015b; Lalone et al., 2017; Moore and Leonardi-Bee, 2008; Kurimoto et al., 2012; Amorosa et al., 2011; Cowie et al., 2015). Some studies that also used PRWE as the outcome measure six months (MacDermid et al., 2002), one year (Grewal et al., 2007; Mehta et al., 2015b; Lalone et al., 2017), and four years (Dewan et al., 2017) post-DRF concluded that sex has no influence on recovery (Grewal et al., 2007; Mehta et al., 2015b; Lalone et al., 2017). Similarly, using the DASH, sex was reported as a non-significant predictor of outcome one year post-DRF (Moore and Leonardi-Bee, 2008). Still, other studies have reported that women experience worse outcomes when examined at 18 months using the Hand20 (Kurimoto et al., 2012), 30 months using the DASH (Amorosa et al., 2011), and one year post-DRF using manual examinations (Cowie et al., 2015). It is important to note that these studies assessed outcome at one point in time, but here, we compared people based on their recovery trajectories. However, our finding that more men experienced a non-recovery trajectory was unexpected, and the potential reasons are merely hypotheses. First, it is possible that since DRF occurs more commonly in women and most studies have a majority of female volunteers, treatment algorithms may be more optimized for women. Second, due to the high prevalence of osteoporosis (which is a risk factor for poor prognosis) in women in the age group where DRF is most common, osteoporosis in men may have been under-recognized. Previous research has also shown that men are more likely not to receive treatment for osteoporosis (Jennings et al., 2010), possibly because of insufficient osteoporosis awareness (Cawthon, 2011). Third, poorer nutritional status and a larger number of comorbidities are known to contribute to poorer recovery amongst men with hip fractures (Carpintero et al., 2005). Additionally, male gender has been shown to be a risk factor for the development of postoperative medical complications in patients with hip fractures (Endo et al., 2005). Thus, the greater predominance of poor outcome trajectories in men could have a number of underlying reasons.

4.1. Strengths and limitations

The study undertook a unique approach using LGCA to categorize recovery trajectories post-DRF using the valid and reliable outcome measure of PRWE, in a relatively large cohort of patients. Depression was measured prior to knowledge of the outcome trajectory, which mitigates any potential for response bias. The principal limitation of this study is that depression data was acquired through self-report using the SCQ and not a depression screen test, therefore accuracy of the depression diagnosis is unknown. However, self-reported depressive symptoms are easily collected in clinical practice and may represent a more practical predictor. In addition, our depression data was only collected at baseline and changes in depressive status could have occurred over time. Thus, we were unable to control for people's recovery from depression or circumstances that cause depression affecting outcomes over time. Nevertheless, we were able to discover that baseline self-reported depression acquired through a single question from the SCQ is a distinguishing factor between people in the non-recovery and rapid-recovery classes.

In summary, using LGCA we identified three classes of recovery post-DRF: rapid-recovery, slow-recovery, and non-recovery. The distinguishing factors between the classes were greater self-reported depression and a higher proportion of males in the non-recovery class. Although not significant, the rapid-recovery class had the lowest baseline PRWE score and proportion of smokers and the highest proportion of people that had finished post-secondary education and were working. The non-recovery class had the highest proportion of smokers, people not working due to the injury, people with no post-secondary education, and the highest baseline PRWE scores. The results may help clinicians identify patients who would benefit from closer monitoring early to facilitate optimal recovery after DRF.

Conflicts of interest

None declared.

Ethics approval

The process for data collection and storage was approved by the Western University Research Ethics Board.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.07.012.

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